SECTION 2

CONCLUSIONS

I. ACCURACY OF ESTIMATES

A. Accuracy and Sampling Error

The major findings of this survey are the national estimates made from the data. These are presented in tabular form, along with statements based on the data. The numbers are statistically unbiased estimates based on a national probability sample, and represent a sample estimate of the result that would be obtained from a census of the target universe in which standard questionnaire data collection and physical tank testing was conducted for all tanks and establishments in the target universe. The size of the difference between sample results and results from such a hypothetical census are measured by sample variances estimated from the survey data. Thus, the accuracy of the figures can be objectively assessed as far as sampling error is concerned. Non-sampling error is discussed below.

Estimates are given together with 95 percent confidence limits in parentheses. These confidence limits are based on the sampling variances estimated from the survey data. (The estimation procedures are discussed in Section 4 and Appendix A.) The limits can be expressed as the following statements. For the first entry in Table 2-1 for the total of all establishments, which is 326 (296-356) thousand, one would say, "It is estimated with 95 percent confidence that the number of establishments with underground motor fuel storage tanks is between 296,000 and 356,000 establishments, with a point estimate of 326,000

Table 2-1. Estimates, by type of establishment, of the number of underground motor fuel storage tanks and the number of establishments with underground motor fuel storage tanks in the continental United States (95% confidence bounds in parentheses)

Type of establishment	Number of establishments with tanks (1,000's)	Number of tanks (1,000's)	Number of tanks per establishment	
			Mean	Median
Government and military	**45** (29-62)	**98** (69-128)	**2.2** (1.8-2.5)	**2** -
Gas stations owned by major petroleum companies	**33** (26-41)	**118** (87-148)	**3.6** (3.3-3.8)	**3** -
Gas stations owned by other companies	**58** (50-67)	**204** (174-233)	**3.5** (3.2-3.8)	**3** -
Other fuel-related establishments	**36** (30-43)	**77** (64-90)	**2.1** (1.8-2.4)	**2** -
Large non fuel-related estabments (with ≥ 20 employees)	**74** (55-93)	**142** (97-187)	**1.9** (1.6-2.2)	**2** -
Total for business and government establistments	**247** (220-275)	**638** (584-692)	**2.6** (2.4-2.8)	**3** -
Total for farms	**79** (58-100)	**158** (<453)	**2.0** (<5.0)	**1** -
TOTAL	**326** (296-356)	**796** (503-1,090)	**2.4** (1.6-3.2)	**3** -

establishments." This means that there is only a 5 percent chance that the actual value falls outside of this range. When an upper limit is given, as in the estimate of number of eligible tanks on farms in Table 2-1, where the entry is 158 (less than 453) thousand, this indicates that the lower bound of the confidence interval is a small number. The statement for this estimate would be, "It is estimated with 95 percent confidence that the number of underground motor fuel storage tanks on farms is less than 453,000, with a point estimate of 158,000." This means that there is only a 5 percent chance that the actual value is greater than the upper limit.

B. Non-Sampling Error

As in any data collection effort, non-sampling error is also present in these data. This type of error is not quantified in the confidence intervals but has been explored and reported on in several places in the report. Potential non-sampling errors include deficiencies in the sampling frame, respondent errors, physical test errors, and inventory recording and analysis errors. In this survey, one potential non-sampling error investigated in depth comes from the physical tank testing. Several parts of the report discuss the test method. Section 1, in particular, has reviewed the limitations in the interpretation of the results which stem from the testing method chosen. First, a leak detected by the test may represent a hole anywhere in the system of tank vessel and associated lines, pipes and fittings, or indeed a loose connection within this system. Second, it cannot be definitively determined from the data where the detected hole or loose connection is or when or whether a leak occurs under operating conditions. Section 8 offers two relevant pieces of information: Tanks do tend to be nearly or completely filled at delivery (so that holes or loose fittings at or near

the top of the tank would have occasion to leak in practice); and when distribution line tests were possible, the measured rate of the line leak accounted for very little of the measured tank system leak (so that detected leaks do not appear to be in the distribution lines). As is described in Sections 6 and 7, factors which could lead to difficulties with the physical testing such as uneven product temperature, change in temperature, erratic measurements, vapor pockets, and tank end deformation due to test pressure have been carefully accounted for in the the test procedure and subsequent data reduction process.

II. NATIONAL ESTIMATES

The major findings are given in Tables 2-1 through 2-3.

- Number of Establishments with Tanks -- Table 2-1 presents survey estimates of the number of underground motor fuel storage tanks and the number of establishments with such tanks, as well as the mean and median number of tanks per establishment, by type of establishment. The national estimate for the number of tanks is 796,000 with 95 percent confidence bounds of 503,000 to 1,090,000. This total includes farms. Since so few farms surveyed actually had underground motor fuel storage tanks (20 out of a sample of 600), further national estimates including farms could not be accurately made and therefore are not presented. The national estimate of business and government tank establishments is 247,000 (220,000-275,000) and the number of non-farm tanks is estimated to be 638,000 (584,000-692,000).

- Percentage of Tank Systems Judged to be Leaking under Test Conditions -- Table 2-2 shows the estimated number and percent of business and government tanks judged to be leaking under test conditions by establishment type, based on the physical tightness test results. Based on tested tank systems which yielded valid test results, an estimated 35 percent of tank systems are judged to be leaking under test conditions, with 95 percent confidence bounds of 30 to 40 percent.

Table 2-2. Estimated number and percent of tank systems[1,2] judged to be leaking under test conditions by establishment type (95% confidence bounds in parentheses)

Establishment type	Number of tank systems judged to be leaking (in 1,000's)	Percent of tank systems judged to be leaking (of tanks with conclusive test results)[3]
Government and military	**29** (5-54)	**36** (16-55)
Gas stations owned by major petroleum companies	**25** (11-38)	**32** (19-45)
Gas stations owned by other companies	**56** (40-71)	**30** (22-37)
Other fuel-related establishments	**35** (25-45)	**57** (43-71)
Large nonfuel-related establishments	**45** (19-71)	**33** (18-47)
Total	**189** (153-226)	**35** (30-40)

[1]In this table, tank test results are reported for individual tank systems unless the tanks were tested as a part of a manifolded tank system that was not broken apart. These manifolded systems are included in the table.

[2]Does not include farm tanks.

[3]Excludes tank systems for which test results were inconclusive. (Therefore the estimated number in this table, when divided by the estimated totals in Table 2-1, will not give the percentages shown here.)

Table 2-3. Estimates by establishment type of mean and median leak rates among tank systems[1,2] judged to be leaking under test conditions (95% confidence bounds on the means in parentheses)

Establishment type	Mean adjusted leak rate (gph)[5]	Median adjusted[3] leak rate[4] (gph)
Government and military	**0.26** (0.06-0.47)	**0.27**
Gas stations owned by major petroleum companies	**0.42** (0.18-0.68)	**0.29**
Gas stations owned by other companies	**0.24** (0.13-0.34)	**0.28**
Other fuel-related establishments	**0.45** (0.20-0.71)	**0.32**
Large nonfuel-related establishments	**0.25** (0.14-0.36)	**0.14**
Total	**0.32** (0.24-0.39)	**0.25**

[1]In this table, tank test results are reported for individual tank systems unless the tanks were tested as a part of a manifolded tank system that was not broken apart. Results for manifolded systems are included in the table.

[2]Does not include farm tanks.

[3]Leak rates of leaking tank systems were adjusted to operating pressure.

[4]Calculation of median adjusted leak rate includes tanks judged to have unquantifiably large leaks.

[5]Calculation of mean adjusted leak rate includes only those tank systems judged to be leaking which had quantifiable leak rates.

- Percentage of Tank Systems Leaking Under Operating Conditions -- Under operating conditions, the percentage of tank systems that are leaking might be somewhat less. This could vary from 18 percent at a random point in time to 29 percent at the time of product delivery the way tanks are normally filled, and to 35 percent at the time tanks are filled if they are filled to capacity. (See further discussion in III below.)

- Leak Rates -- Table 2-3 presents the mean and median leak rate for tank systems judged to be leaking under test conditions by establishment type for business and government tanks. These leak rates have been adjusted to typical operating conditions (see Section 8). The mean leak rate for all business and government tanks is 0.32 gallons per hour with 95 percent confidence bounds of 0.24 to 0.39 gallons per hour. This is based on tank systems judged to be leaking which had quantifiable leak rates. Some tanks showed leaks too large to quantify so the estimated mean leak rate is conservative.

- Incidence of Underground Motor Fuel Tanks Among Various Types of Establishments -- The screening effort revealed a low incidence of underground motor fuel tanks for certain types of establishment. Twenty-four percent (19-28%) of fuel-related establishments (other than gas stations) have underground motor-fuel storage tanks. Thirteen percent (9-16%) of large establishments not in fuel-related establishments have eligible tanks. Three percent (2-4%) of farms have eligible tanks. **However, as is seen in Tables 2-1 and 2-2, a substantial proportion of the tank and tank establishment universe is found in these types of establishments** even though many such establishments do not have underground motor fuel storage tanks.

III. LEAK STATUS UNDER OPERATING CONDITIONS

Certain features of the tank testing method are different from typical operating conditions, especially the overfilling of the tank during the test.

It is certainly reasonable to ask whether some of the leaks detected under test conditions might have been due to holes near the top of the tank or in lines, pipes and fittings above normal fill levels. Data from the survey reveal that it is common practice to fill tanks to 100 percent capacity when product is delivered. In fact, 100 percent was the modal value for this variable, and the median of the reported average fill level was 83 percent of capacity. Thus, the data suggest that even holes near the top of the tanks would be subject to leaking, at least just after product delivery.

On the other hand, the average tank fill level just prior to delivery had a median value of about 20 percent of tank capacity. Therefore, as a rough approximation, a typical operating level might be midway between the high and low point, or 52 percent of capacity. If one were to further assume that holes were evenly distributed between the top and bottom of the tank, then an estimated 52 percent x 35 percent = 18 percent of the tank systems would be leaking on the average at any point in time under typical fill level conditions.[1] Furthermore, using average percent filled after delivery may be a conservative estimate of operational fill levels. When asked about the maximum gallons ever stored, most respondents reported 100 percent, and only one-quarter were below 92 percent full.

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[1]This is a rough approximation which could be refined by calculating highest and lowest fill levels for each tank separately, and then computing the median and mean fill levels as fuel is withdrawn. Fuel withdrawal rate could be assumed as uniform over time or simulated from inventory data. Finally, refinements could be made to account for the fact that the assumption of uniform leak distribution over the surface of the tank is not identical to uniform leak distribution over volume. However, since actual leak distribution is unknown, such refinements do not seem warranted at present.

In summary, if we are willing to assume that holes are uniformly distributed around the tank circumference (we have no data to verify this assumption), we could calculate that:

- Approximately 35 percent of the tank systems would be leaking if they were filled to capacity;
- If all tanks are ever filled to capacity during the year, then an estimated 35 percent of the tank systems in the country are leaking at one time or another during a year;
- Approximately 29 percent (.35 x .83) of tank systems are leaking just after the time of product delivery the way tanks are normally filled; and
- Approximately 18 percent (.35 x .52) of the tanks are leaking at a random point in time.

Based on a limited set of 43 leaking tank systems where it was possible to test the leak status of distribution lines separately, it was found that the distribution line leak rate makes up a very small portion of total tank system leak rate. Distribution line leaks made up a small portion of the total system leak rate.

IV. ESTABLISHMENT CHARACTERISTICS

Descriptive statistics for establishments include:

- Thirty-one percent (27-35%) of establishments with underground storage of motor fuels also store waste oil underground.
- Fourteen percent (11-17%) of establishments with in-use underground motor fuel storage tanks also have one or more abandoned underground storage tanks on site.

- Seventy-eight percent (73-83%) of establishments used clean sand, pearock or peagravel to backfill around tanks (one-quarter of owner/operators did not know the backfill material).

- Twenty-nine percent (21-37%) of establishments are required to have tank operating licenses (whether this was required was not known by 16% of owner/operators).

- Sixty-nine percent (64-75%) of establishments believe they are insured for non-catastrophic leaks (22% of owner/operators did not know the answer to this question).

V. TANK CHARACTERISTICS

Other descriptive findings include:

- The mean age of eligible business and government tanks is 12 years (11-13 years). The mean capacity is 5,405 gallons (5,026-5,783 gallons).

- Forty-two percent (37-46%) of business and government tanks store unleaded gasoline, 33 percent (30-36%) store leaded gasoline and 21 percent (17-26%) store diesel fuel. The remaining tanks store aviation fuel, jet fuel, gasohol or other products used as motor fuel.

- Eleven percent (7-15%) of tanks with known construction material are fiberglass.

- Twenty-one percent (17-25%) of tanks with known positions in relation to the water table are partly or completely below the water table (tank owner/operators do not know this status for one-third of tanks).

- Twenty-three percent (18-27%) of tanks are part of a manifolded system.

- Five percent (3-6%) of tanks for which the owner/operators knew whether cathodic protection was installed do have such protection (tank owner/operators did not know the answer to this question for 13% of tanks; it is unlikely that such a system would work well if the operator were unaware of its existence).

- Twenty percent (14-26%) of tanks were installed by the owner/operators themselves (this is among the 54% of owner/operators who knew the identity of the installer).

VI. TANK CHARACTERISTICS ASSOCIATED WITH LEAKS

Statistics describing tank systems judged to be leaking under test conditions include:

- Fifty-seven percent (46-67%) of tank systems storing diesel fuel are judged to be leaking under test conditions, while 18 percent (9-26%) of tank systems storing leaded gasoline are judged to be leaking under test conditions. Thirty percent (26%-41%) of tank systems storing unleaded gasoline are judged to be leaking under test conditions. These differences in percent leaking by fuel type could be due to some other variable associated with fuel type. No conclusion should be drawn about the effect of fuel type without further research.

- Fifty-four percent (39-68%) of tanks in manifolded systems are judged to be leaking under test conditions, while 31 percent (26-36%) of single tank systems are judged to be leaking.

- Thirty-one percent (15-48%) of fiberglass tank systems (i.e., tank systems in which the tank is made of fiberglass although lines, pipes, and fittings may not be) are judged to be leaking under test conditions. This figure is quite similar to the proportions of steel tank systems judged to be leaking, whether bare (uncoated) with 32 percent (14-49%), or coated, with 38 percent (30-46%).

- Steel tanks, which comprise 89 percent of all underground motor fuel storage tanks, show little increase in percentage of tank systems judged to be leaking as they age except for the oldest tanks (over 20 years of age) for which the percent judged to be leaking increases substantially to 58 percent (29-77%). No fiberglass tanks over 20 years old were found in our sample, so percent judged to be leaking cannot be compared across material type for this age category. Fiberglass and steel tank systems show similar

The statistical analysis did not identify any single explanatory variable (such as age of tank, type of material, or fuel type) that is strongly correlated with either leak status or tank system leak rate. Additional multiple regression and logistic models were developed which suggested the possible influence of a few variables, but their ability to predict leak status or leak rate was weak, as described in Section 9, Subsection VI, and Appendix I. Soil characteristics were not among the variables analyzed because they were not available in the data base during this study. Soil data more recently developed by EPA and General Software Corporation are described in Appendix H.

A. Tightness Test Method Development

There were a number of possible tank system testing methods commercially available at the time of the survey. OTS modified an existing method in order to improve the reliability for the survey (see MRI draft report, November 7, 1985 for OTS, "Development of a Tank Test Method for a National Survey of Underground Storage Tanks," which is summarized in Appendix C).

B. Establishment Manager Cooperation and Inventory Participation in the Field Interview Phase

Participation in the field interview phase of the survey was nearly 100 percent overall. As indicated in Table 2-4, 99.3 percent of all eligible respondents completed interviews. The highest response rate among the sample segments was among the large establishments where 100 percent of the eligible establishments provided interview data.

It is very difficult to obtain accurate and usable inventory data. Owners and operators had trouble following even simple inventory data collection procedures. The 78 percent response rate was achieved only after extensive followup efforts. About 90 percent of these respondents required technical assistance to collect the inventory data. This contrasts with the 60 percent of owner/operators who responded "yes" to the questionnaire item, "Do you reconcile your stick inventory with your book inventory?" The lowest inventory data response rate was from the farm sample, where only 35 percent of all eligible farms provided inventory. Of all eligible respondents, 16 percent have not yet provided any inventory. Problems that establishment operators encountered in keeping inventory records are described in detail in Section 5.

C. Tightness Test Cooperation

The physical tank testing response (cooperation) rate was 95 percent and complete, usable results were obtained from 85 percent of the subsample of tank systems and manifolded tank systems. Test results were judged reliable in about 89 percent of the tank systems and manifolded tank systems where tests were

Table 2-4. Field interviewing and inventory response rates

	Farms	Large establishments	Fuel-related establishments*	Total
A. Number of eligible establishments	20	76	800	896
B. Response rate (percent of eligible respondents who completed interview)	95%	100%	99.4%	99.3%
C. Refusal rate (percent of eligible respondents who refused interview)	5%	0%	0.6%	0.7%
D. Inventory response rate (percent of eligible respondents who returned inventory)	35%	79%	78.8%	77.8%
E. Inventory refusal rate (percent of eligible respondents who refused to record inventory)	30%	1.3%	1%	1.7%
F. Percent of establishments delinquent in returning inventory	20%	11.8%	16.4%	16.1%
G. Percent of establishments for which inventory measurements are impossible	15%	7.9%	3.8%	4.4%

*including government and military establishment

attempted. Approximately 5 percent of the tank systems and manifolded tank systems where tests were attempted were not testable for technical reasons which are discussed in more detail in Section 6. Table 2-5 presents the tightness test completion rates for the survey.

The testing methods used in the survey required that the tank be out of service for one day and be filled to capacity at the start of the test. Difficulties in arranging for a fuel delivery, scheduling an acceptable test time, or physical problems with the tank and with its associated plumbing add significantly to both the time required and the cost of physical testing. Severe operational difficulties requiring excavation were encountered in about 14 percent of the tanks. More details on these problems appear in Section 6.

Table 2-5. Tank testing completion statistics

		Single tank or manifolded tank systems	Total number of individual tanks at these systems
A.	Number selected for tightness testing	484	561
	1. Percent of out of scope of survey[1]	0.8%	0.7%
	2. Percent at sites refusing to participate	5.0%	4.8%
B.	Number of tests attempted	456	530
	1. Percent untestable for technical reasons	5%	5%
	2. Percent for which test results were unreliable or inclusive	6%	5%
	3. Percent with reliable, conclusive test results	89%	90%
		100%	100%
C.	Response rate for estimates of the percentage of tank systems that are leaking[2]	85%	86%

[1]Became out of scope after the interview phase (for example, went out of business).

[2]These response rates are the number of reliable test results out of the eligible cases selected. From the figures presented above, they can be calculated as (0.89 x 456)/((1.0 - 0.008) x 484) = 0.85 and (0.90 x 530)/((1.0 - 0.007) x 561) = 0.86.