CITY OF PROVIDENCE, RHODE ISLAND • MAYOR JOSEPH A. DOORLEY, JR.

Vincent Vespia
City Clerk

Clerk of Council

Clerk of Committees

Rose M. Mendonca
First Deputy

Michael R. Clement
Second Deputy

DEPARTMENT OF CITY CLERK
CITY HALL

June 14, 1974

Mr. Vincent Vespia
City Clerk
City Hall
Providence, Rhode Island

Dear Mr. Vespia:

I submit the accompanying, being a copy of the Technical Report - A Hazards Analysis of a Proposed Addition to the Liquefied Natural Gas Storage Terminal at Providence, R. I.

You are hereby requested to submit the same to the City Council for its consideration, all in accordance with Resolution of the City Council No. 308, approved May 20, 1974.

Sincerely yours,

Robert J. Haxton

Robert J. Haxton
President - City Council

pf

IN CITY COUNCIL
JUN 17 1974
READ:
WHEREUPON IT IS ORDERED THAT
THE SAME BE RECEIVED.
Vincent Vespia
CLERK

382

FMRC Serial No. 22340

TECHNICAL REPORT

A HAZARDS ANALYSIS OF A PROPOSED ADDITION TO THE LIQUEFIED NATURAL GAS STORAGE TERMINAL AT PROVIDENCE, R.I.

By

Robert C. Merritt

Prepared For

City of Providence, R.I.

May 1974

Factory Mutual System

Factory Mutual Research

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RC74-T-25

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Factory Mutual System

Factory Mutual Research

1151 Boston-Providence Turnpike
Norwood, Massachusetts 02062

ABSTRACT

The Factory Mutual Research Corporation has evaluated the potential hazardous impact upon the City of Providence and its people presented by the proposed installation of two additional 600,000 barrel LNG storage tanks at the Algonquin LNG terminal. The Algonquin LNG terminal will be designed, constructed, operated and inspected in accordance with applicable codes and standards to minimize the likelihood of an LNG or gas release. In addition, if such an incident were to occur, the Algonquin LNG terminal will have an intended fire protection and safety design, which far exceeds the requirements of the applicable codes and standards, to cope with such an incident (i.e. minimize and confine the hazardous impact to within the terminal site). Based on a detailed review of these factors, we have concluded it is possible, but highly improbable, that an incident could occur within or outside this terminal which would adversely affect people and property outside the terminal.

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I INTRODUCTION

In October 1972, Algonquin LNG Inc. petitioned the City of Providence for permission to build two additional 600,000 barrel LNG storage tanks at the Algonquin LNG terminal. A permit had been previously given for the construction of one 600,000 barrel LNG storage tank which was completed in late 1973. The city fire marshal recommended that the Providence Building Board of Review defer action on Algonquin's petition pending a study by consultants in fire protection engineering of the impact of the proposed installation on the city and its residents. Subsequently, after several meetings between the interested parties (i.e., Algonquin LNG Inc., Arthur D. Little, Inc., consultant to Algonquin LNG Inc., the Commissioner of Public Safety for Providence, Providence Fire Department officials, and Factory Mutual Research Corporation), Factory Mutual Research Corporation was retained to perform the subject study for the City of Providence. This study, to a large extent, is based on a review of the adequacy and validity of a previous study conducted by Arthur D. Little, Inc. for Algonquin LNG Inc.[(1)] Descriptive material herein was obtained from the above study and testimony given in support of Algonquin LNG Inc.'s petition to the Federal Power Commission for the proposed installation (Docket No. CP 73-139).

II SCOPE

The Factory Mutual Research Corporation agreed to cover the following items:

1. Determination of the possible extent of deflagration resulting from a maximum forseeable spill of LNG from a tanker, unloading operations, pipeline breaks, etc. and the resultant spread of liquid and/or vapor on land and water. Importance of the influence of topography, prevailing winds and their effects, tidal effects, and storage tank dike capacities would be investigated.
2. A study of fire exposure from a pool fire in situ involving calculations of radiative heat fluxes to determine limits outside of which levels of energy would not be sufficient to result in pilot ignition of wood. If necessary, a survey of properties would be made, in the unsafe area determined, for both fire and explosion to determine the general character of the occupancies, property values and their contribution to a conflagration.
3. An assessment of the suitability and adequacy of public fire department equipment, looking into the accessibility to fire areas (including docks and wharves) and making an evaluation of the degree of hazard to fire department personnel. Should it be found that inadequacies exist, an opinion relative to the economic impact would be offered.
4. An appraisal of on-site combustible vapor and fire detection equipment, automatically and manually controlled fixed extinguishing equipment and portable fire fighting equipment, as well as plant manpower and training.
5. Probabilities of accidents to tanks and directly associated equipment from off-site causes resulting from aircraft collision, acts of nature including floods, tidal waves, etc. Other accident experiences, which would involve mobile equipment, would be investigated for truck transport of LNG through Providence and tanker transport. The latter would consider spillage, as well as collision which could occur from river traffic or docking.
6. A review of the LNG facilities including dock and unloading arrangements. Operating procedures, personnel training, and emergency organization, as proposed, would be checked.

III GENERAL OPERATING DESCRIPTION OF THE PROVIDENCE LNG TERMINAL (FIGURE 1)

The Providence LNG Terminal will receive LNG from 125,000 cu. meter ships (approximately 29 shipments per year) at the dock and unloading area. The terminal is also designed to receive or send out LNG by 30,000 barrel barges at the dock and unloading area.

3.1 DOCK AND UNLOADING AREA

The dock and unloading area will consist of a solid concrete dock with adequate mooring facilities, an unloading platform for a specially designed marine arm installation, and an LNG sump of approximately 60,000 gal. capacity. The dock area will be graded towards the sump. A cryogenic splash shield will also be provided to channel any possible LNG release which might develop at the unloading arms to the sump at the dock.

LNG will be transferred from the ships to the storage tanks at a nominal flow rate of 45,000 gpm through a marine arm installation feeding a 36 in. diameter insulated cyrogenic pipeline. The 36 in. pipeline will run from the dock to the top of each storage tank. The marine arm installation consists of five 16 in. diameter counter-weighted marine unloading arms. The marine arms are designed to allow for tidal variation and both outward and parallel ship drift. Four of the marine arms will be used for LNG unloading and the fifth arm will be used for vapor return to the ship to maintain positive pressure on the ship's storage tanks. For barge loading or unloading, a barge mounted marine arm will connect to a 12 in. diameter insulated cryogenic pipeline at dock side with a nominal flow rate of 7000 gpm. Interlock switches will override all other controls and close the valves at the dock in the event of high tank liquid level or high tank pressure.

3.2 STORAGE TANK AND DIKE AREA

The three storage tanks, each with a capacity of 600,000 barrels will be designed as double wall, suspended deck LNG storage tanks. They are double bottom, double shell, single roof, vertical cylindrical tanks, with a diameter of 190 ft. and a shell height of approximately 140 ft. Essentially, the design is a "tank within a tank" where only the inner tank (suspended deck and 9% nickel steel shell) is subjected to cryogenic temperatures and hydrostatic pressures of the LNG in storage. The outer tank (mild steel) retains the non-

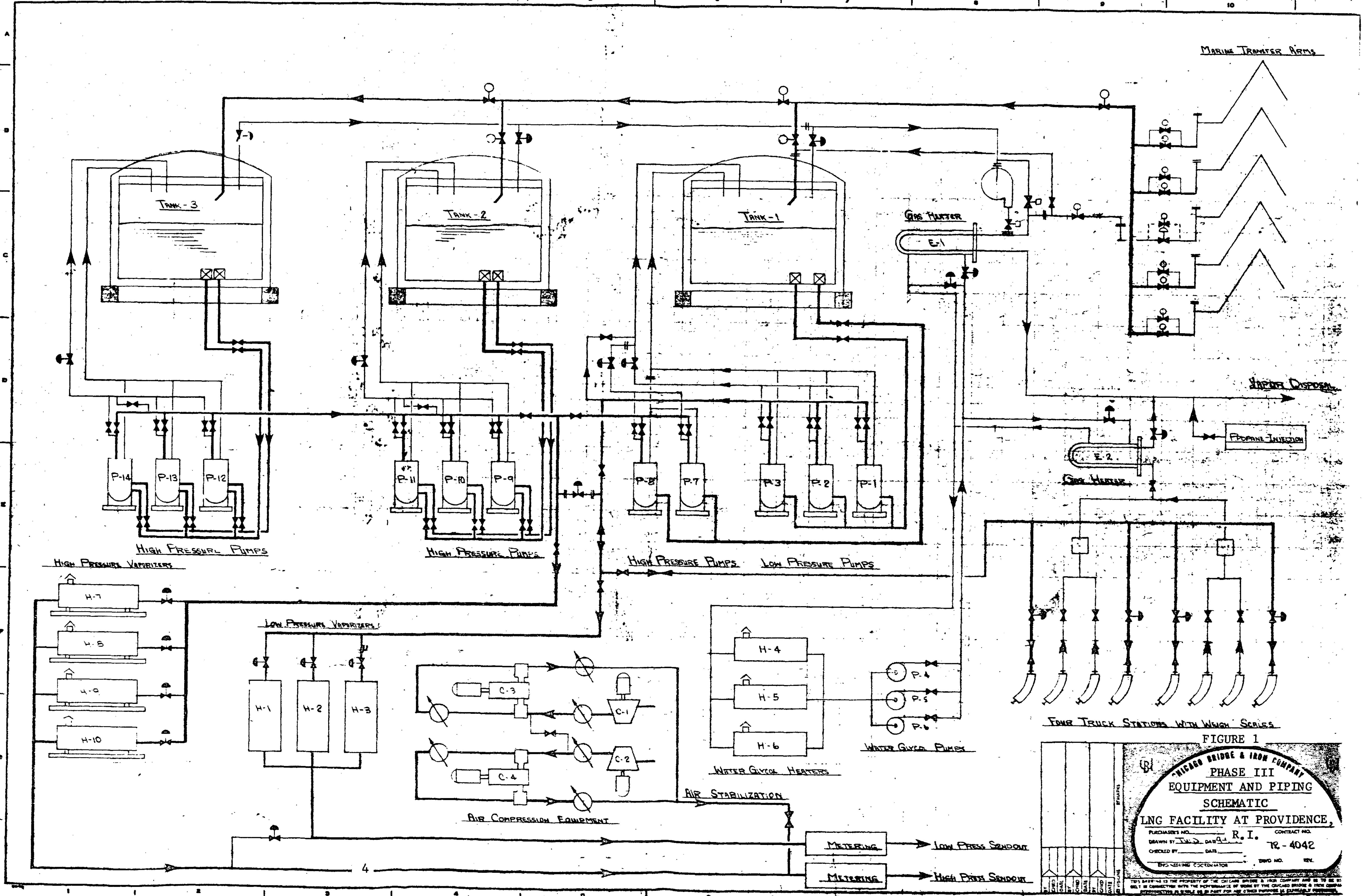
Marine Transfer Arms
Tank - 3
Tank - 2
Tank - 1
Gas Heater
E-1
E-2
Vapor Disposal
Propane Injection
P-14
P-13
P-12
P-11
P-10
P-9
P-8
P-7
P-3
P-2
P-1
High Pressure Pumps
High Pressure Pumps
High Pressure Pumps
Low Pressure Pumps
High Pressure Vaporizers
H-7
H-8
H-9
H-10
Low Pressure Vaporizers
H-1
H-2
H-3
C-3
C-4
C-1
C-2
Air Compression Equipment
Air Stabilization
H-4
H-5
H-6
Water Glycol Heaters
P-4
P-5
P-6
Water Glycol Pumps
Four Truck Stations with Weigh Scales
Metering
Metering
Low Press Sendout
High Press Sendout
Chicago Bridge & Iron Company
PHASE III
EQUIPMENT AND PIPING
SCHEMATIC
LNG FACILITY AT PROVIDENCE, R.I.
78-4042

FIGURE 1

combustible insulation, perlite, which surrounds the inner tank and is designed for an internal gas pressure of approximately 1.5 psig.

Each LNG storage tank will be individually diked. Each dike is capable of holding the entire contents of a full LNG storage tank. Within each dike, a 15 ft deep concrete sump having dimensions of 90 x 90 ft will be provided. The dike area will be graded toward the sump.

3.3 VAPOR HANDLING SYSTEMS

3.3.1 Daily Operations Between Unloadings

During daily operations, boil-off vapor (i.e. normal heat leak into LNG storage tanks, equipment, and piping causes vaporization of LNG) from the storage tanks and terminal facilities will be collected, heated and sent out through the vapor handling system to the Providence Gas Company gas holders.

3.3.2 Ship Unloading Operations

During ship unloading operations, vapor generated due to pump heat input, vapor generated due to fill line heat leak, LNG flash gas upon filling, vapor displaced during tank filling and boil-off vapor from normal tank heat leak will be handled as follows: a portion will be returned from the land tanks to the ship through a 16 in. marine arm to replace the volume of liquid pumped from the ship's tanks so that a positive pressure will be maintained in these tanks and the balance will be sent out through the vapor handling system to the Providence Gas Company gas holders.

Enrichment of the boil-off vapors delivered to the gas holders, if required, will be accomplished by propane injection. Vapor flow to the gas holders will be measured during daily operating conditions when ships or barges are being unloaded.

3.4 LNG TRANSFER FROM STORAGE TANKS

LNG from the storage tanks will normally be either vaporized for send out through gas pipeline distribution systems (90%), low pressure (225 psig) or high pressure (750 psig), or sent out as a liquid via LNG truck (10%).

3.4.1 Low Pressure Send-out System

The low pressure send-out system will consist of three pumps, three gas-fired LNG vaporizer units and measurement facilities.

The liquid pumps will each be capable of a maximum pump-out rate of approximately 300 gpm. The LNG in liquid phase will be pumped from the bottom of the storage tank to the LNG vaporizer units by three identical vertical centrifugal type pumps located adjacent to the existing storage tank. Common suction and discharge piping manifolds will permit parallel pump operation. The liquid flow to the vaporizers will be controlled by a flow controller. The pressure of the liquid when delivered to the vaporizers will be sufficient to permit delivery of vaporized LNG at required pressures without additional compression.

Each vaporizer unit is capable of receiving LNG in liquid phase, vaporizing it, and discharging it in vapor phase at a maximum rate of approximately 33,300 MSCF (thousand standard cubic feet) per day. The temperature of the vaporized LNG at the vaporizer outlets will be maintained at approximately 40°F by automatic fuel feed to the vaporizer burners. After leaving the vaporizers, the quantity of vaporized LNG will be metered and delivered to the Providence Gas Company pipeline system.

3.4.2 High Pressure Send-out System

The high pressure send-out system will consist of eight liquid pumps, four high pressure vaporizers and Btu stabilization and odorization equipment.

The liquid pumps will be capable of a maximum output rate of approximately 900 gpm. Two of the centrifugal-type pumps will be installed adjacent to the existing storage tank, and three which includes one spare, will be installed adjacent to each of the other proposed additional storage tanks. Common suction and discharge pumping manifolds will permit parallel pump operation. The pump will deliver the liquid to the vaporizers at pressure sufficient to permit delivery of vaporized LNG at required pressures without additional compression. The liquid flow will be controlled by a flow controller.

Each high pressure vaporizer will have a capacity of approximately 100,000 MSCF per day. The discharge temperature will be maintained at approximately 40°F by automatic fuel feed to the vaporizer burners. The high pressure vaporized LNG will be stabilized with air to the uniform heating value desired by Algonquin Gas. The vaporized LNG will also be odorized prior to delivery; the odorization injection system will consist of a storage tank and positive metering pump and connecting pipe.

3.4.3 Truck Loading Stations

Two dual truck loading stations will be provided, each capable of loading two trucks simultaneously at a rate of 300 gpm per truck. Trucks provided by New England LNG will have an approximate capacity of 10,000 gallons of liquid. Piping will also be provided to allow unloading of trucks to the storage tanks.

IV HAZARDS OF AN LNG TERMINAL

The principal hazard of an LNG terminal is the possibility of accidentally releasing LNG or gas. An LNG or gas release could happen within an LNG terminal due to operator error or equipment failure or off site due to an accident during shipping or trucking of LNG.

LNG is a readily ignitable cryogenic fluid, mostly methane. That is, LNG is normally handled or stored at approximately -260°F and will form readily ignitable vapors in the presence of air if accidentally released.

A large LNG fire, if not controlled, can present a thermal radiation hazard to people and property at considerable distances. If an LNG release is not ignited immediately, a flammable vapor air cloud will be formed capable of traveling great distances (e.g. up to several thousand feet) from the spill origin depending upon quantity and rate of release, vaporization rate (i.e. much higher for LNG spilled on water as opposed to land), weather conditions and presence of ignition sources within the vapor cloud travel path. Consequently, an LNG terminal, under very adverse circumstances, could pose a fire and/or explosion hazard off site.

V PROPOSED TERMINAL FIRE AND SAFETY PROTECTION (FIGURE 2)

The Providence LNG terminal will be designed, constructed and operated in accordance with DOT* Part 192, NFPA** 59A and API*** 620. These codes and standards contain extensive provisions whose intent is to assure safe plant operation. In addition, Algonquin LNG will provide safety equipment and measures which far exceed the provisions of these codes and standards.

The terminal will be staffed 24 hours a day with personnel thoroughly trained in the operation of various safety systems. The terminal operators will be specially trained in Algonquin's operating and maintenance plan which will include complete emergency operating procedures. These procedures, combined with the basic fire suppression and control systems, are designed to meet Algonquin's operating objectives and provide complete protection to the terminal and its surroundings.

5.1 GENERAL APPROACH TO FIRE PROTECTION AND SAFETY

As above, the Algonquin terminal will be designed, constructed and operated to minimize the probability of an incident. However, in the event of an LNG or gas release and a possible subsequent fire, rapid detection and suppression or control are proposed by the use of gas detectors, fire detectors and fixed, mobile, and hand-portable fire fighting equipment. All fire protection equipment will be either Underwriters' Laboratories listed or Factory Mutual approved or both, where applicable, and will be installed and maintained in accordance with the appropriate NFPA standards.

5.1.1 Gas Detectors

Gas detectors will be provided at strategic locations throughout the terminal to alert personnel to any appreciable LNG or gas release. These fixed detectors will be set to activate at a methane concentration of 0.2 LFL (lower flammable limit) or approximately 1% methane since the LFL of methane in air is approximately 5% methane. Activation of the fixed gas detectors will be indicated at the fire control panel in the main control room.

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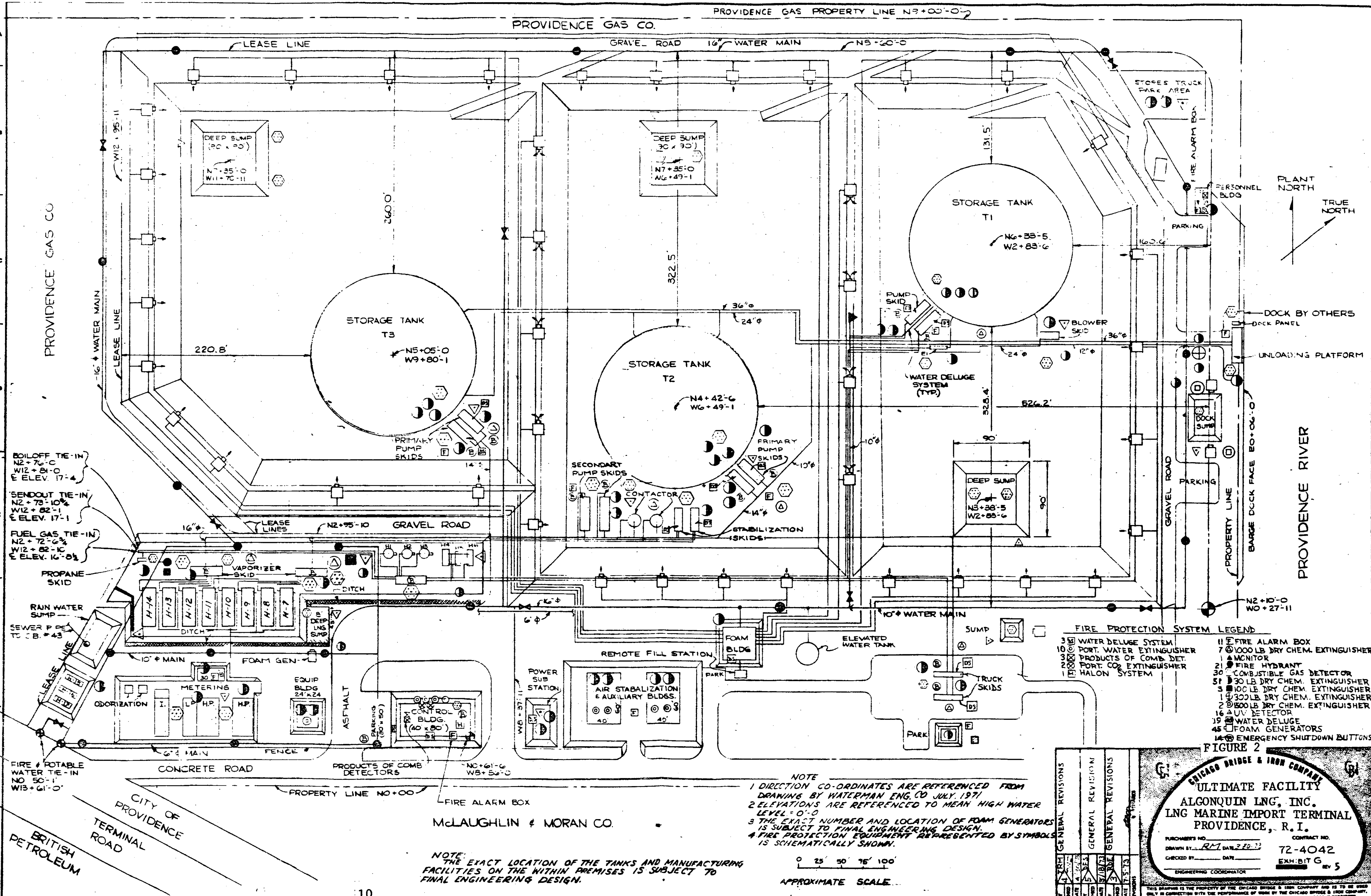
*DOT: Department of Transportation
**NFPA: National Fire Protection Association
***API: American Petroleum Institute


PROVIDENCE GAS PROPERTY LINE N9+00-0
PROVIDENCE GAS CO.
LEASE LINE
GRAVEL ROAD
16" WATER MAIN
N5+20-0
W12+95-11
16" Φ WATER MAIN
DEEP SUMP (90 x 90)
N7+35-0
W11+70-11
DEEP SUMP (90 x 90)
N7+35-0
N6+49-1
260.0'
322.5'
131.5'
STORES TRUCK PARK AREA
FIRE ALARM BOX
PERSONNEL BLDG
PLANT NORTH
TRUE NORTH
STORAGE TANK T1
N6+38-5
W2+83-6
PARKING
STORAGE TANK T3
N5+05-0
W9+80-1
220.8'
STORAGE TANK T2
N4+42-6
W6+49-1
36"Φ
24"Φ
12"Φ
PUMP SKID
BLOWER SKID
WATER DELUGE SYSTEM (TYP)
DOCK BY OTHERS
DOCK PANEL
UNLOADING PLATFORM
626.2'
328.4'
90'
DEEP SUMP
N3+38-5
W2+83-6
PRIMARY PUMP SKIDS
SECONDARY PUMP SKIDS
CONTACTOR
STABILIZATION SKIDS
14"Φ
10"Φ
DOCK SUMP
GRAVEL ROAD
PARKING
PROPERTY LINE
BARGE DOCK FACE E0+06-0
PROVIDENCE RIVER
BOILOFF TIE-IN
N2+76-0
W12+81-0
℄ ELEV. 17-4
SENDOUT TIE-IN
N2+73-10¾
W12+82-1
℄ ELEV. 17-1
FUEL GAS TIE-IN
N2+72-6¾
W12+82-10
℄ ELEV. 16-8½
PROPANE SKID
RAIN WATER SUMP
SEWER PIPE TO C.B. #43
16"Φ
LEASE LINES
N2+95-10
GRAVEL ROAD
VAPORIZER SKID
DITCH
H-14 H-13 H-12 H-11 H-10 H-9 H-8 H-7
DEEP LNG SUMP
6"Φ
16"Φ
10"Φ WATER MAIN
N2+10-0
W0+27-11
SUMP
ELEVATED WATER TANK
FOAM BLDG
REMOTE FILL STATION
PARK
LEASE LINE
10"Φ MAIN
FOAM GEN.
METERING
ODORIZATION
EQUIP BLDG 24'x24
ASPHALT
PARKING (80'x50)
CONTROL BLDG. (40'x80')
POWER SUB STATION
W8+37-11
AIR STABILIZATION & AUXILIARY BLDGS.
TRUCK SKIDS
PARK
FIRE PROTECTION SYSTEM LEGEND
3 WATER DELUGE SYSTEM
10 PORT. WATER EXTINGUISHER
3 PRODUCTS OF COMB. DET.
2 PORT. CO2 EXTINGUISHER
1 HALON SYSTEM
11 FIRE ALARM BOX
7 1000 LB DRY CHEM. EXTINGUISHER
1 MONITOR
21 FIRE HYDRANT
30 COMBUSTIBLE GAS DETECTOR
51 30 LB DRY CHEM. EXTINGUISHER
3 100 LB DRY CHEM. EXTINGUISHER
1 300 LB DRY CHEM. EXTINGUISHER
2 500 LB DRY CHEM. EXTINGUISHER
16 U.V. DETECTOR
19 WATER DELUGE
45 FOAM GENERATORS
14 EMERGENCY SHUTDOWN BUTTONS
6" MAIN
FENCE
FIRE & POTABLE WATER TIE-IN
NO 50-1
W13+61-0
CONCRETE ROAD
PRODUCTS OF COMB DETECTORS
N0+61-6
W8+56-0
PROPERTY LINE N0+00
FIRE ALARM BOX
CITY OF PROVIDENCE
TERMINAL ROAD
BRITISH PETROLEUM
McLAUGHLIN & MORAN CO.
NOTE:
THE EXACT LOCATION OF THE TANKS AND MANUFACTURING FACILITIES ON THE WITHIN PREMISES IS SUBJECT TO FINAL ENGINEERING DESIGN.
NOTE
1 DIRECTION CO-ORDINATES ARE REFERENCED FROM DRAWING BY WATERMAN ENG. CO JULY, 1971
2 ELEVATIONS ARE REFERENCED TO MEAN HIGH WATER LEVEL = 0'-0
3 THE EXACT NUMBER AND LOCATION OF FOAM GENERATORS IS SUBJECT TO FINAL ENGINEERING DESIGN.
4 FIRE PROTECTION EQUIPMENT REPRESENTED BY SYMBOLS IS SCHEMATICALLY SHOWN.
0 25' 50' 75' 100'
APPROXIMATE SCALE
GENERAL REVISIONS
GENERAL REVISION
GENERAL REVISIONS
5/18/73
7-5-73
FIGURE 2
CHICAGO BRIDGE & IRON COMPANY
ULTIMATE FACILITY
ALGONQUIN LNG, INC.
LNG MARINE IMPORT TERMINAL
PROVIDENCE, R.I.
CONTRACT NO.
72-4042
EXHIBIT G
REV 5
ENGINEERING COORDINATOR

Several rechargeable, battery-operated, portable gas detectors will be available for personnel use while monitoring plant operations.

5.1.2 Fire Detectors

Ultraviolet (UV) detectors and smoke actuated ionization-type fire detectors will be provided. UV detectors are flame sensitive. They will be strategically located throughout the plant. The smoke-actuated ionization-type detectors will be located in the main control building where the motor control centers are located. Activation of fire detectors will be indicated at the fire control panel in the main control room.

5.1.3 Fire Fighting Equipment

Looped water mains with hydrants and hose will be provided for control of Class A* type fires and also for cooling equipment and structures exposed to Class B** type fires. Portable dry chemical extinguishers and fixed dry chemical hose line systems will be strategically located throughout the terminal for control of Class B and Class C*** fires. In addition, dike and sump areas will be protected with automatic high expansion foam systems designed to produce 500:1 expansion foam. The automatic foam systems will have a manual override that the operator may use if surveillance by visual means or by television monitor indicates that foam application is unnecessary. A truck, with both high expansion foam (15000 cfm of 500:1 expansion foam for at least 30 minutes) and dry chemical (1000 lb. hose line-turret combination) capabilities, will also be provided at the terminal. Self-contained breathing apparatus and protective clothing will be provided for plant personnel.

5.1.4 Plant Layout

Important structures and equipment are isolated from each other and located as recommended in NFPA 59A. In addition, the plant facility will be graded so that a potential LNG release would be directed to a sump or contained in a dike to limit exposure to important structures, equipment or adjoining property.

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*Class A: Ordinary Combustibles
**Class B: Flammable Liquids and Gases
***Class C: Electrical

5.1.5 Surveillance and Security

The main control room will be equipped with a control panel and annunciators to provide the operator with current process information and control of terminal functions. A fire control panel will also be located in the control room. This panel will provide information on the status of all fire and gas detectors as well as the automatic high expansion foam systems. The control room is the focal point for all intraplant communications. A closed circuit television monitor system for surveillance of plant activities will be located in the main control room with television cameras at the process area, the storage tank and dike areas, the truck station area and the dock area.

Operators will periodically inspect major pieces of equipment and visually observe areas within the plant. During their inspections, it is anticipated that operators will carry portable gas detectors. A fence will be provided at the facility to minimize entry by unauthorized personnel.

Fire alarm pull-boxes, in compliance with, "Minimum Requirements for the Installation of Master Fire Alarm Boxes and Auxiliary Systems Connected Thereto in the City of Providence", will be provided at the following locations with direct tie to the City of Providence Fire Department: the main control room, the air stabilization building, each dike pump-out area, the truck station area, the dock unloading platform, and the dock personnel building.

5.2 SPECIFIC AREA PROTECTION

There are seven basic areas within the terminal which are described and protected as follows:

5.2.1 Process Area

The process area consists basically of high-pressure and low-pressure vaporizers, glycol heaters and the "sendout" connections. The ground surface in the process area will be graded so that LNG releases will be directed to a sump capable of holding at least 32,000 gallons. A sump of this size would be capable of containing a 10-minute total discharge of LNG from piping leading to the vaporizers.

There will be eight detectors in the process area; four combustible gas detectors and four UV detectors. A combustible gas detector in the sump will be set to activate at 0.2 LFL. Activation of this detector will automatically start a high-expansion foam generator located at the sump edge. The foam generator will be capable of generating foam at 12,000 cfm with an expansion ratio of 500:1. The foam will be discharged directly into the sump which will be surrounded by a 5-foot high foam-retention fence. The three other combustible gas detectors, set to alarm at 0.2 LFL, will be placed in the vicinity of the vaporizers. The four UV detectors will be installed in the process area positioned to detect UV radiation from the sump or vaporizers.

In addition, seven fire hydrants will be located around the periphery of the process area and four 30-pound portable and one 100-pound wheeled dry chemical extinguishers and two 1,000-pound dry chemical hand-hose-line systems will be strategically located within the area.

5.2.2 Truck Station Area

The truck station area will be graded so as to direct any accidental release of LNG during truck loading or unloading to a sump with a capacity of at least 20,000 gallons. This sump can contain the full capacity from the piping leading to the truck stations for 10 minutes in addition to the contents of a full LNG trailer.

Two combustible gas detectors will be installed in the truck station area and will be set to activate upon sensing a 0.2 LFL concentration of methane. One detector will be mounted in the sump and the other at the truck station. The sump detector will automatically activate a high-expansion foam generator. The foam generator will have a capacity of 12,000 cfm of 500:1 expansion foam, which will flow directly into the sump. A 5-foot high, foam-retention fence will surround the sump. One UV detector will be installed to overlook the sump and truck station area.

A remote manually operated water-deluge system with a discharge density of 0.2 gpm/ft^2 will be installed at the truck station. Two 30-pound portable and one 100-pound wheeled dry chemical extinguishers and one 1,000-pound dry chemical hand-hose-line system will be located in this area, along with two fire hydrants and a fire alarm pull-box.

5.2.3 Storage Tank and Dike Area

Each of the three LNG storage tanks at the terminal will be surrounded by a dike capable of holding at least 100 percent of the tank contents. Each dike will contain an LNG sump (approximately 730,000 gallon capacity) and the dike floor will be graded so that any accidental release of LNG would be directed to the sump. Each diked area will be provided with a fixed automatic high-expansion foam system capable of generating approximately 525,000 cfm of 500:1 expansion foam. Foam generator piping will either be buried or suitably protected to withstand thermal radiation. Similarly, each foam generator will be insulated with Maranite or other comparable material. A 5-foot high fence will be placed on top of each dike for foam retention. Water for the foam system will be provided by direct connection with the municipal water system as well as an elevated water tank of at least 25,000-gallon capacity. The foam concentrate will be stored in two 50,000 gallon fiberglass storage tanks in the foam concentrate building.

Combustible gas detectors will be mounted in each diked area. One or more detectors will be mounted in the vicinity of the pump area and two will be mounted in each LNG sump. All detectors will be set to alarm upon sensing 0.2 LFL concentrations of methane. Activation of two or more detectors in a dike area will automatically activate the high-expansion foam system. Each diked area will be under closed-circuit television surveillance from the main control room. This surveillance capability will enable the facility operators to monitor conditions within the diked area and to take appropriate action if an abnormal situation should develop.

Each diked area will contain a number of 30-pound portable dry chemical extinguishers and at least one 1000-pound dry chemical hand-hose-line system. Several water hydrants are located on the perimeter of the outer dike walls. Three UV detectors will also be installed in each diked area. Finally, a fire alarm box will be installed at each dike pump out area.

5.2.4 Foam-Concentrate Building

The foam-concentrate building will house the foam concentrate tanks and the associated pumps and piping. The building will have concrete walls and a Class I steel deck roof. The roof will be protected externally with a water deluge system that can be manually activated from the main control room. A water density of 0.2 gpm/ft^2 will be provided. A 30-pound dry chemical extinguisher will be located within the building.

5.2.5 Main Control Building

The main control building has concrete walls and a Class I steel deck roof. The roof will be protected externally with a manually actuated water-deluge system with a discharge density of 0.2 gpm/ft^2. A combustible gas detector will be located at the roof-mounted air conditioning intake duct. The detector, upon activation, would automatically shut off the air intake to prevent methane from entering the control building, and it would also activate an alarm and a light on the panel board.

Portable water and carbon dioxide extinguishers will be provided in the control building. The motor control cabinets in the main control room will be protected with a Halon 1301 flooding system. The Halon system will be actuated by a heat detector and will release Halon 1301 through a spray nozzle. The nozzle consists of a length of metal tubing with a series of drilled holes. It will be fabricated during installation to provide coverage of the particular cabinet configuration involved. Two products of combustion detectors will be located in the motor control centers in the building. A fire alarm pull-box will also be located in this area.

5.2.6 Power Substation

The power substation will be fed by buried power cables. The substation area will be fenced and will contain two 30-pound portable dry chemical extinguishers and one UV detector. A manually operated water-deluge system activated from within the main control building will provide a water discharge density of 0.2 gpm/ft^2 over the substation.

5.2.7 Dock Area

The dock area consists of a dock, an unloading platform containing the marine arms and cryogenic splash shield and an LNG sump. The dock area will be graded toward the sump, which will have a capacity of approximately 60,000 gallons. This sump will be surrounded by a 5-foot foam-retention fence. This area will contain a combustible gas detector in the sump and at either end of the unloading platform. These detectors will be set to automatically actuate the dock foam system, which consists of two 12,000-cfm high-expansion foam generators placed alongside of the sump. Four fire hydrants, four portable 30-pound dry chemical extinguishers, one wheeled 300-pound dry chemical extinguisher, two 1,500-pound skid mounted dry chemical hand-hose-line systems, one UV detector at the sump will be provided. A television camera will be provided to provide surveillance of the dock from the main control room. A fire alarm pull-box will also be installed at the unloading platform.

5.3 OTHER AREAS

Other areas for which protection will be provided include the metering area, the air stabilization building, the propane skid, the equipment building, the truck weigh station, the dock personnel building, the stores area, and the top of the LNG tanks.

The metering area will be provided with two 30-pound portable dry chemical extinguishers, two combustible gas detectors, and a fire alarm pull-box.

The air stabilization building will be provided with two 30-pound portable dry chemical extinguishers, two portable water extinguishers, and a fire alarm pull-box.

The propane skid will be provided with a combustible gas detector, a 30-pound portable dry chemical extinguisher and a 100-pound wheeled dry chemical extinguisher.

The equipment building will be provided with two 30-pound portable dry chemical extinguishers and one portable water extinguisher.

The truck weigh station will be provided with a 30-pound portable dry chemical extinguisher and a 100-pound wheeled dry chemical extinguisher.

The dock personnel building will be provided with one 30-ound portable dry chemical extinguisher, one portable water extinguisher, a products of combustion detector, and a fire alarm pull-box.

The stores area will be provided with a UV detector and two 30-pound portable dry chemical extinguishers.

Three 30-pound portable dry chemical extinguishers and a combustible gas detector will be provided at the top of each tank.

5.4 EMERGENCY IGNITION SYSTEM

Although a large LNG release is considered highly unlikely, an emergency ignition system, manually actuated from the control room will be provided at the terminal boundaries.

5.5 EMERGENCY SHUTDOWN SYSTEM AND SAFETY INTERLOCKS

An emergency shutdown system (ESD) will enable a plant operator to shutdown and isolate the plant facility from the dock area, the existing Providence Gas Company facility, and the gas sendout lines from the terminal. An ESD station will be provided at the main control room, each pump area, the entrance and exit to the terminal, the truck station area and the vaporizer areas.

Safety interlocks are also provided to automatically shutdown given pieces of equipment. These interlocks are intended to minimize the effects of an operational upset. Examples of operational shutdowns are as follows: storage tank liquid inlet on high liquid level, or high tank pressure; storage tank outlet and sendout system on low tank pressure or low liquid level; vaporizer shutdown on high or low outlet gas temperature, high or low sendout gas pressure, high stack temperature, low fuel gas pressure, or flame-out; and truck loading on liquid overfill or high fill pressure.

VI DISCUSSION: ITEMS 1 THROUGH 6 OF SCOPE

6.1 ITEM 1

A catastrophic tank failure, such as occurred at East Ohio Gas Company, Cleveland, Ohio, in 1944, is not considered a credible incident based on the current state of the art in cryogenic technology. Chicago Bridge and Iron Company, the designer and installer of the proposed installation, has experience in designing, constructing and operating at least 25 complete LNG facilities. The tanks will also be adequately protected against overpressurization and subsequent release of LNG. Nevertheless, the Algonquin LNG terminal will have an intended design to limit the fire and vapor cloud travel hazard potential from a tank failure (i.e. automatic high-expansion foam protection for each diked area and the manually actuated ignition system at the terminal boundaries).

According to calculations performed by A. D. Little, Inc.[(1)], if a dike was rapidly filled with LNG, a flammable vapor cloud, under the most adverse weather conditions, could possibly travel downwind 12,500 ft from the dike involving populated areas. However, in the event of LNG release and subsequent vapor cloud formation, the prevailing winds are from the northwest and southwest depending on the time of year and would cause vapor travel toward the Providence River and away from any occupied areas. Also, strong winds (i.e., in excess of 10 mph) would tend to minimize the extent of vapor travel by dilution and dissipation.

Furthermore, A. D. Little Inc. points out that one could realistically expect ignition of such a cloud either intentionally (i.e., operator action in the control room) or otherwise (i.e., accidentally) before the cloud raches the nearest populated area, approximately 1500 ft south of the terminal, with a resultant burnback to the spill origin. This obviously does not rule out the possibility of a vapor cloud being ignited off site with extensive damage (fire and/or explosion damage).

The next largest potential LNG spill source within the terminal would be rupture of a withdrawal line from the storage tanks. However, it should be recognized that this also is a highly unlikely incident. The tank withdrawal lines are bottom-connected and have pneumatically actuated internal valves (fail-safe closing action upon loss of air pressure). The internal valve can be actuated locally or remotely. The internal valve is also interlocked into the emergency shutdown system. Arthur D. Little has postulated an incident involving failure of this withdrawal line resulting in a release of 51,000 gallons of LNG. We believe this incident has been very conservatively estimated and the proposed fire protection systems will control such an incident without having an adverse impact outside the terminal.

Arthur D. Little has also postulated incidents during the following transfer operations: vaporization (approximately 10,400 gallons), truck station filling (approximately 14,800 gallons) and storage tank filling from a ship at the dock (approximately 47,900 gallons). These incidents are also very conservatively estimated and we believe that the proposed fire protection systems will control such incidents without having an adverse impact outside the LNG terminal.

The topography of the site is such as to contain any credible LNG spill within the plant boundaries. The general topography of the area is flat which would facilitate dissipation of any LNG vapors and radiant energy from a fire.

Each dike will be designed to hold at least 100% of the contents of an LNG storage tank and will be located 29 ft above mean high water. All other main components of the terminal will be located at least 15 ft above mean high water. The highest recorded water level is 13.4 ft above mean high water which occurred during the 1938 hurricane.

LNG Transportation on Water

The possibility of an LNG spill on water exists during vessel transit in the Providence Harbor. LNG will be transported by 125,000 cu. meter ships (approximately 29 shipments per year maximum) and 30,000 barrel barges.

The United States Coast Guard has complete jurisdiction of transportation of LNG via water in the Continental United States via the Ports and Waterways Safety Act of 1972. Ship and barge transportation of LNG in the Providence Harbor will be very stringently regulated by the Captain of the Port, Providence, Rhode Island. The Captain of the Port is presently working on an LNG/LPG contingency plan similar to that issued by the Captain of the Port, Boston, Massachusetts; an excellent comprehensive plan[2]. LNG has been successfully transported without incident in the Port of Boston for over three years. The LNG/LPG contingency plan emphasizes that a fire incident would be the responsibility of the public fire department(s).

Arthur D. Little, Inc., has done a very thorough hazards analysis of LNG ship transportation in Providence Harbor[3]. The probability of an incident in Providence Harbor resulting in an LNG release is extremely low. Nonetheless, Arthur D. Little, Inc. has postulated an extreme incident. The 125,000 cu. meter ships have 5-25,000 cu. meter tanks. If the entire contents of one 25,000 cu. meter tank were instantaneously released and ignited, people and property within 2000 ft of the center of the spill could be adversely affected for 5 to 6 minutes from the burning LNG. The LNG pool could possibly attain a radius of 1800 ft. Although such an incident could obviously have an impact on the City of Providence, we also believe that any incident resulting in an LNG release is unlikely under the regulations to be imposed by the United States Coast Guard.

6.2 ITEM 2

Ignition of a spill covering the entire surface area of the dike could result in dangerous heat flux levels to people 1300 ft away and insulated tanks 700 ft away if left to burn uncontrolled. If the high expansion foam system could not control such a fire, the other LNG tanks would be seriously exposed, particularly if the fire originated at the proposed middle tank. It is doubtful that manual fire fighting could be effectively used to keep the other LNG storage tanks cool. Consequently, if these tanks did fail from exposure, a fire involving all three diked areas simultaneously could eventually occur. If so, we estimate the safe distance for people would be approximately 3000 ft from the diked area. Piloted ignition of wood (i.e., ignition source needed) would occur at a distance of approximately 1500 ft from a diked area and unpiloted (i.e., spontaneous) ignition at a distance of 700 ft. Under such conditions, we believe a major conflagration involving areas outside the LNG terminal could result (e.g., Providence Gas Company, Texaco, Inc., New England Bituminous Terminal Corporation, Sun Oil Company, McLaughlin-Moran, Inc. and British Petroleum Corporation).

To put the above in proper perspective, we believe there is only a remote possibility that such a spill could occur. Also, it is possible that the high expansion foam protection would be effective in controlling an LNG pool fire.

It is not anticipated that any credible LNG spill and subsequent fire during LNG transfer operations would pose a thermal radiation hazard outside the terminal.

6.3 ITEM 3

In the event of a fire at the Providence LNG facility, the Providence Fire Department will initially respond with 4 pumpers, 2 ladder trucks and a battalion chief with additional similar equipment available. Access to the terminal is via Terminal Road, although emergency access would also be possible through the Providence Gas Company property. For the conservatively estimated incidents postulated by Arthur D. Little, Inc.[(1)] and referred to in our comments under Item 1 accessibility to the facility and public fire department equipment are adequate. Also, the degree of hazard to fire department personnel would appear to be acceptable.

6.4 ITEM 4

The proposed selection and arrangement of combustible gas detectors and fire detectors will be adequate. The proposed selection and arrangement of manual fire fighting equipment will be adequate. The adequacy of high-expansion foam protection for a large LNG fire is unknown although small scale LNG fire tests indicate it could be effective in controlling such fires. That is, the basis for high-expansion foam protection is an American Gas Association sponsored test program at the Ansul Company Fire Test Center at Marinette, Wisconsin[(4)]. Fire test work was conducted with 400 sq ft (20 ft x 20 ft) and 1200 sq ft (30 ft x 40 ft) LNG pools. One fire test resulted in control of the 1200 ft^2 LNG pool fire in approximately 5 min. using an application rate of 2.9 cfm/ft^2 of 500:1 expansion foam. Control within 2 min. required an application rate in excess of 6 cfm/ft^2. The Ansul tests were compared with other small-scale fire tests (5 and 10 ft diameter LNG fires) conducted at Philadelphia Gas Works. The test results correlated well with little difference due to scale-up. No larger scale LNG fire tests (i.e. larger than 1200 sq ft) have been conducted. The proposed application rate for the Providence LNG terminal is approximately 3.0 cfm/ft^2 over an approximate area of 175,000 ft^2 (i.e. 525,000 cfm). Therefore, as previously indicated, we consider the adequacy of high-expansion foam protection for such a large area to be unknown. Also, high winds would possibly adversely affect the build-up of a foam cover.

The Ansul tests also indicated that high-expansion foam was very effective in controlling LNG vapor cloud travel.

We would recommend a minimum discharge density of 0.30 gpm/ft^2 for the deluge system at the truck station. Other proposed fixed protection systems will be adequate.

Proposed plant manpower and training will be adequate.

6.5 ITEM 5

External events which could cause an LNG or gas release at the terminal can be divided into natural events and human induced events.

Natural events include tornadoes, storms (hurricanes and flooding) and earthquakes. The probability of a tornado hitting the LNG terminal has been calculated to be once every 3,000 years[(1)]. The terminal will be designed to withstand the impact of a hurricane or other windstorm with winds up to 100 mph. The terminal will be protected against flooding by elevating all important buildings and equipment at least 15 ft above mean high water. As previously indicated, the highest recorded water level in the terminal area was 13.4 ft above mean high water during the hurricane of 1938. The LNG storage tanks will be designed to withstand the expected forces of earthquakes of Zone II characteristics which is adequate for the area. The LNG storage tanks will have adequate lightning protection.

Human-induced events include aircraft impact and sabotage. The probability of an aircraft impacting at the terminal site is extremely low. Arthur D. Little Inc., has estimated the probability to be 4.58×10^{-6}/year or approximately one occurrence every 220,000 years. In essence, this type of incident is possible but not very probable. If it were to occur, a major conflagration could possibly result since the fixed fire protection systems would undoubtedly be impaired. The Algonquin LNG terminal will be reasonably protected against sabotage by complete fencing of the terminal with plant personnel present 24 hours/day, seven days a week.

LNG truck traffic at the Providence LNG Facility will be a maximum of 64 trucks daily during peak winter periods. Almost all truck traffic out of the terminal will proceed directly to I-95 North toward Lowell, Mass., or Fall River-New Bedford, Mass. or Springfield, Mass. or Cumberland, R.I. The Providence Traffic Engineering Department provided us with traffic and accident statistics for the terminal area for the years 1971 and 1972. The accident history is minimal for the route which would be followed from the terminal to

I-95 North. We did not obtain traffic and accident statistics for I-95 in Providence or the other major interconnecting highways, within the Providence area. We believe the accident history of LNG trucks is more meaningful than the traffic and accident history for the above mentioned highways. That is, there have been a few serious traffic accidents involving LNG carriers but in none of these accidents has there been involvement of the LNG. The most serious accident involved a head-on collison between an LNG carrier and a flatbed semi-trailer in Whitehall, Wisconsin on October 8, 1971. The driver of the LNG carrier and an occupant of the other truck were killed and a fire ensued involving diesel fuel, tires and the cab of the LNG carrier. The public fire department responded and controlled the fire which never involved the LNG cargo. Other serious accidents have involved ripping the outer shell of an LNG carrier when it struck an embankment and an LNG carrier flip-over. This is not to suggest that a serious fire or explosion involving LNG cannot occur, but rather that LNG carriers are very resistant to tank or equipment failure resulting in release of the LNG contents due to their double-wall construction. Also we understand that the drivers of LNG carriers for New England LNG, Inc. will be thoroughly trained and certified to handle LNG.

A release of LNG or gas during LNG vessel transit in Providence Harbor or docking is highly unlikely under the stringent regulations to be enforced by the United States Coast Guard as commented on under Item 1.

6.6 ITEM 6

The Algonquin LNG terminal, as proposed, will be well arranged and operated to minimize the probability of an LNG or gas release with an intended fire protection design to cope with any such incident that should occur.

Algonquin LNG, Inc. has prepared an Operating Procedures Manual. We have reviewed Algonquin's operating procedures and we have concluded that their proposed operating procedures will be excellent. In addition, Algonquin LNG, Inc. has benefited from the operating experiences of others in the LNG industry and continues to receive additional information from them. Personnel training for normal and emergency operating conditions was being extensively conducted during the month of November, 1973 and additional periodic training programs will be conducted.

Algonquin LNG, Inc. will have an adequate emergency organization to complement their Emergency Shutdown Systems to effectively isolate important areas of the facility in the event of an abnormal incident.

VII REFERENCES

1. "Potential Impacts Due to Abnormal Events at the Algonquin LNG Terminal in Providence", Final Report to Algonquin LNG Inc. by Arthur D. Little Inc., C-75032, August 1973.

2. LNG/LPG Contingency Plan, Department of Transportation, United States Coast Guard, Captain of the Port, Boston, Massachusetts, June 15, 1973.

3. "Prepared Direct Testimony of Donald S. Allan on Behalf of Eacosgas LNG, Inc. to the Federal Trade Commission", Docket No. CP 73-88.

4. "LNG Fire Control, Fire Extinguishment and Vapor Dispersion Tests", Report by University Engineers, Inc., Norman, Oklahoma, July 19, 1972.

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