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Research and Development

Control Technology Evaluation for Gasoline Loading of Barges

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Control Technology Evaluation for Gasoline Loading of Barges

by

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SECTION 1

INTRODUCTION

1.1 PURPOSE

This study undertakes both an assessment of feasibility for developing new vapor control systems for loading barges with gasoline and development of background information for use in designing a demonstration facility. Specifically, the study was designed to:

A. Determine the feasibility of controlling gasoline vapors during barge-loading operations by using carbon adsorption, refrigeration, or thermal incineration technologies.

B. Identify and solve the problems of safety hazards related to vapor control.

C. Determine the achievable emission level and expected efficiency for each control technology.

D. Determine the secondary emissions resulting from implementation of each gasoline vapor control technology.

E. Project the capital and annualized costs for each vapor control alternative.

1.2 SOURCES AND TECHNIQUE

Equipment manufacturers were contacted to determine the effectiveness, cost, and operating history of their vapor control units. Several alternatives were proposed for rendering the potentially flammable vapor mixtures from barges non-flammable. These alternatives included dilution with air, saturation with gasoline, and blanketing with fuel gas or inert gases. Combinations of safety and control modules were studied to evaluate costs, safety, emissions, and reliability.

SECTION 2

SUMMARY

Feasibility, safety, vapor emissions and costs constitute the basis of evaluation in this study for controlling gasoline-barge loading emissions. The evaluation involves application of carbon adsorption, refrigeration, and thermal incineration control technologies to control gasoline-barge vapors. Gasoline loading emissions consist of two portions, an arrival portion and a generated one. Arrival emissions consist of evaporated residual gasoline from a previous load. Generated emissions are produced as the barge is loaded with gasoline. A hydrocarbon loading emission factor of 4 #/1000 gallons of gasoline loaded, for uncleaned gasoline barges, was used for economic analysis. In practice, emitted vapors have a hydrocarbon concentration ranging from 4% to over 50% by volume. A significant amount of these vapors are within the 1.4% to 8.4% nominal limits of flammability and they represent a serious safety hazard since they introduce flammable mixtures into the vapor control systems. Should an ignition occur within the vapor control system, not only would it be hazardous to the vapor control system, but a flame front could travel by connecting pipe to the interior of the barge and ignite the vapors within the barge. This could result in a fire and explosion that could demolish the barge and dock facilities, and result in loss of life.

Dilution, saturation, and inertion have been investigated as primary safety methods for rendering the barge vapors non-flammable before collection and disposal or recovery. Safety modules were developed using these methods for combination with the three control technologies. A secondary protection device (a hydraulic flash arrestor) is used to prevent transmission of flames between the barge and control system in case an ignition occurs that is caused by a primary system malfunction. Each combination of safety module and control module was studied first for compatibility in safety and control. The more promising schemes were subjected to a detailed analysis of safety, reliability, operability, control efficiency, and cost (capital and annualized). Eleven cases passed the initial screening and became the basis for the balance of the study.

After studying the design and operation of gasoline-barge loading terminals operated by different oil companies, a hypothetical gasoline-barge loading terminal has been formulated for use in this report. Since design and operation of barge terminals and shipping procedures vary substantially for the various operators, the hypothetical barge terminal incorporates features common to actual terminals although it can not be construed to be typical of all terminals. The hypothetical terminal uses an annual gasoline throughput of six million barrels per year. Two loading berths for gasoline barges are assumed. Maximum liquid gasoline loading rate was 4200 gpm (6000 barrels per hour) for the terminal. The gasoline barges are assumed to be 20,000 barrel liquid capacity each, and they are in dedicated gasoline service. The gasoline barge loading emissions for the terminal in the uncontrolled base case are calculated to be 1,008,000 #HC/yr.

Control equipment manufacturers were contacted for information concerning capital cost estimates, control efficiencies, utility requirements, theory of operation, safety, operating history, and other technical features. The vendors' costs for vapor control units for similar applications when using carbon adsorption or refrigeration, were roughly equal. The costs of thermal incineration in the same applications were substantially less. Control efficiencies estimated by the manufacturers for the various cases were 99.9% for thermal incineration, 98 to 99% for carbon adsorption, and 91 to 94% for refrigeration.

The economics of applying vapor control to gasoline barge loading are studied here, and estimates of total installed capital costs, annualized costs, and cost effectiveness are calculated. Capital costs for barge modifications are also estimated. The safety modules are found to contribute significantly to the annualized and capital costs of the control cases. The proportion of annualized cost attributed to the safety module ranges from 64% to 98% of the total. The safety module portion of total capital cost ranges from 24% to 70%. Cost effectiveness is calculated by dividing the pounds of HC controlled (compared to the base case) by the annualized cost. The most cost effective case is carbon adsorption with inert gas generation at 8.50 #HC/$. The next two most cost effective systems also use inert gas generation, and are thermal incineration (8.01 #HC/$) and refrigeration (6.08 #HC/$). At the annual throughput of six million barrels per year, none of the schemes are profitable, and all represent a net operating loss. Projections of cost effectiveness are made for other throughputs and show that higher throughputs increase cost effectiveness. Some of the recovery systems are capable of recovering gasoline whose value is greater than the direct operating cost.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

A. Installing vapor emission controls systems on gasoline barges introduces the potential for large scale catastrophic fires and explosions of significantly greater magnitude than exists in present day gasoline-barge loading facilities.

B. Excluding safety considerations, application of any of several technologies to destroy or capture gasoline emissions is straightforward and presents no unusual problems.

C. The control efficiencies of the vapor control systems in descending order are; thermal incineration, carbon adsorption, and refrigeration. The overall control system efficiencies range from 86% to 97% reduction in HC.

D. Capital costs for the control systems range from $347,000 to $973,000. Capital costs for cases using thermal incineration are significantly lower than those using carbon adsorption or refrigeration.

E. Annualized costs for the control systems range from $114,000 to $215,000. Those systems using inert gas generators for their safety modules have the lowest annualized costs, and the least costly combination of safety and control modules is carbon adsorption with inert gas generation.

F. Safety modules are the largest contributors to the capital and annualized costs of the systems. From 64% to 98% of the annualized costs and 24% to 70% of capital costs are contributed by the safety modules.

G. Cost effectiveness, expressed in pounds of hydrocarbons controlled per dollar of annualized cost, range from 8.50 #HC/$ to 4.20 #HC/$. The most cost effective systems use inert gas generation for the safety module. The best of these uses carbon adsorption for the control module.

H. Cost effectiveness increases with increased gasoline throughput. At higher throughputs some recovery schemes have a positive cash flow. At the 6 million barrels per year throughput used in the study, all control cases result in a net operating loss.

I. The cost and emissions evaluations developed in this report are based on a hypothetical barge terminal. A specific terminal has its own unique design, throughput, operation, and location which differ from the hypothetical one; therefore, the cost and emissions data generated in this report cannot be applied directly to a specific terminal.

3.2 RECOMMENDATIONS

A. The design of any control system for emissions from gasoline barges should provide means for rendering the vapors non-explosive as they exit the barge manifold.

B. A secondary, passive device should be installed at the exit of the barge vapor manifold, and at other critical locations in the system to prevent passage of a deflageration or detonation should the primary (active) system fail.

C. Hydraulic flash arrestors should be used as the secondary protection devices, and the type used in acetylene service should be considered for use in gasoline vapor service.

D. Any flash arrestor chosen for use in an emission control system should be tested and certified by an independent laboratory prior to installation in a commercial facility.

SECTION 4

DISCUSSION

4.1 DESCRIPTION AND OPERATION OF A GASOLINE-BARGE LOADING TERMINAL AND A BARGE

Initially, this control technology study for gasoline barge loading considers some of the operational and physical features of the loading terminal. Although there is no standard gasoline-barge loading facility, and individual installations vary widely, there are some common functions and details. The terminals are normally multi-purpose facilities that are adjacent to, or part of, a refinery, and usually they are owned by the oil company that owns the refinery. The one or more docks from which barges are loaded may also be used for ships, and in addition to gasoline, they are often used to load other liquid petroleum products including fuel oils, kerosene, naphtha, etc. It is not uncommon for the docks to be used for unloading petroleum materials - most often, crude oil from ships. The docks usually use dedicated or segregated lines for different services, and since individual lines serve a particular product solely, the docks tend to be filled with piping, valves, loading arms, and hoses. Since space is at a premium, the docks generally have no fixed machinery, but this is also a function of safety considerations. The crowding is especially true at older facilities where the available dock space has been used for facility expansions. The circumstances just described are normal; however, some facilities do have docks used exclusively for gasoline or barges.

The gasoline loading pumps are usually located in the tank farm area. Generally, dedicated pumps, storage tanks, and suction lines are used. Totalizing flow meters may be used on the loading lines as part of an inline blending station or custody transfer system. A significant potential for contamination between leaded- and unleaded gasoline stocks exists, and, therefore, the storage and transfer facilities are usually dedicated for each grade. The loading rates for barges vary between individual operators but are usually in the range of 3000 bph (2100 gpm) to 8000 bph (5600 gpm) at design flow. The loading lines can be throttled to a lower flow rate. Individual arrangements will vary widely if the same pumps or dock manifolds are also used for ship loading.

The barges used in gasoline service are somewhat easier to typify than the loading terminals. Barges used in gasoline service are usually 20,000 bbl capacity and have eight separate cargo compartments. The overall dimensions of the barge are approximately 50 feet wide, 250 feet long and 13 feet deep.

The barges are most commonly in dedicated gasoline service, and they are not ballasted, cleaned, or degassed between loadings. A common submerged manifold is used for loading and unloading, and a series of valves permits isolation of tanks along the manifold.

The barge is equipped with two pumps for unloading cargo and stripping the compartments. The pumps are located on the rear deck and are driven by diesel engines. A diesel fuel oil tank and a slops tank are standard equipment. Pressure/vacuum relief valves are mounted on a header and configured to relieve either single tanks or pairs of tanks.

The loading operation for barges is similar for most terminals. After the barge is moved into position at the dock, it is made fast by mooring lines. The cargo loading hose is lifted into position (manually or by hoist) and bolted both to the barge loading manifold flange and the dock manifold flange. The barge operator prepares for loading by opening the proper valves in the loading manifold and by opening the ullage caps on the compartments to be filled. Opening the ullage caps serves two purposes; it permits displacement of vapor and thereby relieves pressure, and it allows manual gauging of the cargo level in the tank. Vapor release through the ullage caps, rather than through the pressure/vacuum relief valve prevents a defective valve from overpressurizing a barge compartment. Although no flow rating for the valves has been obtained, it appears that the valves are intended primarily for breathing applications and are undersized for loading applications. Manual gauging is accomplished by inserting a calibrated rod into the tank to determine the liquid level. The barge operator inspects the liquid level visually throughout loading operations and advises the onshore operator to reduce the flow rate as the tank approaches the desired level.

Initial filling is performed by gravity feed. All valves along the flow path are opened allowing the gasoline to flow into the barge. After ensuring that gasoline is flowing to the correct tanks, the loading pump is started. When the tank level approaches full, the barge operator signals the onshore operator to reduce the pumping rate and begin closing the valves. Shutting down operations must be handled slowly to avoid hydraulic transient shock or "water hammer." After the shore side valves are closed, the gasoline remaining in the hose is drained into the barge and the hose is disconnected.

4.2 DISCUSSION OF CONTROL TECHNOLOGIES IN RELATION TO GASOLINE LOADING

As the introduction to this paper indicates, the three different types of control technology being studied with respect to gasoline-barge loading are refrigeration, carbon adsorption, and thermal incineration. The following paragraphs discuss the three methods individually.

4.2.1 Carbon Adsorption

Carbon adsorption utilizes the affinity of activated carbon for hydrocarbon compounds to remove gasoline vapors from air. A typical carbon adsorption system consists of two or more carbon adsorber beds and a regeneration system for the carbon beds. (See Figure 4.2.1.) Two or more beds are necessary to maintain the unit onstream because one bed is kept in adsorption service while the other bed is being regenerated. The number and size of beds are determined by the loading

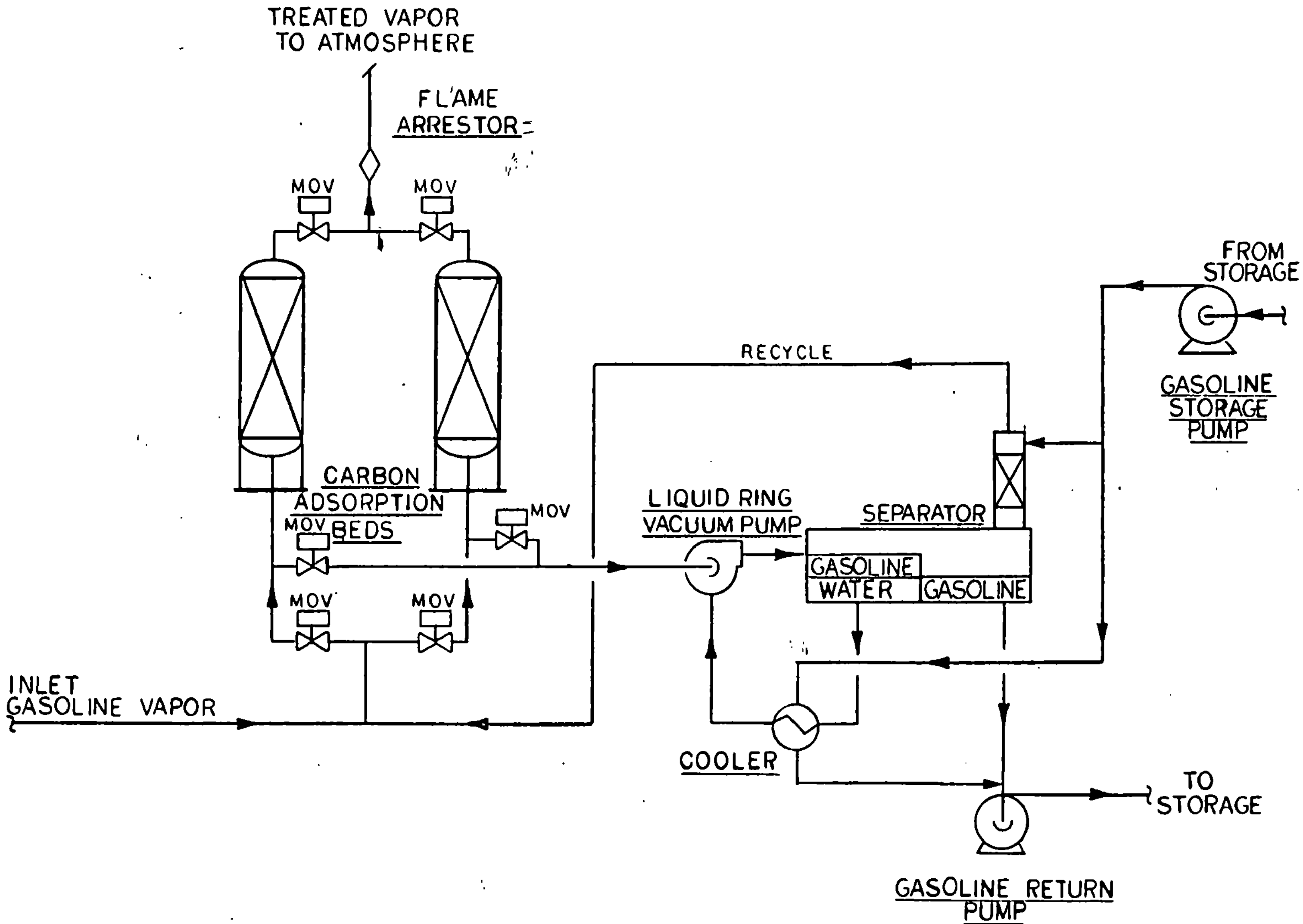

Figure 4.2.1 Carbon Adsorption Module

period, the time required for regeneration, and the working capacity of the activated carbon under the operating conditions. Regeneration (in situ) can be performed by vacuum or steam or both. Each of these methods relies on elevating the vapor pressure of the adsorbed hydrocarbons relative to the absolute pressure in the void space at the bed. The gasoline vapors desorb from the carbon particles into the void space where they are removed.

In the vacuum regeneration system (Figure 4.2.1) the carbon bed is placed under a high vacuum, approximately 25mm Hg, by a liquid-ring-seal vacuum pump. Vacuum regeneration is especially useful where temperature limitations exist due to polymerization or safety problems. The gasoline vapor desorbed and evacuated is reclaimed by condensation or adsorption into gasoline liquid. After desorption (which regenerates the bed) the bed is returned to service. Advantages of vacuum regeneration include an uncontaminated recovery product, low operating temperature, and fewer utility requirements.

Steam regeneration uses direct steam contact with carbon to heat the carbon and desorb gasoline vapors. The flow of steam through the bed carries the gasoline vapor out for reclamation. The purged steam and gasoline vapors are condensed by cooling and the gasoline liquid is decanted and recovered. After steam desorption and purging, the beds are cooled before being returned to service. Advantages of steam regeneration include higher working capacity and increased desorption of heavier compounds.

Hybrid regeneration systems utilizing both vacuum and indirect steam heating have been designed for carbon adsorption systems. These techniques permit additional flexibility in the types of hydrocarbons treated by combining the advantages of steam and vacuum.

This section of the barge loading study presumes the use of a carbon adsorption system incorporating vacuum regeneration and adsorption at atmospheric pressure. The system was selected because it has been used by several operators for gasoline-truck loading, and because records of the operating results are available. Approximately 10 units in the United States are now in service for gasoline-truck loading, and they have design flowrates of up to 6000 gpm.

NOTE

For convenience, flow rates of vapors displaced by liquid tank will be given in gpm rather than the more familiar ft^3/min.

The efficiency of recovery for carbon adsorption is high; as much as 99% recovery in some commercial installations.

The estimated costs obtained from the manufacturer for the two units considered in the study are $335,000 and $229,000 depending on the safety technique used with the system. The vendor package is complete except that utility connections must be made prior to operation. The carbon adsorber beds, vacuum pump, gasoline transfer pumps, adsorber-separator, and the associated piping and instruments are included, and all are skid mounted. The package does not include any supplemental safety devices although explosion proof electrical construction is used. The danger of spark generation in the vacuum pump is minimal and an over-rich condition is maintained. Hot spots in the adsorber beds are unlikely because of the working capacity used, the type of components adsorbed, and the frequency of bed cycling.

4.2.2 Refrigeration The refrigeration system studied utilizes two cooling stages operating at approximate temperatures of 35° F and -100° F. (Refer to Figure 4.2.2.) The principle of operation is simple condensation at atmospheric pressure caused by refrigerating the vapor mixture to temperatures below the boiling points of the hydrocarbon components. Since gasoline is a mixture of compounds, each with a unique vapor pressure- temperature curve, cooling to any given temperature will condense components that exist as liquids at that temperature and atmospheric pressure and only to the extent permitted by vapor-liquid equilibrium.

Of the three vapor control technologies considered in this study, refrigeration is most likely to be impacted by the various mixtures of gasoline. For instance, one recent, detailed analysis of a full-range, motor gasoline lists over 200 different compounds with a range of boiling points from -43° F, to 421° F, all of which, of course, would condense in the -100° F environment of the refrigeration system. On the other hand, gasoline-loading vapor analyses by two oil refineries showed a significant difference in vapor composition for gasoline. One refiner gave the volume percentage of C_1 and C_2 compounds in the vapor at ambient temperatures as 0.02% while another gave 3.38% as the C_1 and C_2 composition at ambient temperatures.

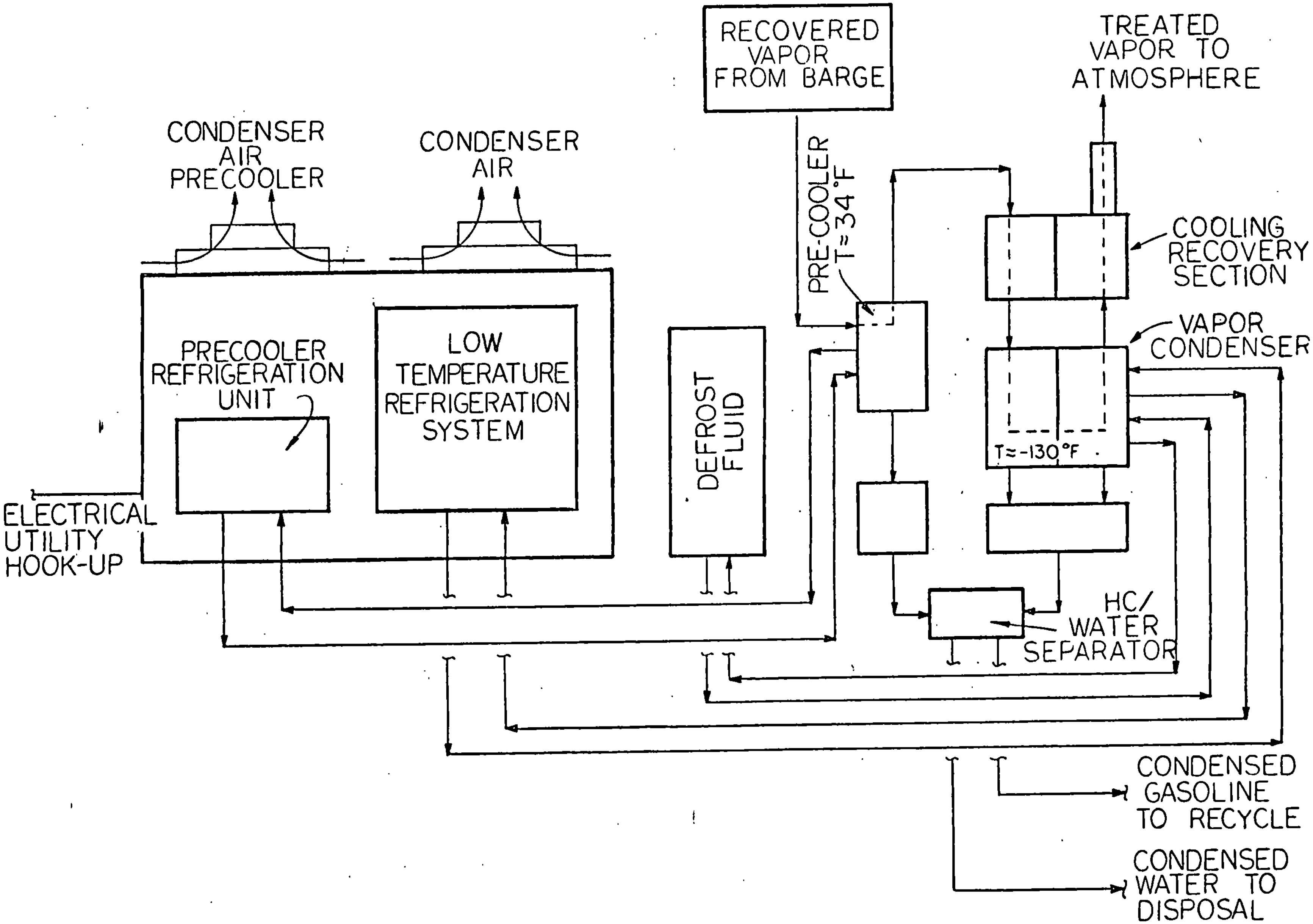

Figure 4.2.2 Refrigeration Vapor Recovery Module

NOTE

EPA does not consider methane and ethane emissions a problem since they do not enter into the reaction that produces smog.

While the refiners' analyses may not be significant from an environmental protection point-of-view, they are important with respect to this basic study of vapor control by refrigeration because C_1 and C_2 compounds (primarily methane and ethane) are unlikely to be removed to any significant degree by cooling to -100°F. The normal boiling points of methane and ethane are -259°F and -127°F respectively. However, a small amount will be absorbed into heavier compounds and thus removed. In fact, overall recovery efficiencies of 94% have been observed. In the first or precooler stage, the inlet vapors are cooled to 34°F which allows high removal of water vapor as well as the higher boiling hydrocarbon components. In the next step, vapors are introduced to the low-temperature vapor condenser, which operates between -80°F and -115°F, where additional condensible HC vapors are removed. The condensed liquids are separated into hydrocarbon and water components by decanting. The recovered gasoline from the condenser is returned to storage, the water is sent to the wastewater system, and the non-recoverable HC and air are vented to the atmosphere. The refrigeration system uses a cooling recovery section for increased efficiency. Incoming vapors to the condenser pass through the cooling recovery section and are cooled by heat exchange with the exiting non-recoverable vapors. The exiting vapors warm to approximately 75°F during this process step.

A warm brine system is included in the equipment for periodic defrosting of the low temperature vapor condenser section. The defrosting operation is performed during non-loading periods and requires one to two hours. Applications which require dual condensers are those in continuous service or those which operate in high humidity and build up ice rapidly. The condensers are cycled between defrost and operating modes. The models used for evaluation and costing in this study include dual condensers.

Gasoline vapor recovery by refrigeration for truck loading operations has been accepted by some oil companies and approximately 70 units are now in use.

The price estimates, obtained from the manufacturer's local representative, for the two refrigeration vapor recovery units described in the study are $300,000 each. The vendor package is complete except that utility connections must be made prior to operation. The skid mounted package contains the cascade refrigeration units, defrost system, condensers, separator, recovered gasoline pump, and the piping and instruments. The unit is constructed to meet applicable explosion proof codes, but it does not normally include any additional safety devices such as flame arrestors. However, the precooler and vapor condenser coils (Operating at approximately -100°F) could be regarded as wetted flame arrestors.

4.2.3 Thermal Incineration

Thermal incineration (Figure 4.2.3) disposes of gasoline vapors by burning rather than by product

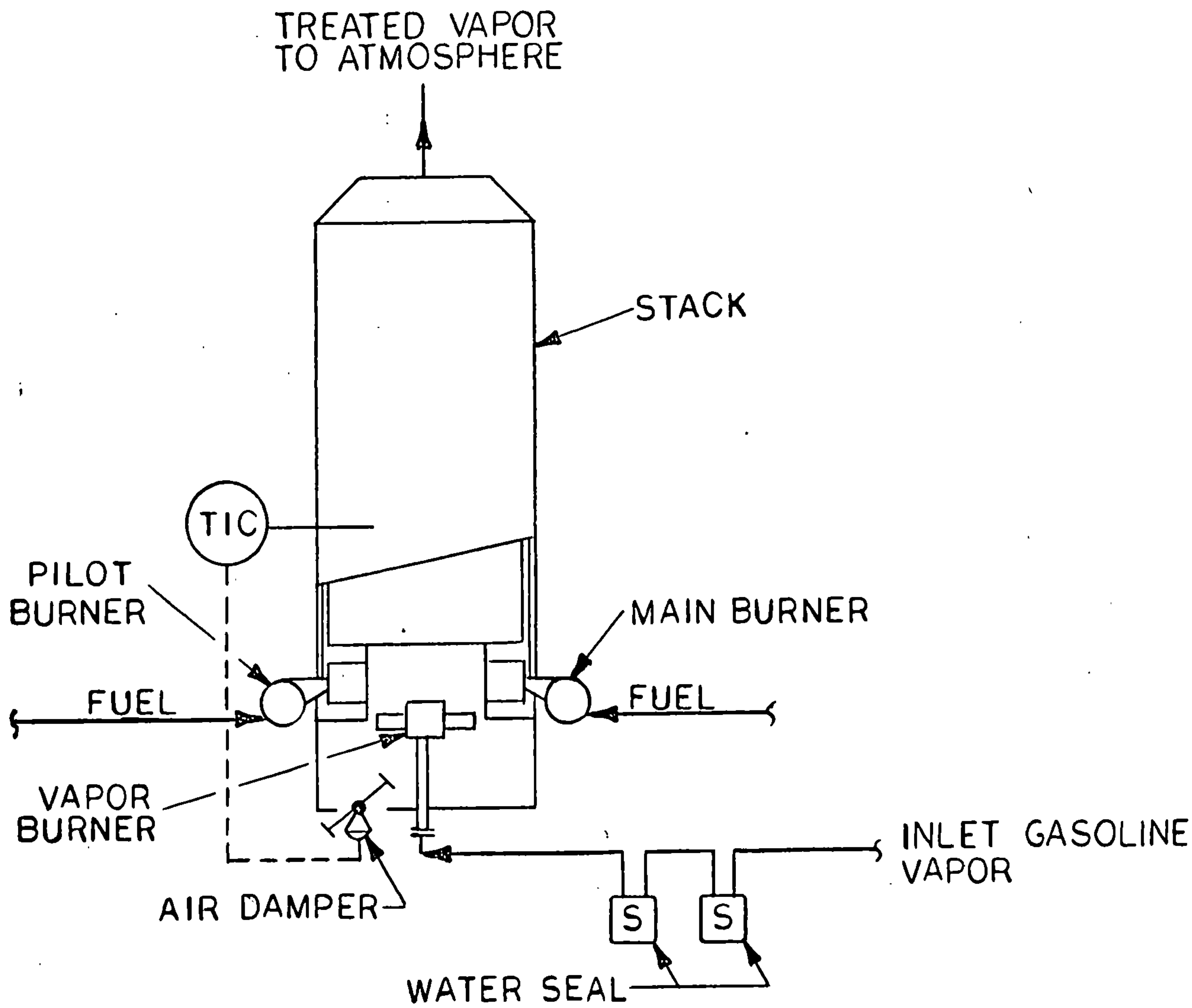

Figure 4.2.3 Thermal Incinerator Module

recovery methods. It provides the simplest and most direct control technology for gasoline and other hydrocarbon vapors. A typical unit as provided by one manufacturer is described in this study. The collected gasoline vapors are injected into the combustion chamber of the incinerator through a burner manifold. A temperature of approximately 1500°F is maintained in the chamber.

The residence time in the chamber is on the order of one second. Pilot burners provide ignition and main burners (supplementally fueled) are used, as necessary, to maintain the proper combustion temperature. Automatic air dampers admit combustion air and are set on temperature control. The efficiency of thermal incineration is higher than that of competing technologies. Over 99.9% of the hydrocarbon vapors are converted to non-hydrocarbon combustion products such as CO_2 or CO. With little or no incinerator modifications, similar results are obtained for a wide range of hydrocarbon compounds, and, of course, this is one of thermal incineration's chief advantages. Thermal incinerators are available from several manufacturers, and they have been installed by a number of gasoline-truck loading terminal operators. The estimated cost given by one manufacturer of an incinerator with a design flow of 5000 gpm, is $64,000. Their estimate of a duplex unit capable of 10,000 gpm is $128,000. The price includes the incinerator, monitoring devices, and protective water seals. The vendor supplied package requires only utility connections for operation.

The incinerator operates at atmospheric pressure. The total pressure drop across the unit is approximately 12" H_2O, and it is due almost entirely to the water seals on the vapor inlet. The thermal incinerators investigated for the report include several safety features:

1) As previously mentioned, for greater reliability, two water seals are installed in the vapor inlet.

2) An interlock for low-water seal level is used to prevent startup.

3) Ultraviolet radiation detectors are incorporated into the pilot and main burner interlock controls.

4) Emergency shutdown is used to prevent damage by excessive temperature.

5) The incinerator shutdown and interlock systems have a safety interface with the vapor collection and gasoline loading systems.

6) The incinerator burners themselves are designed with quenching slots to prevent flashback in the combustible vapor stream.

4.3 GENERAL DISCUSSION OF SAFETY TECHNOLOGY

The two major safety problems associated with gasoline barges and vapor control systems are fire (and/or explosion) and overfilling.

The following study considers safety problems as they exist and as they would be if vapor control and safety technology were used.

4.3.1 Fire and Explosion

With the current gasoline loading system, it is routine for fuel and air, two of the three elements required to initiate a fire or explosion, to be present around the barges. They are there because the heavier-than-air gasoline vapors displace the air near the deck of the barge. The third element, ignition, is a constant danger since the potential for static electrical and friction sparks, improper or malfunctioning electrical equipment, unauthorized smoking, operating tug boats, etc., can never be controlled absolutely. Until now, fire prevention philosophy has been to accept the presence of combustible mixtures both inside and outside of the barge, and to concentrate on eliminating ignition sources while hoping the air currents are sufficient to disperse the vapors and keep them too lean to ignite.

Addition of a vapor control system would eliminate one problem since vapors would no longer be released near deck level. However, a new problem caused by connecting an on-shore control facility to the barge - with both containing explosive mixtures - would be created. Since the facilities would be connected, new ignition sources would be created. Effectively, there would be a closed system, and a chain ignition could occur in either direction. Ignition from the shore to the barge would be of most concern since blowing up the barge would have the more disasterous consequence. Safety problems attendant to this closed system are more severe than the safety problems with the present system since ignition using the current loading technique should, at worst, cause a flash fire on the deck of the barge.

Potential ignition sources in the onshore equipment include rotating parts, static electricity, tramp metal in lines, and external fires.

The philosophy adopted in this study for protection of barges and vapor control systems from fire/explosion utilizes two systems employed together. These systems are:

1) A primary (active) system that renders the vapors emitted from the barge non-flammable by one of three means;

   a) Dilution with air,

   b) Replacement or reduction of air by fuel gas, N_2, or combustion gases (also called blanketing or inerting),

   c) Saturation of the vapors with gasoline.

2) A secondary (passive) system uses a single device that would preclude allowing a flame front (deflagration) or a detonation to pass either to the barge or to the dockside facility. Both components must be used in the overall system. The primary system, no matter how well designed, can have

equipment fail and allow exploding vapors to enter the vapor control system. Should an ignition occur under these conditions, the secondary system must be installed to prevent the flame from reaching the barge and creating a major catastrophe.

4.3.1.1 Primary (Active) System.- The primary system protects the barge loading area from fire or explosion by altering the barge vapors to make them non-combustible. The principles of the three active fire prevention techniques are discussed in the following paragraphs.

A. Dilution. - Dilution of the gasoline vapors recovered from the barge constitutes the simplest technique for rendering the mixture non-flammable. Dilution is accomplished by adding and mixing enough air with the vapors to reduce the HC concentration below the lower explosion limit (LEL) (approximately 1.4% gasoline by volume). The initial HC concentration determines the amount of dilution required.

To determine the volume of air required for diluting a given HC concentration, the maximum concentration by volume for a given set of conditions is established, and the volume of air required to reduce this to 1.4% by volume is calculated. The theoretical maximum HC concentration is the ratio of the gasoline true vapor pressure (TVP) to the absolute (atmospheric) pressure of the system. For a TVP of 7.4 psia, the theoretical maximum is 50.4% HC by volume. To reduce the HC concentration to the LEL, (ratio of HC to LEL or 50.4:1.4) the volume of air required is 35 additional volumes of air per volume of initial mixture. Allowing a safety factor of four (25% LEL) the required air volume is 143 times the initial volume. Therefore, the maximum efficient dilution air flow rate is 143 times the gasoline vapor flow rate.

B. Inertion. - Another means of rendering the mixtures non-flammable is by inertion. This technique uses gases such as N_2, CO_2, treated flue gases, or fuel gas, to replace air in the barge vapors and reduce the percentage of oxygen present. Depending on the type of inert gas used and the HC mixture, the maximum oxygen concentration allowable in the mixture is approximately 12-15% by volume. Inert gas can be introduced to the gasoline vapors by several methods. The preferred method is to admit inert gas into the barge as the liquid gasoline is unloaded by the receiver. Theoretically, this precludes an explosive mixture being encountered. As the gasoline is unloaded, the air that would normally enter the barge and create an explosive mixture is replaced by the inert gas. During unloading and the return transit, gasoline would evaporate as it normally does, but it would do so in an essentially inert atmosphere. When the barge is reloaded with gasoline the non-explosive mixture is displaced into the vapor collection-treatment system. The amount of vapor that is treated is at a minimum because no other gases are added.

C. Saturation. - Saturation of hydrocarbon vapors renders the mixtures non-flammable by enriching the

HC concentration of the stream significantly above the upper explosion limit. The upper explosion limit is about 8.4%, and the saturation concentration (which varies with temperature) ranges from 30 to 50% for normal temperatures. The vapors are saturated by passing them through a vessel, specifically designed for this purpose, where gasoline liquid is sprayed into the stream. As the gasoline spray evaporates, the HC concentration of the stream increases.

4.3.1.2 Secondary (Passive) Systems.- Several secondary devices are available to prevent flame or flashback propagation in the vapor control system. The devices are based on one of two principles although some may utilize both. One device uses metal tubes or plates which offer a large surface area to the vapor flow. The principle is to provide a large metal surface which acts as a heat sink and quenchs the fire preventing its propagation. The other type uses a liquid seal leg to disrupt the continuous vapor flow and prevent flame propagation. A variation of the liquid seal type has been used to contain and stop detonations in acetylene plants. Their effectiveness was demonstrated in a plant accident where a large detonation, between acetylene plants, in a pipeline was contained (Refer to Trade Journal #1). A demonstration of the usefulness in gasoline vapor service is warranted. This device is shown in Figure 4.3.1. Several secondary protection devices are used to isolate various portions of the system (e.g., the barge is separated from the active portion of the safety module and both will be isolated from the vapor control module). A flame arrestor is also required for the vent stack of the carbon adsorption and refrigeration vapor recovery units

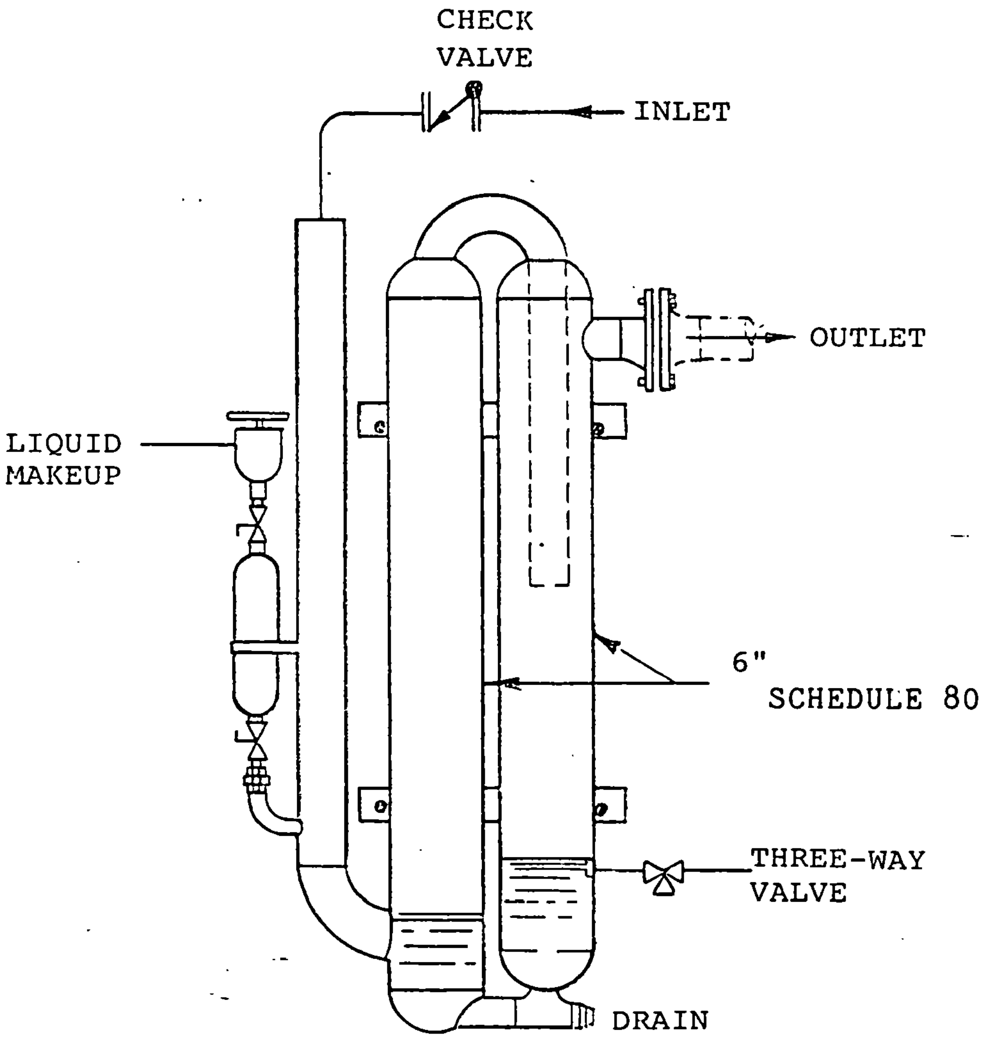

Figure 4.3.1 Hydraulic Flash Arrestor

because these systems can emit flammable vapors.

4.3.2 Barge Overfilling

The present method used to load barges requires one or more open hatches per compartment for the operator to gauge liquid levels by direct sight. While this method is extremely simple and reliable, it poses emission and safety problems. Vapor control for gasoline barges would require discontinuation of this system and use of a closed gauging system. Since the consequences of overflowing a compartment are severe, a combination of a gauging system and warning devices to indicate excessive liquid levels is warranted. A direct reading level indicator utilizing a stainless steel tape and float (housed in a stilling well) are used. (Refer to Figures 4.3.2 and 4.3.3.) High level floats with externally mounted switches provide the warning and they could be used to shutdown the systems. As an alternate to the level indicator, a transparent window for an observation port could be used for direct sighting, provided lighting and a method to prevent obscuring the level are furnished.

4.4 APPLICATIONS OF SAFETY AND CONTROL TECHNOLOGIES

There are fifteen combinations of safety and control modules available when studying the three control technologies and the five safety technologies. Refer to Figures 4.2.1, 4.2.2, and 4.2.3 for the carbon adsorption, refrigeration, and thermal incineration controls, and to Figures 4.4.2, 4.4.3, 4.4.4, and 4.4.5 for the safety technologies using dilution, saturation, and inerting with three different gases. Also refer to Figure 4.4.1 for the overview or system block diagram.

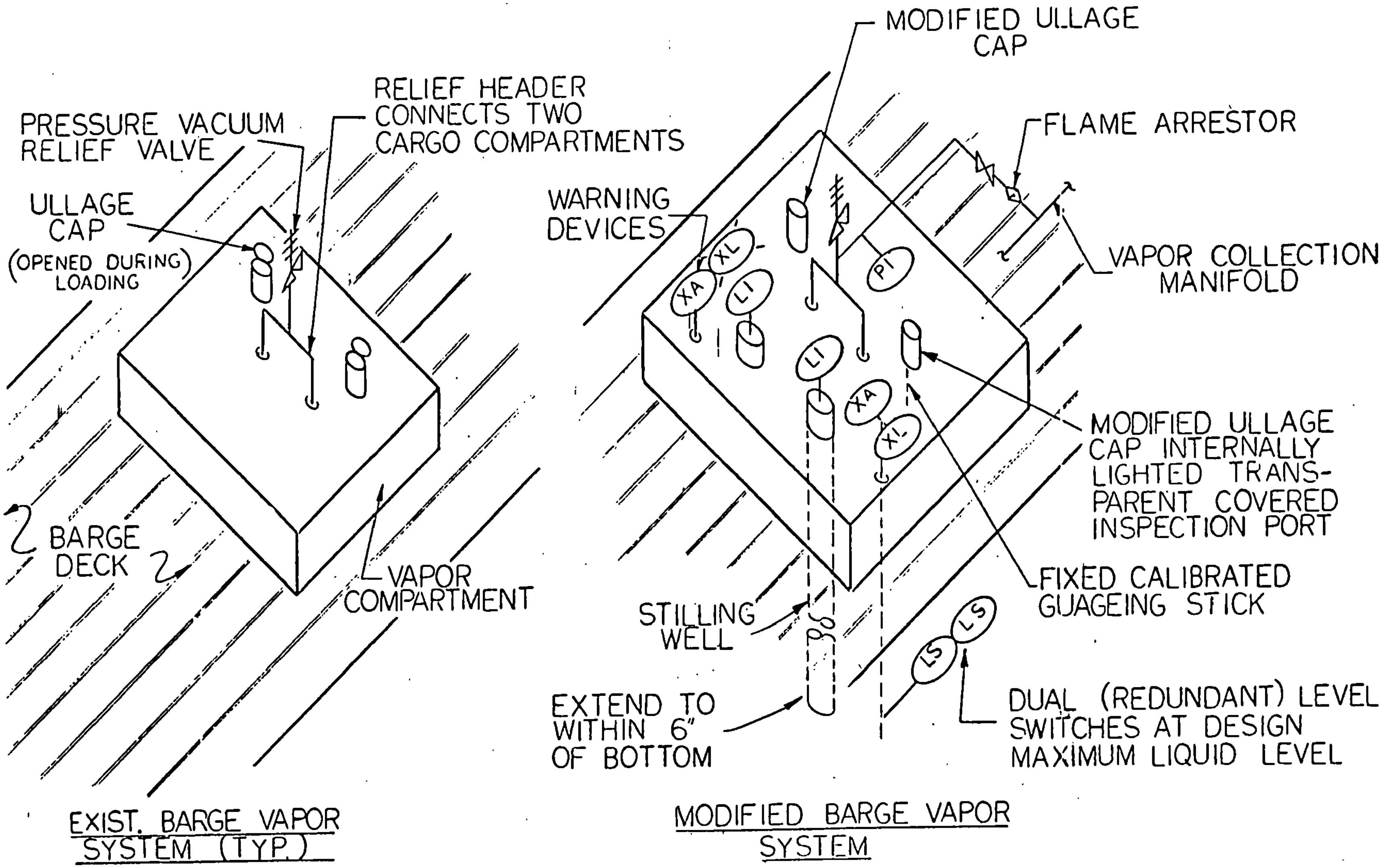

Figure 4.3.2 Barge Modifications

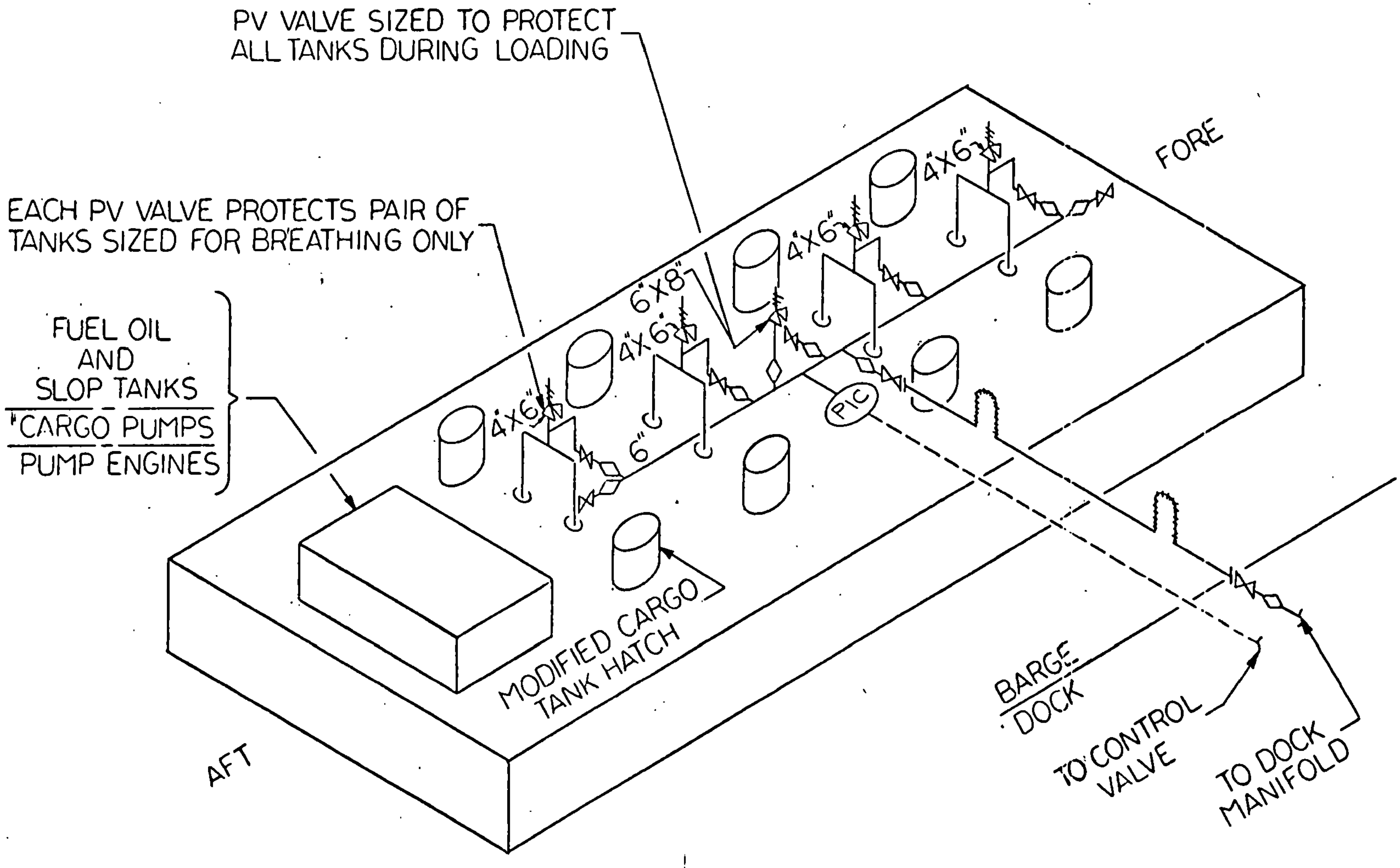

Figure 4.3.3 Barge Vapor Collection Manifold

A number of these combinations can be eliminated from analysis because of incompatability between the control and safety modules for technical or economic reasons. The dilution scheme is incompatible with carbon adsorption or refrigeration due to the high cost of the control equipment and low removal efficiencies. Enrichment of the barge vapors with fuel gas is also incompatible with carbon adsorption or refrigeration because virtually all of the light HC components would be emitted to the atmosphere at an economic loss.

Eleven cases have been investigated. Thermal incineration is used with all five safety modules. Carbon adsorption and refrigeration are used with saturation, with inerting using N_2, and with inerting using an inert gas generator. The inert gas generator used in the study burns natural gas under carefully controlled conditions to produce an oxygen-free product of scrubbed and cooled combustion gases.

The predicted exit vapor compositions from each of the safety modules is given in TABLE 4.4.1. Compositions are given for the three different initial HC concentrations used (5%, 18%, and 50%). These compositions represent the vapors that are received by the treatment units.

The control efficiencies and economics that are developed in this report are based on an initial HC concentration of 18%. The design gasoline loading rate is 6000 barrels per hour (bbl/hr) or 4200 gpm. The annual gasoline throughput for the barge terminal is six million barrels per year. It is assumed that 300 barges, each 20,000 bbl capacity, are loaded each year.

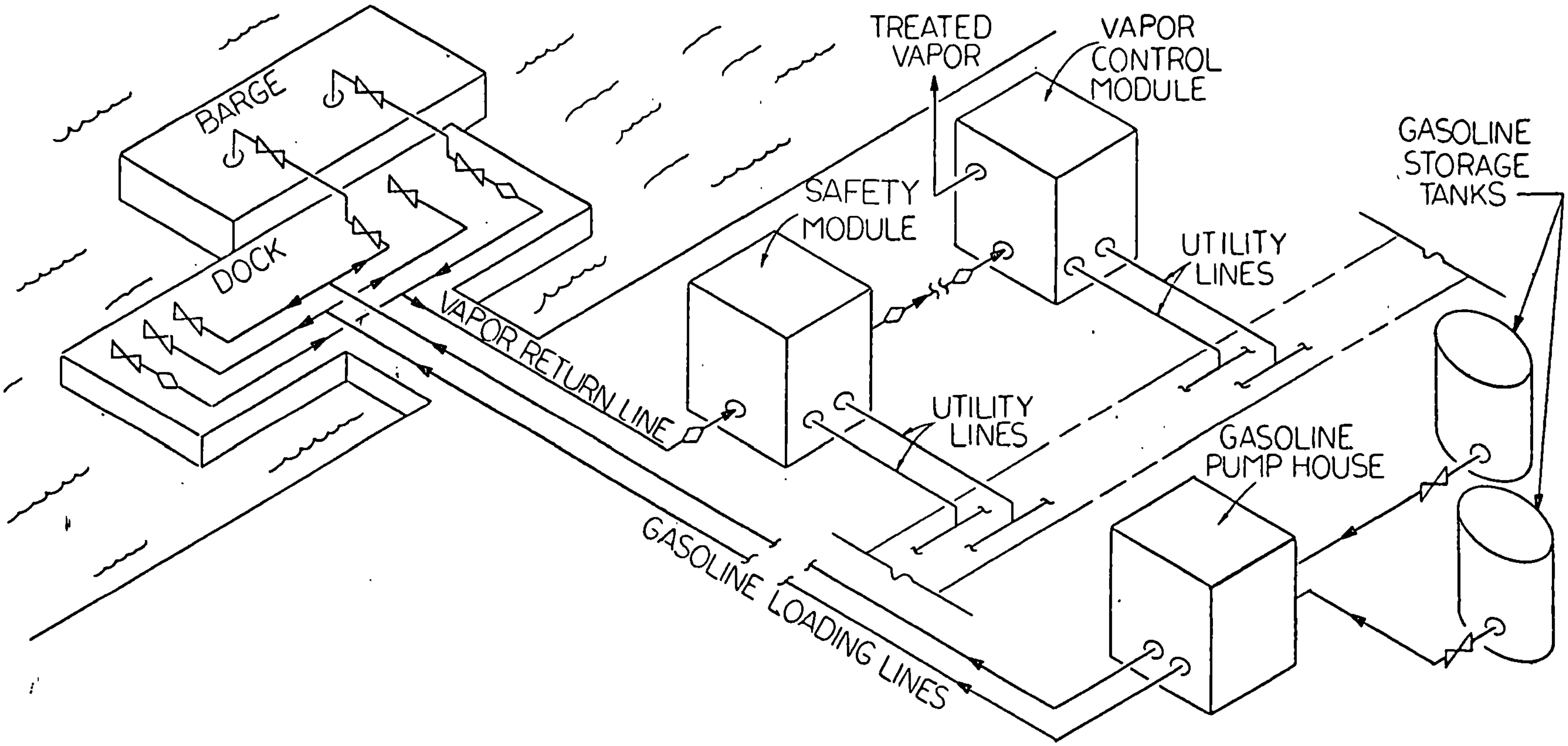

Figure 4.4.1 Loading and Collection System Layout

TABLE 4.4.1

PREDICTED VAPOR COMPOSITIONS

Safety Technique: Dilution with air to maintain 25% L.E.L. (= .35% total HC by volume) @ 50% initial concentration

Design Flow Rate = 353,000 GPM (47,000 ACFM)

Vapor Analyses for Design			
Initial Total HC	5%	18%	50%
Components by Volume			
$C_1 + C_2$	7.7 ppm	26.6 ppm	.01%
C_3	50.4 ppm	182 ppm	.05%
C_4	168 ppm	605.5 ppm	.17%
C_5 + Heavier	123.9 ppm	445.9 ppm	.12%
Air	99.96%	99.87%	99.65%
Additional Volumes of Air Added	141.86	141.86	141.86

Safety Technique: Fuel Gas is used to blanket the system and maintain 50% fuel gas in the vapors

Design Flow Rate = 9900 GPM (1325 ACFM)

Initial Total HC	5%	18%	50%
Components (% by Volume)			
$C_1 + C_2$	.06	.19	.53
C_3	.36	1.30	3.61
C_4	1.20	4.33	12.10
C_5 and Heavier	.89	3.19	8.90
Fuel Gas*	50	50	50
O_2	9.98	8.6	5.25
Additional Volumes of F.G. Added	1.0	1.0	1.0

*Fuel Gas can be assumed to be 100% CH_4

TABLE 4.4.1 (Cont)
PREDICTED VAPOR COMPOSITIONS

Safety Technique: Saturate vapors to 30% HC
Design Flow Rate = 5900 GPM (800 ACFM)
Vapor Analysis for Design

Initial Total HC	5%	18%	50%
Components (%)			
$C_1 + C_2$	.66	.66	1.06
C_3	4.32	4.32	7.22
C_4	14.4	14.4	24.03
C_5 and Heavier	10.62	10.62	17.70
Final Total HC	30	30	50*
Volume Increase due to Gasoline Saturation	36%	17%	0

* Fully Saturated

Safety Technique: Inert Gas Blanket
Design Flow Rate = 4950 GPM (660 ACFM)
Vapor Analysis for Design

Components (%)	5%	18%	50%
$C_1 + C_2$	.11	.38	1.06
C_3	.72	2.60	7.22
C_4	2.40	8.65	24.03
C_5 and Heavier	1.77	6.37	17.70
Inerts	95	82	50
O_2	0	0	0

4.4.1 Thermal Incineration by Dilution (Figures 4.2.3 and 4.4.2)

A dilution system reduces the HC concentration from the initial concentration (as high as 50%) to 25% L.E.L. (.35% HC). Dilution is accomplished using a 47,000 CFM blower which would be 100% spared. The vapors are diluted upstream of the blower, a potential spark source. The barge vapors are introduced into the suction side of the blower at 50% of the maximum loading rate, which is 2100 gpm. This step increases the loading time and was taken to reduce the size and cost of the system. This safety module is simple to operate and extremely reliable. However, it is compatible only with thermal incineration. The diluted vapors are transferred to the thermal incinerator and raised in temperature using supplementally fueled burners. In the event of incinerator failure, the vapors are safely released to atmosphere since they are not flammable. Interlocks are provided on the incinerator to prevent operation if the dilution system fails. An emergency shutdown for loading pumps, in case of dilution system failure, is desirable. Overall system simplicity insures very high reliability. Disadvantages of this system are the high fuel usage necessary to burn the lean vapors and the large flowrate which necessitates large and expensive equipment.

4.4.2 Thermal Incineration with Saturation (Figures 4.2.3 and 4.4.3)

Vapors displaced from the barge go directly to the saturator tower. There they are contacted with

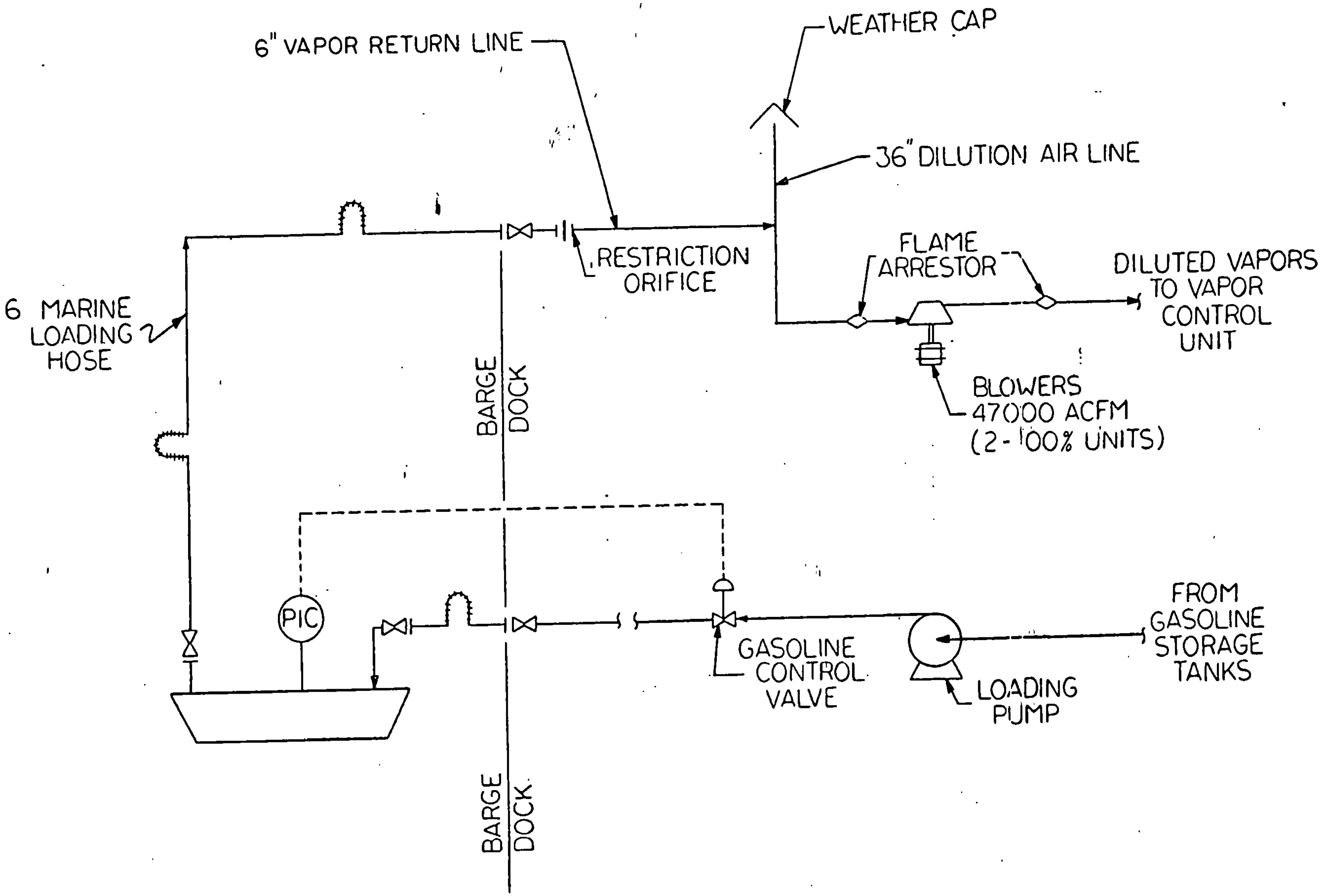

Figure 4.4.2 Dilution Module

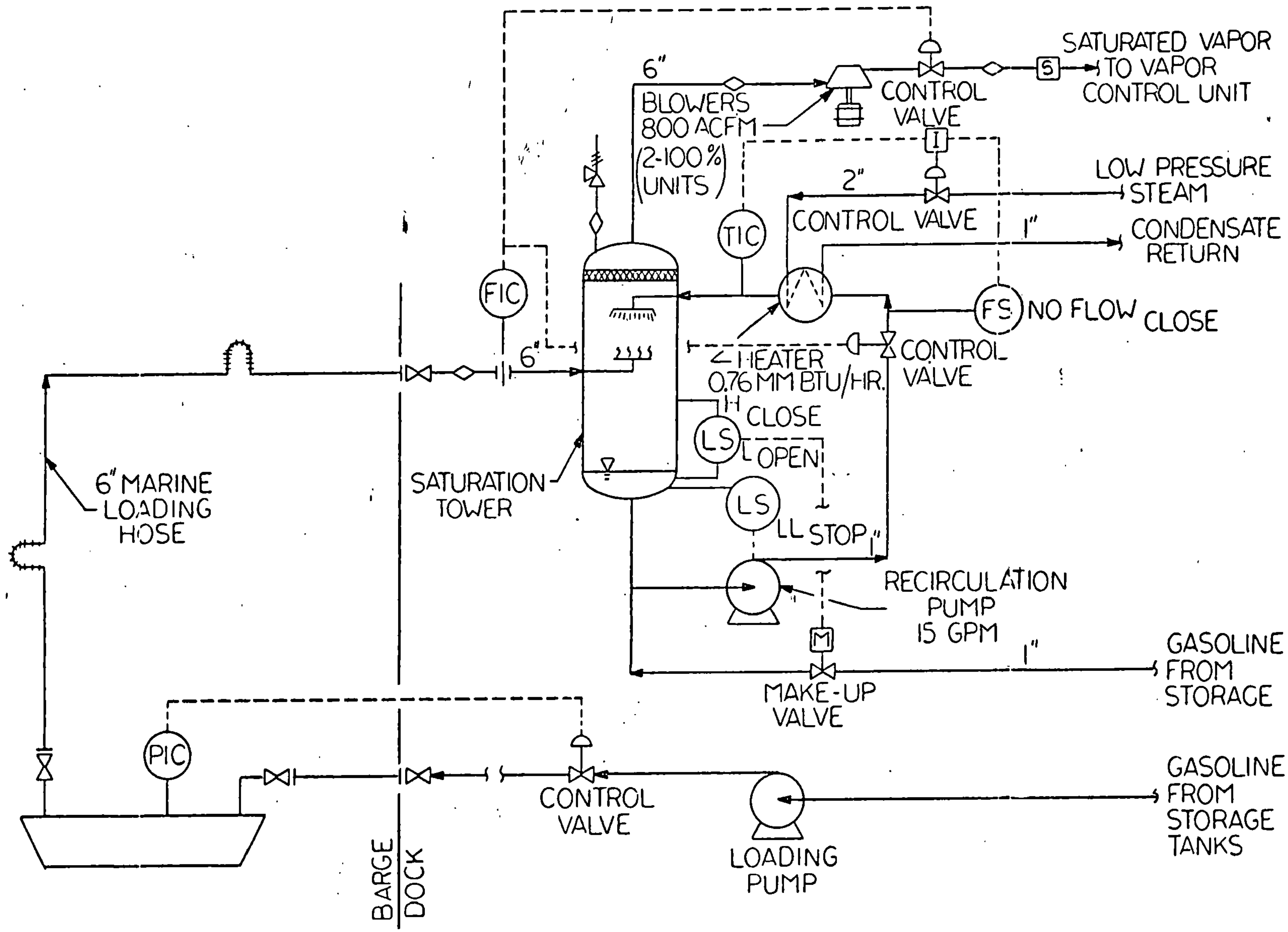

Figure 4.4.3 Saturation Module

gasoline which raises the concentration of HC in the vapors well above the upper explosion limit (UEL). The gasoline is recirculated by a small pump through a steam heated heat exchanger to maintain the gasoline at the temperature required for adequate vaporization. A demister on the outlet removes entrained droplets. Level switches control the gasoline make-up valve and prevent the pump from operating dry. The steam control valve is set on temperature control with a flowswitch override. Liquid gasoline flow rate can be varied with the vapor flow rate by means of a fixed ratio controller. The vapors are transported by blower to the thermal incinerator. Combustion air is added in the incinerator because the vapors are too rich for efficient direct combustion. However, no supplemental fuel is necessary and only the pilot burners are used to maintain combustion. Upon failure of the saturator, the thermal incinerator is automatically prevented from operating. A disadvantage of a saturator is its relative complexity compared to the other safety modules, and this reduces its overall reliability.

4.4.3 Thermal Incineration with Fuel Gas Blanketing (Figures 4.2.3 and 4.4.4)

Fuel gas blanketing of the barge vapors is accomplished by mixing equal volumes of fuel gas and vapors which cause blanketed vapors to be 50% fuel gas and too rich to burn. Assuming the fuel gas is mostly methane, the UEL of which is 13.5%, a safety factor of 4 is used. The fuel gas blanketing system resembles the dilution

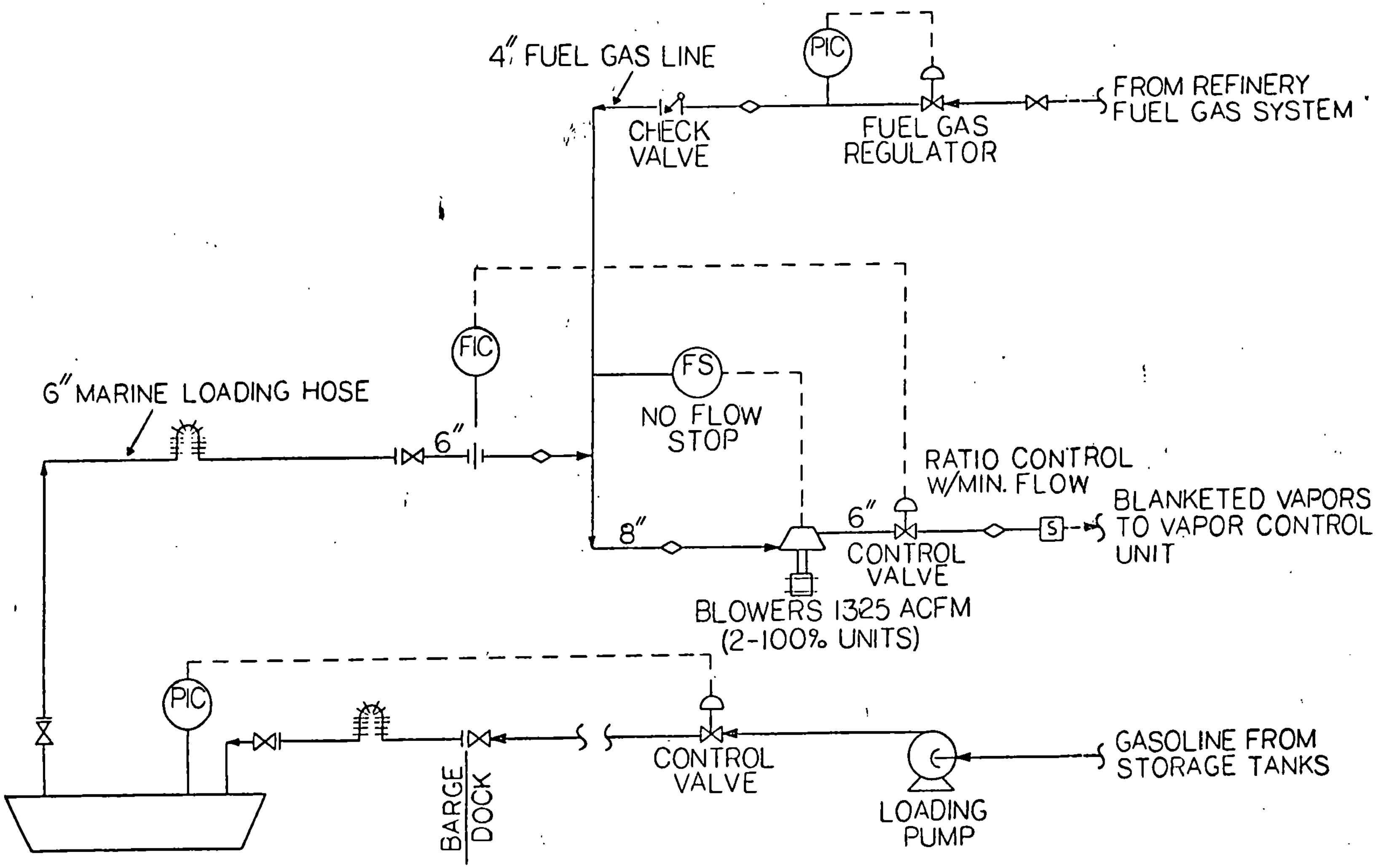

Figure 4.4.4 Fuel Gas Blanketing Module

module closely except that fuel gas is used instead of dilution air.

A fuel gas regulator maintains the flow of fuel gas at the proper pressure and a restriction orifice prevents the barge vapor flow rate from exceeding a predetermined maximum. The over-rich gas is sent to the incinerator by a blower where combustion air is added. No supplemental fuel is necessary and only the pilot burners are necessary. The reliability is almost the same as the dilution system and the same interlocks and safeguards apply.

4.4.4 Thermal Incineration with N_2 Blanketing
(Figures 4.2.3 and 4.4.5)

The proposed N_2 blanketing scheme varies from the earlier safety schemes in that the barge vapors are made safe at the barge unloading terminal. This is done by introducing the N_2 gas as the barge is emptied, and the gas replaces the air that would normally be allowed to enter the barge. The N_2 gas is stored as a liquid and vaporized as necessary in an ambient air vaporizer. When the barge is loaded, the expelled vapors contain a mixture of gasoline and N_2 which is non-flammable. These vapors are transported by blower to the incinerator. Since the average HC concentration (18%) is above the UEL, only combustion air and pilot burners are necessary for incineration.

The pressure vacuum relief valves must be operating correctly to prevent excess air infiltration from forming an explosive mixture in the barge. Sampling

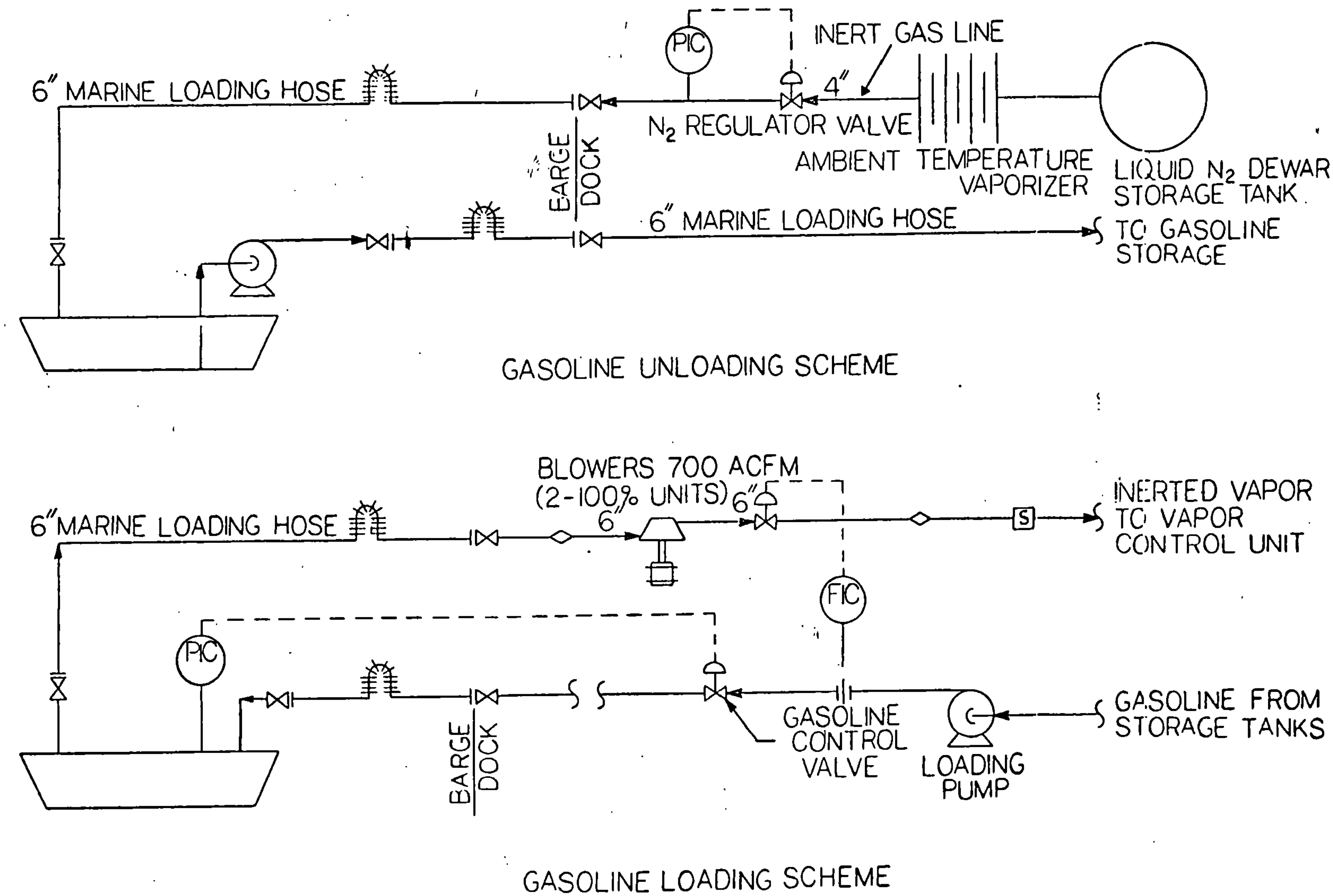

Figure 4.4.5 N_2 Blanketing Module

the barge vapors might be required before gasoline loading is started. N_2 blanketing is simple, and its reliability is high.

4.4.5 Thermal Incineration with Inert Gas Generation (Figures 4.2.3 and 4.4.5)

Except for using an inert gas generator rather than liquid N_2 as the blanketing medium, this scheme is similar to the N_2 blanketing scheme. The inert gas generator supplies scrubbed and cooled combustion gas to the barge. An inert gas generator burns a stoichiometric mixture of fuel (gas or oil) and air carefully to obtain a gas with virtually no free oxygen. The inert gas generator is more complex than the N_2 storage and vaporizer system and, therefore, is considered to be somewhat less reliable - but not enough so to warrant its rejection. The system offers many of the same advantages as N_2 gas and is equally compatible with the control equipment.

4.4.6 Carbon Adsorption with Saturation (Figures 4.2.1 and 4.4.3)

The saturation module operation is discussed in detail in Section 4.4.2. The carbon adsorption system receives the saturated mixture downstream of the blowers. The effect of saturation is to increase the removal efficiency of the carbon adsorption unit; however, due to the higher HC loading, the beds must be sized larger than they would if receiving vapors directly from the barge. Switching from the adsorbing mode to the regenerating mode is initiated automatically by a timer. All valves are actuated automatically. The desorbed vapors are passed through a adsorbing/condensation separator column of cool gasoline from storage. Condensed water is decanted in a separator. The water is sent to sewer for subsequent treatment and disposal. The recovered gasoline product is returned to storage. Because no segregation of vapors from leaded and unleaded stocks is proposed, the coolant gasoline is leaded to prevent contamination of unleaded gasoline. Reliability for this case is lower than average for the cases studied due to the complexity. It is possible for the exit vapors to be flammable, even though the influent vapors are over-rich. To prevent a fire that originates at the vent from propagating, flame arrestors and careful positioning of the vent is necessary.

4.4.7 Carbon Adsorption with N_2 or Inert Gas Generator (Figures 4.2.1 and 4.4.5)

These cases are sufficiently similar that they can be discussed together. The operations of the N_2 module and inert gas generator module are discussed in 4.4.4 and 4.4.5 respectively. The carbon adsorption system operates in the same way as that used with saturation. However, due to the lesser HC loading, the carbon requirements are lower. The possibility for flammable exit gases is reduced by the presence of N_2 or inert gas. With respect to reliability relative to the other systems, this system ranks about average.

4.4.8 Refrigeration with Saturation (Figures 4.2.2 and 4.4.3)

Operation of the saturation module has been described in Section 4.4.2. The refrigeration unit is designed to operate automatically without operator attention. Condensed water and HC are collected and separated. Recovered gasoline is sent to leaded gasoline storage tanks to prevent contamination. The refrigeration system also handles defrosting automatically. It is possible that the exit vapors will be in the flammable range. Therefore, flame arrestors and proper placement of the vent is mandatory. The overall complexity of this case is among the highest studied and for this reason reliability is affected.

4.4.9 Refrigeration with N_2 or Inert Gas Generator
(Figures 4.2.2 and 4.4.5)

The operation of the N_2 blanketing and inert gas generators is discussed in Sections 4.4.4 and 4.4.5. Due to their similarity they can be discussed together. The type of refrigeration system for use with these two safety modules need not be changed from that used with saturation because they are designed for saturated vapors. The possibility of flammable exit vapors is low due to the presence of N_2 or inert gas. Based on the degree of complexity for the overall systems, the reliability is about average for the cases studied.

4.4.10 Other Design Considerations
The features of individual gasoline barge terminals are significantly different than those of the hypothetical terminal. These differences would, of course, change the specific design conditions. For example, if the cargo services for the barge were switched from gasoline to diesel oil, gasoline vapors (the arrival

component) would be displaced when diesel was loaded. Although the HC concentration of the evolved vapors would be lower than for gasoline loading, they would still present significant safety and emissions problems. It would, therefore, be desirable to control this mixture of gasoline and diesel vapors. However, if gasoline and diesel were loaded at separate docks, the gasoline barge vapor control system would have to serve the diesel oil loading dock. This is not a design consideration used on the model and would affect the conclusions as well as the design and operation of the control facility.

Some means for handling condensed and entrained liquid hydrocarbons within the vapor collection system is necessary. Condensed HC is a problem particularly with respect to the saturation and inertion safety modules, because the lines are full of vapors that condense due to nocturnal cooling when the system is shut down. This problem can be solved by sloping the vapor collection lines to a liquid knock-out drum. The condensed liquids will drain to the drum and can be removed periodically. Another solution for the condensation problem is to purge the system with air by continuing to operate the control system after loading is completed.

4.5 EMISSIONS AND CONTROL EFFICIENCIES

4.5.1 Primary Emissions

A hypothetical, non-explosive composition for vapors emitted from the barges is used in this study. The composition of the stream is altered by various safety modules to insure that explosive mixtures are never sent to the vapor recovery system. Composition of the unaltered vapor as it leaves the barge is shown in TABLE 4.5.1. The hydrocarbon vapor has a concentration of 18% by volume, which is equivalent to an emission factor of 4#HC/1000 gallons of gasoline filled, assuming an average molecular weight of 66 #/#mole. These figures are based on test data developed by Exxon and as reported in EPA-450/3-76-038a, page 127. For full loading of a 20,000 bbl capacity barge, the HC loss, therefore, is 3360 pounds when the vapors are allowed to vent directly to atmosphere. Since this is the method by which barge vapors are being handled, the 3360 pounds HC loss per barge loading is the emission quantity used for the base case. For an annual rate of 300 barges, the predicted loss is 1,008,000 pounds of hydrocarbons per year for the hypothetical terminal.

The stated efficiencies for the vapor control modules were obtained from the equipment manufacturers, or their representatives, for optimum operation under the vapor conditions given to them. These vapor conditions are listed in TABLE 4.5.2.

TABLE 4.5.3 describes the manufacturers' predicted efficiencies. For comparison, a short survey of EPA test reports of tank-truck loading controls was performed to obtain some actual, measured results of control efficiencies. (EPA Reports PB-243-363, PB-275-060, EMB-77-GAS-19, EMB-76-16, and EMB 77-18.) The results of this survey are shown in TABLE 4.5.4, and they indicate that for carbon adsorption, the

TABLE 4.5.1
GASOLINE BARGE VAPOR COMPOSITION

COMPONENT	VOLUME CONCENTRATION (%)
$C_1 + C_2$	.38
C_3	2.60
C_4	8.65
C_5 and Heavier	6.37
Air	82
Total HC	18

TABLE 4.5.2
BARGE VAPOR COMPOSITIONS AFTER SAFETY MODULE

Safety Technique: Dilution with air to maintain 25% L.E.L.(= .35% total HC by volume) @ 50% initial concentration

Design Flow Rate = 353,000 GPM (47,000 ACFM)

Vapor Analyses for Design			
Initial Total HC	5%	18%	50%
Components by Vol.			
$C_1 + C_2$	7.7 ppm	26.6 ppm	.01%
C_3	50.4 ppm	182 ppm	.05%
C_4	168 ppm	605.5 ppm	.17%
C_5 + Heavier	123.9 ppm	445.9 ppm	.12%
Air	99.96%	99.87%	99.65%
Additional Volumes of Air Added	141.86	141.86	141.86

Safety Technique: Fuel Gas is used to blanket the system and maintain 50% fuel gas in the vapors

Design Flow Rate = 9900 GPM (1325 ACFM)

Initial Total HC	5%	18%	50%
Components (% by Vol.)			
$C_1 + C_2$	.06	.19	.53
C_3	.36	1.30	3.61
C_4	1.20	4.33	12.10
C_5 and Heavier	.89	3.19	8.90
Fuel Gas*	50	50	50
O_2	9.98	8.6	5.25
Additional Volumes of F.G. Added	1.0	1.0	1.0

*Fuel Gas can be assumed to be 100% CH_4

TABLE 4.5.2 (CONT.)
BARGE VAPOR COMPOSITIONS AFTER SAFETY MODULE

Safety Technique: Saturate vapors to 30% HC

Design Flow Rate = 5900 GPM (800 ACFM)

Vapor Analysis for Design

Initial Total HC	5%	18%	50%
Components (%)			
$C_1 + C_2$	.66	.66	1.06
C_3	4.32	4.32	7.22
C_4	14.4	14.4	24.03
C_5 and Heavier	10.62	10.62	17.70
Final Total HC	30	30	50*
Volume Increase due to Gasoline Saturation	36%	17%	0

* Fully Saturated

Safety Technique: Inert Gas Blanket

Design Flow Rate = 4950 GPM (660 ACFM)

Vapor Analysis for Design

Components (%)	5%	18%	50%
$C_1 + C_2$	.11	.38	1.06
C_3	.72	2.60	7.22
C_4	2.40	8.65	24.03
C_5 and Heavier	1.77	6.37	17.70
Inerts	95	82	50
O_2	0	0	0

TABLE 4.5.3
Manufacturers Predicted Vapor Control Unit Efficiencies

Control Technology	Removal Efficiency	Comments
Carbon Adsorption	98.3%	For use with N_2 or Inert Gas Generator
	99 %	For use with Saturator
Refrigeration	91.4%	For use with N_2 or Inert Gas Generator
	93.9%	For use with Saturator
Thermal Incineration	99.9%	For use with all Safety Modules

TABLE 4.5.4
CONTROL EFFICIENCIES REPORTED IN EPA LITERATURE

Control Technology	Range of Efficiency	Test Period Length	EPA Report Reference No.
Carbon Adsorption	91.0-99.5%	3 days	EMB-77-GAS-19
Refrigeration	80.4-93.1%	3-4 days	PB-275-060 EMB-76-GAS-16 EMB-77-GAS-18
Thermal Incineration	99.8%	1 year	PB-243-363

control unit had a three day average recovery efficiency of 95.9%, with a range (for a single day) of 91 to 99.5%. A recovery efficiency of 91% occurred when the carbon adsorption system failed to cycle properly between the twin beds, and the system operated primarily on one bed. Outlet HC concentrations from the control unit for individual runs ranged from 0% to 12.77% by volume expressed as propane. The daily averages ranged from 3.5% to 0.2%.

Although interpreting these reported test results provides useful data, there is no direct applicability to the present barge loading case because differences in vapor flow rates and HC concentrations between truck and barge loadings prevent comparison of numbers. The data, however, could be typical of variations that occur with actual operations. The important difference is in HC concentrations; the average concentration for truck vapors entering the recovery unit ranges from 30 to 55% for trucks with vapor balance, while barge vapors for the conditions of this study vary from 5% to over 50%, with an average value of 18%. In general, for a given carbon adsorption unit, when inlet concentrations are reduced, the recovery efficiency is also reduced. This occurs because the exit concentration is relatively fixed as long as breakthrough or overloading the carbon bed has not occurred.

The reported test results for three refrigeration systems gave recovery efficiencies of 80.4%, 93.1%, and 84.4%. (Detailed descriptions were obtained for only one of the units.) The unit that achieved 84.4% recovery was reported to have experienced refrigerant leakage which resulted in the condenser operating at a higher-than-design temperature. Efficiencies for individual runs ranged from 49 to 91% on one day and 71 to 95% on the other day. The reported inlet HC concentrations in the vapor were in the range of 10.8 to 30.5% with an average of 15.4%. These HC concentrations compare favorably with expected barge vapor HC concentrations. Exit vapor concentrations of 1.7 to 4.8% (as propane) were observed in the tests; the average was 3.2%.

A reduction in control efficiency occurs in refrigeration systems as the inlet HC concentration is reduced. This occurs because outlet concentration is set by the temperature and pressure of operation, and it does not vary with inlet concentration.

Reported test results for thermal incineration systems have shown that very high control efficiencies are obtainable. Reductions of 99.8% occurred in normal operation at a truck loading terminal, and HC concentrations between 1 and 45 ppm (expressed as methane) were reported at the outlet of the incinerators.

The claimed efficiencies of the control technologies correspond to the efficiencies demonstrated in testing under normal circumstances (i.e., in the absence of malfunctioning equipment). A greater effort is made under test circumstances to ensure proper operation of the equipment than under normal day-to-day operation. Therefore it is reasonable to expect that the efficiency of the control units in normal use will not be the same as observed in test situations, or as given by the manufacturers.

However, due to the limited data base, it is impossible to predict reasonably the normal operating efficiencies. It can be said, however, that the results are likely to be lower than results achieved in testing.

The data that have been obtained demonstrate that thermal incineration, at 99.8%, has the highest control efficiency of the technologies evaluated. The second most efficient technology is carbon adsorption at 98.3% and 99% reduction, depending on the safety system used.

Emission rates for each of the control cases have been calculated using the control unit reduction efficiencies from TABLE 4.5.3 and an estimated collection system efficiency of 98%. These rates are given in TABLE 4.5.5. The collection efficiency is theoretically 100%. Most of the vapor collection systems in service for truck loading depend on vapor displacement by differential pressure to transport vapors to treatment. They have experienced collection efficiencies from 30% to greater than 90%. The single most prevalent reasons for the leakage have been poor sealing at the truck to vapor return line connection and malfunction of pressure relief valves. It is reasonable to expect a higher efficiency in the barge vapor collection system because bolted-flange piping connections are used.

4.5.2 Secondary Emissions

The secondary emissions produced by the adoption of any of the control or safety technologies are minor, and they will be discussed by type and source rather than a quantitatively.

TABLE 4.5.5
PREDICTED ANNUAL HC EMISSION RATES FOR CONTROL CASES
LB/YR HC EMITTED
(Percent reduction from Uncontrolled Base Case)

Control Modules	Safety Modules: Dilution	Saturation	Fuel Gas Blanket	N_2 Blanket	Inert Gas Generator
Carbon Adsorption	N/A	50,061 (95)	N/A	36,954 (96.3)	36,954 (96.3)
Refrigeration	N/A	134,028 (86.7)	N/A	105,111 (98.6)	105,111 (89.6)
Thermal Incineration	21,150 (97.9)	35,246 (96.5)	49,887 (95)	21,150 (97.9)	21,150 (97.9)

N/A - Not Applicable

Gaseous secondary emissions are produced by the combustion processes of the inert gas generator and the thermal incinerator. The combustion gases evolved will contain CO_2, CO, unburned HC, NO_x, and SO_x (if the fuel contains sulfur). The inert gas product from the inert gas generator is a water-cooled and scrubbed combustion gas; therefore, a portion of the contaminants are removed. Tests on other thermal incinerators in gasoline-tank-truck loading service have reported measured concentrations of CO as high as 35 ppm and NO_x as high as 10 ppm. Refrigeration and carbon adsorption control modules are not producers of gaseous secondary emissions.

Liquid secondary emissions from the safety and control modules include a number of contaminated water streams. The inert gas generator produces a cooling water stream which is used for contact cooling of the combustion gases. The absorbed CO_2, NO_x and SO_x (if present) cause the cooling water to become acidic and corrosive, and they must be sent to waste water disposal. The refrigeration system condenses water vapor and gasoline vapors together and separates them by decanting. The water is contaminated by hydrocarbons and must be properly disposed. A final source of secondary liquid wastes is the overflow stream from the water seals used to isolate portions of the vapor collection system. This overflow is contaminated by the hydrocarbon vapors.

Solid emissions are not a problem with the safety modules or with the refrigeration technology. Also particulate emissions from the thermal incinerators are predicted to be minor. The carbon adsorption produces small carbon fines as the carbon particles abrade. The most significant solids disposal problem occurs when the carbon in the beds must be replaced, but the replacement interval is on the order of 10 or more years and then the problem can be resolved by returning the carbon to the manufacturer for disposal or regeneration.

4.6 ECONOMICS

Capital (total erected) and annualized (operating and depreciation) costs were calculated for each of the control cases studied. All costs are given in terms of U.S. dollars (second quarter 1978). The basis and discussions of the capital and annualized costs are presented in the following paragraphs.

The costs of the modules were calculated separately and then assembled into specific control cases. By adding together the capital and annualized costs of the safety module and control module, the capital or annualized cost for the specific control case was obtained. The cost of using a particular control module will vary with the type of safety module used, and is dependent on the degree of compatibility between the safety module and the control module. Therefore, the cost effect of the safety module on the control module is apparent by direct comparison.

4.6.1 Capital Costs

The capital cost estimate for any particular safety or control module represents the total cash outlay required for the design, procurement, and installation of the equipment and material within the module. The costs for major equipment items were obtained from vendors as engineering estimates or budget prices. The major equipment items include the specialty vapor control units, the inert gas generator, and the blowers. Bulk commodity items such as piping, steelwork, foundations, electrical supply, and paint were estimated and priced by Pullman Kellogg's cost estimating department. An allocation for minor spare parts was made as a percentage of the total material cost; however, no spare or backup control units were included. It was assumed that no additions in utility plant capacities for cooling water, steam, electricity, sewers, or fuel gas were required (utility cost rates include depreciation). Only the costs for short (200 feet) local utility distribution connections were included. Sales and use taxes were estimated as a percentage of the total material cost. Home office costs, insurance, commissioning, contingency, and contractor overhead and profit were estimated as percentages of the material and labor costs.

The safety module includes all items from the loading dock to the control module connection. The total capital costs for each of the safety modules are shown in TABLE 4.6.1. The itemized cost listings for the safety modules are in Appendix B. The costs for fuel-gas and nitrogen-blanketing modules are grouped at $200,000, and the remaining modules are

TABLE 4.6.1
CAPITAL COST OF SAFETY MODULES

MODULE	COST
Dilution	$330,800
Saturation	307,200
Fuel Gas Blanketing	209,100
N_2 Blanketing	198,300
Inert Gas Generator	364,100

grouped between $300,000 and $365,000. It should be noted that the safety module utilizing N_2 for blanketing does not include the capital cost for the liquid N_2 storage tank and vaporizer. This equipment is leased and thus becomes an operating expense rather than a capital expenditure. If these items were purchased rather than leased, N_2 blanketing would not be the least expensive module, and it would most likely cost about $320,000.

The control module cost includes the vapor control unit and the associated utility connections. Total capital costs for each of the control modules are shown in TABLE 4.6.2.

The costs for thermal incineration as a group are much less expensive than the competing technologies. The capital cost of thermal incineration control schemes range from $148,800 to $297,600, depending on the safety module applied. Control module costs for use with saturation and N_2 or inert gas generator modules are lowest since flow rates are not increased substantially, as compared to dilution or fuel gas blanketing which raise flow rates substantially. Capital cost for a thermal incineration module to be used with the dilution safety module was not obtained; however, the excessive operating cost makes it prohibitive due to high fuel requirements.

Carbon adsorption is the highest capital cost technology. Carbon adsorption with saturation costs $661,800 and carbon adsorption with inertion cost $458,300. The difference in cost is caused because larger carbon beds

TABLE 4.6.2
CAPITAL COST FOR CONTROL MODULES

Carbon Adsorption	
- For Use W/ Saturation	$661,800
- For Use W/N_2 or Inert Gas Generator	$458,300
Refrigeration	
- For Use W/Saturation	$614,800
- For Use W/N_2 or Inert Gas Generator	$614,800
Thermal Incineration	
- For Use W/Dilution	N/A
- For use W/Saturation	$171,100
- For use W/Fuel Gas Blanketing	$297,600
- For Use W/N_2	$148,800
- For Use W/Inert Gas Generator	$148,800

are required for saturation than for inertion due to the gasoline added.

Refrigeration modules are identically priced at $614,800 for use with saturation or inertion since the refrigeration duty is based on a saturated gasoline-air mixture.

The cost of each case studied is shown in TABLE 4.6.3. As the table indicates, thermal incineration systems establish the lowest capital expenditure, from a low of $347,100 to a high of $506,900 and an average cost of $459,800. The carbon adsorption systems range from $656,600 to $969,000 with an average figure of $814,000. The refrigeration systems range from $813,000 to $972,900 and average $902,600. For any of the three control technologies, the lowest capital cost is incurred when nitrogen inert blanketing is employed.

The capital cost for barge modifications reported by others ranged from $50,000 to $150,000 (1976 dollars) per barge. (Refer to EPA-450/3-76-038a, page 159). A detailed description of the modifications covered by these reported costs could not be determined however. The total erected costs for modifying the barges to conform with the modifications shown in Figures 4.3.2 and 4.3.3 (with the exception of the direct sighting port) are estimated to be $152,000 per barge. These costs do not include the costs due to cleaning, degassing, or lost revenue during the period the barge is removed from service. These costs are all incurred by the barge owner.

TABLE 4.6.3
CAPITAL COSTS OF BARGE LOADING EMISSION CONTROL SYSTEMS ($)

Emission Control Module Type	Safety Module Type				
	Dilution	Saturation	Fuel Gas Blanketing	N_2 Blanketing	Inert Gas Generator
Carbon Adsorption	N/A	969,000	N/A	656,600	816,400
Refrigeration	N/A	922,000	N/A	813,100	972,900
Thermal Incineration	-	478,300	506,700	347,100	506,900

4.6.2 Annualized Costs

Components included in annualized costs are utilities, maintenance, labor, capital recovery charges, and gasoline recovery credits (if any). Utility costs include electricity, fuel gas, N_2 gas, steam, cooling water, and gasoline.

The costs for the utilities are:

Electricity	$.04/KWH
Natural Gas	$2.73/1000 ft^3
N_2 Gas	$2.90/1000 ft^3 (delivered as liquid)
N_2 Storage and Vaporizer	$1350/month
Steam	$3.50/1000 lb
Cooling Water	$.15/1000 gal
Gasoline	$.40/gal

The unit costs for these utilities are representative of prices obtainable on the Texas Gulf Coast. Maintenance costs for equipment have been estimated as a percentage of the capital cost.

The percentages used for maintenance costs of the safety modules are:

Dilution	2%
Fuel Gas Blanketing	1%
Inert Gas Generator	3%
N_2 Blanketing	1%
Saturation	5%

The percentages used for maintenance costs of the control modules are:

Carbon Adsorption	3%
Refrigeration	2%
Thermal Incineration	1%

Additional labor (over the uncontrolled case) has been assumed to be one extra operator during the loading periods for both safety control modules. The labor rates are approximately union scale for the area and include fringe benefits. A labor rate of $12/operator-hour is used. Capital charges are based on a 10% annual interest rate and 15 year equipment life with a capital recovery factor of 0.13147. Administrative expenses are calculated as 4% of the capital cost. A credit for gasoline recovery is taken at $.40/gal for those cases where a reduction in gasoline losses is achieved.

TABLE 4.6.4 contains the annualized costs for each of the safety modules. The annualized cost for the inert gas generator is lowest at $95,600, with dilution only slightly higher at $99,200. The remaining safety modules rank upward from fuel gas blanketing to gasoline saturation, to N_2 blanketing. These three modules range from $142,500 to $162,200.

Annualized costs for the control modules are listed in TABLE 4.6.5. The cost for each control module depends on the safety module used with it. For the control modules that recover gasoline (carbon adsorption and refrigeration), the annualized costs are reduced dramatically when the saturation safety module is used. This is due to the credit for the increased gasoline

TABLE 4.6.4

ANNUALIZED COSTS FOR SAFETY MODULES ($)

	Dilution	Saturate	Fuel Gas	N_2	Inert Gas Generator
Gasoline	-	76,800	-	-	-
Electricity	11,936	328	597	298	578
Fuel Gas	-	-	91,973	-	8354
N_2	-	-	-	113,903	-
Steam	-	2919		-	-
Cooling Water	-	-	-	-	2520
Total Utilities	11,936	80,047	92,570	114,199	11,452
Capital and Administrative Costs	56,670	52,675	38,854	34,002	61,403
Maintenance	6,610	15,360	2,091	1,983	10,743
Labor	24,000	12,000	12,000	12,000	12,000
Total Annualized Cost	99,216	160,082	142,515	162,184	95,598

TABLE 4.6.5
ANNUALIZED COSTS FOR CONTROL MODULES
($)

Control Module	Carbon Adsorption		Refrigeration	
Safety Module	Saturation	N_2 or Inert Gas Generator	Saturation	N_2 or Inert Gas Generator
Utilities	3,640	2,432	5,960	5,960
Capital and Administrative Costs	113,479	78,584	105,420	105,420
Maintenance and Labor	19,854	13,749	12,296	12,296
(Gasoline Credit)	(130,447)	(76,186)	(121,252)	(70,814)
Total Costs	6,526	18,579	2,424	52,862

Control Module		Thermal Incineration		
Safety Module	Dilution	Saturation	Fuel Gas Blanketing	N_2 or Inert Generator
Utilities	453,464	473	946	473
Capital and Administrative Costs	N/A	29,342	51,030	25,515
Maintenance and Labor	N/A	1,711	2,976	1,488
(Gasoline Credit)	(0)	(0)	(0)	(0)
Total Costs	N/A	31,526	54,952	27,476

N/A = Not Applicable

recovered. Thus the reduction in control module annualized cost when using saturation rather than blanketing with carbon adsorption is 65%, and with refrigeration it is 95.4%. Ranking the average annualized costs for each control technology starting with the lowest indicates carbon adsorption is least costly, followed by refrigeration, and finally by thermal incineration. The annualized cost calculation for thermal incineration used with dilution was abandoned due to a utility cost of $453,000, which makes it non-competitive. The utility cost is for the fuel gas that must be used to burn the dilute gasoline vapor mixture.

The annualized costs for the complete systems which include the safety and control modules are shown in TABLE 4.6.6. The costs range from $115,000 to $215,000. The lowest cost for each control technology is achieved when an inert gas generator is used as the safety module. As a group, the carbon adsorption systems have the lowest average annualized cost at $153,800. The average costs for refrigeration and thermal incineration systems are virtually identical at $175,300 and $175,500 respectively. In each case (except for the dilution-thermal incineration) annualized cost was greater due to the safety module than due to the control module.

If the barges are owned by the terminal operator, the capital charges are amortized along with the dockside equipment. However, if the barges are leased from an independent barge operator (which appears to be the more common procedure) the costs are reflected in the

TABLE 4.6.6

ANNUALIZED COSTS FOR ONE GASOLINE BARGE LOADING EMISSION CONTROL SYSTEM

Emission Control Module Type	Total Annualized Cost for Each Combination of Safety and Control Modules ($1,000)				
	Dilution	Saturation	Fuel Gas Blanketing	Nitrogen Blanketing	Inert Gas Generator
Carbon Adsorption	N/A	165	N/A	180	115
Refrigeration	N/A	160	N/A	215	150
Thermal Incineration	>550	190	195	190	125

lease price, since the barge operator must recover the cost of modification. How these costs are reflected in leasing prices depends on the terms negotiated between the barge operator and the oil company.

From 64.4% to 98.5% of the total annualized cost is a function of safety which has the effect of obscuring the relative costs of the control modules themselves.

4.6.3 Economic Analysis

This analysis will center on the determination of cost effectiveness for each of the control cases. Cost effectiveness must relate some parameter of cost to some parameter of performance. The annualized cost will be used as the cost parameter. The performance parameter will be the net reduction in HC emissions over the uncontrolled or base case. It is assumed that the annualized cost of the uncontrolled case is zero. The cost effectiveness will be measured in terms of pounds of HC controlled annually per dollars spent annually. Thus the cost effectiveness index is expressed as # HC/ $ and the higher the index, the greater the cost effectiveness. The cost effectiveness of each control case is shown in TABLE 4.6.7. The cost effectiveness ranges from 4.2 # HC/$ to 8.50 # HC/$. The most cost effective system is carbon adsorption with inert gas generation at 8.50 # HC/$. The next two cases are thermal incineration and refrigeration, both using inert gas generation, at 8.01 # HC/$ and 6.08 # HC/$ respectively.

As an alternate approach to evaluation of the control systems, consider the additional cost of the product

TABLE 4.6.7
COST EFFECTIVENESS FOR CONTROL CASES
LB. HC CONTROLLED/$ OF ANNUALIZED COST ($/LB)

	Safety Module Type				
	Dilution	Saturation	Fuel Gas Blanketing	N	Inert Gas Generator
Emissions Control Module Type		#HC($/LB)		#HC($/LB)	#HC($/LB)
Carbon Adsorption	N/A	5.75(0.17)	N/A	5.37(0.19)	8.50(0.12)
Refrigeration	N/A	5.37(0.19)	N/A	4.20(0.24)	6.08(0.16)
Thermal Incineration	N/A	5.08(0.20)	4.85	5.20(0.19)	8.01(0.12)

N/A - Not Applicable

shipped by barge when using a vapor control system. For the proposed 6 x 10^6 bbl annual gasoline throughput, the effect of the least cost effective control scheme (refrigeration with N_2 blanketing at 4.2 # HC/$) on the cost of gasoline is approximately one dollar per 1230 gallons or 0.08¢ per gallon. For higher throughputs, or more cost effective schemes, the unit cost would be even lower.

Significantly, at least some of the cost analysis results are peculiar to the annual gasoline throughput selected. The control and safety equipment are sized on the basis of barge loading flowrate which determines the capital costs for the modules and the fixed portions (i.e., capital related) of the annualized cost. However, the remainder of the annualized cost components (utilities, operating labor, maintenance, and gasoline recovery credits) are determined by throughput. As throughput is increased, the direct costs (utilities, operating labor, and maintenance) rise as do gasoline credits (if any) while capital charges and administrative costs remain fixed. When gasoline credits are greater than the direct cost for a given scheme, there exists a break even point for throughput. When throughput is raised above this point the recovered gasoline will begin to pay for the construction of the gasoline barge vapor control system. Therefore under different throughput conditions the relative cost effectiveness of the schemes may shift substantially.

Projections of cost effectiveness with different annual gasoline throughputs were made for each of the control cases. The annual throughputs used varied from three to 24 million barrels per year. The projected results are shown in TABLE 4.6.8. Figures 4.6.1, 4.6.2, 4.6,3, and 4.6.4 are curves of cost effectiveness versus annual throughput for the various control cases. The information in TABLE 4.6.8 is plotted in these figures. When the cost effectiveness index for recovery schemes reaches 12.8 # HC/$, a break even point is reached, i.e. the value of the gasoline recovered is equal to the annualized cost required to recover it. Above this point the vapor recovery system begins to pay back direct operating costs and capital charges. If only direct operating expenses are considered and capital charges neglected, the break even point would be lower.

TABLE 4.6.8

SUMMARY OF RESULTS OF COST EFFECTIVENESS CURVES (HC/$)

Throughput (10^6 BBL/YR)	3	6	9	12	18	24
Carbon Adsorption						
w/Saturation	2.89	5.75	8.61	11.47	17.16	22.81
w/N_2	3.31	5.37	6.78	7.80	9.19	10.08
w/Inert Gas Gen.	3.82	8.50	14.38	21.98	46.56	105.70
Refrigeration						
w/Saturation	2.73	5.37	7.96	10.47	15.30	19.89
w/N_2	2.55	4.20	5.36	6.21	7.40	8.17
w/Inert Gas Gen.	2.86	6.08	9.72	13.88	24.24	38.68
Thermal Incin.						
w/Saturation	3.56	5.08	5.92	6.46	7.10	7.47
w/Fuel Gas Blanket	3.37	4.85	5.69	6.22	6.87	7.24
w/N_2	3.96	5.20	5.81	6.17	6.58	6.80
w/Inert Gas Gen.	4.70	8.01	10.48	12.40	15.15	17.04

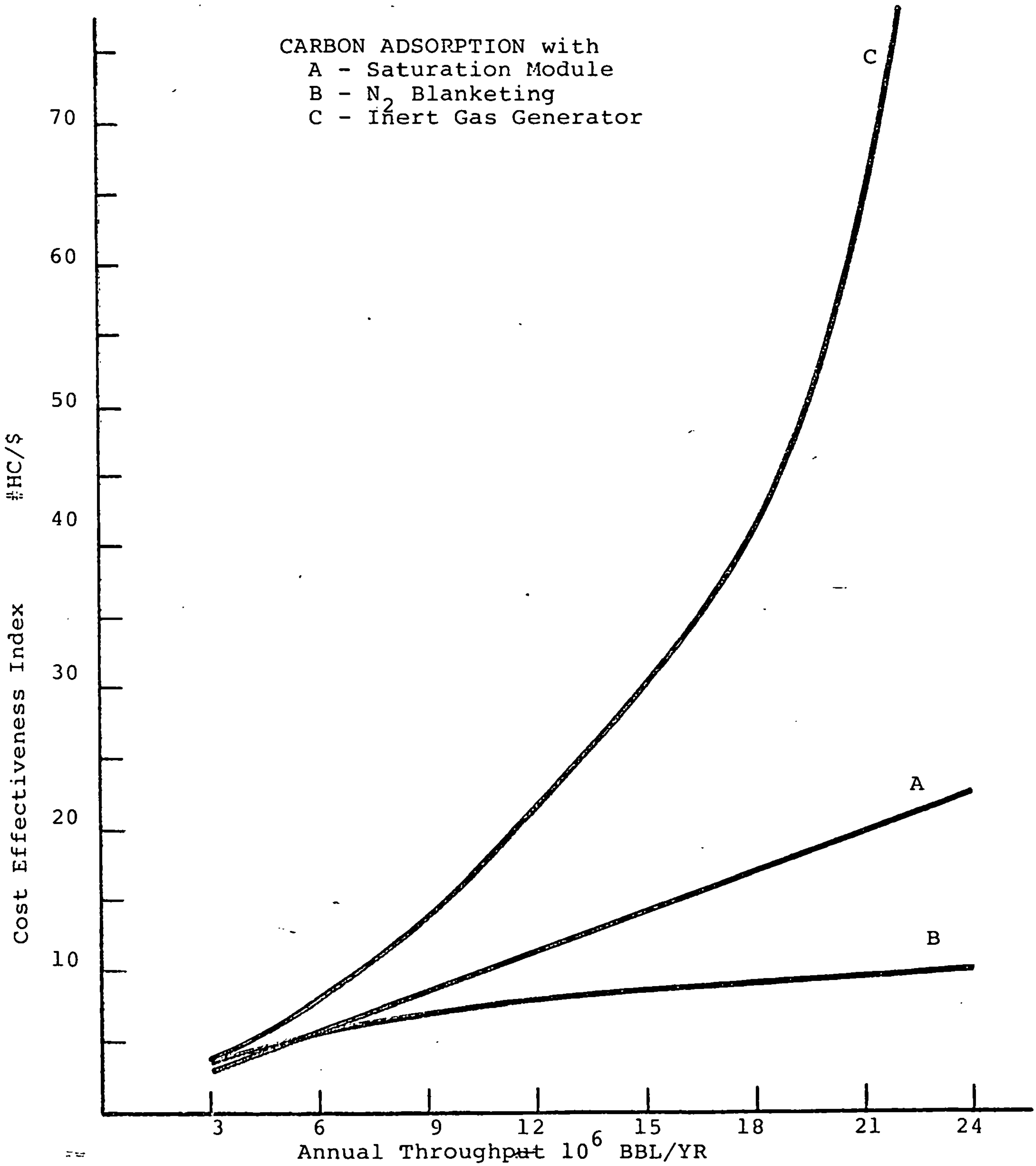

Figure 4.6.1 Cost Effectiveness Projections Carbon Adsorption

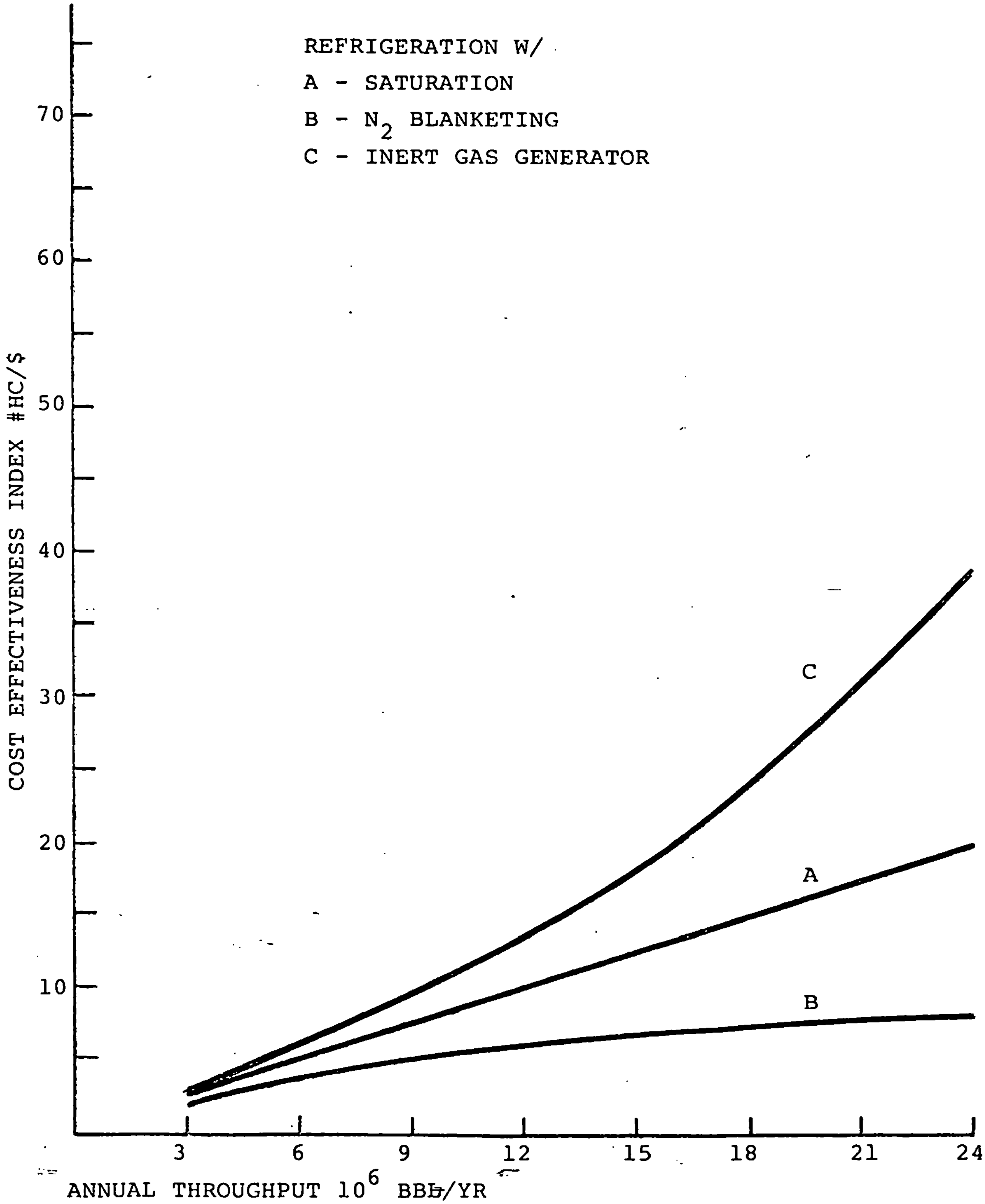

Figure 4.6.2 Cost Effectiveness Projections Refrigeration

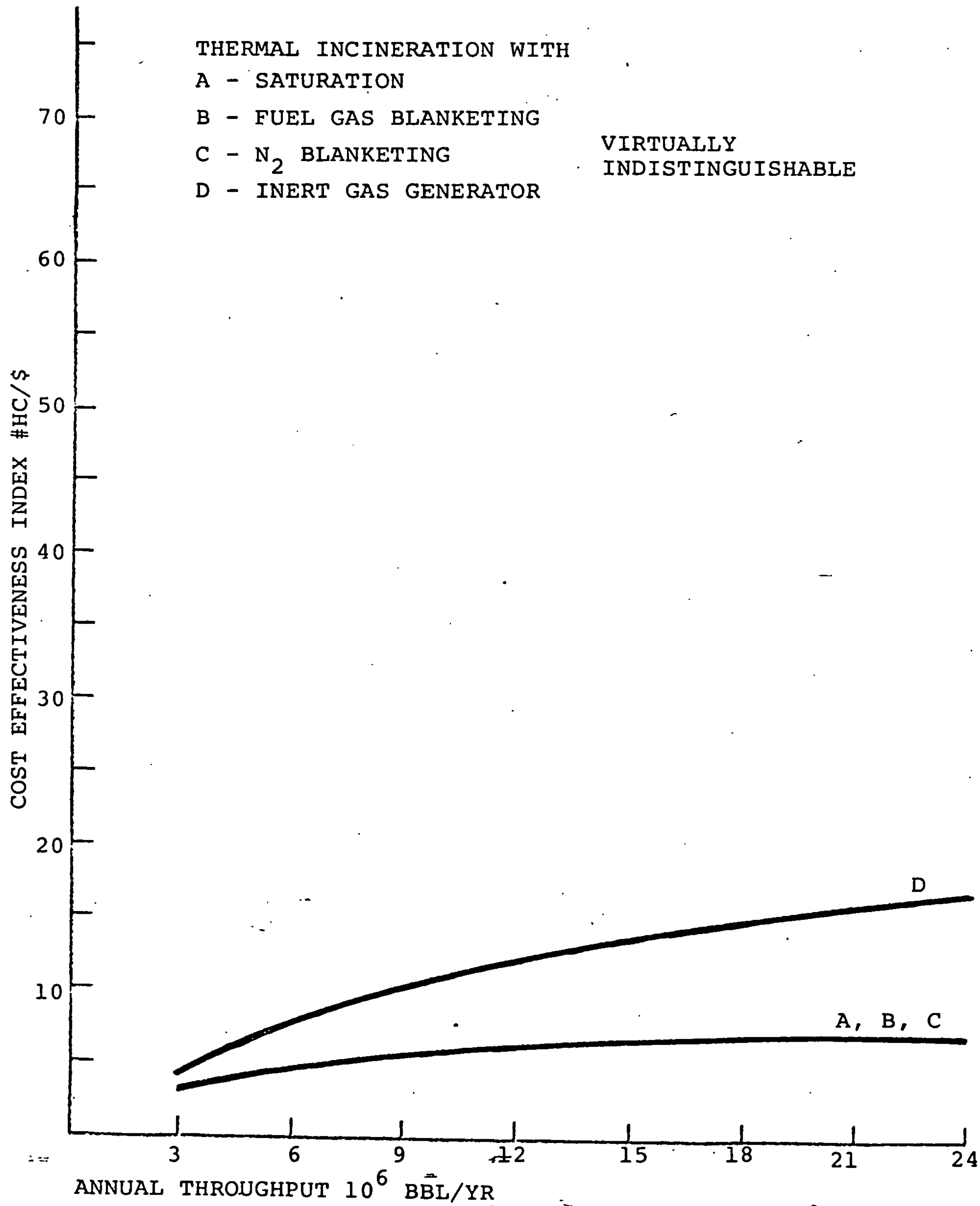

Figure 4.6.3 - Cost Effectiveness Projections
Thermal Incineration

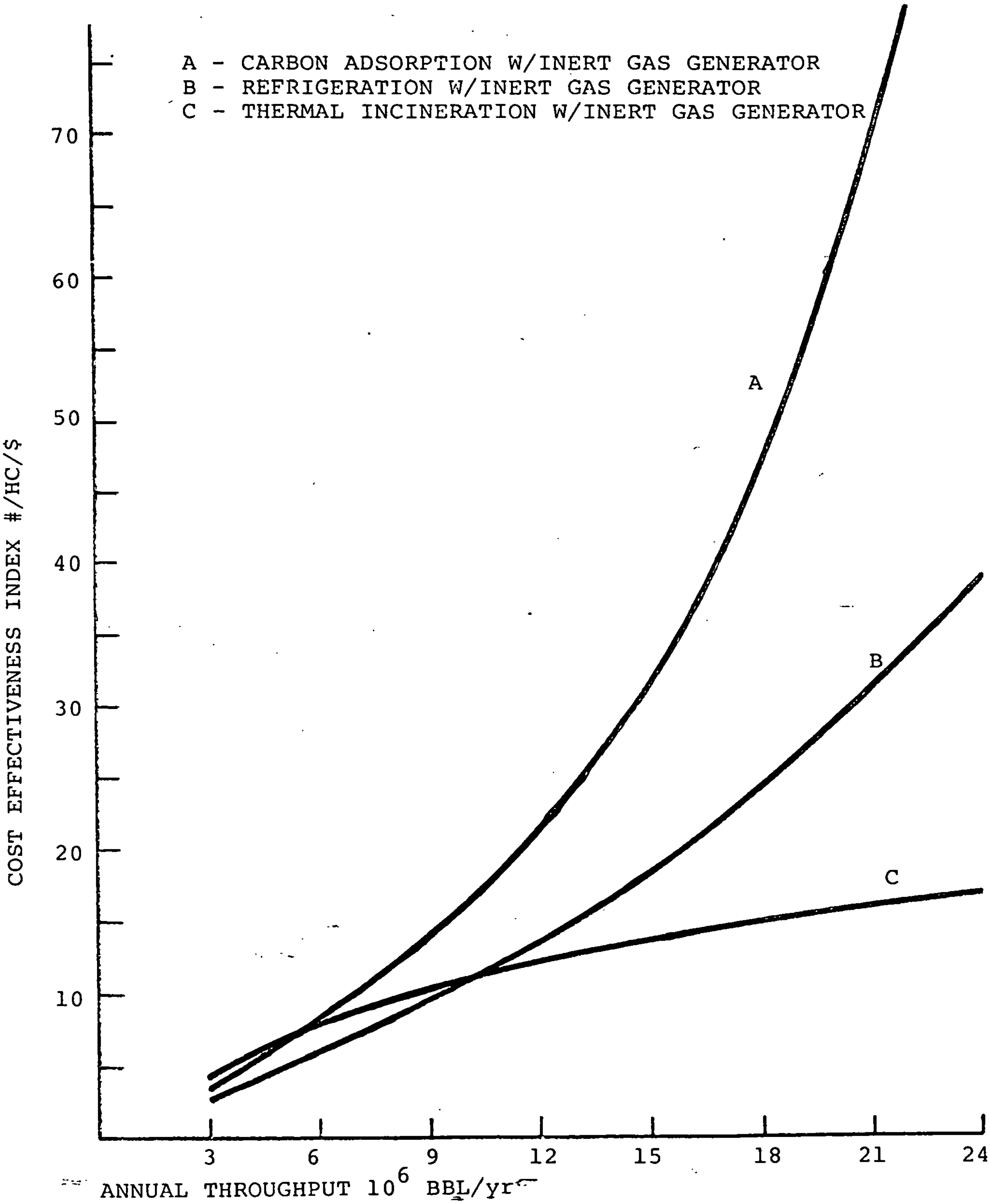

Figure 4.6.4 Cost Effectiveness Projections Comparison

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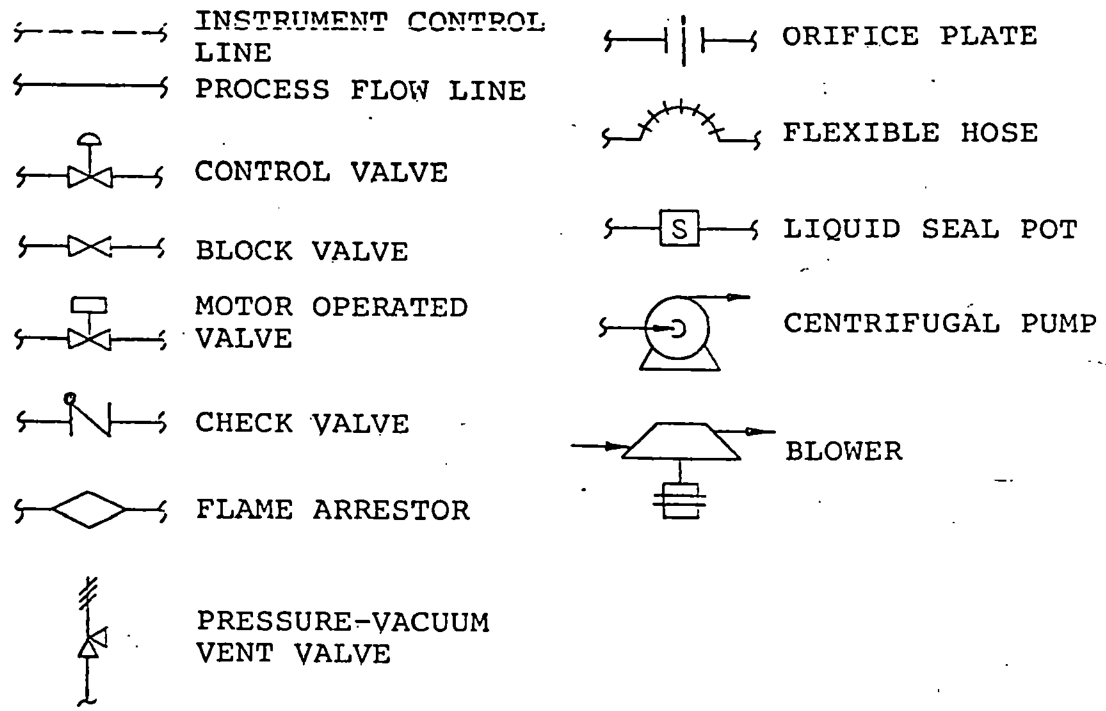
APPENDIX A

LEGEND

EQUIPMENT AND PIPING SYMBOLS



Instrument Abbreviations

FIC - Flow Indicating Controller
FS - Flow Switch
I - Interlock
LI - Level Indicator
LS - Level Switch
PI - Pressure Indicator
PIC - Pressure Indicating Controller
TIC - Temperature Indicating Controller
XA - Warning Alarm (Audible)
XL - Warning Light

APPENDIX B
CAPITAL COST DATA
FOR SAFETY AND CONTROL MODULES

CAPITAL COST DATA
MODULE - DILUTION

DESCRIPTION	COST(MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	71.0
Special Equipment	-
Fire & Safety Equipment	-
Concrete Work	8.0
Steel Work	4.0
Piping	99.1
Electrical	8.0
Instruments	10.6
Insulation & Paint	3.0
Freight (Unallocated)	1.1
Field Construction Costs	20.9
Home Office Costs	20.9
Sales & Use Taxes	4.3
Insurance	3.1
Spare Parts	1.1
Project Completion	2.6
Contractors OH & P	52.2
Contingency	20.9
Total Erected Costs	330.8

CAPITAL COST DATA
MODULE - SATURATION

DESCRIPTION	COST (MATERIAL AND LABOR) ($ x1000)
Exchangers	5.2
Towers	12.4
Pumps & Compressors	26.7
Special Equipment	-
Fire & Safety Equipment	4.0
Concrete Work	22.5
Steel Work	10.0
Piping	54.6
Electrical	7.0
Instruments	45.5
Insulation & Paint	3.0
Freight (Unallocated)	2.0
Field Construction Costs	19.2
Home Office Costs	19.2
Sales & Use Taxes	3.5
Insurance	2.9
Spare Parts	0.9
Project Completion	2.4
Contractors OH & P	48.0
Contingency	19.2
Total Erected Costs	307.2

CAPITAL COST DATA
MODULE - FUEL GAS BLANKETING

DESCRIPTION	COST (MATERIAL AND LABOR) ($ x1000)
Exchangers	–
Towers	–
Pumps & Compressors	19.7
Special Equipment	-
Fire & Safety Equipment	4.0
Concrete Work	4.0
Steel Work	6.0
Piping	48.7
Electrical	4.0
Instruments	41.4
Insulation & Paint	3.0
Freight (Unallocated)	1.0
Field Construction Costs	13.1
Home Office Costs	13.1
Sales & Use Taxes	2.2
Insurance	2.0
Spare Parts	0.5
Project Completion	1.6
Contractors OH & P	32.7
Contingency	13.1
Total Erected Costs	209.1

CAPITAL COST DATA

MODULE - N_2 BLANKETING

DESCRIPTION	COST (MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	19.7
Special Equipment	-
Fire & Safety Equipment	4.0
Concrete Work	4.0
Steel Work	6.0
Piping	51.4
Electrical	4.0
Instruments	30.8
Insulation & Paint	3.0
Freight (Unallocated)	1.0
Field Construction Costs	12.4
Home Office Costs	12.4
Sales & Use Taxes	2.3
Insurance	1.8
Spare Parts	0.6
Project Completion	1.5
Contractors OH & P	31.0
Contingency	12.4
Total Erected Costs	198.3

CAPITAL COST DATA

MODULE - INERT GAS GENERATOR

DESCRIPTION	COST(MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	19.7
Special Equipment	91.7
Fire & Safety Equipment	4.0
Concrete Work	8.0
Steel Work	6.0
Piping	57.4
Electrical	4.0
Instruments	30.8
Insulation & Paint	3.0
Freight (Unallocated)	1.5
Field Construction Costs	22.6
Home Office Costs	22.6
Sales & Use Taxes	6.0
Insurance	3.4
Spare Parts	1.5
Project Completion	2.8
Contractors OH & P	56.5
Contingency	22.6
Total Erected Costs	364.1

CAPITAL COST DATA
MODULE - CARBON ADSORPTION W/INERTION

DESCRIPTION	COST(MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	-
Special Equipment	231.3
Fire & Safety Equipment	-
Concrete Work	12.0
Steel Work	4.0
Piping	-
Electrical	30.0
Instruments	-
Insulation & Paint	3.0
Freight (Unallocated)	2.5
Field Construction Costs	28.3
Home Office Costs	28.3
Sales & Use Taxes	9.8
Insurance	4.2
Spare Parts	2.4
Project Completion	3.5
Contractors OH & P	70.7
Contingency	28.3
Total Erected Costs	458.3

CAPITAL COST DATA
MODULE - CARBON ADSORPTION W/SATURATION

DESCRIPTION	COST(MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	-
Special Equipment	338.4
Fire & Safety Equipment	-
Concrete Work	12.0
Steel Work	4 .0
Piping	11.5
Electrical	36.0
Instruments	-
Insulation & Paint	3.0
Freight (Unallocated)	3.5
Field Construction Costs	40.8
Home Office Costs	40.8
Sales & Use Taxes	14.2
Insurance	6.1
Spare Parts	3.5
Project Completion	5.1
Contractors OH & P	102.1
Contingency	40.8
Total Erected Costs	661.8

CAPITAL COST DATA
MODULE - REFRIGERATION W/INERTION OR SATURATION

DESCRIPTION	COST(MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	-
Special Equipment	303.0
Fire & Safety Equipment	-
Concrete Work	12.0
Steel Work	4.0
Piping	12.3
Electrical	42.0
Instruments	-
Insulation & Paint	3.0
Freight (Unallocated)	3.2
Field Construction Costs	38.0
Home Office Costs	38.0
Sales & Use Taxes	12.8
Insurance	5.7
Spare Parts	3.2
Project Completion	4.7
Contractors OH & P	94.9
Contingency	38.0
Total Erected Costs	614.8

CAPITAL COST DATA
MODULE - THERMAL INCINERATION W/SATURATION

DESCRIPTION	COST (MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	-
Special Equipment	75.4
Fire & Safety Equipment	-
Concrete Work	9.2
Steel Work	2.3
Piping	7.1
Electrical	6.9
Instruments	-
Insulation & Paint	3.5
Freight (Unallocated)	1.1
Field Construction Costs	10.6
Home Office Costs	10.7
Sales & Use Taxes	3.5
Insurance	1.3
Spare Parts	1.1
Project Completion	1.2
Contractors OH & P	26.6
Contingency	10.6
Total Erected Costs	171.1

CAPITAL COST DATA
MODULE - THERMAL INCINERATION W/FUEL GAS BLANKETING

DESCRIPTION	COST(MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	-
Special Equipment	131.2
Fire & Safety Equipment	-
Concrete Work	16.0
Steel Work	4.0
Piping	12.4
Electrical	12.0
Instruments	6.0
Insulation & Paint	2.0
Freight (Unallocated)	2.0
Field Construction Costs	18.4
Home Office Costs	18.4
Sales & Use Taxes	5.8
Insurance	2.8
Spare Parts	2.0
Project Completion	2.2
Contractors OH & P	46.0
Contingency	18.4
Total Erected Costs	297.6

CAPITAL COST DATA
MODULE - THERMAL INCINERATION W/INERTION

DESCRIPTION	COST (MATERIAL AND LABOR) ($ x1000)
Exchangers	-
Towers	-
Pumps & Compressors	-
Special Equipment	65.5
Fire & Safety Equipment	-
Concrete Work	8.0
Steel Work	2.0
Piping	6.2
Electrical	6.0
Instruments	-
Insulation & Paint	3.0
Freight (Unallocated)	1.0
Field Construction Costs	9.2
Home Office Costs	9.2
Sales & Use Taxes	2.9
Insurance	1.4
Spare Parts	1.0
Project Completion	1.1
Contractors OH & P	23.0
Contingency	9.2
Total Erected Costs	148.8

APPENDIX C

COMPANIES SUPPLYING PRICING AND TECHNICAL INFORMATION

Name	Item
Air Products & Chemicals, Inc. 260 North Belt East, Suite 200 Houston, Texas 77060	Nitrogen Blanketing Systems
Buffalo Forge Co. Fred P. Heinzmann Co., Inc. 1425 Blalock Rd., Suite 220 Houston, Texas 77055	Blowers
Edwards Engineering Corp. Hendricksen Co., Inc. P. O. Box 55565 Houston, Texas 77055	Refrigeration Vapor Recovery Units
Hydrotech Engineering, Inc. P. O. Box 45042 Tulsa, Oklahoma 74145	Carbon Adsorption Vapor Recovery Units
Liquid Air Inc. P. O. Box 15313 Houston, Texas 77020	Nitrogen Blanketing Systems
National Air Oil Burner Co., Inc. 3717 Montrose Blvd., Suite 431 Houston, Texas 77006	Thermal Incineration

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-79-069	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Control Technology Evaluation for Gasoline Loading of Barges		5. REPORT DATE March 1979 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) D. Gee and W.M. Talbert		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Pullman Kellogg, 16200 Park Row, Industrial Park Ten, Houston, Texas 77084		10. PROGRAM ELEMENT NO. 1AB604B 11. CONTRACT/GRANT NO. 68-02-2619, Task 9
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15. SUPPLEMENTARY NOTES IERL-RTP project officer is Irvin A. Jefcoat, MD-62, 919/541-2547. For details contact B.A. Tichenor at same phone; Jefcoat is no longer with EPA.

16. ABSTRACT The report gives results of a study to determine the feasibility, safety, and cost of methods to control the emission of hydrocarbon vapor during the loading of gasoline barges. Approximately 4 lb of hydrocarbons are emitted per 1000 gal. of gasoline loaded; annually about 1 million lb of hydrocarbons may be emitted at a terminal pumping 6 million barrels of gasoline. Vapor control techniques evaluated included carbon adsorption, refrigeration, and thermal incineration. Hydraulic flash arrestors prevent flame transmission between the barge and vapor control system. Safety methods are also required to render the barge vapors non-flammable prior to collection and transport. Safety methods evaluated were dilution, saturation, and blanketing with fuel gas, liquid nitrogen, and inert gas. All combinations of vapor control/safety systems were evaluated. In terms of cost, dilution was determined non-applicable for all three vapor control methods; fuel gas blanketing was applicable only with thermal incineration. Costs for the applicable combinations range from $0.12/lb of hydrocarbon vapor (for inert gas blanketing combined with carbon adsorption) to $0.24/lb (for liquid nitrogen blanketing/refrigeration). These costs correspond to gasoline cost increases of 0.048¢ to 0.096¢/gal., respectively. More accurate estimates await demonstration of one or more vapor control/safety systems

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Carbon	Pollution Control	13B	07B
Gasoline	Refrigeration	Stationary Sources	21D	
Fueling Systems	Incinerators	Carbon Adsorption		
Barges	Nitrogen		13A	
Hydrocarbons	Blanketing		07C	07A,13H
Vapors			07D	

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