Stage II Vapor Recovery System Operations & System Installation Costs

PUBLICATION 1645
FIRST EDITION, AUGUST 2002

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Downstream Segment

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FOREWORD

The objective of this report is to provide general cost information that will be useful in determining the cost impact of proposed air quality regulations. The selection of the appropriate vapor recovery system for a specific site requires the careful evaluation of a variety of parameters. The report is not intended to compare the feasibility of the various systems or to provide any guidance in the selection of a particular technology. The cost data was compiled in 2000 by White Environmental Associates for the American Petroleum Institute.

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CONTENTS

Stage II Vapor Recovery System Operations & System Installation Costs

1 Executive Summary

Stage II vapor recovery is a well-known air quality control measure that reduces ozone precursors from gasoline dispensing facilities (GDFs). As a result of its relative high-visual profile, Stage II vapor controls are sometimes proposed as a part of a regional air quality attainment strategy without adequately comparing its overall cost effectiveness to other available control measures. Changes in equipment technology and system testing techniques continue to raise new issues associated with installing, operating and maintaining compliance of Stage II systems.

The purpose of this Stage II costs study partially comes from the U.S. EPA's more stringent ozone standard that will bring additional metropolitan areas into non-attainment status. These additional metropolitan non-attainment areas may consider Stage II controls as a priority air quality control measure. As a further consideration, the U.S. EPA has also implemented an on-board refueling vapor recovery (ORVR) requirement for new vehicles. It is designed to capture gasoline vapors at the nozzle/vehicle gas tank interface during refueling.

Adding to the complexity of the matter, the California Air Resources Board (CARB), a nationally-recognized lead agency in the certification of Stage II equipment and systems, has recently promulgated major changes to the California Stage II vapor control program. This is important because many states have linked their Stage II programs to the CARB equipment and system certification process. However, this paper is focused on the current average cost of installing Stage II vapor controls to meet the requirements of pre-EVR CARB approved systems.

This study considered three different types of retail gasoline outlet (RGO) vapor recovery systems:

1. vapor balance,
2. passive vacuum assist,
3. and active vacuum assist.

The "vapor balance" system, configured with a corrugated bellows over the nozzle spout designed for capturing vapor, has been in use since vapor recovery was first required. The system has been refined and upgraded with improving technology.

A more recent technology initially pioneered in the Midwest is the "passive vacuum assist" system. Initial versions of this system used reciprocal vacuum pumps for each active nozzle powered by the flow of gasoline to the vehicle fuel tank. Subsequent versions of this type of "dispenser-based" approach use electrical pumps to return the collected vapor back to the gasoline storage tanks, using electronic signals from the dispenser meters to regulate the vapor pump speed.

Finally, the "active vacuum assist" system has also undergone many improvements since it was first used. This system maintains a vacuum on the entire Stage II recovery system and processes the excess vapor collected through a central vapor processor or burner.

A survey of API members and several other sources of information produced average Stage II installation cost data representing company-specific typical Stage II system configurations for the three targeted vapor recovery system types. The collected data was adjusted to conform to a consistent refueling system configuration that should not be considered typical for the industry. The equipment configuration used in this paper were an equalized number of nozzles, hoses, dispensers and refueling positions for all three types of vapor recovery systems evaluated. [See Table 1.]

2 Stage II Program Background

In many major U.S. metropolitan areas, Stage II vapor controls are required at gasoline dispensing facilities (GDFs) as a part of an air quality attainment strategy or as part of an air quality maintenance program.

Table 1—API Stage II Cost Study Survey Data Summary[a]

Initial Capital and Expense Costs	Retrofit Passive Vac	Retrofit Balance	Retrofit Active Vac	New Passive Vac	New Balance	New Active Vac
Nozzles/Hoses. . .Dispensers	12. . .6	12. . .6	12. . .6	12. . .6	12. . .6	12. . .6
Refueling Positions	12	12	12	12	12	12
Design, Engineering and Permitting	$2,750	$1,500	$2,750	$4,000	$2,500	$4,000
Equipment (*Nozzles/Hoses, Dispensers, Other Ancillary Equipment*)	$16,340	$7,385	$14,640	$19,700	$7,625	$15,000
Installation[b]	$16,750	$12,100	$16,750	$7,400	$4,600	$8,250
System Test	$1,200	$750	$1,200	$1,500	$1,000	$1,500
Totals	**$37,040**	**$21,735**	**$35,340**	**$32,600**	**$15,725**	**$28,750**

Note: [a]Costs do not include operational costs such as equipment replacement due to failure, periodic testing, or station shutdown for periodic testing.
[b]Not including lost revenues, accelerated depreciation for retrofit locations.

Given the role that gasoline vapors (in the form of volatile organic compounds [VOCs]) play in the formation of ozone, retail gasoline outlets (RGOs) become a high-profile target in efforts to attain the ozone standard. As an obvious source of VOC emissions, RGOs generally receive high priority for further controls in metropolitan areas that have not met ozone attainment standards. The total emissions controlled and the costs associated with the installation and maintenance of Stage II vapor controls are not always adequately compared to other air pollution control strategies, especially those associated with mobile tailpipe emissions (on-road and off-road) that may be less obvious but more cost effective.

In December 1988, API published the API Survey of Actual Stage II Implementation Costs in the St. Louis Metropolitan Area. At the time, the average cost of installing Stage II on a per-nozzle basis was $1,660. In the 14 years since the publication was issued, new generations of Stage II equipment with improvements and variations have been introduced and put into service. For example, the "vapor balance" system nozzle is now lighter, easier to use and more durable. A new type of passive vacuum assist Stage II system has also been developed and has become prevalent.

Up-to-date average costs associated with installing Stage II vapor recovery systems at typical RGOs are provided in this research. Equipment and installation costs for the more commonly used Stage II vapor recovery systems are also identified. Significant effort was made to ensure that the Stage II cost analyses in this research reflect credible, current averages.

Cost data was derived from a survey of API member companies and interviews with selected Stage II installation and maintenance experts. Although information was solicited on all types of vapor recovery systems, information on active vacuum assist systems was not received. Other alternative sources were consulted for this information. An explanation of how the data was collected, analyzed, and reduced to a presentation of findings, is also included in the study.

Although costs from several different geographical areas were requested for the survey, cost differences between geographical locations did not appear significant relative to Stage II equipment and installation costs. However, at least one respondent noted that the cost of certified/qualified labor is proportional to the distance between a job site and a metropolitan center.

This report does not address equipment performance or emission reduction rates related to the various equipment capabilities. Although collected data was API member-company specific, all data was de-identified before it was compiled and summarized for use in the report. The information collected was from RGOs with throughputs ranging from 100,000 gallons per month to 225,000 gallons per month. The paper does not intentionally reflect favorably on one Stage II system or equipment manufacturer over another.

3 Stage II Survey Assumptions & Approach

This study was conceived and scoped to address the “vapor balance” system and two categories of vacuum-assist systems, “active” and “passive.” The vapor balance system operates based on the principal of vapor displacement by providing a vapor recovery return line to collect vapors from the vehicle fuel tank pushed out by the incoming liquid gasoline. It uses the seal between the vehicle being refueled and the faceplate of the fueling nozzle. The vapors then move through a bellows, which surrounds the nozzle, to piping back to the gasoline storage tank.

Passive vacuum assist systems may be distinguished from active vacuum assist systems by their dispenser-based approach to vapor recovery. Passive vac-assist stations use flow controls at the dispenser to return vapor to the gasoline storage tank, whereas active vac-assist systems use a central vacuum unit to recover vapor from the entire system to the tank, processing excess vapor by incineration or by other means.

The earliest version of passive vac-assist systems relied on reciprocal pumps within each dispenser housing that inherently varies the speed of vapor recovery based on product flow through the dispenser. The greater the product flow, the more gasoline vapor is recovered. Newer versions use electrical pumps to return recovered vapor to the gasoline tank, where the amount of vacuum generated to recover vapors is based on the gasoline flow rate detected electronically through the dispenser meter.

As the basic principal behind the passive vac-assist system is to recover vapors equivalent to those generated during the refueling process, passive vac-assist systems do not employ vapor processors. For this reason, the ratio of product dispensed to the vapor recovered is important to the effectiveness of the system.

Consequently, some regulators have placed increased emphasis on A/L testing to ensure that passive vac-assist systems remain within certified 95% effectiveness levels. A few agencies demand compliance testing at greater than the annual frequency outlined in the California Air Resources Board (CARB) Executive Orders certifying the passive vac-assist systems. This more frequent testing increases the annual maintenance costs borne by those operating passive vac-assist equipment.

A significant number of “active vacuum” processor-type systems are in use. These systems differ from the “passive vacuum” assist systems chiefly in the deployment of a single-unit vacuum generator applying a vacuum to the whole vapor recovery system. This application actively removes vapors during gasoline dispensing. Because these systems generate excess vapors with the centrally applied vacuum, they either use incinerators or other types of treatment technologies to process the recovered excess vapors.

3.1 SURVEY ASSUMPTIONS

The assumptions used in the development of the survey and the compilation of survey data and other information used to formulate this paper were based on the following descriptions of Stage II vapor control systems.

3.1.1 Stage II Vapor Balance System

The vapor balance system is one of the original Stage II control technologies. (See Figure 1.) This system uses the natural balance of pressures between the product drawn from the retail gasoline outlet (RGO) storage tank developing a negative pressure, to the positive pressure developed as fuel is dispensed into the vehicle fuel tank without the use of additional motors or pumps. The net effect is the flow of vapor from the vehicle fuel tank back to the RGO storage tank as the fuel is dispensed into the vehicle tank.

The bellows nozzle is a key and most recognizable element of the balance system. The system works when the nozzle—with its bellows over the spout with a faceplate—is snugly placed over the vehicle fuel tank opening, thereby creating a seal.

The fueling hose is typically coaxial. The gasoline flows through the inner hose while vapors are returned to the underground storage tank (UST) through the outer hose. Liquid from condensation or splash back may pool in the lowest part of the outer hose and block the vapor path, thereby defeating the system. For this reason, liquid collection tubes or devices are often installed in the hose for continuous removal of this liquid.

The installation of a pressure/vacuum (P/V) valve on the end of the tank vent pipe has been shown to improve the "vapor balance" system's ability to contain vapors in the total system.

3.1.2 Stage II Passive Vacuum Assist System

Of the two types of vacuum-assist vapor recovery, the newest system—and one gaining in popularity primarily due to consumer preference—is referred to as a passive vacuum assist system. (See Figure 2.)

Passive vac-assist systems use a dispenser-based technology to recover vapor from the refueling process. In previous versions of the passive vac-assist system, the amount of vapor recovered may be regulated by the use of a reciprocal pump in the dispenser, where the dispensing fuel passes through one section of the pump and generates a vacuum in another section. This vacuum pulls gasoline vapor from the vehicle gasoline tank fill area to the gasoline storage tank on a roughly 1:1 ratio.

Over the past decade, modifications to the initial concept of the passive vac-assist system have emerged and have proved to be very popular among RGOs nationwide. These newer versions typically use electric pumps to return vapor to the gasoline tanks. The 1:1 ratio of the vapor recovery process of these newer versions is maintained by regulating the speed of the dispenser-based electric vapor pumps by monitoring the dispensing rate electronically through the dispenser meter.

To the customer, the passive vacuum assist appears similar in configuration to a refueling system without vapor recovery due to its "bellow-less" nozzle. The nozzle appears conventional but in fact is a spout within a spout (a coaxial spout). The outer spout has a series of small holes located near and around the end through which the vacuum developed by the reciprocating/electric pump in the dispenser draws the dispensed fuel vapors.

The fueling hose is coaxial, but unlike the "vapor balance" system, product flows through the outer hose while vapors are returned to the UST through the inner hose, making the need for a liquid removal device unnecessary.

Because this system places a slight pressure on the UST system at all times, a pressure vacuum valve (P/V) is required on the UST vent and vapor check valves must be installed typically at the nozzle, hose or dispenser to prevent the escape of vapor emissions from the system.

3.1.3 Stage II Active Vacuum-Assist System

Active vacuum assist vapor recovery systems have been an option since Stage II vapor control implementation. These vacuum systems are configured with a central vacuum generating unit that pulls a vacuum on all of the vapor lines leading from each nozzle to the tank system with excess vapors going to a central vapor processing unit. (See Figure 3.) The central processing unit either uses a burner or other processor to dispense of the excess vapors gathered from the refueling process.

The first generation "active vacuum" nozzles had a short, open-ended bellow configuration over the spout through which the centrally generated vacuum draws vapors. Current nozzles more closely resemble the coaxial nozzle spouts used by the passive vacuum systems with a coaxial nozzle spout and perforations near the end where fuel is dispensed.

Because this system places pressure on the UST system at all times, a pressure vacuum valve (P/V) is required on the UST vent and vapor check valves must be installed typically at the nozzle, hose or dispenser to prevent the escape of vapor emissions from the system.

3.2 SURVEY APPROACH

Under the direction of the API Project Oversight Task Force, a survey form was developed and distributed to designated API members. The survey was carefully constructed and instructions drafted to assure simplicity for ease of response and to maximize consistency and accuracy of col-

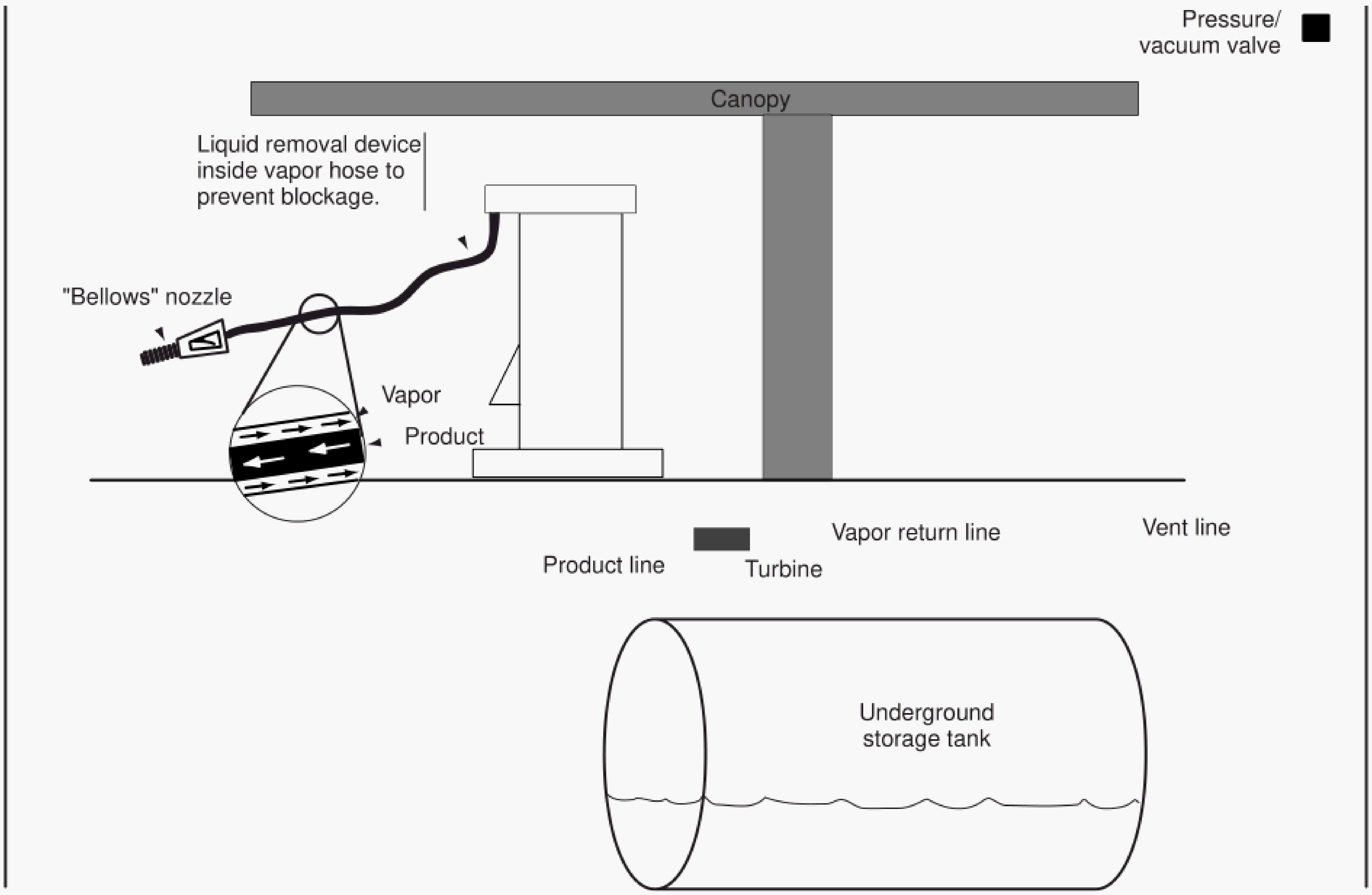

Figure 1—Balance Vapor Recovery System

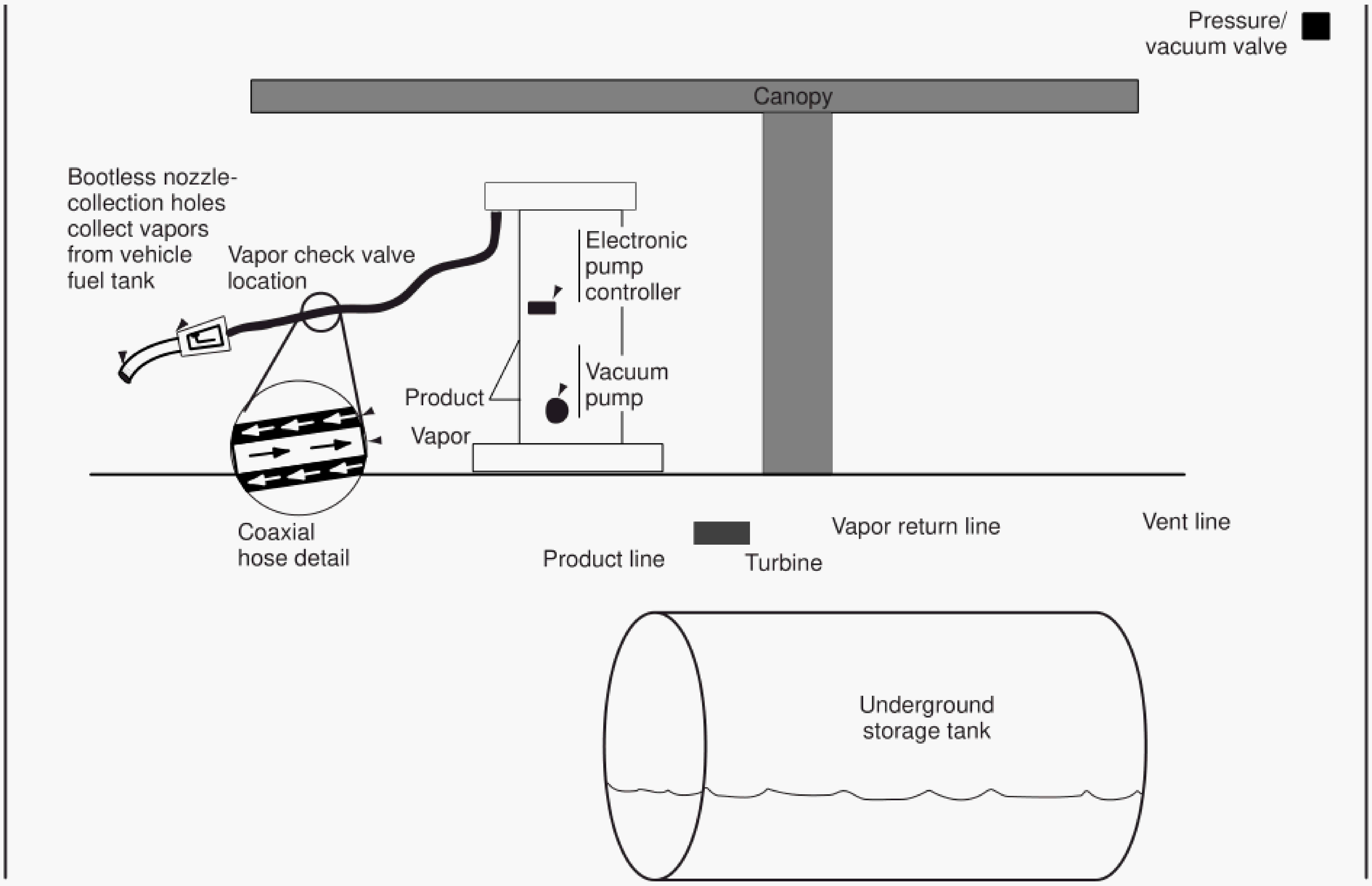

Figure 2—"Passive Vacuum Assist" Vapor Recovery System

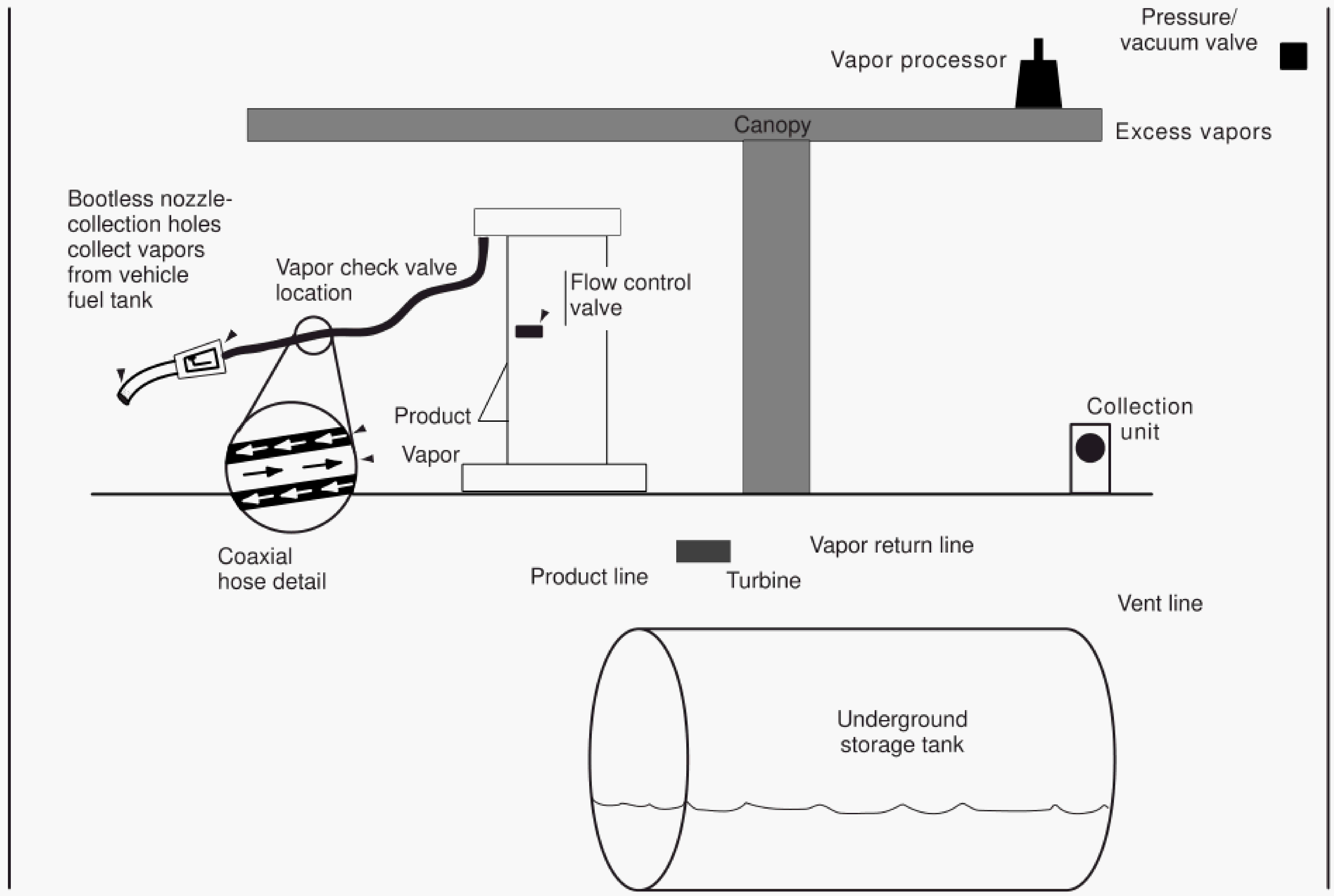

Figure 3—Active Vacuum-Assist Vapor Recovery System

lected data. The following Stage II-related information was requested:

a. Design/engineering costs.
b. Permit acquisition and fees.
c. Equipment prices and shipping costs.
d. Installation times and costs.
e. Annual operating/maintenance costs.
f. Performance and compliance testing times and costs.

The survey form requested information about each type of Stage II system organized into one of three survey categories – balanced, active vacuum or passive vacuum systems. There were no survey responses for active vacuum assist systems. Installation times and downtimes associated with periodic maintenance related to retrofitting, concurrent installations, and compliance and performance testing was also incorporated into the survey.

Some general information was requested regarding the individual survey submittals, including geographic location, average throughput, and number of fueling positions. Each survey form also requested whether the installation information was applicable to new, retrofit or concurrent installations. All responses came in as either new or retrofit. In the survey, responders could indicate owner/operator responsibilities relative to the installation, repair and maintenance of Stage II equipment and other related matters.

In addition to collecting the survey forms for compilation and analysis, an interview was conducted with a major Stage II equipment distributor/installer/maintainer and a few individual survey responders. The interview with this equipment distributor of Stage II systems obtained historic information from another industry perspective to supplement and further develop a balanced evaluation of Stage II installation and maintenance costs. The interviews were also used to assemble information about active vacuum assist systems.

4 Stage II Data Compilation and Analysis

Survey responses were received by the consultant from API member companies representing eight individual oil companies that were in the process or had just completed the process of merging or establishing alliances with each other. Although the survey did not produce any data on active vacuum assist systems, it included interviews and data collection from other sources to address these systems. All survey responses were screened for completeness with resolution of noted anomalies. The few survey forms that needed follow up, were either incomplete or had contained data that fell outside "normal parameters" based on other collected information.

After the completed survey forms were screened, the compiled data was used to piece together a Stage II system cost table. The following separate construction scenarios for balance systems and vacuum-passive systems were considered:

a. The incremental costs for Stage II installations at new locations, and

b. The costs of retrofitting Stage II at facilities without other tangential improvements.

Equipment and installation related costs were broken down into the following:

a. Design, engineering & permitting costs.

b. Equipment costs [Average costs that include equipment shipping/freight costs.]

c. Installation costs.

d. Performance testing costs.

All data from the received survey forms was de-identified and compiled by the consultant onto spreadsheets. All expense and time details were included on these initial compilation sheets. Each survey entry from each survey was compared to other like entries for ambiguities and/or significant inconsistencies. Suspect data was identified and corrections were qualified.

The adjusted data on these detailed sheets were then further compiled and summarized into more general categories of more meaningful significance relative to installation expenses. Following the data collection, the compiled results were summarized and sent to API members for additional review and comment. API members did not receive any raw data. Following the receipt and incorporation of comments, the costs were calculated for a standard configuration of 12 nozzles/hoses, 6 dispensers and 12 refueling positions.

Of a more general nature was the data regarding owner/operator responsibilities relative to the installation and subsequent maintenance of Stage II facilities. The survey also sought data to determine significant differences in the cost of equipment, installation or maintenance on a geographic basis. No significant differences were found. The range of throughputs for the Stage II facilities was from 100,000 to 225,000 gallons per month.

5 Closing Summary

The initial introduction of Stage II vapor recovery came with fairly straightforward engineering. Over 25 years since its first use in California, innovations and refinements in system designs and the equipment have become more sophisticated, user friendly, and high-tech with regard to materials and engineering. While the magnitude of costs for equipment, installation and maintenance have remained fairly stable over the years, the annual costs associated with equipment inspections, system testing, and compliance continue to escalate.

For the nozzle/hose and refueling position configuration used in this cost study, the costs of retrofitting Stage II vapor controls range from more than $22,000 for the vapor balance system to $37,000 for vac-assist systems. For the same configuration, the costs of installing Stage II vapor controls at a new RGO range from $16,000 for the vapor balance system to $33,000 for vac-assist systems.

In addition to the exercise of evaluating Stage II control cost effectiveness to other alternatives, it is fair to ask the following questions:

1. Is Stage II vapor control a viable and cost-effective air quality control measure for areas newly designated as non-attainment for the ozone standard?

2. Should Stage II vapor controls be implemented in additional metropolitan areas with the increasing population of vehicles that have on-board refueling vapor recovery (ORVR)?

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