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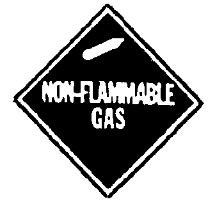
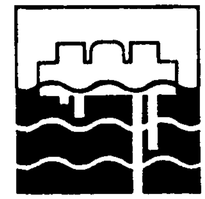
W.P.



NH$_3$



CL$_2$

Guam Coastal Zone Management Program

IMPACT ASSESSMENT OF AMMONIA AND CHLORINE TRANSSHIPMENT RELATIVE TO COMMERCIAL OTEC PLANT OPERATION IN GUAM, USA

GUAM ENERGY OFFICE
TECHNICAL REPORT No 8102

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IMPACT ASSESSMENT OF AMMONIA AND CHLORINE TRANSSHIPMENT RELATIVE TO COMMERCIAL OTEC PLANT OPERATION IN GUAM, USA

A STUDY CONDUCTED FOR

THE GUAM ENERGY OFFICE

GOVERNMENT OF GUAM

COASTAL ENERGY IMPACT PROGRAM

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SUMMARY

A large and varied transportation system exists that can move ammonia and chlorine from producing plants to the OTEC storage tanks.

Anhydrous ammonia and chlorine can be transported to Guam in bulk, handled and stored safely if standard industry safety practices are followed. The transshipment would not create unreasonable health or safety hazards.

Shipment of the chemicals in bulk quantities will require personnel specifically qualified in the bulk transfer of the chemicals involved. The Coast Guard will require that satisfactory documentary evidence be furnished as proof that the person in charge is capable of competently performing all potential operations that could evolve in a cargo transfer of a hazardous chemical. OTEC plant technicians may be able to perform this function.

Bulk shipments of these chemicals will require additional equipment in the form of a pipeline or tank trucks specifically designed for that chemical, in order to transport the chemical from the Commercial Port to the OTEC plant storage tanks.

The facilities at the Commercial Port are best suited for any handling and transfer of ammonia and chlorine as compared to privately maintained facilities adjacent to the Commercial Port. The port would primarily serve a function as a transshipment center and storage area for the chemicals.

A comprehensive plan, to include procedures for general emergencies, fire control, emergency lighting and power systems, first aid, dock emergencies, and responses to releases of all hazardous substances as well as routine Commercial Port operations, should be formulated as soon as possible.

CHAPTER 1

INTRODUCTION

1.1 Study Objectives

The objective of this study is to develop a detailed report on all of the parameters embracing the transfer of large quantities of anhydrous ammonia (NH_3) and chlorine (Cl_2) at the Commercial Port of Guam for delivery to a proposed Ocean Thermal Energy Conversion plant (OTEC). The study focuses on the Commercial Port's involvement in transportation, handling and storage of these two chemicals in the quantities anticipated. The OTEC plant site is presumed to be the Cabras Island site designated by the Government of Guam although transshipment of chemicals to a possible sea based plant is also discussed. The study considers ammonia and chlorine transshipment and is not intended to address details of on-site storage.

1.2 Study Methodology

This study was conducted under the authority of the U.S. Coastal Energy Impact Program (CEIP). The purpose of the CEIP is to study and plan for any economic, social or environmental consequence that is likely to occur as a result of siting, constructing, or expanding energy facilities within the coastal zone.

This study relied on existing literature concerning the transportation, handling and storage of anhydrous ammonia and chlorine and the conceptual and preliminary design studies on OTEC performed by Westinghouse and TRW. Department of Energy Document: Ocean Thermal Energy Conversion Power System Development[1] was used as a reference for conceptual design of the OTEC plant. Anticipated quantities of anhydrous ammonia and chlorine needed to operate a 50 MWe OTEC plant were extrapolated from data contained in these volumes.

The transportation, handling and storage of anhydrous ammonia and chlorine are regulated primarily by three government agencies: the U.S. Coast Guard, Environmental Protection Agency and Occupational Safety and Health Administration. Relevant regulations of these agencies are discussed throughout the report as they pertain to Commercial Port operations.

The Chlorine Institute, Inc. and The Fertilizer Institute are private, nonprofit trade associations organized for the purpose of promoting safety in all aspects of production, handling and use of chlorine and anhydrous ammonia respectively. Their publications were used extensively in the writing of this report.

1.3 Report Format

Chlorine and anhydrous ammonia are individually classified as nonflammable and nonexplosive; they may react violently when in contact with each other. Given their divergent chemical natures, ammonia and chlorine are treated as distinct segments within the report to as great an extent as possible.

Chapter II deals with aspects common to both ammonia and chlorine regarding the Commercial Port and the use of the chemicals in the OTEC plant. Thereafter anhydrous ammonia is discussed in chapters III thru V and chlorine is discussed in chapters VI thru VIII.

CHAPTER II

THE ROLES OF COMMERCIAL PORT OF GUAM AND THE PROPOSED OTEC PLANT IN NH_3 AND CL_2 TRANSFER

2.1 The OTEC Concept

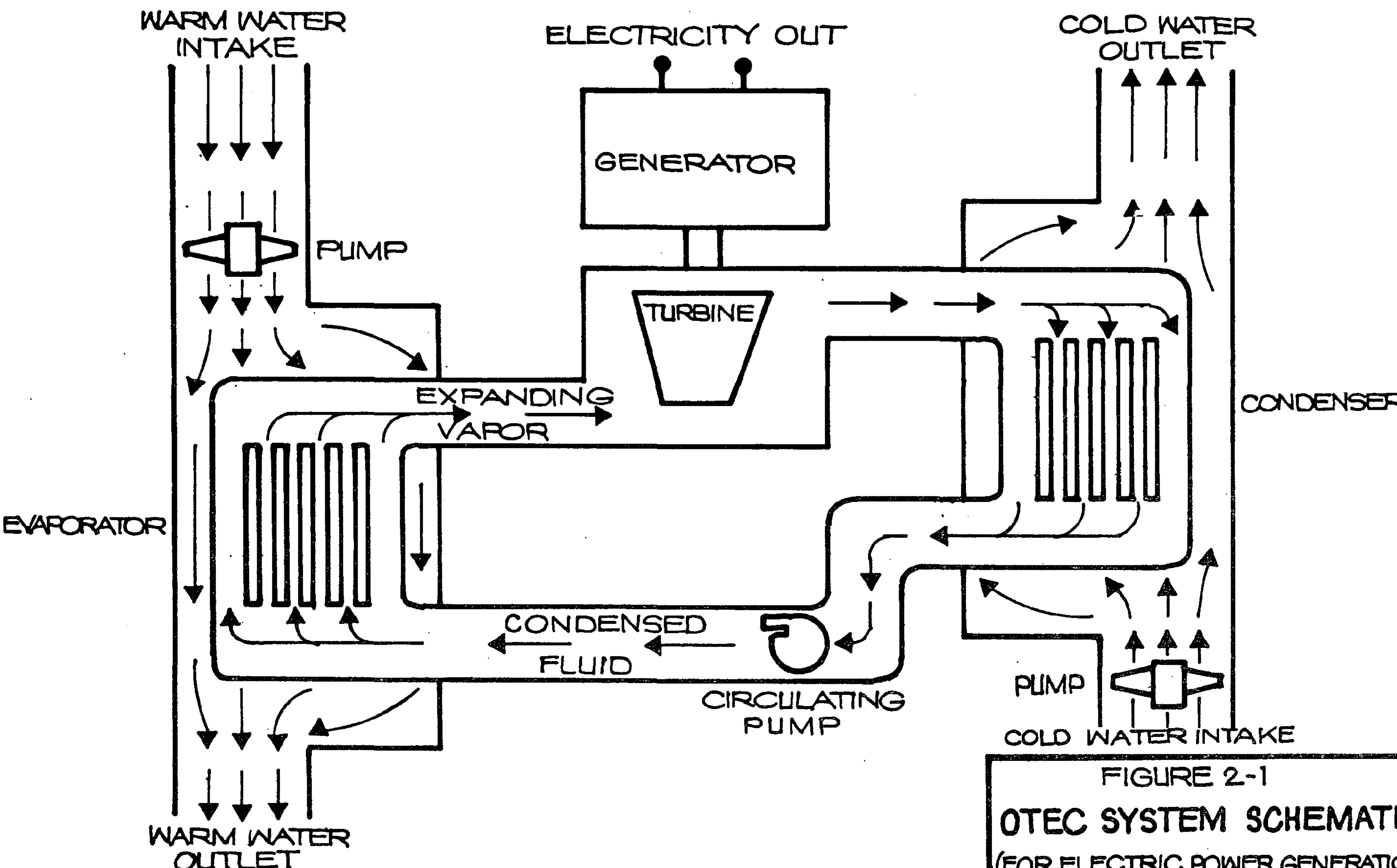
Guam, with almost total dependence on imported petroleum to meet its increasing energy needs, has recognized the need to develop renewable energy resources. Wind, solar and OTEC technology are available now, but OTEC is the singular viable baseload alternate energy resource at this time.

Ocean Thermal Energy Conversion is a method for converting the solar energy stored in warm tropical waters into electrical energy. Approximately one million kilocalories per square yard per year of solar radiation fall on the earth's surface.[2] The oceans store immense quantities of this incident solar energy in the form of heat. Stored thermal energy can be converted to electrical energy in a heat engine by utilizing the warm surface waters as a heat source and the cold deeper waters as a heat sink. Because of the high entropy character of this stored energy and the low resulting efficiency of the heat engine, maximum achievable efficiencies of an Ocean Thermal Energy Conversion plant range between four to ten percent.[3] This means that very large quantities of water must be moved to extract usable amounts of energy. However, the amount of available energy is nearly limitless.

The proposed OTEC plant will utilize anhydrous ammonia as a working fluid. Using warm seawater as a heat source, the ammonia is changed from liquid to vapor within a heat exchanger. The vapor then turns a turbine that is connected to an electrical generator. The ammonia vapor is then recondensed in a second heat exchanger using cold, deep ocean water which has been pumped to the surface. This cycle is repeated continuously. (Figure 2-1)

Biofouling is the growth and deposition of marine organisms on surfaces in contact with seawater. Prevention of biofouling is an important consideration for maximizing heat transfer rates. Although biofouling rates are considerably less on Guam compared with mainland and Hawaii sites, the plant will probably utilize chlorine to prevent biofouling of heat transfer and hydraulic systems. The need for continuous chlorination is assumed, requiring large quantities of the chemical. Most of the plant's chlorine needs can be generated on site, as hypochlorite, by electrolysis. This is discussed further in Chapter VI.

Both ammonia and chlorine have unique individual and combined hazard traits. Hazards associated with the handling of these chemicals by the Commercial Port will be discussed as they pertain to Commercial Port operations.



SOURCE :
GUAM ENERGY OFFICE
GOVERNMENT OF GUAM

FIGURE 2-1
OTEC SYSTEM SCHEMATIC
(FOR ELECTRIC POWER GENERATION)

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2.2 Commercial Port of Guam

Ammonia and chlorine must be imported to Guam, thus necessitating handling and possible storage of these chemicals at the Commercial Port. The Port of Guam is the only commercial seaport on Guam and the principal seaport in Micronesia. It is located at the northeast corner of Apra Harbor. The Commercial Port is vital to Guam because of the import-dependent nature of the local economy.

The Commercial Port consists of a total of 32 acres of land area presently comprising 12 acres of container yard and 2,700 feet of wharf. The land area will increase substantially if the recently completed Commercial Port Master Plan (dated September 1980) is executed.[4] The facilities at the Commercial Port are best suited for any handling and transfer of ammonia and chlorine for OTEC, in comparison to private facilities in the Cabras Industrial Park area.

Approximately 85% of the Port's total annual volume of 650,000 gross revenue tons is containerized cargo. Crude oil, refined petroleum products and cement are transferred through privately maintained facilities in the Cabras Island Industrial Park, adjacent to the Commercial Port. Figure 2-2 depicts present configuration of the Commercial Port and surrounding area.

At the present time, Guam is served by eleven regularly scheduled steamship lines, two in the United States-Guam trade, seven in inter-regional trade with foreign areas, and three in intra-regional trade including transhipment with Micronesia.

2.3 Proposed OTEC Plant Site

The prime consideration in siting a land-based OTEC plant is proximity to cold, deep, ocean water which can be pumped a minimum distance to the facility. Proximity of the OTEC plant to deep ocean waters reduces the costs of construction and minimizes the warming of the cold water prior to its delivery at the plant.

An additional site consideration for an OTEC plant is its need for an extensive electrical distribution network. Proximity to the existing power plants will preclude construction of a major electrical network for the plant.

The requirements for deep ocean water and an electrical distribution network are both met by the proposed location on Cabras Island, (see Figure 2-2). Waters 3,000 feet deep occur within a mile from shore. In addition, the proposed site is adjacent to the Piti and Cabras power plants which comprise the major electrical switching center for Guam.

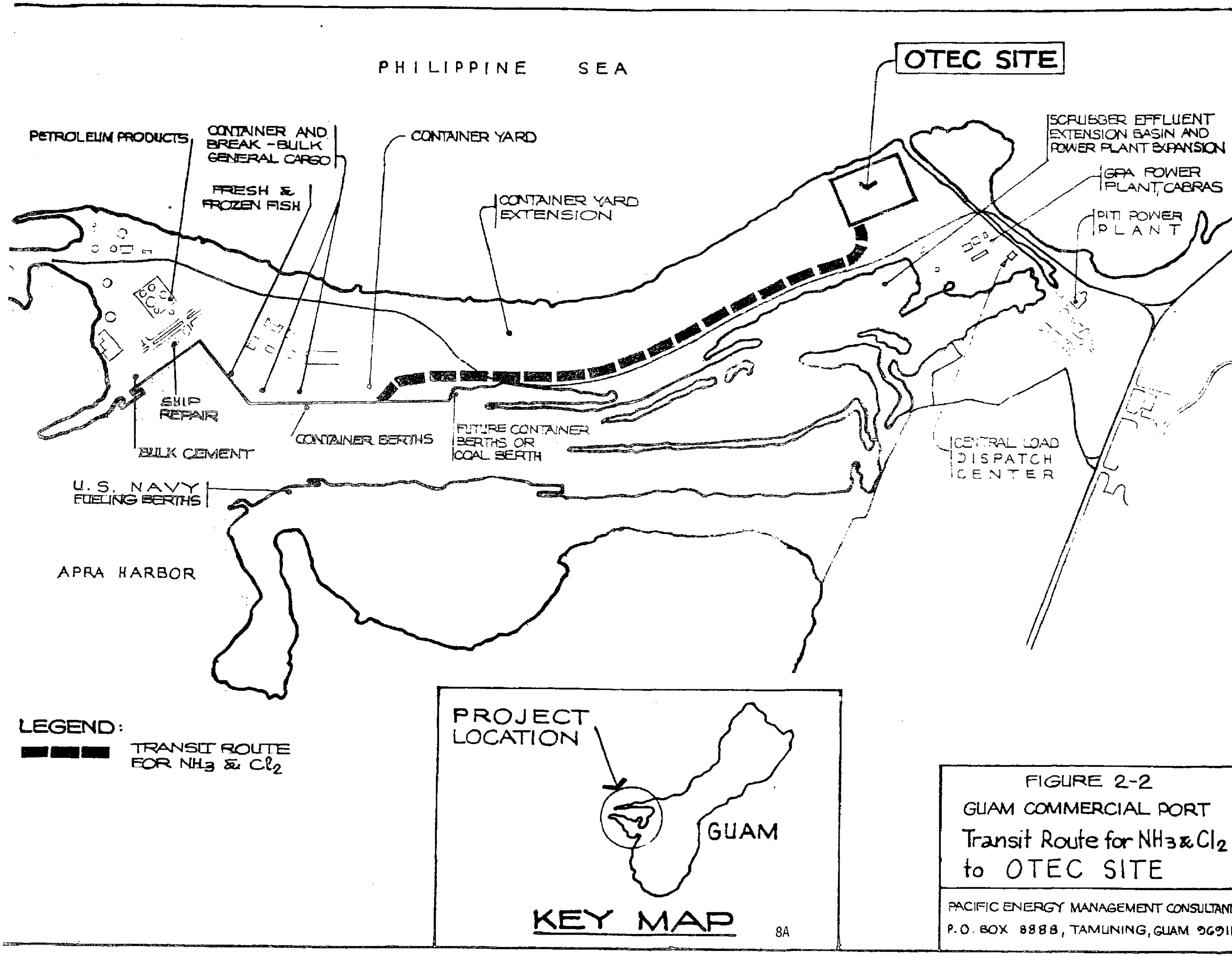

FIGURE 2-2
GUAM COMMERCIAL PORT
Transit Route for NH_3 & Cl_2 to OTEC SITE

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The 1980 Master Plan for the Commercial Port and surrounding area recommends that the land northwest of Cabras Power Plant be reserved for the OTEC plant or for an alternative coal storage site. This area is approximately one mile from the Commercial Port and adjacent to the power plants.

The focus of this study is on the land-based OTEC plant. Guam is unique in its proximity to deep ocean water which can be pumped a short distance to the OTEC plant. Waters 3,000 feet deep occur close to shore in the vicinity of the glass breakwater.

An alternative to the land-based system is the sea-based OTEC facility. The OTEC equipment would be contained in a large vessel commonly called a platform. Several designs have been proposed, either dynamically positioned or moored. A sea-based facility would be positioned about 1-1/2 miles off the Glass Breakwater and the mouth of Apra Harbor.

The considerations and constraints associated with a land-based OTEC plant would be relevant to a sea-based system. The Commercial Port would primarily serve a function as a transshipment center and storage area for anhydrous ammonia and chlorine. Handling procedures, health hazards, personal protective equipment and such like would be equally applicable to transshipment operations. The potential for an accident would be increased somewhat due to the increased handling of the products.

The initial shipment of ammonia can be delivered directly to the OTEC platform without any need for Commercial Port handling of the chemical. Subsequent shipments of make up quantities in containers would involve the port in handling and storage.

A sea-based plant would necessitate storage of chemical at the Commercial Port given the limited space on board the platform and the shipping distances and time frames involved in re-supply from off-island. The additional space needed cannot be quantified at this time. If the recommended expansion of the container yard is undertaken, ample storage area will be available.

A sea-based plant would increase the Commercial Ports handling and storage of hazardous chemical and would effect the quantity, mode and frequency of hazardous chemical shipments.

CHAPTER III

QUANTITIES AND PROPERTIES OF AMMONIA

3.1 Required Quantities And Importation of Ammonia

Ammonia has been produced commercially for use in refrigeration equipment for at least one hundred years. A large and varied transportation system exists that can move ammonia from producing plants to the OTEC storage tanks.

Ammonia is stored as a liquid either in refrigerated tanks at atmospheric pressure or in unrefrigerated carbon steel pressure vessels. In order to avoid the operating and maintenance costs involved with a refrigerated system, the ammonia system for the OTEC plant includes pressurized storage vessels.

The ammonia storage system for the 50 MWe OTEC plant is anticipated to consist of fourteen 30,000 gallon pressurized vessels or a total of 420,000 gallons.[5] These tanks will be located at the OTEC plant site. There will be no permanent storage of ammonia at the Commercial Port. The quantity (420,000 gallons) required to initially charge the system can be shipped in bulk via barge, small tanker or break-bulk in containers as described in Chapter V. If system losses during plant operation prove to be minimal, replenishment quantities of the chemical could be shipped thereafter in break-bulk.

There are no local producers of anhydrous ammonia on Guam. Ammonia in the quantities required for OTEC, therefore, must be imported via shipping vessels. Whether the source of the chemical is foreign or domestic is immaterial to Commercial Port operations, provided all pertinent U.S. regulations governing the transportation, handling and storage of ammonia are met.

3.2 Properties and Hazards of Ammonia

Although the explosion and fire hazards associated with NH_3 are limited, the health hazards are serious. The objective of this section is to identify the hazards that will be presented in the transportation, handling and storage of this chemical.

At atmospheric pressure, liquid ammonia boils at about $-28^{o}F$; at a vapor pressure of about 108 psia, it boils at $60^{o}F$. Ammonia can be in a liquid state when either refrigerated or at ambient temperature depending upon storage pressure. Ammonia is very soluble in water, and the dissolution process is exothermic. Releases of ammonia are harmful for two primary reasons: first, the vapor is toxic, and second, a solution of ammonia in water (ammonium hydroxide) is deadly to both flora and fauna.

The major hazard from an ammonia vapor cloud is its toxicity. Ammonia is an extremely irritating gas, even in relatively small concentrations. In the case of excessive exposure, deleterious reactions from anhydrous ammonia occur in the upper respiratory tract as spasms, inflamation, or edema of the larynx. Fortunately, the human olfactory system is capable of detecting the presence of ammonia long before the toxic limit is reached. These hazards and safety precautions are discussed in Chapter IV.

TABLE 3-1

CHEMICAL AND PHYSICAL PROPERTIES OF AMMONIA

Chemical Formula	NH_3
Molecular Weight	17.03
Boiling Temperature at Atmospheric Pressure, C	-2.22 (-28.0 F)
Freezing Temperature at Atmospheric Pressure, C	-77.77(-108.0 F)
Critical Temperature, C	133.0 (271.4 F)
Critical Density, lb per cu ft	14.6
Density of Liquid at -28.0 F, lb per cu ft	42.56
Specific Volume of Saturated Vapor at -28.0 F, cu ft per lb	18.00
Specific Heat of Liquid at 86 F, Btu per (lb) (F)	1.143
Color	Clear and water white
Odor and Detection	Irritating, odor, readily detectable by smell. Burning sulphur used for locating leaks.
Flammability Limits (Per cent by volume)	15 to 25
Toxicity, Underwriters' Laboratories Classification	Group 2

CHAPTER IV

HAZARDS AND SAFETY PRECAUTIONS FOR AMMONIA

4.1 General

The hazards of ammonia have been well investigated because of its long use as a refrigerant and agricultural fertilizer. Anhydrous ammonia possesses the potential to inflict serious personal injury. A mishap involving ammonia will usually cause the victim great pain and may well blind him if contact with the chemical is on the face.

Under normal atmospheric conditions, anhydrous ammonia in an open vessel is always boiling and escaping into the atmosphere. To prevent its escape, the anhydrous ammonia is stored in pressurized vessels. Anhydrous ammonia weighs approximately 5 pounds per gallon. The weight per gallon varies with the pressure and temperature. It is stored, transported, and otherwise handled as a liquid under pressure in cylinders and tanks. It may also be stored under refrigerated conditions.

Upon release into the atmosphere, liquid ammonia vaporizes and expands rapidly. As vapor it occupies about 850 times its liquid volume. Liquid ammonia absorbs heat as it vaporizes and expands into a gas. This property makes ammonia useful as a refrigerant. Liquid ammonia released suddenly to the atmosphere usually results in a white cloud of water vapor, which lasts a short time until dispersed by air currents. This cloud is formed by the condensation of water vapor in the air surrounding the liquid ammonia.

4.2 Ammonia Vapor Hazards

Ammonia can be released in two fashions. The first is the release of gas or liquid in a continuous emission over a finite period of time. The second is the instantaneous or slug release in which the material is released in a very short period of time, as in the catastrophic failure of a pressurized container or a pipeline.

The failure of a valve or fitting on a container or pipeline usually results in a continuous release, and the downwind hazard prevails as long as the emission continues. When such a failure is associated with a container, the rate of emission will steadily decrease as the pressure within the vessel decreases. The rate of emission from pipeline ruptures will depend on the line size, pressure, flow rate, line contents (liquid or gas), and the time to stop the flow. The area affected by a gaseous release is dependent upon the quantity released, rate of emission, total elapsed time of emission, atmospheric conditions and the terrain.

Timely evacuation of an area contaminated by an ammonia discharge may not always be possible. Recommended evacuation distances are listed in Table 4-1, based on a prevailing wind of 6-12 mph. The safe evacuation distance may not be practical to

TABLE 4-1

EVACUATION TABLE - BASED ON PREVAILING WIND OF 6-12 MPH

Approximate Size of Spill	Distance to Evacuate From Immediate Danger Area	For Maximum Safety Downwind Evacuation Area Should Be
200 square feet	40 yards (48 paces)	1,056 feet long, 528 feet
400 square feet	60 yards (72 paces)	1,584 feet long, 1,056 feet wide
600 square feet	80 yards (96 paces)	2,112 feet long, 1,056 feet wide
800 square feet	90 yards (108 paces)	2,112 feet long, 1,584 feet wide

In the event of an explosion, the minimum safe distance from flying fragments is 2,000 feet in all directions.

Source: Emergency Action Guide for Selected Hazardous Materials, 1978.

attain. In such circumstances personnel should remain upwind of spills or leaks, if possible, or remain indoors with windows shut until the hazard has passed.

4.3 Personal Protective Equipment

Skin, eye or respiratory contact is not likely to occur except during nonroutine operations involving accidental release of ammonia into the atmosphere. The American National Standard Institute (ANSI) requirements recommend that all storage areas have on hand, as a minimum, the following equipment for emergency and rescue purposes

(1) One full face mask with anhydrous ammonia refill canisters
(2) One pair of protective gloves
(3) One pair of protective boots
(4) One protective slicker
(5) Easily accessible shower and/or at least 50 gallons of clean water in an open container
(6) Tight-fitting vented goggles or one face shield

Gloves, boots, slickers, jackets and pants should be made of rubber or other material impervious to ammonia.

4.4 Storage Area Precautions

Consideration must be given to the physiological effects of ammonia as well as to adjacent fire hazards. Storage areas must be kept free from oxidizers and readily ignitible materials such as waste and weeds.

Chlorine is incompatible and may react violently with ammonia. These materials may not be stored immediately adjacent to each other.

4.5 Labeling/Posting

All shipping containers of ammonia must bear the label shown in Figure 4-1 in addition to, or in combination with, labels required by other statutes.

The following warning sign should be affixed in a readily visible location at or near entrances to areas containing anhydrous ammonia and in which there is a reasonable potential for emergencies. This sign should be printed both in English and in the predominant languages of non-English-speaking workers. All employees should be trained and informed of the hazardous areas, with special instruction given to illiterate workers.

FIGURE 4-1

AMMONIA SHIPPING LABEL

AMMONIA, ANHYDROUS

DANGER! HAZARDOUS LIQUID AND GAS

LIQUID CAUSES BURNS

GAS EXTREMELY IRRITATING

DO NOT BREATHE GAS

DO NOT GET IN EYES, ON SKIN, ON CLOTHING

IN CASE OF EXPOSURE, EVACUATE TO FRESH AIR

IN CASE OF CONTACT, IMMEDIATELY FLUSH

SKIN OR EYES WITH PLENTY OF WATER FOR

AT LEAST 15 MINUTES. GET MEDICAL ATTENTION

AT ONCE IN CASE OF EYE CONTACT OR BURNS

TO THE NOSE OR THROAT, OR IF THE PATIENT IS UNCONSCIOUS.

WARNING!

AMMONIA HAZARD AREA

UNAUTHORIZED PERSONS KEEP OUT

CAUSES BURNS, SEVERE EYE HAZARD

INHALATION OF HIGH CONCENTRATIONS MAY BE FATAL

GAS MASKS LOCATED AT ______________________ [6]

4.6 Fire Hazard

While not considered to be a serious fire or explosion hazard, ammonia will burn or explode under some conditions, such as a large, intense source of ignition and a high concentration of ammonia gas. The presence of iron appreciably decreases the ignition temperature, and the presence of oil or a mixture of ammonia with other flammable substances increases the fire hazard. Increasing the oxygen content of the air or increasing the temperature and pressure of the ammonia broadens the flammable (explosive) range. Contact with other chemicals such as mercury, silver oxide, iodine, chlorine halogens, calcium, and hypochlorite can cause spontaneous explosions due to chemical reactions.

4.7 Leak Hazard

A leak in an ammonia system can be detected by odor. The location of the leak may be determined with moist phenolphthalein or red litmus paper which change color in an ammonia vapor. Another means of detection is the use of sulfur dioxide, which forms a white fog in contact with ammonia vapor.

Only personnel trained for and designated to handle emergencies should attempt to stop a leak. Respiratory equipment of a type suitable for ammonia must be worn. All persons not so equipped must leave the affected area until the leak has been stopped.

If ammonia vapor is released, the irritating effect of the vapor will force personnel to leave the area long before they have been exposed to dangerous concentrations. With good ventilation or rapidly moving air currents, ammonia vapor, being lighter than air, can be expected to dissipate readily without further action being necessary.

4.8 Health Hazards

4.8.1 Warning Properties

At atmospheric temperatures and presures, ammonia is a pungent and colorless gas and serves as its own warning agent; special detection meters are not necessary to determine dangerous concentrations of ammonia vapor. The human nose will detect ammonia vapor in concentrations far below the injurious level. The odor is so uncomfortable that personnel will not voluntarily remain exposed to injurious concentrations. Table 4-2 shows the general physiological effects of selected concentrations of ammonia.

4.8.2 Severe Exposure

There are a number of well documented cases of severe exposure to ammonia.[7] The severity of the symptoms is, of course, a function of the degree of exposure. Some symptoms which may be expected if exposure is severe are irritation to inflammatory processes of the entire respiratory tract, pulmanary edema, bronchopneumonia, acute skin burns, and eye injury among others.

4.8.3 Exposure Countermeasures

4.8.3 (a) Inhalation

Exposed persons must be removed at once to an uncontaminated area. If the exposure has been to minor concentrations for a limited time, usually no treatment will be required.

When there is severe exposure to higher concentrations, and if oxygen apparatus is available, oxygen can be administered but only by a person authorized by a physician. If the patient is not breathing, an effective means of artificial respiration must be initiated immediately. Call a physician.

TABLE 4-2

PHYSIOLOGICAL EFFECTS OF AMMONIA

CONCENTRATION NH_3 VAPOR (PPM)	PERCENT	GENERAL EFFECT	EXPOSURE PERIOD
50	1/200	Odor detectable by most persons.	Prolonged, repeated exposure produces no injury.
100	1/100	No adverse affects for average person	Maximum allowable concentration for 8-hour working exposure.
400	4/100 to 7/100	Nose and throat irritation. Eye irritation with tearing.	Infrequent short (1 hour) exposures ordinarily produce no serious effect.
2,000 to 3,000	2/10 to 3/10	Convulsive coughing; severe eye irritation.	No permissible exposure. May be fatal after short exposure.
5,000 to 10,000	1/2 to 1	Respiratory spasm. Rapid asphyxia.	No exposure permissible. Rapidly fatal.

Source: Operational Safety Manual for Anhydrous Ammonia

The patient should be kept comfortably warm but not too hot and kept at rest. Never attempt to give anything by mouth to an unconscious patient.

4.8.3 (b) Taken Internally

If liquid anhydrous ammonia has been swallowed, call a physician immediately. If the patient is conscious and able, he should drink large amounts of water to dilute the chemical. Do not induce vomiting if the patient is in shock, extreme pain or unconscious. If vomiting begins, place the patient face down with head lower than hips. This prevents vomitus from entering the lungs and causing further injury.[8]

4.8.3 (c) Contact With The Eyes

While respiratory injuries may be lethal and skin burns disfiguring, eye injuries constitute the most serious hazard in regard to permanent disability. Ammonia is one of the most damaging substances affecting the eyes. Ammonia is fat-soluble but the key to its rapid penetration is its extreme solubility in water and its destructiveness in an alkaline solution. Because of the rapid penetration of ammonia, even prompt flushing will not remove all of the chemical. Although complete elimination of the chemical is hopeless, the degree of injury varies with duration of exposure; rapid, copious flushing is essential to limiting damage.

4.8.3 (d) Contact With Skin and Mucous Membranes

Speed in removing ammonia from contact with the patient and in moving the patient to an uncontaminated atmosphere is of primary importance. If skin contact is extensive and emergency showers available the employee should get under the shower. Flushing with large amounts of running water should be continued for at least 15 minutes.

Under no condition should salves or ointments be applied to the skin or mucous membrane burns during the 24-hour period following the injury. Subsequent medical treatment is otherwise the same as for thermal burns.

4.8.4 Procedures For Obtaining Medical Assistance

Procedures specified below should be formulated in advance and employees should be instructed and drilled in their implementation. Procedures should include assignment of individual and/or team responsibilities and pre-arranged plans for:

1. Immediate evacuation of workers with signs or symptoms of adverse effects resulting from exposure.

2. Transportation of injured persons to medical facilities.

3. Any necessary calls to alert medical facilities of the impending arrival of injured persons.

4. Designation of medical receiving facilities and names of physicians trained in anhydrous ammonia emergency procedures.

4.8.5 Suggestions to Physicians

There is no specific treatment for over-exposure or direct local contact to anhydrous ammonia vapors. Oxygen has been found useful in the treatment of inhalation exposures of many chemicals, especially those capable of causing either immediate or delayed harmful effects in the lungs.[9]

In most exposures, administration of 100% oxygen at atmospheric pressures has been found to be adequate. This is best accomplished by use of a face mask with a reservoir bag of the non-rebreathing type. Inhalation of 100% oxygen should not exceed one hour of continuous treatment. After each hour therapy may be interrupted; and it may be reinstituted as the clinical condition indicates.[10]

Some believe that superior results are obtained when exposures to lung irritants are treated with oxygen under an exhalation pressure not exceeding 4 cm water.[11] Masks providing for such exhalation pressures are obtainable. A single treatment may suffice for minor exposures to irritants. It is believed by some observers that oxygen under pressure is useful as an aid in the prevention of pulmonary edema after breathing irritants.

Caution: It may not be advisable to administer oxygen under positive pressure in the presence of impending or existing cardiovascular failure.

4.9 Personnel Safety Training

4.9.1 Informing Employees of Hazards of Ammonia

At the beginning of employment, workers whose jobs may involve exposure to ammonia should be informed of the hazards, relevant symptoms of overexposure, appropriate emergency procedures, and precautions to ensure safe use and to minimize exposure. First aid procedures should be included, with emphasis on the importance of prompt, copious irrigation of the eyes despite the initial lack of pain. The information must be posted in the workplace and kept on file, readily accessible to workers at all places of employment where ammonia is involved.

A continuing educational program, conducted by a person or persons qualified by reason of experience or special training, must be instituted to ensure that all workers have current knowledge of job hazards, first-aid procedures, maintenance procedures and clean up methods, and that they know how to use respiratory protective equipment and protective clothing. Retraining should be repeated at least annually.

4.9.2 Training and Drills

Members of emergency teams and employees who will work adjacent to ammonia systems where a potential for emergencies due to ammonia exists should be subjected to periodic drills simulating emergency situations appropriate to the work situation. These should be held at intervals not exceeding 6 months. Drills should cover, but not be limited to, the following:

1. Evacuation procedures;
2. Handling of spills and leaks, including decontamination and use of emergency repair kits;
3. Location and use of emergency firefighting equipment;
4. Handling of containers in case of fire;
5. First aid and rescue, including procedures for obtaining medical care;

6. Location, use, and care of protective clothing and respiratory equipment;
7. Location and use of shut-off valves;
8. Location, reason for, and use of safety showers, eyewash fountains, and other sources of water for emergency use;
9. Operating procedures;
10. Entry procedures for confined spaces; and
11. Emergency phone numbers.

CHAPTER V

TRANSPORTATION OF AMMONIA

Anhydrous ammonia can be imported to Guam in bulk, break-bulk, or a combination of both. The final decision on shipping mode will depend upon the results of a detailed cost analysis. Such an analysis is beyond the scope of this present work. In this study the influence on Commercial Port operations during receipt and handling of both bulk and break-bulk shipments are discussed.

5.1 Containerized Break-Bulk Shipment

Break-bulk shipment of ammonia is shipment in tanks mounted on the chassis of open hopper containers. Tanks transported in this manner are handled in the same fashion as other containerized cargo and require no equipment not presently available at the Port. The Commercial Port is primarily a containerized operation now, with 85% of the general cargo being containerized.

In a typical unloading scenario, the containers are removed from the ship by gantry crane, placed on a chassis and taken directly to the plant site. In the event that the containers cannot be taken directly to the plant site because of either insufficient chassis or storage space at the OTEC plant, the Commercial Port container yard space will have to be reserved. The current Master Plan for the Commercial Port recommends expansion of the existing container yard facilities. A temporary storage area must be designated prior to delivery of a container shipment in event that immediate transfer to the OTEC plant is delayed. It is anticipated that adequate storage space will be available at the OTEC plant site for containers.

Portable tanks should be removed from the Commercial Port as soon as possible. If temporary storage is necessary, the tanks must be kept away from sources of heat, including direct sunlight, that could increase the ammonia gas pressure, activating the relief valve. Care must be taken to prevent mechanical damage to the container and its appurtenances.

An accident involving a motor vehicle transporting a portable tank can create a serious hazard. Only persons engaged in the removal of such a hazard and wreckage should be allowed near the accident scene. The rescue and salvage operation should be supervised by competent personnel experienced in handling ammonia. Telephone notice of ammonia related accidents must be given by the carrier to the DOT and followed with a written report. These requirements are covered by 49 CFR 171.15, 171.16, 177.854 and 177.859. Motor vehicle requirements are discussed in section 5.2.2.

The hazardous chemical transfer route from the Commercial Port to the OTEC plant is uninhabited with no intersections or transit trafic. The route is approximately one mile from the Port to the OTEC plant. (Figure 2-2)

Portable tanks used for transportation of ammonia must comply with current DOT specifications.[12] This is of concern if the ammonia is procured from a foreign source. These tanks are designed to be temporarily attached to a motor vehicle and equipped with skids, mountings or accessories to facilitate handling of the tank by mechanical means.

5.2 Bulk Shipment

Anhydrous ammonia can be shipped in bulk quantities via barge or small tanker. The quantity of ammonia initially required is about 420,000 gallons. Two viable options for transshipment of the chemical from the port to the OTEC plant site are pipeline or tank truck.

5.2.1 Ammonia Pipeline

Should a pipeline be installed for transportation of anhydrous ammonia from the port to the OTEC plant, the most probable location for the receiving manifold would be in the area of Wharf F-6, as depicted on Figure 2-2.

The F-6 location at the east end of the Commercial Port, is close to the proposed OTEC plant site and offers the least interference with other berthing areas and container yard activities. In addition, the distance from Wharf F-6 to the

Commercial Port office complex is approximately 2,000 feet and offers maximum downwind safety in event of a hazardous chemical spill or leak.

Other potential receiving areas for bulk ammonia shipments are the Mobil, GORCO and Navy fuel piers. Each of these facilities are a greater distance than F-6 to the proposed OTEC plant site and offer no advantage over the Commercial Port location. The existing oil pipelines at these facilities cannot be used for ammonia transfer.

A fixed piping system from the Commercial Port to the proposed OTEC plant site will be about one mile in length. Fixed piping, either surface or underground, will require a considerable investment. The system can be expected to be idle for long periods of time while incurring maintenance costs. Due to the high concentration of salt spray on Cabras Island, pipeline maintenance costs are high. An aboveground pipeline would be subject to vehicle collisions and will require periodic painting, leak tests, and cathodic protection among other procedures. Both aboveground and underground pipelines are subject to earthquake damage.

A thorough engineering study of an ammonia pipeline is required before a final decision; the pipeline may require unconventional equipment design and pressure ratings to solve potential problems.

5.2.1 (a) Pipeline Leaks

The problem of potential leaks is present in any pipeline. Consequences of a leak and means of minimizing or handling leaks must be considered in the early stages of design.

Leaks in ammonia handling equipment must be repaired immediately. Some repairs are simple: valve packing gland leaks may require only tightening of the nut. Other repairs, however, require that all ammonia be purged from the system before attempting to dismantle or repair it. All repairs must be made in compliance with the code under which the pipe is fabricated. Only code welding is permitted on pressure vessels, after completely purging the line with nitrogen or water.

The presence of ammonia leaks is ordinarily obvious from scent; the nose detects ammonia fumes in minute quantities. Locating leaks, however, will often require special equipment and procedures. One method of testing uses moistened strips of red litmus paper which turn blue in the presence of ammonia; another uses sulfer dioxide, which forms a white fog in contact with ammonia vapor.

5.2.1 (b) Routing

Special care must be given to design criteria for long pipelines due to the amount of ammonia which they may contain. Also, the potential liability to the owner and/or operator of a pipeline in event of leaks must be considered. Any above ground line is subject to the hazards of fire; the route should be cleared of grass, brush, and other combustible materials.

5.2.1 (c) Government Regulations

Code of Federal Regulations, Title 49, Chapter 1, Parts 190-192 and 195 govern the transportation of gas by pipeline; subparts included cover "Accident Reporting", "Design Requirements", "Construction", and "Operation and Maintenance".

5.2.1 (d) Design

Moist ammonia corrodes copper, zinc and their alloys. Iron and steel are, therefore, ordinarily used in piping and fittings. Extra heavy steel (Schedule 80) is preferable for ammonia pipeline and welded, not threaded, joints must be used. Only all steel pressure gages must be used. Furthermore, any pumps or compressors used for ammonia must be expressly recommended and labeled for that purpose by the manufacturer. Buried pipelines must be protected by a suitable cathodic protection system.

5.2.1 (e) Installation

Pipelines may be installed above or below ground. The entire system should be evaluated to determine the preferred installation. For monitoring purposes, the above ground system is preferred. An above ground installation must be designed so as to preclude damage by vehicles.

If an ammonia line is run in a pipe rack where it shares space with other pipelines carrying flammable materials, the ammonia line should be protected from fire resulting from a leak or break in one of the other lines. Such protection can be achieved through: (1), adequate physical separation of the line; (2), erection of a steel barrier between lines; or (3), proper insulation of the line with a fire-resistant material.

Above ground or buried pipelines must be suitably marked at intervals of not over 200 feet. Permanent metal signs are recommended. Recommended wording for liquid lines is: "Liquified Gas Under Pressure--Ammonia". In addition, the name and telephone number of the operator must be shown.

5.2.2 Tank Trucks

A barge or small tanker could unload ammonia into tank trucks designed specifically for that chemical. The maximum tank capacity is restricted by highway weight load limits (76,000 lbs.). Two 8,000 gallon capacity tank trucks can transfer 420,000 gallons of ammonia from a barge or small tanker to the proposed OTEC plant site in approximately 30 hours. The U.S. Coast Guard has required minor improvements to Route 11 prior to authorizing transshipment of explosives by truck. Maintenance and repair work (fixing pot holes, soft shoulders etc.) can be required prior to transshipment if deemed necessary by the Coast Guard.

5.2.2 (a) Trailers and Semitrailer Requirements

Trailers must be firmly and securely attached to their tractors by means of suitable drawbars, supplemented by suitable safety chain or safety cables.

Every trailer or semi-trailer must be equipped with an emergency braking system to be activated in the event of a hitch failure.

5.2.2 (b) Protection Against Collision

Each tank motor vehicle must be provided with properly attached bumpers or chassis extensions to protect the tank, piping, valves and fittings from physical damage in case of minor collision.

5.2.2 (c) Safety Equipment

All tank trucks, trailers and semi-trailers must be equipped with the following equipment for emergency and rescue purposes:[13]

One full face mask with anhydrous ammonia refill canisters.

One pair of protective gloves made of rubber or other material impervious to ammonia.

Tight-fitting goggles or one full face shield.

A container of not less than five gallons of readily available clean water.

Additionally, special markings indicating the special characteristics of the ammonia cargo must be displayed on the vehicle in accordance with Title 49, Code of Federal Regulations.

CHAPTER VI

QUANTITIES AND PROPERTIES OF CHLORINE

6.1 Required Quantities and Importation of Cl_2

A chlorination system is provided in plant design to control biofouling of heat transfer and hydraulic systems. Prevention of biofouling is an important consideration for maximizing heat transfer rates. Biofouling is caused by development and deposition of micro-organisms and marine growth on surfaces in contact with seawater. Although chlorination has been selected as the primary method to control biofouling, a supplemental system may be incorporated if data at the time of installation indicates that chlorination is not sufficient to control biofouling.[14]

Chlorine can be generated on-site, in the form of hypochlorite, by passing a direct current through seawater:

$$NaCl + H_2O + \text{Electric Current} \Rightarrow NaOCl + H_2$$

The chlorine dosage is expected to be 0.25 ppm into the evaporator seawater and 0.1 ppm into condenser seawater.[15] This amounts to approximately 11,700 lbs. of chlorine per day.[16][17] Although not specifically stated in the preliminary design studies, the plant is expected to be able to produce its total daily chlorine needs while in operation.

The total cost and effectiveness of alternate fouling control methods will ultimately determine the system chosen to control biofouling. These costs include capital, installation, operating, maintenance, and parasitic power requirements. Chlorine can be added in the form of gaseous chlorine, concentrated hypochloride or on-site electrolytically generated dilute hypochlorite. The latter method of on-site generation is preferred at present for reasons of cost, safety and equipment availability.

Effective biofouling control will be required from the first day of flooding the system.[18] In addition, yearly maintenance schedules will require plant shutdown for approximately two weeks. During these periods on-site generated chlorine will not be available. Therefore, for the purposes of Commercial Port planning, limited importation of chlorine should be assumed.

6.2 Properties and Hazards of Chlorine

The properties of chlorine (in the form of hypochlorite) applicable to OTEC are its effectiveness in deterring marine biofouling. In addition this chemical can be electrolytically generated on-site realizing savings in procurement and transportation.

Chlorine is a chemical element. Neither its gas nor liquid state is explosive or flammable; however, both react chemically with many substances. Chlorine is only slightly soluble in water. The gas has a characteristic odor and greenish yellow color and is about two and one-half times as heavy as air. Thus, if it escapes from a container or system, it will seek the lowest adjacent level. Liquid chlorine is transparent, amber in color and is about one and one-half times as heavy as water. At atmospheric pressure, it boils at about $150^{o}F$ and freezes at about $-30^{o}F$. One volume of liquid chlorine, when vaporized, will yield about 460 volumes of gas. Chlorine is very reactive when moisture is present.

Chlorine is classified as nonflammable and nonexplosive. The major hazard associated with chlorine is toxicity. Some symtoms from severe exposure are pulmanary congestion, difficult or labored breathing, burning of the eyes, throat, skin or nasal passages, choking, nausea, and vomiting. Hazards and safety considerations associated with Cl_2 are discussed in Chapter VII.

TABLE 6-1

CHEMICAL AND PHYSICAL PROPERTIES OF CHLORINE

Molecular weight	70.906 g/mole
Vapor pressure, 21 C	6.0 kg/sq cm gage (85.3 psig)
Specific volume, 21 C, 1 atm	0.34 liters/g
Boiling point, 1 atm	-34 C
Freezing point (bp), 1 atm	-101 C
Specific gravity of gas at 0 C, 1 atm (air = 1)	2.49
Specific gravity of liquid at 20 C	1.41
Density of gas at 0 C, 1 atm	3.214 g/liter
Density of liquid at 0 C, 3.65 atm	1468 g/liter
Critical temperature	144 C
Critical pressure	78.64 kg/sq cm absolute (76.1 atm)
Latent heat of vaporization at bp	68.8 calories/g
Solubility in water at 20 C, 1 atm	7.30 g/liter
Color of gas	Yellowish green
Color of liquid	Clear amber
Flammability	Nonflammable
Reactivity	Highly reactive
Odor	Disagreeable, strong, suffocating, pungent, irritating, characteristic

CHAPTER VII

HAZARDS AND SAFETY PRECAUTIONS FOR CHLORINE

7.1 General

Chlorine gas is primarily a hazardous respiratory irritant. It is so intensely irritating that very low concentrations in the air are readily detectable. In higher concentrations the severely irritating effect of the gas makes it unlikely that any person would remain in a chlorine contaminated atmosphere unless he is unconscious or trapped.

When a sufficient concentration of chlorine gas is present, it will irritate the mucous membranes, the respiratory system and the skin. Large amounts cause irritation of eyes, coughing and labored breathing. If the duration of exposure or the concentration of chlorine is excessive, general excitement of the person affected results, accompanied by restlessness, throat irritation, sneezing and copious salivation. Additional symptoms of exposure to high concentrations are retching and vomiting, followed by difficult breathing. In extreme cases, the difficulty of breathing may increase to the point where death can occur from suffocation.

7.2 Chlorine Vapor Hazards

A hazardous chemical can be released in two fashions. The first is the release of gas or liquid in a continuous emission over a finite period of time. The second is the instantaneous or slug release in which the material is released in a very short period of time, as in the failure of a pressurized container.

The failure of a valve or fitting on a container usually results in a continuous release, and the downwind hazard continues as long as the emission continues. When such a failure is associated with a container, the rate of emission will steadily decrease as the pressure within the vessel decreases. The area affected by a gaseous release is dependent upon the quantity released, the rate of emission, the total elapsed time of emission, the atmospheric conditions and the terrain.

The timely evacuation of a contaminated area by chlorine discharge may not always be possible. Furthermore, the safe evacuation distance may not always be practical to attain. In such circumstances, personnel should remain upwind of spills or leaks if possible or remain indoors until the hazard has elapsed.

7.3 Personal Protective Equipment

Normal work clothing will provide all the protection that is required for the period of time it takes to escape from an emergency. Skin, eye or respiratory contact is not likely to occur except during nonroutine operations involving accidental release of chlorine into the atmosphere. Protective clothing should never be required under routine operating conditions. When an emergency occurs, the personnel in the area would be expected to escape from the hazard without special protective clothing.

Possible exposure to chlorine gas in the performance of essential duties of rescue, fire and emergency repair crews will necessitate availability of rubber clothing, including boots and hoods in combination with some form of life support system. When such is used, it is essential that it be used by persons who have been specifically and recently trained in the use and limitations of such equipment.

7.4 Storage Area Precautions

Chlorine should be stored in adequately ventilated unoccupied warehouses or outdoors shielded from the direct rays of the sun, unless the containers are properly insulated and designed for unshaded outdoor storage. Consideration must be given to the physiological effects of chlorine as well as to adjacent fire hazards. Storage areas must be kept free from oxidizers and readily ignitable materials such as waste and weeds.

Gaseous chlorine is about 2.5 times as heavy as air.[19] Therefore, in the absence of air currents, leaking chlorine tends to accumulate in low spots. Storage areas must be planned and occupied with this chlorine property in mind.

If indoor storage areas are utilized, at least two exits, remote from each other and opening outward of the building, must be provided for all chlorine storage rooms.

Chlorine is incompatible and may react violently with ammonia. These materials may not be stored immediately adjacent to each other. It is not anticipated that chlorine will be stored at the Commercial Port for any significant length of time. Other incompatible materials which can react violently with chlorine are hydrogen, acetylene, fuel gases, ether, turpentine, most hydrocarbons, finely divided metals and organic matter. These materials must not be stored immediately adjacent to chlorine. The degree of separation required will be dictated by quantities stored and the type of storage facility.

Containers of chlorine should be used on a first-in-first-out (FIFO) basis because valve packings may harden during prolonged storage and cause leaks when containers are finally used.

7.5 Labeling/Posting

All shipping containers of chlorine must bear the following label shown in Figure 7-1 or in combination with, labels required by other statutes.[20]

The warning sign should be affixed in a readily visible location at or near entrances to areas in which chlorine is present in containers or systems. This sign should be printed both in English and in the predominant languages of non-English-speaking workers. All employees must be trained and informed of the hazardous areas, with special instruction given to illiterate workers.

7.6 Container Handling Procedures

It is illegal to ship a leaking chlorine container or one partially or fully loaded which has been exposed to fire. The Coast Guard and the manufacturer must be consulted for advice under such circumstances.[21]

If a ton container or its valves are found out of order, the nearest distributor from whom the chlorine was purchased must be notified, giving the container number and the nature of the damage. Containers are carefully inspected before shipping, but rough handling in transit may damage containers and their valves.

FIGURE 7-1

CHLORINE SHIPPING LABEL

CHLORINE

DANGER! HAZARDOUS GAS OR LIQUID UNDER PRESSURE

EXTREMELY IRRITATING

MAY BE FATAL IF INHALED

CAUSES BURNS

SEVERE EYE HAZARD

Do not breathe gas; use only with adequate ventilation. In case of inhalation, remove to uncontaminated atmosphere, get medical attention immediately. If breathing has stopped, start artificial respiration. Do not get in eyes, on skin, or on clothing. In case of contact, immediately flush skin or eyes with plenty of water for a least 15 minutes, and get medical attention immediately.

All chlorine containers must be handled with extreme care. Containers cannot be allowed to drop or strike any object with force. Heat should never be applied to containers or their valves.

Containers or their valves should never be altered or repaired.

Leaks around valve stems can usually be corrected by tightening the packing nut in a clockwise direction. All threads on chlorine valves are right hand threads.

Containers should never be presumed to be empty and therefore non hazardous.

7.7 Trailer and Semitrailer Requirements

Every trailer or semi-trailer must be equipped with an emergency braking system to be activated in event of a hitch failure.

Each tank motor vehicle must be provided with properly attached bumpers or chassis extensions arranged to protect the tank, piping, valves and fittings from physical damage in case of minor collision.

DOT regulations specify that as a minimum a gas mask approved for chlorine must be on each chlorine motor vehicle. Although these regulations pertain to tank trucks specifically designed for that chemical, compliance with the regulation for trailers and semitrailers would be advisable for obvious safety reasons.

7.8 Fire Hazard

Chlorine is classified as nonflammable and nonexplosive. However, it will support combustion of certain materials[22], reacting explosively in some cases. At elevated temperatures, it reacts vigorously with most metals. Carbon steel, for example, ignites in an atmosphere of chlorine at (250°C) 483°F. It is important that precautionary measures be taken to prevent chlorine from coming into contact with materials with which it may react.

In case of fire, chlorine containers must be removed to a safe place or cooled with water if leaks do not exist. Water cooling must not be used at chlorine leaks because the water forms hydrochloric acid and accelerates corrosion, enlarging the leak. Fusible plugs in chlorine containers melt at 158-164°F, every effort should be made to prevent containers from reaching this temperature.

The Chlorine Institute recommends that: (1) firefighters approach chlorine emergencies from an upwind direction while wearing full protective clothing including self-contained breathing apparatus, (2) only personnel required to remedy the problem should enter the contaminated area; (3) for safety, firefighters should work in pairs; and (4) as an added precaution a lifeline should be attached to each firefighter.

7.9 Leak Hazard

As soon as the presence of chlorine in the air becomes apparent, the condition must be corrected. Chlorine leaks rapidly become worse if not corrected immediately.

When a chlorine leak is discovered, all persons should stay upwind of the leak and at a higher level. Only trained personnel equipped with gas masks should be permitted to attempt repairs on leaking chlorine equipment. All persons not properly equipped with gas masks must be prohibited from the contaminated area. Nonessential employees should be evacuated from exposure areas during emergencies. Perimeters of areas of hazardous exposure must be delineated, posted and secured. Only personnel who have appropriate training and who are adequately protected against the attendant hazards should take appropriate control action: e.g. leak isolation and repair, cleanup of spills, etc.

If a chlorine container is leaking, it should be shifted so that gaseous rather than liquid chlorine will escape. A much smaller amount of chlorine will be dissipated into the atmosphere if gaseous rather than liquid chlorine is leaking. The removal of gaseous chlorine from a container tends to lower the temperature of the remaining chlorine, consequently, the pressure in the container is reduced.

Chlorine leaks can be conveniently located by holding an open bottle of strong aqueous ammonia near the suspected area, preferably at a slightly lower level. The formation of dense white fumes will indicate the point of leakage.

Standardized kits for control of leaks are available. The Chlorine Insitute maintains current listings of the locations of these kits.[23] The Chlorine Institute should be contacted for the nearest location if emergency kits are not available locally. These kits operate on the principle of capping off leaking valves or sealing off a rupture in the side wall. It should be noted, however, that the use of leak kits requires some training prior to use in an emergency situation.

Studies by the Bureau of Mines[24] indicate that pinhole leaks in chlorine containers are rapidly enlarged by corrosion if moisture is present. Furthermore, the control of chlorine leaks or spills by the use of water is not effective because of the limited solubility of chlorine in water. Even the coldest water will supply sufficient heat to cause an increase in the evaporation rate of chlorine. Therefore, water must never be used on leaking containers of chlorine or to control spills.

A safe method of absorbing the contents of leaking chlorine cylinders or ton containers should be provided. Caustic soda solutions furnish a convenient and cheap means of chlorine disposal. Suitable containers and sufficient caustic soda to absorb the contents of at least one full container should be available if chlorine is to be stored at the Commercial Port.

7.10 Health Hazards

7.10 (a) Warning Properties

The readily identifiable odor of chlorine and the attendant disagreeable reactions are the most common means by which workers are warned of impending excessive exposure. However, determinations of the threshold of odor have given varying results. The variation of these results probably reflects differences in methods of determination, and possibly differences in the development of odor adaptation.[25] While a noticeable odor of chlorine may indicate a potentially hazardous exposure, it should not be relied on as a quantitative indication.

7.10 (b) Severe Exposures

The dramatic response to substantial exposure is well documented. Chlorine was used as a war gas during WWI and a number of industrial accidents have been carefully recorded. The severity of the symptoms is, of course, a function of the degree of exposure. Some symtoms of severe exposure are severe pulmonary congestion, difficult or labored breathing, burning of the eyes, throat, or nasal passages, choking, nausea, vomiting, anxiety and brief loss of consciousness.

7.10 (c) Exposure Countermeasures

7.10 (c)(1) General

Prompt treatment is essential. Immediately remove the patient to an uncontaminated area. Liquid chlorine and chlorinated water destroy clothing; and if such clothing is next to the skin it will cause irritation and acid burns. In such cases, remove contaminated clothing and wash contaminated body parts.

7.10 (c)(2) Gas Inhalation

If breathing has ceased, commence artificial respiration immediately and administer oxygen as soon as possible. If breathing has not ceased, place the patient in a comfortable position and administer oxygen as soon as possible. Keep the patient warm, at rest and render other necessary first aid.

A carbon dioxide and oxygen mixture, not to exceed seven percent of carbon dioxide, can be given. This mixture, ready prepared and sold with the necessary apparatus, can be administered intermittently for periods of two minutes followed by two-minute rest periods over a total period not to exceed thirty minutes. Instructions of the purveyor of the gas apparatus should be carefully obeyed. If carbon dioxide and oxygen mixture is not readily available, oxygen alone can be used.[26][27]

7.10 (c)(3) Chlorine Eye Contact

Flush the eyes immediately with copious amounts of running water for 15 minutes. The eyelids must be forcibly held open to ensure complete irrigation of all eye and lid tissues. Chemical neutralization of any kind should not be attempted.

7.10 (c)(4) Chlorine Skin Contact

Wash well with copious amounts of soap and water. Greases or salves should not be applied unless ordered by a physician.

7.10 (d) Procedures For Obtaining Medical Assistance

The following procedures should be formulated in advance and employees should be instructed and drilled in their implementation. Procedures should include assignment of individual or team responsibilities and pre-arranged plans for:

1. Immediate evacuation of workers with signs or symptoms of adverse effects resulting from exposure.

2. Transportation of injured persons to medical facilities.

3. Any necessary calls to alert medical facilities of the impending arrival of injured persons.

4. Designation of medical receiving facilities and names of physicians trained in anhydrous ammonia emergency procedures.

7.11 Personnel Safety Training

7.11 (a) Informing Employees of Hazards of Chlorine

At the beginning of employment, workers whose jobs may involve exposure to chlorine must be informed of the hazards, signs, symptoms and effects of overexposure, emergency procedures, and precautions to take to ensure safe use of chlorine and to minimize exposure to chlorine. Information pertaining to first-aid procedures should be included. The information must be posted in the workplace and kept on file, readily accessible to workers at all places of employment where chlorine is involved.

A continuing educational program, conducted by a person or persons qualified by reason of experience or special training, must be instituted to ensure that all workers have current knowledge of job hazards, first-aid procedures, maintenance procedures and cleanup methods, and that they know how to use respiratory protective equipment and protective clothing. Retraining should be repeated at least annually.

7.11 (b) Training and Drills

The value of drills and training in handling emergencies and in using equipment for personal protection and control of escaping chlorine is emphasized in professional literature about the management of chlorine accidents. National Institute for Occupational Safety and Health (NIOSH) reported a chlorine spill caused by a rail car which discharged chlorine following a collision. A total of 55 tons of chlorine could have been released into the atmosphere; however, only a few tons escaped because of quick action by employees and supervisory personnel. The quick action was credited to rigorous and thorough training and drills.[28]

Members of emergency teams and employees who will work adjacent to chlorine systems or containers should be subjected to periodic drills simulating emergency situations appropriate to the work situation. These should be held at intervals not exceeding 6 months. Drills should cover, but should not be limited to, the following:

1. Evacuation procedures;
2. Handling of spills and leaks, including decontamination and use of emergency repair kits;
3. Location and use of emergency firefighting equipment;
4. Handling of containers in case of fire;
5. First aid and rescue, including procedures for obtaining medical care;
6. Location, use, and care of protective clothing and respiratory equipment;
7. Location and use of shut-off valves;
8. Location, reason for, and use of safety showers, eyewash fountains, and other sources of water for emergency use;
9. Operating procedures;
10. Entry procedures for confined spaces; and
11. Emergency phone numbers.

Deficiencies noted during the drill should form the basis for a continuing educational program to ensure that all workers have current knowledge. Records of drills and training conducted should be established.

TABLE 7-1

EVACUATION TABLE - BASED ON PREVAILING WIND OF 6-12 MPS

Approximate Size of Spill	Distance to Evacuate From Immediate Danger Area	For Maximum Safety Downwind Evacuation Area Should Be
200 square feet	160 yards (192 paces)	1 mile long, 1/2 mile wide
400 square feet	240 yards (288 paces)	1-1/2 miles long, 1 mile wide
600 square feet	300 yards (360 paces)	1-1/2 miles long, 1 mile wide
800 square feet	340 yards (408 paces)	2,112, feet long, 1,584 feet wide

In the event of an explosion, the minimum safe distance from flying fragments is 2,000 feet in all directions.

Source: Emergency Action Guide for Selected Hazardous Materials, 1978

CHAPTER VIII

TRANSPORTATION OF CHLORINE

Chlorine is shipped as a liquid under pressure in steel containers conforming to federal Department of Transportation specifications. The transportation system needed to move chlorine from the supplier to the OTEC storage tanks requires no new technology.

Chlorine can be shipped in bulk, break-bulk or a combination of both. How the product is finally shipped will be dependent upon a detailed cost comparison of various modes of shipment which are feasible for this product and determination of the additional quantity of chemical needed by the plant during periodic shut down for maintenance. These quantities will be determined during the preliminary design and engineering stages of the OTEC plant.

8.1 Break-bulk Shipment

Break-bulk shipment of chlorine is shipment in tanks mounted on the chassis of open hopper or closed containers. Tanks transported in this fashion are handled the same as other containerized cargo and require no equipment not presently available at the Port. The Commercial Port is primarily a containerized operation, 85% of general cargo being containerized.

In a typical unloading scenario, the containers are removed from the ship by gantry crane, placed on a chassis and taken directly to the plant site. In event that the containers cannot be taken directly to the plant site because of either insufficient chassis or lack of storage space at the OTEC plant, Commercial Port container yard space will have to be reserved. The current Master Plan for the Commercial Port recommends expansion of the existing container yard facilities. A temporary storage area must be designated and reserved prior to delivery of a container shipment in event that immediate transfer to the OTEC plant site is delayed. It is anticipated that adequate storage space will be available at the OTEC plant for shipping containers.

8.2 Ton Containers

Limited quantities of chlorine needed to service the plant during shut down periods could be imported utilizing one-ton containers. Ton containers for liquid chlorine are of steel construction. They are fitted with valves of a type approved by the Chlorine Institute and which comply with the specifications and regulations of the Interstate Commerce Commission.

The average ton container is about 30 inches outside diameter and about 82 inches in length. Average tare weight is about 1,500 pounds and average gross weight is about 3,500 pounds, leaving 2,000 pounds net weight.

Each end of a ton container is concave, the sides being crimped inward over the ends to form chimes that provide suitable grips for hooks which are used in handling the ton containers. A ton container is equipped with two valves, both of which are located in the same end, near the center. The valves are connected to eduction pipes. With the container placed so that the two valves are in vertical alignment, the lower valve will deliver liquid chlorine from above the liquid level.

There are six fusible metal plugs, three at each end, of a ton container. The fusible metal in these plugs melts at about 158°F.[29] This safety device is designed to protect the ton container against excessive pressure, caused by high temperatures, through melting and allowing the contents of the container to escape. The fusible metal plugs should not be tampered with under any circumstances.

The container number, dates of hydrostatic tests and capacity are stamped in the metal of an unpainted portion of chime at the valve end of each ton container. The tare weight of each ton container is stenciled on the end opposite the valves.

Portable tanks should be removed from the Commercial Port as soon as possible. If temporary storage is necessary, the tanks should be kept away from sources of heat that could increase the pressure causing the relief valve to open. The safety plug protects the chlorine cylinder against excessive pressure, caused by high temperatures, through melting and allowing the contents of the cylinder to escape. As with any cylinder, care must be taken to prevent mechanical damage to the container or its appurtenances.

CHAPTER IX

GOVERNMENT AUTHORITY AND REGULATIONS FOR HANDLING AMMONIA AND CHLORINE

Federal government regulations governing the transportation, handling and storage of ammonia and chlorine are divided among three agencies: the U.S. Coast Guard, the Environmental Protection Agency and The Occupational Safety and Health Administration. The U.S. Coast Guard has the greatest influence on the Commercial Port operations due to its wide range of authority in the shipping, handling, storage, safety and environmental areas pertinent to waterfront facilities and vessels. The EPA and OSHA Regulations influence Commercial Port operations to a much lesser degree.

9.1 U.S. Coast Guard

The U.S. Coast Guard Marine Safety Office (MSO), located in the Commercial Port office complex, is responsible for enforcing federal laws and regulations for ports, waterways, port facilities as well as for protecting vessels, persons, and property in the vicinity of the ports from accidental or intentional destruction, damage, loss or injury.

The District Commander, as principal agent and representative of the Commandant of the Coast Guard, is responsible for the command

and support of MSO Guam. This office, located in Honolulu, also performs an appellate review role.

The Commandant, located in Washington, D.C., directs the policy and administration of the Coast Guard, and its implementation of legislation, under the general supervision of the Secretary of Transporation. In these matters he is assisted by a staff of management and technical assistants who serve as principal advisors.

9.1.1 Statutory Authority

The following statutes are sufficient to point out the Coast Guard's very broad, and sometimes overlapping, authority to promote safety and protect the marine environment in the transportation and handling of hazardous substances.

9.1.1 (a) Title 33 CFR 6.12 "Supervision and Control of Explosives or Other Dangerous Cargo" gives the Coast Guard authority to designate waterfront facilities for the handling, storage, and vessel loading and discharging of explosives, flammable or combustible liquids in bulk, or other dangerous articles. Authority to require permits for such handling, storage, loading and unloading is also provided.

9.1.1 (b) Title 33 CFR 6.14 "Security of Waterfront Facilities and Vessels in Port" authorizes the Coast Guard to prescribe conditions and restrictions relating to the safety of waterfront facilities and vessels in port as deemed to be necessary under existing circumstances.

9.1.1 (c) 33 U.S.C. 1221 et seq "The Ports and Waterways Safety Act of 1972". This Act promotes the safety and environmental quality of ports, harbors, waterfront areas, and navigable waters of the United States. The Secretary of the department in which the Coast Guard is operating has been given broad authority to take necessary action to prevent damage to, or the destruction or loss of, any vessel, bridge, or other structure on or in the navigable waters of the United States, or any land structure on shore area immediately adjacent to those waters; and to protect the navigable waters and resources therein from environmental harm resulting from vessel or structural damage, destruction, or loss.

9.1.1 (d) FWPCA 33 U.S.C. 1321. Section 311 of the "Federal Water Pollution Control Act" established United States policy that there shall be no discharges of oil or hazardous substances in harmful quantities into or upon the navigable waters of the United States or adjoining shorelines. The Coast Guard has been designated with responsibility for enforcing federal laws on Guam with regard to oil and hazardous substances entering marine areas.

9.1.1. (e) Executive Order 11735. This order delegates the following facility inspection-related functions of the FWPCA to the Coast Guard: "... the establishment of procedures, methods, and equipment and other requirements for equipment to prevent discharges of oil and hazardous substances from vessels and transportation-related onshore and offshore facilities, and to contain such discharges."

9.1.2 Local Coast Guard Requirements

Designated dangerous cargo may be handled, loaded, discharged or transported at any designated waterfront facility only if a permit has been issued by the Coast Guard. The permit will terminate automatically at the conclusion of the operation and also may be terminated or suspended whenever the Coast Guard deems that the security or safety of the port, vessels, or waterfront facilities is jeopardized. The Coast Guard may require additional constraints in the permit other than those found in 33 CFR Part 126.

The following are two lists of possible additional requirements for vessels and facilities which may be required by the local Coast Guard Marine Safety office to reduce risks of hazardous materials incidents within the port area:

9.1.2 (a) Possible Vessels Requirements

* Require the vessel to anchor and be inspected prior to permitting transit or commencing transfer.

* Provide an escort vessel.

* Require tugs to be in attendance while the vessel is transiting the port area or port complex.

* Establish a moving safety/security zone around the vessel during transit.

* Restrict vessel entry and movement to periods of good visibility.

* Require communications to be constantly maintained between the vessel and the escort vessel(s) including towing vessel(s).

* Specify exact transit times permitted.

* Require a report prior to entry, that all hazardous material cargo alarms, safety devices, and shut-down devices have been tested by the ship personnel and are in good working order.

9.1.2 (b) Possible Facility Requirements

* Require a pre-transfer conference between ship and terminal personnel.

* Require effective communications during cargo transfer.

* Require test of terminal alarm devices and emergency shutdown prior to commencing transfer operations.

* Prohibit other cargo operations during transfer operations.

* Prohibit welding, burning, hot-work, smoking, open lights, etc., while the vessel is moored at the terminal.

* Prohibit bunkering during cargo transfer operations.

* Require facility operator to post guards and restrict access to those personnel who are essential to the operation.

* Establish a safety/security zone in the area where the vessel is moored.

* Require facility owners to furnish equipment and resources to patrol the safety/security zones.

* Require the facility to provide or make available, additional firefighting equipment and personnel to operate it.

9.1.3 Facility of Particular Hazard

A "facility of particular hazard" is defined in 33 CFR 126.05 (b). The Commercial Port would be designated a "facility of particular hazard" by the U.S. Coast Guard upon authorization to handle a cargo of particular hazard in bulk such as anhydrous ammonia or chlorine. The basic requirements or conditions which must be met are the same as for a "designated waterfront facility", which the Commercial Port now meets, plus the requirement to have a warning alarm and light.

9.2 U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (USEPA) office for the Pacific Islands is located in San Francisco. There are no USEPA offices on Guam. The Guam Environmental Protection Agency

(GEPA) has been designated by the USEPA to enforce selected USEPA regulations on island. In addition, GEPA administers local laws and regulations.

The federal responsibility for pollution prevention is divided between the U.S. Coast Guard and the U.S. Environmental Protection Agency. The USEPA responsibility includes all facilities, both onshore and within the territorial sea limits (within three miles), that are not transportation-related. Included in this definition of "non-transportation-related" facilities are those facilities that drill, produce, gather, store, process, refine, transfer, distribute or consume oil and hazardous substances. USEPA regulations on determination of reportable quantities for hazardous substances (40 CFR 117) sets forth reportable quantities for hazardous substances when discharged into or upon the navigable waters of the United States or adjoining shorelines. The minimum reportable quantity for an ammonia spill is 100 lbs. (approximately 20 gals.) The minimum reportable quantity for a chlorine spill is 10 lbs. (approximately one gallon).[30]

Facility owners and/or operators are subject to a fine of not more than $10,000 for failure to notify the United States Government of the prohibited discharge.

The owner, operator, or person in charge of a vessel or onshore facility from which is discharged a minimum reportable quantity of a hazardous substance is subject to a civil penalty of not more than $5,000.

The owner, operator or person in charge will be liable to the United States Government for the actual cost incurred in the removal of a hazardous substance discharged into local waters. It is very unlikely that removal or cleanup operations would be initiated with respect to ammonia or chlorine due to their solubility in sea water.

The USEPA has no legal authority over the transportation , storage, and handling of ammonia or chlorine.

9.3 Occupational Safety and Health Administration

The Williams-Steiger Occupational Safety and Health Act of 1970 sets forth a wide range of standards which require conditions, or the adoption or use of one or more practices, means, methods, operations or processes, to provide safe and healthful working conditions. The U.S. Department of Labor has primary responsibility for administering the act.

OSHA regulations are applicable to the Commercial Port and are enforced on island by the Guam Department of Labor in the absence of a federal OSHA office. The Commercial Port is subject to numerous regulations in 29 CFR Part 1910. This study will only consider additional constraints which can be imposed upon the Commercial Port for storage and handling of anhydrous ammonia or chlorine (29 CFR Part 1910.111).

OSHA regulations regarding permanent storage areas are not of concern to the Commercial Port. Since permanent anhydrous ammonia storage containers will be located on the OTEC plant site, portable containers, used to transport ammonia, would be stored at the Port on a temporary basis only.

If anhydrous ammonia is obtained from a U.S. supplier and shipped on U.S. Flag vessels, containers will meet or exceed OSHA requirements. U.S. Coast Guard regulations regarding standards for portable containers are stringent and U.S. manufacturers of ammonia utilize containers which meet nationally recognized standards for such equipment set forth in OSHA and Coast Guard regulations.

There are no additional OSHA constraints addressed specifically to the handling or transportation of chlorine.

OSHA regulations pertaining to full trailers and semitrailers that serve the Port are discussed in section 5.2.2 of this study.

CHAPTER X

SUMMARY OF TASKS

10.1 Determine Mode and Frequency of Hazardous Chemical Shipments

The ammonia system for a 50 MWe OTEC plant will require an initial shipment of approximately 420,000 gallons of ammonia. The initial shipment can be shipped in container or in bulk quantities. If make-up quantities needed thereafter are minimal, containerized shipments will be feasible.

The quantity, mode and frequency of shipment for NH_3 is directly dependent upon the continuous and intermittent losses of ammonia in plant processes. Continuous losses are possible at the glands of pumps and valves, the turbine seal system, and the evaporator and condenser tube or tubesheet. Activities creating potential intermittent ammonia losses are manual opening of vent, drain, or instrument valves, relief activation, startup and shutdown, equipment venting and ammonia loading operations.[31]

Quantities of ammonia needed on a recurring basis will be determined during preliminary design. Hence, mode and frequency of ammonia shipment cannot be finally determined until operational system losses are quantified. Ammonia losses and the costs associated with the capital and operating costs of the ammonia recovery equipment are factors in the economic viability of the plant. Leakproof design and ammonia recovery are noted as an early design requirement for all equipment.[32]

Plant chlorine needs can be generated on board, in the form of hypochlorite, by passing a direct current through seawater. The plant is assumed to be able to produce its total daily chlorine needs while in operation. Supplemental quantities, needed during plant start up and during shutdown periods, will be determined during the preliminary design and engineering stages of the OTEC plant.

Government, safety, hazard and training requirements are, for the most part, equally applicable to bulk or container shipment of chlorine.

10.2 Determine Storage Area Needs

The Commercial Port Master Plan recommends the expansion of the container yard. If this expansion is undertaken, adequate storage capacity for hazardous chemicals will be available at the port if needed.[33]

Limited space on board an OTEC platform and considerable shipping distances involved in resupply will necessitate Commercial Port storage of chemical for a sea based alternative.

Safety and hazard constraints previously delineated should be examined when considering storage areas for ammonia and chlorine. The U.S. Coast Guard Marine Safety Office recommendations should be sought if Commercial Port storage capacity is required for OTEC.

10.3 Coordinate with U.S. Coast Guard

The Coast Guard has indirect facility control by way of operational safety regulations and enforcement. The Commercial Port management should consult with the Coast Guard, at the earliest possible time, after determination of the quantity, frequency and mode of hazardous chemical shipment has been defined.

10.4 Determine Medical Facilities and Support Available

Liaison with local medical facilities should be established to ensure prompt access to medical support in the event of a chemical spill. Medical facilities should be aware of the types of chemical products handled by the Commercial Port that they may be better prepared in event of an accident.

The following must be established:

* Procedures for timely evacuation
* Medical facilities capable of treating exposure victims
* Procedures for alerting medical facilities of impending arrival of injured persons

* Names of physicians trained in ammonia and chlorine emergency procedures

10.5 Coordinate with Fire Department

Fire departments likely to respond to a Commercial Port fire must be aware of the hazardous chemicals which are handled in significant quantities at the port. Local fire stations which would respond to a port fire alarm must be equipped with self-contained breathing apparatus and protective clothing impervious to chemicals. Only personnel properly equipped and trained should enter the contaminated area. Ability of local fire stations to respond to a fire involving hazardous chemicals must be determined.

10.6 Establish Employee Education and Training

Shipment of ammonia and/or chlorine in bulk quantities will require personnel specifically qualified in the bulk transfer of the chemical(s) involved. OTEC plant technicians may be capable of supervising cargo transfer operations, thereby releasing the Commercial Port from the need to have their personnel trained. The Coast Guard Marine Safety Office will require that satisfactory documentary evidence be furnished as proof that the person in charge is capable of competently performing all potential operations that could evolve in a cargo transfer of a hazardous chemical.

Safety in handling hazardous chemicals depends, to a great extent, upon the effectiveness of employee education, proper safety instructions, intelligent supervision and use of suitable equipment.

Training of employees will primarily concern safety considerations involved with possible exposure to ammonia and chlorine. If the chemicals are shipped in break-bulk quantities, the mode of handling will be the same as for any other container operation.

The education and training of employees in safe work practices and the use personal protective equipment and other safeguards provided for them are the responsibility of management. Training classes for both new and old employees should be conducted periodically to maintain a high degree of competence. Employees must be thoroughly informed of the hazards that may result from improper handling procedures. Each employee must know what to do in an emergency and should be fully informed as to appropriate first aid measures.

The Fertilizer Institute (NH_3) and the Chlorine Institute are resources for audio-visual training aids which can be used in an employee education and training program.

10.7 Establish a Written Contingency Plan for Emergencies

A comprehensive contingency plan should be formulated to minimize the potential effects of accidents at waterfront facilities. A contingency plan must include procedures for general emergencies, fire control and fire fighting systems, emergency lighting and power systems, first aid, dock emergencies, response to release of hazardous substances and response to other potential emergency situations. The generation of such a plan is a separate project which should incorporate all of the parameters embracing the transfer of large quantities of ammonia and chlorine as noted in the report in addition to routine Commercial Port operations.

Timely notification of any discharge of hazardous substances into coastal waters is required by federal law. A discharge includes (but is not limited to) any spilling, leaking, pumping, pouring, emitting, emptying or dumping of a hazardous substance. Procedures should be established in a contingency plan for timely notification of the Coast Guard Marine Safety Office and designated Commercial Port personnel. The Coast Guard is presently considering a requirement for all facilities to have an emergency manual which would basically cover procedures suggested for inclusion in a Commercial Port contingency plan for emergencies.

FOOTNOTES

1. U.S. Department of Energy, Ocean Thermal Energy Conversion Power System Development, National Technical Information Service, December 4, 1978.

2. Dames and Moore, Environmental Impact Report Projected OTEC Development for Territory of Guam, p. 4, August 15, 1979.

3. Ibid.

4. Maruyama Associates, Ltd. and Dravo Van Houten, Inc., Commercial Port of Guam Master Plan, draft report September 1980.

5 U.S. Department of Energy, Ocean Thermal Energy Conversion Power System Development, National Technical Information Service, SAN 1569-2, p. 7-65, December 4, 1980.

6. National Institute for Occupational Safety and Health, Criteria for a Recommended Standard....Occupational Exposure to Ammonia, NEW publication No. 74-36, p. 5, 1974.

7. Ibid., p. 24.

8. The Fertilizer Institute, Operational Safety Manual for Anhydrous Ammonia, p. 14, 1971.

9. Ibid. p. 24.

10. The Fertilizer Institute, Chemical Safety Data Sheet TFI Publication SD-8 p. 15.

11. Ibid.

12. Compressed Gas Association, Inc., Anhydrous Ammonia, CGA pamphlet G-2, p. 23, 1977.

13. American National Standards Institute, Inc., Safety Requirements for the Storage and Handling of Anhydrous Ammonia, ANSI K61.1, p. 23, 1972.

14. U.S. Department of Energy, Ocean Thermal Energy Conversion Power System Development, National Technical Information Service, SAN 1569-2, p. 6-80 - 6-82, December 4, 1978.

15. U.S. Department of Energy, Ocean Thermal Energy Conversion Power System Development, National Technical Information Service, SAN 1569-1, Vol. 3, PT. 1 p. 159, December 4, 1978.

16. Ibid. p. 7-39.

17. Cafky, J.W., Calculations performed September 1980.

18. U.S. Department of Energy, Ocean Thermal Energy Conversion Power System Development, National Technical Information Service, SAN 1569-1 Vol. 3, PT. 1, p. 160, December 4, 1978.

19. The Chlorine Institute, Inc. Chlorine N.Y., N.Y. p. 20-21, 1969.

20. National Institute for Occupational Safety and Health, Criteria for a Recommended Standard....Occupational Exposure to Chlorine, NEW publication 76-170, p. 3, 1976.

21. Diamond Shamrock, Inc., op. cit. p. 16.

22. NIOSH, op. cit. p. 109.

23. The Chlorine Institute, Inc., 342 Madison Ave., New York, N.Y. 10017.

24. NIOSH, op. cit. p. 106-107.

25. NIOSH, op. cit. p. 111.

26. Diamond Shamrock, Inc. op. cit. p. 24.

27. The Chlorine Institute, Inc. First Aid Medical Management of Chlorine Exporures, Edition 3, June 1978.

28. NIOSH, op. cit. p. 106.

29. Diamond Shamrock, Inc., Chlorine Handbook p. 14, 1976.

30. Title 40, Code of Federal Regulations, part 117, Environmental Protection Agency Regulations on Determination of reportable Quantities for Hazardous Substances, Wash. D.C., Government Printing Office.

31. U.S. Department of Energy, Ocean Thermal Energy Conversion Power System Development, National Technical Information Service, SAN 1570-2/1 p. 2.8-6 December 4, 1978.

32. Ibid.

33. Don Hill phone conversation with author 11/13/80.

BIBLIOGRAPHY

American National Standard. _Practice for Occupational and Educational Eye and Face Protection_. ANSI Z87.1, 1979.

American National Standard. _Safety Requirements for the Storage and Handling of Anhydrous Ammonia_. ANSI pamphlet K61.1, 1972.

The Chlorine Institute. _Chlorine Institute Emergency Kit 'A' For 100-lb. & 150 lb. Chlorine Cylinder_. Edition 4, July 1978.

The Chlorine Institute. _Chlorine Institute Emergency Kit 'B' For Chlorine Ton Containers_. Edition 5, July 1978.

The Chlorine Institute. _Chlorine Manual_. Edition 4, 1969.

The Chlorine Institute. _Chlorine Pipelines_. Report: 60, Edition 1, June, 1971

The Chlorine Institute. _Chlorine-Related Audiovisual Training Aids_. Pamphlet 58, May 1975.

The Chlorine Institute. _Facilities and Operating Procedures for Chlorine Storage_. Pamphlet 5, Edition 3, Revision 3, October, 1977.

The Chlorine Institute. _Estimating Area Affected by a Chlorine Release_. Report 71, March, 1979.

The Chlorine Institute. _Explosive Properties of Gaseous Mixtures Containing Hydrogen and Chlorine_. Edition 1, Report 121, August 1977.

The Chlorine Institute. _Facilities and Operating Procedures for Chlorine Storage_. Pamphlet 5, Edition 3, Revision 3, October, 1977.

The Chlorine Institute. _First Aid and Medical Management of Chlorine Exposures_. Pamphlet 63.

The Chlorine Institute. _Handling of Chlorine Barges_. Pamphlet 43, Edition 5, November 1975

The Chlorine Institute. _Handling Chlorine Tank Motor Vehicles_. Pamphlet 49, Edition 4, 1973.

The Chlorine Institute. _Locations of Chlorine Emergency Kits_. Pamphlet 35, Edition 13, 1979.

The Chlorine Institute. _Protective Chlothing For Chlorine_. Pamphlet 65, Edition 1, June 1978.

Compressed Gas Association, Inc. _Anhydrous Ammonia_. CGA Pamphlet G-2, Fifth Edition, 1962.

Department of Commerce National Oceanic and Atmospheric Administration. Coastal Energy Impact Program. Federal Register Vol. 44, No. 99, May 21, 1979.

Diamond Shamrock. Chlorine Handbook. 1976

The Fertilizer Institute. Agricultural Anhydrous Ammonia Operator's Manual. Pamphlet M-7, 1978.

The Fertilizer Institute. Operational Safety Manual for Anhydrous Ammonia. Revised April, 1966

The Fertilizer Institute. OSHA Handbook. A compilation of relevant OSHA safety and health requirements.

The Fertilizer Institute. Properties and Recommended Methods for Packaging, Handling, Transportation, Storage and Use of Fertilizer Grade Ammonium Nitrate.

The Fertilizer Institute. Standards for the Storage and Handling of Agricultural Anhydrous Ammonia. ANI Standard No. M-1, November, 1968

GODDU Jr., L.W., Guide For Facility Site Evaluation For Proposed Marine Terminals Handling Cargoes of Particular Hazard. Report No. CG-D-45-79, NTIS, August, 1979.

Hagopian, J., A.S. Kalelkar and P. K. Raj. Prediction of Hazards of Spills of Anhydrous Ammonia on Water. National Technical Information Service, Report No. CG-D-74-74, March, 1974.

Helmers, Scott, Franklin H. Top and L. W. Knapp. Ammonia and Eye Injuries in Agriculture. The Sigat Saving Review, Vol. 41, No. 1, 1971.

National Institute For Occupational Safety and Health. A Guide for Developing a Training Program for Anhydrous Ammonia Workers. Publication No. 79-119, December, 1978.

Kelly, Christopher. Dealing with Chlorine Emergencies. Fire House. Vol. 2, No. 12, December, 1977.

National Highway Traffic Safety Administration and Materials Transportation Bureau. Emergency Action Guide for Selected Hazardous Materials, Wash. D.C., U.S. Government Printing Office, 1973.

National Institute for Occupational Safety and Health. Occupational Exposure to Ammonia. U.S. Government Printing Office, Washington, D.C., 1974.

National Institute for Occupational Safety and Health. Occupational Exposure to Chlorine. U.S. Government Printing Office, Washington, D.C., 1976.

National Institute For Occupational Safety and Health. Respiratory Protection A Guide for the Employee. Report No. 78-193B, October 1978.

National Institute for Occupational Safety and Helath. Respiratory Protection: An Employer's Manual. Publication No. 78-193A, October 1978.

National Institute for Occupational Safety and Health. Working Safely With Anhydrous Ammonia. Publications No. 79-120, January, 1979.

National Safety Council. Chlorine. Data Sheet 207, 1966.

U.S. Coast Guard. Marine Safety Manual (CG-495). Washington D.C. U.S. Government Printing Office, 1977.

U.S. Department of Energy. Ocean Thermal Energy Conversion Power System Development (SAN 1569-1, Vol. 2, Pt. 1)

U.S. Department of Energy. Ocean Thermal Energy Conversion Power System Development (SAN 1569-1, Vol. 2, Pt. 2), NTIS

U.S. Department of Energy. Ocean Thermal Energy Conversion Power System Development. (SAN-1569-2) NTIS, 1978

U.S. Department of Energy. Ocean Thermal Energy Conversion Power System Development (SAN 1570-2/1) NTIS

U.S. Department of Energy. Ocean Thermal Energy Conversion Power System Development. (SAN 1570 2/3). NTIS

U.S. Department of Labor. Chlorine Handling in Operations. Bulletin No. 241, 1962.

U.S. Department of Labor. Occupational Safety and Health Administration. General Industry Safety and Health Standards (29 CFR 1910). January 1976.