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Tank Corrosion Study

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FINAL REPORT

TANK CORROSION STUDY

EPA ASSISTANCE ID NO. X-813761-01-0

By

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NOVEMBER 1988

For

OFFICE OF UNDERGROUND STORAGE TANKS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

401 M STREET, S.W.

WASHINGTON, D.C. 20460

ATT: MR. DAVID O'BRIEN

COUNTY OF SUFFOLK

EPA 510-K-92-802

PATRICK G. HALPIN
SUFFOLK COUNTY EXECUTIVE

DEPARTMENT OF HEALTH SERVICES

DAVID HARRIS, M.D., M.P.H.
COMMISSIONER

November 17, 1988

Mr. David O'Brien
Office of Underground Storage Tanks
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. O'Brien:

In accordance with EPA Assistance ID No. X-813761-01-0 enclosed please find Suffolk County's final report on the Tank Corrosion Study.

Very truly yours,

David Harris, M.D., M.P.H.
Commissioner

DH/lst
Enclosure

225 RABRO DRIVE EAST
HAUPPAUGE, N.Y. 11788
(516) 348-2900

TABLE OF CONTENTS

END OF TABLE

LIST OF ILLUSTRATIONS

50,000 Gal.__ 100,000 Gal. or more __ No idea__.

Approximate Burial Depth Below Grade: __________'

Buried Tank Deflection: total length: ____'____"
(minus) to tank top: ____'____" BURIED
A. tank diameter: ____'____"

total length: ____'____"
(minus) to tank top: ____'____" REMOVED
B. tank diameter: ____'____"

Diameter A.: ____'____"
(minus) Diameter B.: ____'____"
Deflection : ____'____"

Description of Tank EXTERIOR Corrosion:

Point Corrosion: __nominal __mild __moderate __severe

General Corrosion: __nominal __mild __moderate __severe

Description of Tank INTERIOR Corrosion:

Point Corrosion: __nominal __mild __moderate __severe

General Corrosion: __nominal __mild __moderate __severe

INTRODUCTION

This is the final report for the United States Environmental Protection Agency of the TANK CORROSION STUDY performed in Suffolk County, New York by the Suffolk County Department of Health Services. This report covers the observations made on 500 underground tanks spanning the time period from February 24, 1987 to September 1, 1988. This report is the summation of four interim reports plus observations and conclusions. The first interim report was issued on July 31, 1987 and covered the first 100 tanks. The second was issued on November 10, 1987 and covered 200 tanks (including the first 100). The third interim report was issued on February 8, 1988 and covered exempt heating oil tanks. The fourth was issued on May 2, 1988 and covered 320 tanks.

The study was conceived as a means of gathering information about old buried steel tanks and the nature of corrosion that plagues them, by closely observing them as they are removed from the ground for disposal. Suffolk County was chosen for the study because a large number of tanks are being removed in a relatively short time to meet the requirements of a local tank replacement ordinance - Article XII of the Suffolk County Sanitary Code (Appendix A).

The tanks involved in the study varied from 175 gallons to 50,000 gallons and from 2 years old to 70 years old. All but 18 contained some type of petroleum product. All of the 500 tanks included in the statistics were plain welded steel tanks. During the period of the study there were also 12 tanks other than plain steel that were examined. The results of these were not included with the 500 but instead were covered in a seperate section toward the end of the report (Appendix D).

SUMMARY

Five hundred plain steel tanks plus twelve corrosion protected tanks were removed from the ground over an eighteen month period in Suffolk County, Long Island, New York. They were examined carefully before disposal to gather statistics on the nature and extent of corrosion that had attacked them. Information was gathered on the number, type, location, and size of perforations; the general interior and exterior corrosion condition; soil, backfill, and groundwater conditions; the presence of leaked product; and tank statistics such as volume, plate thickness, location, product, age, etc. The statistics were compiled and compared, observations made and conclusions developed.

The major conclusions can be summarized as follows:

1) Size is more important than age in predicting tank failure;
2) In general, small tanks are much more likely to perforate than large tanks due to the thinner walls found in smaller tanks;
3) Compared to external corrosion, internal corrosion is insignificant;
4) Fuel oil tanks are just as susceptible to perforation as gasoline tanks of the same size;
5) Existing tanks are in worse shape than is demonstrated by testing;
6) Tanks do not always leak immediately upon perforation,

BACKROUND

GEOGRAPHY

Suffolk County is located in southeastern New York State and encompasses the eastern two-thirds of Long Island. It is bordered on the west by Nassau County. The other three sides are bounded by bodies of water: Long Island Sound to the north, Block Island Sound to the east, and the Atlantic Ocean to the south.

The county has a land area of approximately 885 square miles. It is 86 miles in length and varies in width (on the main body) between 12 and 20 miles. The eastern end of the county is split in two forks which are seperated by the Peconic Bay System. There are 5 significant islands on the east end which are also under the county's jurisdiction.

The geographical features of Suffolk County are a result of the last ice age, which ended some 12,000 years ago. Two lines of terminal moraine hills were formed during this period. They reach a maximum height of 400 feet above sea level and traverse the length of the county. A moderately flat land surface (called an outwash plain) forms most of the southern area of the county. This plain terminates at off-shore barrier beaches that are seperated from the mainland by shallow bays. The north shore is characterized by headlands that have been eroded away into steeply vertical bluffs that reach almost 100 feet high in some places. There are also several harbors and wetland areas along this shore.

The updated 1988 planning data indicated a population of approximately 1.37 million people with an additional transient seasonal population of approximately 200,000 people.

The county's land use (of approximately 566,000 acres) is broken down as follows: residential (25%), commercial (3%), industrial (2%), transportation (8%), institutional (6%), recreational and open space (14%), agricultural (9%), and vacant (33%). This is based on 1981 figures and remains fairly accurate according to latest planning estimates.

GEOLOGY AND HYDROLOGY

The Upper Glacial Aquifer compromises the uppermost layer of the land surface in the county. This layer consists of glacial material, which itself consists mostly of sand. The whole layer is composed of sand, gravel, clay, silt, organic mud, peat, loam, and shells. The gravel ranges in size from pebbles to boulders, and the sand from fine to very coarse. This composition creates a filter-like effect allowing any liquid to percolate easily from the surface all the way down to the water table.

All of Suffolk County's water supply comes from below its surface. For this reason, the United States Environmental Protection Agency declared the groundwater of Suffolk as a sole-source aquifer. This means Suffolk is dependent on its groundwater and the recharge capabilities of the ground to maintain it's water supply.

The average rainfall is approximately 45 inches per year. For the main body of the county, approximately 48 % of the precipitation is lost to evaporation, 1.4 % is lost as direct run-off, and the remaining 50.6 % is recharged. The water table in the county is always above sea level and tends to vary seasonally (by up to several feet in some areas). The water table ranges between 0 and 110 feet above sea level, while the land elevation varies between approximately 0 and 300 feet above sea level.

SOILS

According to the US Soil Conservation Service[1] there are 10 major soil associations in the county, depending on location and relation to the glacial moraines and plains. Among these, there are 18 soil series and 67 mapping units. The series are a more specific classification of the soil associations and the mapping units are a direct soil label. These all contain glacial sands. The pH ranges from approximately 3.5 to 6.5, with most soils in the 4.5 to 5.5 range. This is more acidic than the average United States soil. The corrosivity ranges from low to high depending on soil type, location, and soil characteristics.[2] The permeability ranges from < 0.2 inches per hour to > 6.3 inches per hour. The available moisture capacity of the soil ranges from 0.01 inches of water per inch of soil (very low / dry) to 0.2 inches of water per inch of soil (high / moist).

It has been previously established[1,2] that Suffolk County soil corrosivity ranges from low to high (this is the entire range of corrosivity - low, moderate, high). This rating is based on several factors: drainage class and texture, acidity, resistivity (field), and conductivity (saturated). Soil reaction (pH) correlates poorly with corrosion potential and is not included in the rating. But there is a notable exception - a pH of less than 4.0 almost always indicates a high corrosion potential. Resistivity values range from less than 2,000 ohm-cm for high corrosivity potential to greater than 5,000 ohm-cm for low potential. Suffolk County soil encompasses this entire range with resistivity readings varying from 35 ohm-cm in tidal locations to approximately 120,000 ohm-cm in typical dry, sandy locations.

The following is a description of each of the soil series.[1]

Carver Soils - Generally a coarse textured sandy loam. It is excessively drained with a very low available moisture capacity and rapid permeability throughout. The soil reaction (degree of acidity or alkalinity) is strongly acid to very strongly acid (pH range of 4.5 - 5.5).

Cut & Fill Land - Generally a loam and sand mix associated with Carver and Plymouth soils. It has a low moisture capacity and follows most other characteristics of the mentioned series.

Haven Loam - A medium textured loam. It is well drained with a moderate to high available moisture capacity and varying permeability (moderate in the upper layers and rapid in the lower layers). The soil reaction is strongly acid to very strongly acid.

Made Land - This type of land consists of many materials including rubble, soil, non-organic material, and non-soil material. Its characteristics are variable.

Montauk Soils - Generally a fine sandy loam and silt loam. It is a medium to moderately coarse textured soil that is moderately - well to well drained. It has a moderate to high available moisture capacity with varying permeability (moderate to moderately-rapid in the upper layers and moderately slow in the lower layers). The soil reaction is strongly acid to very strongly acid throughout.

Muck - Poorly drained organic soil. This type of soil is usually located near wetlands or in areas of high water table.

Plymouth Loamy Sand - A coarse textured loamy sand. It is excessively drained with a low to very low available moisture capacity and varying permeability (rapid in the upper layers and moderate in the lower layers). The soil reaction is strongly acid to very strongly acid.

Riverhead & Haven Soils - Generally a medium to moderately coarse textured loam or sandy loam. They are well drained with a moderate to high available moisture capacity and rapid to very rapid permeability. The soil reaction is strongly acid to very strongly acid.

Riverhead Sandy Loam - Similar characteristics as the above.

Tidal Marsh - Wet, sandy areas near bays and tidal creeks. They are poorly drained areas.

Urban - This type of land has variable characteristics. It has already been developed and the soil characteristics modified.

SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES

FIELD INSPECTION FORM

FIRST DRAFT

Inspection Date ________
Time Start ________
Time End ________
Time Spent ________ Min.

Facility ID: ________ Tank No. ________ Prop.Tax No. ____ ____ ____ ____

Facility Name: ____

Facility Address: ____

Type of Facility: Gas Sta.___ Car dealer__ Commercial__ Residential__ Industrial__ Other__(describe) ________________________________

Type of Tank: Plain steel__ Asphalt or coal tar coated steel__ $STIP_3$__ Other induced current cat.prot.steel___ Imposed current cat. prot.steel__ Bufhide__ Other fiberglas coated steel__ Owen-Corning fiberglas__ Xerxes fiberglas__ Other fiberglas__ Other material___ (describe) ________________________

Contents (Observed): Gasoline__ Fuel oil #2__ Fuel oil #4__ Fuel oil #5__ Fuel oil #6__ Kerosene__ Diesel__ Gasahol__ (% mixture)__ Jet fuel__ Av.gas__ Solvents__ (Describe) ________________________ Waste oil__ Other oil__ (Describe) ________________________ Other material __ (Describe) ________________________

Dimensions: Diameter(x)_____' Diameter(y)_____' Length_____' Width_____' Height_____' Volume_____cu', _____gal.(Calculated from dimensions)

Date Installed: ________ Present age ______

End plate thickness ________" (mic,) ______" (Ultrasonic)

Wall thickness ______" (Ultrasonic)

Holes: Yes__ No__ Total No. observed___ Leak confirmed before removal____ Dia. largest_____" Dia. smallest_____" Average dia._____"(Es

Hole locations Bottom below fill__ Bottom below gage hole__

Elsewhere along bottom__________ Multiple along bottom __________

Top around fittings ___ Eleshere on top___ Along groundwater line__

On side__ On end__ Multiple on sides and/or ends___

Cause of holes: Point corrosion internal__ Point corrosion external__ General Corrosion internal__ General corrosion external__ Combination internal and external corrosion____ Weld failure__ Mechanical damage internal__ Mechanical damage external__

Sludge: Volume_____ gal. Wt.___.___#

Exterior coating: Yes__ No__ Completely intact__ Minor flaws__ Many failed areas__ Completely failed__ ____% Remaining

Interior coating: Yes__ No__ Fiberglas lining__ Other__ Completely intact__ Minor flaws__ Many failed areas___. Completely failed__ ____%Remaining

Natural Soil Conditions: Clean sand or gravel__ Clay__ Bog__ Loam__ Sand w/some clay__ Other__ (describe)____________________________ Can't tell _____

Backfill Conditions: Clean sand or gravel__ Same as natural soil__ Concrete, asphalt, stones or rubble against tank___ Other ____ (describe)____

Groundwater level: Always in contact with tank__ Sometimes in contact with tank __ Never in contact with tank__

Groundwater Quality: Salinity (if near shore)_____ pH_____ Floating product in observation wells__ In excavation dissolved product ____

Closest estimate of total product leaked: Ogal__ 10 Gal.__ 50 Gal.__ 100 Gal,__ 500 Gal__ 1,000 Gal.__ 2,000 Gal.__ 5,000 Gal.__ 10,000 Ga

The United States Soil Conservation Service has developed a corrosivity rating[2] based on several factors. For the soils encountered in this study, the following ratings apply:

Carver Series	-	Low Corrosivity
Haven Series	-	Low Corrosivity
Montauk Series	-	Low Corrosivity
Plymouth Series	-	Low Corrosivity
Riverhead Series	-	Low Corrosivity

These soils generally have an average soil acidity of less than 8 meg/100 gram and are well to excessively drained medium to coarse textured soils. Their resistivity is greater than 5000 ohm-cm and conductivity (of saturated extract) is less than 0.3 mmhos/cm.

Other soils such as tidal marsh and muck have a lower resistivity and will tend to be placed in a higher corrosion category. These soils typically have a high or fluctuating water table.

The initial corrosivity of the soil series leads to the premise that Suffolk County soils are generally of low corrosivity, all 4 determining factors considered.

DEVELOPMENT PATTERN

Prior to World War II, Suffolk County was primarily an agricultural area with scattered small villages. After the war, the wave of population that spread out from New York City engulfing neighboring Nassau County, rolled into western Suffolk and spread eastward. Currently the western two-thirds of the county are solidly developed and agriculture is restricted to the eastern third, even though Suffolk still ranks as the number one agricultural county in the state in production. It is an affluent area, ranking among the highest in the country for family income. The population is well-educated and therefore especially environmentally concerned.

TANK REGULATION

This combination of factors: education, wealth, population density, and restricted water supply has led Suffolk to take a position of leadership in the field of environmental regulation. It led the Suffolk County Board of Health in 1979 to pass sweeping restrictions on the storage and handling of toxic materials including underground petroleum storage. Until that time, nearly all underground tanks installed in the county were constructed of plain steel. Since that time, only non-corrodible tanks such as fiberglass or cathodically protected tanks have been installed.

In addition to establishing new construction standards, the law required replacement of all existing plain steel tanks by January 1, 1990 with non-corrodible single- or double-walled tanks.

The removal and replacement effort has been progressing steadily for several years now and is beginning to accelerate as the due date draws near. It was recognized some time ago that the very large number of old steel tanks being removed constituted a valuable source of information on tank corrosion.

This study was designed to take advantage of that resource and to obtain practical information on the nature of tank corrosion that might be useful in developing regulations in other areas.

TANK POPULATION

The tanks that were examined in this study constituted as random a sample as was available on Long Island, being composed of every tank of any type that was removed during the period of the study. The reasons for removal were not documented, but included: 1) compliance with the replacement requirement of the law (Appendix A); 2) business expansion requiring greater storage capacity; 3) new construction requiring removal to eliminate obstructions; 4) test failure; and 5) change of business. The only major group of tanks conspicuously missing from the study is the very small heating tanks. Though there are some in the study, there are not many because the law still does not require the replacement of heating tanks or even testing of those under 1100 gallons.

Another group that could certainly be considered as underrepresented would be the farm tanks. Because of the difficulties in managing and carrying out a regulatory program in the farming areas, less enforcement effort has been applied to farmers and therefore fewer replacements have been made than in the commercial and industrial areas.

There is one other factor that must have had some effect on the true randomness of the studied sample forcing the results to the conservative side. The tank regulatory program has been in effect since 1980 and by the time the study started, about 1800 tanks had already been removed. This naturally resulted in the removal of many of the worst tanks before the study began.

Tank testing statistics support this contention. By the time of the beginning of the study, over 6000 tanks had been tested in the county. The annual test failure rate had declined steadily from about 15 % in 1981, to about 2 %, apparently indicating that the tanks most likely to be leaking were being removed first and were already gone by the time the study began.

PROCEDURE

In Suffolk County, by regulation, when tanks are removed or abandoned, the Health Department must be notified beforehand. The attached sheet (Appendix B) describes the required abandonment procedure.

Nearly every tank that was abandon during the study period was examined and is included in the statistics. Two Health Department sanitarians, Janet Swords and Tom Nanos, were assigned to accomplish this task.

An inspection information sheet was filled out by the inspector for each tank during the inspection, a copy of which is attached (Appendix C). The information was then computerized to create a usable data base.

While a tank was being excavated, the process was observed and notes taken on the condition of the backfill and any evidence of leakage or spillage.

When the tank was removed, it was set on the surface near the excavation and thoroughly cleaned of clinging dirt and scale by the inspector and then very carefully inspected (visually) for any evidence of perforations. If one was found, it was examined closely and a determination made as to the type of corrosion, internal or external. Information was taken as to the size, location, and number of perforations and any unusual conditions described. The tank was measured for original dimensions and the plate thickness measured with an ultrasonic testor.The ends were then cut out of the tank by the contractor using a pneumatic cutting device and the interior was cleaned of all remaining sludge.

After the tank was cleaned and vented reasonably well, the sanitarian inspected the interior from the end holes using a light. Perforations could be seen as points of light in the dark interior, and these were checked against the information from the outside. The condition of interior corrosion was described and any unusual conditions noted.

Warning

Tank abandonment is dangerous! During the time of this study, there were three explosions of tanks and three fires which fortunately resulted in only two cases of minor injury. All accidents were caused by the extreme carelessness of the individuals working on the tanks. They resulted from the use of torches or abrasive cutting tools on tanks where they should not have been used.

FINDINGS

GENERAL STATISTICS

-Number of tanks inspected	500
-Number of facilities inspected	199
-Number of facilities inspected with perforated tanks	84
-Number of tanks with perforations	143
-Percent of tanks with perforations	28.6 %
-Average number of tanks removed per facility	2.51
-Average number of tanks with perforations removed per facility	.72

Making a generalization of the above numbers yields the following:

1) For every 11 tanks removed, one would expect to find approximately 3 tanks with perforations.
2) For every 2 facilities inspected that had perforated tanks, one would expect to find approximately 3 tanks with perforations.

-Number of Perforated Tanks that Showed Evidence of Having Leaked Product	83
-Percent of Perforated Tanks that Showed Evidence of Having Leaked Product	58.0 %
-Percent of Total Tanks that Showed Evidence of Having Leaked Product	16.6 %

Total volume of the 500 tanks equalled 2,216,650 gallons. Of these, the volume of those which were perforated was 315,525 gallons, or 13.6 % of the total volume.

CONTENTS OF TANKS

Material	All Tanks	% of All Tanks (n/500)	Perf. Tanks	% of Perf.Tanks (n/143)	% of Tanks Perforated According to Material
Gasoline	233	46.6 %	73	51.0 %	31.3 %
#2 Fuel Oil	128	25.6 %	39	27.3 %	30.5 %
Waste Oil	43	8.6 %	7	4.9 %	16.3 %
Diesel Fuel	33	6.6 %	11	7.7 %	33.3 %
Solvents	14	2.8 %	6	4.2 %	42.9 %
#4 Fuel Oil	11	2.2 %	1	0.7 %	9.1 %
Kerosene	11	2.2 %	3	2.1 %	27.3 %
Motor Oil	8	1.6 %	1	0.7 %	12.5 %
Waste Water/Oil	4	0.8 %	0	0 %	0 %
Aviation Fuel	3	0.6 %	0	0 %	0 %
Transmission Oil	3	0.6 %	1	0.7 %	33.3 %
#6 Fuel Oil	2	0.4 %	0	0 %	0 %
Caustic Soda	2	0.4 %	0	0 %	0 %
Jet Fuel - JP5	2	0.4 %	0	0 %	0 %
Sodium Hypochlor.	1	0.2 %	1	0.7 %	100.0 %
Other Oil	1	0.2 %	0	0 %	0 %
Unknown	1	0.2 %	0	0 %	0 %
	500	100.0 %	143	100.0 %	

NOTE: Upon further investigation, two of the tanks that were listed in previous reports as having contained aviation fuel were reclassified as having contained jet fuel.

CAUSE OF PERFORATIONS

GENERAL

	(n)		(n/143)
External Corrosion	108	=	75.5 %
Internal Corrosion	9	=	6.3 %
Combination Internal/External	21	=	14.7 %
Weld Failure	4	=	2.8 %
External Mechanical Damage	1	=	0.7 %
	143		100.0 %

Types of External and Internal Corrosion Causing Perforations
(Note: This information is extracted from above)

External			
Point	105	=	73.4 %
General	3	=	2.1 %
Internal			
Point	7	=	4.9 %
General	2	=	1.4 %

TANK WALL THICKNESS

Average Wall Thickness (inches)

	Endplate (Ultrasonic)	Endplate (mic)	Bottom Plate	Top Plate
1) Avg. Thick. (Perf.Tks.):	.1764	.1747	.1761	.1778
# of records:	65	89	93	60
Range - Low:	.0982	.0770	.1090	.0780
High:	.2814	.2812	.2984	.2852
2) Avg. Thick. (Non-perf.Tks.):	.2296	.2248	.2160	.2203
# of records:	156	205	223	151
Range - Low:	.0981	.1001	.0921	.0927
High:	.4672	.4733	.3920	.4150
3) Avg. Thick. (All Tks.):	.2139	.2096	.2043	.2082
# of records:	221	294	316	211
Range - Low:	.0981	.0770	.2043	.2082
High:	.4672	.4733	.3920	.4150

Since not all tanks had readings taken and those which did, did not necessarily have both ultrasonic and micrometer readings, one or the other was used to obtain the following results. This yielded a greater number of records for use in determining the endplate thickness. All ultrasonic readings were used as the primary readings, and micrometer readings used only on tanks where the ultrasonic meter was not used.

-Item 1 total records for endplate thickness equals 99. Average endplate thickness equals .1736 inches.

-Item 2 total records for endplate thickness equals 237. Average endplate thickness equals .2253 inches.

-Item 3 total records for endplate thickness equals 336. Average endplate thickness equals .2101 inches.

AVERAGE SIZE OF PERFORATION

-The average hole size for 143 tanks was .36 inches.
-The average hole size for 131 tanks on which perforation size was measured was .39 inches.
-The average size for the largest holes was .55 inches based on 121 tanks. The large hole size ranged from .02 inches to 5.0 inches (see note).
-The average size for the smallest holes was .11 inches based on 93 tanks. The small hole size ranged from .02 inches to .40 inches.

Note: A total of twelve tanks were not included in the above calculations for the following reasons: A) Three (3) tanks were not included because they had perforations that were all in excess of 20 inches (20", 26", and 58"), and would not have yielded a true representation of perforation size; B) Nine (9) tanks did not have perfoation size measured. Additionally, if a tank had only one perforation, it was listed as the largest hole.

Of 143 perforated tanks, 99 had more than 1 perforation. The average number of perforations for the population of perforated tanks was 7 perfs./tank. The average number of perforations for the 99 tanks that had more than one perforation was 10 perfs./tank.

AVERAGE THICKNESS BY TANK VOLUME

Perforated Tanks

Volume	Endplate	Bottom Wall	Top Wall
	Average Thickness (inches)		
185	.1308	.1341	n/a
275	.1157	.1244	n/a
315	.1250	.1250	n/a
500	.0770	n/a	.0780
550	.1548	.1589	.1559
1000	.1887	.1720	.1731
1500	.1934	.1884	.1820
2000	.1725	.1736	.1730
3000	.1804	.1789	.1787
4000	.1937	.1747	.1738
5000	.2481	.2596	.2595
12000	n/a	n/a	n/a

n/a - measurement not available

Non-perforated Tanks

Volume	Endplate	Bottom Wall	Top Wall
	Average Thickness (inches)		
275	.1185	.1150	.1212
500	.1788	.1779	.1749
550	.1556	.1640	.1690
575	.1994	.1929	n/a
1000	.1887	.1758	.1858
1100	.1340	.1355	.1344
1500	.2142	.2055	.2564
2000	.1913	.1890	.1894
2500	.2406	.2149	.2125
3000	.1937	.1875	.1936
3500	.3205	.2343	.2539
4000	.1937	.1832	.1825
5000	.2604	.2528	.2541
6000	.2621	.2618	.2623
7500	.3039	.2747	.2703
8000	.2554	.2598	.2663
10000	.2752	.2660	.2771
12000	.2388	.2582	.2535
15000	.3312	.3054	.3062
20000	.3116	.2604	.2810
25000	.4068	.3556	.3544
30000	.3503	.3434	n/a

n/a - measurement not available

AGE OF TANKS

Age in Years	All Tanks	Perforated Tanks	% of Tanks Perforated
70	1	1	100.0 %
60	1	0	0.0 %
57	1	1	100.0 %
55	1	1	100.0 %
50	1	1	100.0 %
48	5	3	60.0 %
47	1	0	0.0 %
46	1	0	0.0 %
44	12	1	8.3 %
43	7	3	42.9 %
41	2	0	0.0 %
40	4	1	25.0 %
37	2	1	50.0 %
36	1	0	0.0 %
35	3	0	0.0 %
34	1	0	0.0 %
33	2	1	50.0 %
32	6	0	0.0 %
31	5	0	0.0 %
30	14	7	50.0 %
29	3	0	0.0 %
28	17	3	17.6 %
27	14	6	42.9 %
26	22	16	72.7 %
25	10	3	30.0 %
24	9	1	11.1 %
23	26	8	30.8 %
22	10	1	10.0 %
21	9	3	33.3 %
20	23	6	26.1 %
19	16	9	56.3 %
18	15	7	46.7 %
17	25	9	36.0 %
16	28	13	46.4 %
15	18	4	22.2 %
14	16	6	37.5 %
13	19	2	10.5 %
12	8	1	12.5 %
11	7	3	42.9 %
10	30	2	6.7 %
9	7	0	0.0 %
8	3	1	33.3 %
7	5	0	0.0 %
3	1	0	0.0 %
2	1	0	0.0 %
UNKNOWN	87	18	20.7 %
Totals	500	143	

In most cases, tanks of unknown age were very old but there was no way of determining exact age.
Average age of all tanks was 21.8 years old (excluding 87 of unknown age).
Average age of perforated tanks was 23.4 years old (excluding 18 of unknown age).

NOTE: Twelve tanks which were included in Interim Report 4 were moved to another database because they were not 'true' unprotected steel tanks - that is: they were either fiberglass, fiberglass-coated, or cathodically protected. None of them had perforations. This accounts for the discrepancy in the eight year old age category and the loss of the six year old age category.

VOLUME OF TANKS

Volume (gals)	All Tanks	Perforated Tanks	% Perf.
175	1	0	0.0 %
185	1	1	100.0 %
275	18	5	27.8 %
315	1	1	100.0 %
500	2	1	50.0 %
550	58	13	22.4 %
575	1	0	0.0 %
1000	64	33	51.6 %
1100	1	0	0.0 %
1500	8	2	25.0 %
2000	73	35	47.9 %
2500	5	0	0.0 %
3000	59	21	35.6 %
3500	1	0	0.0 %
4000	65	25	38.5 %
5000	34	5	14.7 %
6000	12	0	0.0 %
7500	5	0	0.0 %
8000	12	0	0.0 %
10000	51	0	0.0 %
12000	3	1	33.3 %
15000	8	0	0.0 %
20000	5	0	0.0 %
25000	8	0	0.0 %
30000	2	0	0.0 %
50000	2	0	0.0 %
Totals	500	143	

Average volume of tanks was 4433.3 gallons.
Average volume of perforated tanks was 2206.5 gallons.

NOTE: Two of the tanks moved to the other 'non-corrodible' database were 500 gallons, accounting for the discrepancy in this category as compared to Interim IV.

LOCATION OF PERFORATIONS

Location	Perf. Tanks	% Perf.
Single on Side	29	20.3 %
Multiple on Bottom	27	18.9 %
Single on End	25	17.5 %
Multiple on Sides and/or Ends	23	16.1 %
Single Elsewhere on Bottom	20	14.0 %
Single or Multiple Below Gage Hole	7	4.9 %
Top	6	4.2 %
Along Groundwater Line	3	2.1 %
Single or Multiple Below Fill	2	1.4 %
Not Listed	1	0.7 %
	143	100.0 %

NOTE:1) The location designated as 'Not Listed' corresponds to the tank with the external mechanical damage. It was damaged in more than one location.
2) The 'Elsewhere on Bottom' category represents a hole which was not below either the fill or the gage holes.

GROUNDWATER LEVEL

	All Tanks	% of All Tanks (n/500)	Perf: Tanks	% of Perf. Tanks (n/143)
Tank always in groundwater	55	11.0 %	19	13.3 %
Tank sometimes in groundwater	29	5.8 %	17	11.9 %
Tank never in groundwater	379	75.8 %	95	66.4 %
Groundwater level unknown	37	7.4 %	12	8.4 %

Percentage of tanks that were always in groundwater and were perforated is 34.5 % (19/55).
Percentage of tanks that were sometimes in groundwater that were perforated is 58.6 % (17/29).
Percentage of tanks that were never in groundwater that were perforated is 25.1 % (95/379).
Percentage of tanks that groundwater level was unknown and were perforated is 32.4 % (12/37).

Note: The 'Sometimes in Groundwater' category includes those tanks which are subject to tidal or groundwater fluctuation and the tank bottom conditions vary between wet and dry.

OBSERVED SOIL CONDITIONS

The soil conditions listed below were the categories used by the inspectors to best describe the soil conditions at the tank site. This is not the backfill material, but the soil conditions that would have been found prior to tank installation. The table on page 20 compares this same soil list to the backfill condition found at the perforated tank sites.

Number of tanks per soil condition

	All Tanks	% of All Tanks (n/500)	Perf. Tanks	% of Perf. Tanks (n/143)
1) Clean sand/gravel, clay, and loam	159	31.8 %	44	30.8 %
2) Clean sand/gravel	116	23.2 %	20	14.0 %
3) Clean sand/gravel, and loam	107	21.4 %	33	23.1 %
4) Clean sand/gravel, and clay	29	5.8 %	6	4.2 %
5) Clay and loam	23	4.6 %	11	7.7 %
6) Clean sand/gravel, and bog	13	2.6 %	6	4.2 %
7) Bog and loam	8	1.6 %	3	2.1 %
8) Clay and bog	7	1.4 %	1	0.7 %
9) Clean sand/gravel, clay, and bog	6	1.2 %	4	2.8 %
10) Sand w/clay	5	1.0 %	3	2.1 %
11) Loam	4	0.8 %	1	0.7 %
12) Bog and sand w/clay	3	0.6 %	2	1.4 %
13) Bog	2	0.4 %	2	1.4 %
14) Clean sand/gravel, bog, and loam	2	0.4 %	1	0.7 %
15) Clean sand/gravel, clay, bog, and loam	1	0.2 %	1	0.7 %
16) Clay and sand w/clay	1	0.2 %	1	0.7 %
17) Clay, bog, and loam	1	0.2 %	1	0.7 %
18) Clay	1	0.2 %	0	0.0 %
19) Unknown	12	2.4 %	3	2.1 %
	500		143	

Number of perforated tanks per original soil condition in type of backfill and in level of groundwater

The purpose of this list is to compare the backfill conditions to the original soil conditions and the groundwater conditions to the original soil conditions. Regarding the backfill category, 'Clean' refers to clean sand, gravel, or stone brought in to backfill the tank; 'Same as Orig' refers to the backfill being the same as original soil; and 'Rubble' indicates the presence of a foreign material. Regarding the groundwater category, 'Alw' indicates the tank is always in groundwater; 'Some' refers to the tank sometimes being in groundwater; 'Nvr' refers to the tank never being in groundwater; and 'Unk' refers to an unknown condition.

Note: The number of perforated tanks is only additive in each category (ie: backfill or groundwater) and not across each row.

	Perf. Tanks	Backfill Type			Groundwater Level Tank in GW :			
		Clean	Same as Orig	Rubble	Alw.	Some	Nvr	Unk.
1)Clean sand/gravel, clay, and loam	44	0	16	28	2	6	36	0
2)Clean sand/gravel, and loam	33	0	18	15	4	1	28	0
3)Clean sand/gravel	20	3	14	3	0	0	15	5
4)Clay and loam	11	0	3	8	2	0	9	0
5)Clean sand/gravel, and clay	6	1	3	3	0	1	4	1
6)Clean sand/gravel, and bog	6	0	6	0	2	3	1	0
7)Clean sand/gravel, clay,and bog	4	0	4	0	0	3	0	1
8)Bog and loam	3	0	3	0	3	0	0	0
9)Sand w/clay	3	0	3	0	0	3	0	0
10)Bog and sand w/clay	2	0	2	0	2	0	0	0
11)Bog	2	0	2	0	2	0	0	0
12)Loam	1	0	0	1	0	0	1	0
13)Clay and bog	1	0	1	0	0	0	0	1
14)Clean sand/gravel, bog, and loam	1	1	0	0	0	0	1	0
15)Clean sand/gravel, clay, bog, and loam	1	0	0	1	1	0	0	0
16)Clay and sand w/clay	1	0	1	0	0	0	0	1
17)Clay, bog, and loam	1	0	0	1	1	0	0	0
18)Unknown	3	-	-	-	0	0	0	3

BACKFILL CONDITIONS

	All Tanks	% of All Tanks (n/500)	Perf. Tanks	% of Perf. Tanks (n/143)
Clean Backfill	317	63.4 %	80	55.9 %
Backfill with rubble	167	33.4 %	60	42.0 %
Unknown	16	3.2 %	3	2.1 %

Percentage of tanks in clean backfill that were perforated is 25.2 % (80/317).
Percentage of tanks in rubble backfill that were perforated is 35.9 % (60/167).
Percentage of tanks in unknown backfill that were perforated is 18.8 % (3/16).

PERFORATIONS VERSUS LEAKAGE

Fuel Oil

- Total number fuel oil tanks (#2 - #6) with perforations was 40.
- Total number of fuel oil tanks with perforations that showed evidence of leakage was 31.
- Therefore, 77.5 % of all perforated fuel oil tanks showed evidence of leakage. This is 37.3 % of all tanks that showed evidence of leakage.

Gasoline

- Total number of gasoline tanks with perforations was 73.
- Total number of gasoline tanks with perforations that showed evidence of leakage was 37.
- Therefore, 50.7 % of all perforated gasoline tanks showed evidence of leakage. This is 44.6 % of all tanks that showed evidence of leakage.

SLUDGE VOLUME

The remaining average sludge volume in all tanks was 33.3 gallons.

The remaining average sludge volume in perforated tanks was 34.6 gallons.

AGE VERSUS VOLUME - Perforated tanks

Age in Years	Number of tanks by Volume		
70	1 X 500		
57	1 X 1000		
55	1 X 1500		
50	1 X 315		
48	1 X 185	2 X 550	
44	1 X 4000		
43	3 X 1000		
40	1 X 2000		
37	1 X 2000		
33	1 X 3000		
30	1 X 275	2 X 1000	1 X 1500
	1 X 2000	1 X 3000	1 X 5000
28	1 X 3000	2 X 4000	
27	1 X 1000	1 X 2000	2 X 3000
	1 X 4000	1 X 5000	
26	13 X 2000	3 X 4000	
25	1 X 550	2 X 1000	
24	1 X 550		
23	4 X 1000	1 X 3000	1 X 4000
	2 X 5000		
22	1 X 275		
21	1 X 1000	2 X 4000	
20	1 X 1000	1 X 2000	4 X 4000
19	2 X 550	2 X 2000	1 X 3000
	4 X 4000		
18	2 X 550	1 X 1000	2 X 3000
	2 X 4000		
17	3 X 1000	3 X 2000	2 X 3000
	1 X 5000		
16	2 X 550	3 X 1000	2 X 2000
	5 X 3000	1 X 4000	
15	1 X 1000	3 X 3000	
14	3 X 2000	1 X 3000	2 X 4000
13	1 X 1000	1 X 2000	
12	1 X 4000		
11	1 X 1000	2 X 2000	
10	1 X 2000	1 X 3000	
8	1 X 1000		
UNKNOWN	3 X 275	3 X 550	7 X 1000
	3 X 2000	1 X 4000	1 X 12000
		Total	143

Average age of perforated tanks was 23.4 years. Median age was 21 years.
Average volume of perforated tanks was 2206.5 gallons. Median volume was 2000 gallons.

VOLUME VERSUS AGE

Tanks without perforations(greater than 4000 gallons)

Volume (gals)	Number of Tanks by Age in Years		
5000	1 X 11	1 X 12	3 X 13
	3 X 14	1 X 16	4 X 20
	1 X 21	1 X 22	7 X 23
	1 X 24	2 X 25	1 X 28
	1 X 32	2 X Unk.	
6000	3 X 10	1 X 14	1 X 15
	3 X 16	1 X 18	1 X 27
	2 X Unk.		
7500	1 X 18	1 X 30	2 X 44
	1 X Unk.		
8000	2 X 10	1 X 16	1 X 18
	1 X 19	1 X 21	3 X 23
	3 X Unk.		
10000	1 X 7	6 X 9	10 X 10
	1 X 12	4 X 13	1 X 15
	3 X 17	1 X 18	2 X 20
	3 X 26	2 X 27	1 X 29
	1 X 30	1 X 43	1 X 44
	13 X Unk.		
12000	1 X 13	1 X 44	
15000	2 X 14	1 X 25	1 X 26
	1 X 29	1 X 31	1 X 46
	1 X Unk.		
20000	1 X 37	3 X 40	1 X Unk.
25000	2 X 17	2 X 22	3 X 44
	1 X Unk.		
30000	2 X 13		
50000	2 X 35		
		Total	136

Average age of tanks (in the above category) was 20.7 years (excluding 24 unknown).
Total volume of tanks was 1,464,500 gallons.
Average volume of tanks was 10,768 gallons.

<u>Tanks without perforations</u>(less than and equal to 4000 gallons)

Volume (gals)	Number of Tanks by Age in Years		
175	1 X Unk.		
275	1 X 2	1 X 9	1 X 10
	2 X 16	1 X 20	1 X 23
	1 X 25	5 X Unk.	
500	1 X 10	1 X 30	
550	1 X 3	1 X 8	6 X 10
	1 X 13	1 X 14	2 X 15
	3 X 16	2 X 21	1 X 22
	2 X 23	1 X 24	1 X 27
	5 X 28	1 X 43	1 X 47
	1 X 48	14 X Unk.	
575	1 X Unk.		
1000	2 X 7	1 X 8	1 X 10
	2 X 11	2 X 13	1 X 14
	1 X 16	1 X 17	2 X 20
	2 X 25	1 X 27	1 X 30
	2 X 31	1 X 41	1 X 43
	1 X 44	1 X 48	1 X 60
	8 X Unk.		
1100	1 X 29		
1500	1 X 17	1 X 18	1 X 22
	2 X 32	1 X 36	
2000	1 X 10	2 X 12	2 X 13
	1 X 15	1 X 16	3 X 17
	2 X 19	4 X 20	1 X 23
	3 X 24	1 X 25	2 X 26
	5 X 28	2 X 30	1 X 34
	1 X 35	1 X 41	5 X Unk.
2500	1 X 7	2 X 32	2 X Unk.
3000	1 X 7	1 X 10	1 X 11
	2 X 12	1 X 14	3 X 15
	1 X 16	1 X 17	4 X 19
	3 X 20	2 X 22	1 X 23
	2 X 27	2 X 28	1 X 30
	1 X 31	1 X 32	1 X 33
	1 X 43	1 X 44	6 X Unk.
3500	1 X 23		

Volume (gals)	Number of Tanks by Age in Years		
4000	2 X 10	1 X 12	2 X 13
	1 X 14	6 X 15	2 X 16
	3 X 17	3 X 18	1 X 20
	2 X 21	2 X 22	2 X 23
	3 X 24	1 X 27	1 X 28
	1 X 31	2 X 44	5 X Unk.
		Total =	221

Average age of tanks in the above category) was 21.2 years (excluding 47 unknown).
Total volume of tanks was 434,625 gallons.
Average volume of tanks was 1,967 gallons.

OBSERVATIONS

The following observations are based on the inspection of 500 tanks which were removed. In several instances, the data have changed from the last interim report due to the removal of 12 tanks from the database which were placed in a seperate section - Appendix D. These were better classified as "non-corrodible" tanks, being either fiberglass, fiberglass-coated steel, or cathodically protected steel.

Every piece of data was re-examined to ensure accuracy and authenticity. For example, the unknown age of a tank was determined or an odd gallon amount was verified, etc. For cases where the age was still unknown, the tanks were either buried for a long time and the landowner had changed hands many times, were abandon on properties, or it was unknown to the current owner that they had ever existed (ie: they were found when removing other tanks).

1) More than one-quarter (28.6 %) of the tanks removed had perforations in them. Although the overall percentage is lower than previous interim reports, it is reasonably consistent with those findings. The percentage of perforated tanks from the previous reports were: Interim 1 - 36 %, Interim 2 - 33.5 %, Interim 4 - 30.9 %.

A calculation was performed in an attempt to determine the prediction capability of a polynomial regression based on the least squares method. This was based on the first 100 tanks. It was determined that the prediction capability (ie: the ability to predict the number of perforated tanks that would be found based on the first 100 tanks removed) was not accurate and could not be applied. A simple straight line percentage relationship based on the number of failures in 500 tanks appeared as usable for prediction as any other method.

2) Only 58 % of the perforated tanks showed evidence of leakage. This is 16.6 % of all tanks. Assuming the tanks that actually leak would show positive on a tank test, **almost twice as many tanks have holes in them than can be detected by testing** (ie: 16.6 % of all tanks showed evidence of leakage, while 28.6 % of all tanks actually had perforations).

Of 143 perforated tanks, 38 had tank tests associated with them within the two years prior to removal, but it was not necessarily the reason for removal. Of those tanks, 29 passed the test and 9 failed the test. Of the 29 that passed, 11 showed evidence of leakage (37.9 %), while of the 9 that failed, 8 showed evidence of leakage (88.9 %).

3) There is a strong relationship between wall thickness and perforations. Page 12 details the average wall thicknesses for perforated tanks, non-perforated tanks, and all tanks. The wall thicknesses measured were as close to original thickness as possible (ie: taken where the wall appeared in the best condition).

The numbers on page 12 and the numbers on page 14 lead to the formulation of a correlation between wall thickness and perforation. The chart on page 14 that lists wall thickness by volume for both perforated and non-perforated tanks best shows the relationship. By comparing the two charts for the same volumes, it can be seen that the perforated tanks have thinner walls in most instances (refer to Figure 5, Average Plate Thickness). These thin wall tanks also correspond to those of small volume (ie: less than 5000 gallons). Therefore the now obvious can be stated - The smaller tanks are more susceptible to perforation because they are made of thinner material, while the larger tanks are not as likely to fail because they are made with thicker material.

Of all the perforated tanks, only 5 had both endplate and wall thicknesses greater than 0.20 inches. One of these was only 8 years old but had failed from weld failure, which could happen to a tank of any size or age. Of the remaining 4 tanks, the average age was 24 years, slightly above the average age of 23.4 years for all of the other perforated tanks, ie: those with plate thicknesses less than 0.20 inches. These all failed at their thinnest wall.

4) **The percentage of perforated tanks which held gasoline, #2 fuel oil, diesel fuel, and kerosene, respectively, was close to the percentage of all tanks that were perforated** (refer to Figure 1, Tank Contents). Of 233 gasoline tanks, 31.3 % were perforated; of 128 #2 fuel oil tanks, 30.5 % were perforated; of 33 diesel tanks, 33.3 % were perforated; and of 11 kerosene tanks, 27.3 % were perforated. This seems to indicate that no specific product is responsible for causing a greater percentage of perforations in tanks.

5) **There is no clear correlation between tank age and perforations**(refer to Figure 2, Age of Tanks). The range of ages for perforated tanks was between 8 and 70 years, with perforations scattered throughout. The average tank age was 21.8 years (excluding 87 unknown). The average perforated tank age was 23.4 (excluding 18 unknown). The tanks with the greatest population of perforated tanks were the 26 year old tanks, with 72.7 % of the tanks having perforations (this excludes age categories with only a few tanks in the category).

6) **Tanks 5000 gallons and smaller accounted for 99.3 % of all perforated tanks.** Tanks 4000 gallons and smaller accounted for 95.8 % of all perforated tanks. Tank volumes ranged from 175 gallons to 50,000 gallons. Only one tank larger than 5000 gallons had perforations. The average tank volume for all tanks was 4433.3 gallons and the average perforated tank volume was

2206.5 gallons. This fits the pattern as described in #3 above - the smaller tanks succumb to perforations more frequently than the larger tanks.

7) The mean (average) age of perforated tanks was 23.4 years (excluding unknowns). The median age of perforated tanks was 21 years (excluding unknowns). The reason for the difference is the existence of a large number of 26, 27, and 30 year old tanks which yield a high average.

8) The mean volume of perforated tanks was 2206.5 gallons while the median volume was 2000 gallons. The numbers are close due to the fact that most perforated tanks were small and were spread fairly evenly throughout the tanks of less than 5000 gallons (99.3 % were 5000 gallons and less, 63.6 % were 2000 gallons and less).

9) The mean age of <u>all</u> tanks was 21.8 years (excluding unknowns). The median age of all tanks was 20 years (excluding unknowns). Only 44.1 % of all tanks were above the mean age.

10) The mean volume of all tanks was 4433.3 gallons. The median volume of all tanks was 3000 gallons. The fact that the mean is almost 1500 gallons higher than the median results from the extremely large volume of the largest tanks. The median is held low because of the large number of smaller tanks which are in the database.

11) Of the perforated fuel oil tanks, 77.5 % showed evidence of leakage. This was 37.3 % of all perforated tanks that showed evidence of leakage (refer to Figure 4, All Fuel Oil Tanks).

12) Of the perforated gasoline tanks, 50.7 % showed evidence of leakage. This was 44.6 % of all perforated tanks that showed evidence of leakage (refer to Figure 3, All Gasoline Tanks).

13) For both fuel oil and gasoline there was a much higher percentage of perforations for smaller tanks (4000 gallons and less). In addition, on the average, the fuel oil tanks were much smaller than the gasoline with 32 out of 37 perforated fuel oil tanks 2000 gallons and less. This may account for the higher incidence of perforation (44 %) in the fuel oil tanks compared to gasoline (40 %) in the 4000 gallon or less category since the very small tanks have the thinnest walls.

Of 141 fuel oil tanks (#2, #4, and #6 oils), 57 were greater than 4000 gallons in volume. Only 3 of those 57 (5.3 %) had perforations (All were 5000 gallons). Of the 84 tanks 4000 gallons and less, 37 (44.0 %) were perforated. Total occurrence of perforation for all 141 tanks was 40, or 28.4 %.

Of 233 gasoline tanks, 53 were greater than 4000 gallons in volume. Only 1 perforation was found in this category (1.9 % - The tank was 5000 gallons). Of the 180 gasoline tanks 4000 gallons and less, 72 (40.0 %) were perforated. Total occurrence of perforation was 31.3 %.

14) The greatest number of perforations, 75.5 %, was caused by external corrosion (73.4 % point corrosion and 2.1 % general corrosion). Only 6.3 % of the tank perforations were caused by internal corrosion (4.9 % point corrosion and 1.4 % general corrosion). A combination of internal and external corrosion caused 14.7 % of the perforations, meaning that in most of these cases there were too many holes present to determine which caused perforations first, or that varying stages of both types of corrosion did no allow for an accurate determination.

The conclusion that significant internal corrosion does not occur should not be drawn from these numbers. A more appropriate conclusion is that perforations occur much more frequently from the outside than from the inside.

15) Internal and external corrosion were observed in tanks. Both general corrosion and point corrosion were classified as either nominal (<25 % corrosion), mild (>25 % & <50 %), moderate (>50 % & <75 %), or severe (>75 %) in each category. Since it is already known that the external corrosion did the most damage, internal corrosion will be examined below.

There were 17 tanks with severe general internal corrosion and 48 tanks with moderate general internal corrosion. Of these, the number of tanks with perforations in each category was 13 (76.5 %) and 19 (39.6 %) respectively. There were 10 tanks with severe point internal corrosion and 9 tanks with moderate point internal corrosion. Of these, the number of tanks with perforations in each category was 7 (70.0 %) and 9 (100 %), respectively. Of the severe general internal corrosion category, 1 failed from general corrosion, 1 failed from point corrosion, 7 failed from the combination of internal and external, and 4 failed from other causes. Of the moderate general internal corrosion category, 6 failed from the combination of internal and external corrosion, and 13 failed from other causes. Of the severe point internal corrosion category, all 7 failed from the combination of internal and external corrosion. Of the moderate point internal corrosion category, 1 failed from internal point corrosion, 3 failed from the combination of internal and external corrosion, and 5 failed from other causes. If the failure mechanisms that are not internal or external corrosion related are discounted the numbers of tanks with perforations for this observation is reduced by 25 tanks. These adjusted numbers of perforated tanks for the categories severe general, moderate general, severe point, and moderate point (all internal) become: 9 (52.9 %), 6 (12.5 %), 7 (70.0 %), and 4 (44.4 %).

16) Other than the thinnest tank wall, there is no good indicator to predict where perforations will occur. The three locations of perforations occurring most frequently were: 1) Side (20.3 %); 2) Multiple on Bottom (18.9 %); and 3) End (17.5 %).

Approximately 6.3 % of the perforations occurred either below the fill (1.4 %) or below the gage hole (4.9 %).

17) The greatest percentage of perforated tanks were found in changing groundwater conditions where the tank was sometimes in groundwater and sometimes not. This was 58.6 % of the tanks in that category, suggesting that changing water conditions may accelerate the corrosion of tanks. The percentage of tanks always in groundwater and never in groundwater were much lower, with 34.5 % and 25.1 % of the tanks perforated, respectively. The percentage of perforated tanks in unknown groundwater level was 32.4 %.

18) Backfill conditions appear to have an effect on the frequency of perforation. It appears that tanks with non-uniform backfill perforate more frequently than those in a clean backfill. The percentage of perforated tanks with rubble in the backfill was 35.9 % while the percentage of perforated tanks in clean backfill was 25.2 %. Rubble is taken to mean any miscellaneous material not related to native soil or clean backfill. Examples of rubble found include: concrete, asphalt, rock, wood, paper, scrap metal, brick, and shells.

19) The 143 perforated tanks were located in a variety of soil conditions, most of which were composed of well drained sand or sandy loam. They were found in 12 of the 18 series of soils which make up Suffolk County. Approximately one dozen tanks were located in a mixture or on the borderline of two soil series. The twelve soil series were composed of 6 of the 10 major soil associations found in Suffolk. See the soils section on page 5 for a discussion of soil classification. The chart below details the number of tanks and soil series where they were located, according to the soil maps of the USDA Soil Conservation Service.[1]

	No. of Tanks	Corrosivity	Soil Series
1)	1	Moderate to High	Cut & Fill Land Tidal Marsh
2)	2	Low	Carver & Plymouth Sand
3)	2	Low	Carver & Plymouth Sand Plymouth Loamy Sand
4)	2	Low	Montauk Soil
5)	2	Low to High	Riverhead & Haven Soil Tidal Marsh
6)	3	High	Made Land Tidal Marsh

	No. of Tanks	Corrosivity	Soil Series
7)	3	Low to High	Plymouth Loamy Sand Muck
8)	11	Low	Riverhead Sandy Loam
9)	13	Low	Haven Loam
10)	15	Low	Plymouth Loamy Sand
11)	19	Low	Cut & Fill Land
12)	31	Varies	Urban
13)	39	Low	Riverhead & Haven Soil
	143		

FUEL OIL TANKS

General Statistics

Of the 500 tanks removed in this study, 141 were fuel oil tanks of all kinds (ie: #2, #4, and #6). Of these 141 tanks, 125 qualified as exempt tanks under the federal definition, that is, they were strictly for on-premises consumption. Therefore, 25% of the tanks removed in this study were exempt fuel oil tanks.

Of the 125 exempt tanks, 40 had perforations. This is 32% of the exempt tanks. It is interesting to note that none of the non-exempt fuel oil tanks had perforations.

The following data cover the 40 tanks that had perforations.

Volume Distribution

Tank Size	# of Tks. with Perfs.
275	4
550	3
1000	7
1500	2
2000	16
3000	3
4000	2
5000	3
	40

Of the 40 perforated tanks, 39 contained #2 fuel oil. Only 1 contained #4 fuel oil. That tank was 5000 gallons.

Age Distribution

Tank Age	# of Tks. with Perfs.
10	1
16	1
17	2
18	2
20	3
23	1
25	1
26	12
27	4
30	3
37	1
43	2
44	1
55	1
Unk.	5
	40

Analysis

Twenty-nine of the perforated fuel oil tanks failed from exterior corrosion (72.5%), two suffered weld failure (5%), six failed from the combination of internal and external corrosion (15%), and three succumbed to internal corrosion (7.5%). Only 9 of the tanks (22.5%) were in contact with the groundwater some or all of the time. Regarding leakage, 31 of the 40 tanks showed some evidence of leakage (77.5%). Many of the tanks (27/40 - 67.5%) had multiple holes. The average number of holes per perforated tank was 7. Of the 27 tanks with multiple holes the average number of holes was 9. The average age of these perforated tanks was 26.7 years old, and the average volume was 1918.8 gallons. All except 5 tanks had moderate or severe general external corrosion and all but 8 had moderate or severe point external corrosion. In contrast, only 6 tanks had moderate or severe general internal corrosion and only 2 had moderate or severe point internal corrosion.

CONCLUSIONS

1) **Size is more important than age in predicting tank failure.** The age of perforated tanks studied spread widely between 8 and 70 years, but the volume of perforated tanks was almost always less than 5000 gallons.

2) **In general, small tanks are much more likely to perforate than large tanks due to the thinner tank walls found in smaller tanks.** A major dividing line seems to be at the 5000 gallon level because most tanks of that size and above are constructed of 1/4" or thicker steel plate, while most tanks less than that volume are made from lower gauge steel. With steel of 1/4" or greater, there is a reduction in the number of perforations to nearly zero, in the surveyed tanks. One should not go so far, however, as to use the statistics in this report to claim that there is no need to address tanks greater than 5000 gallons, since a very large number of the higher volume tanks had already been removed by the beginning of the study. These most certainly included a significant number with leaks that would have turned up in the survey had they still been in place.

3) **Compared to external corrosion, internal corrosion is insignificant.** However, once external corrosion is eliminated, internal corrosion becomes a very important consideration and should be controlled.

4) **Fuel oil tanks are just as susceptible to perforation as gasoline tanks of the same size.** If the two groups are compared as a whole, fuel oil tanks are even more susceptible than gasoline tanks since they are generally of much smaller size. The study produced no evidence that the contents of tanks (ie: gasoline or fuel oil) significantly affected the rate of perforation of the tanks.

5) **Existing tanks are in worse shape than is demonstrated by testing.** Testing, even if totally successful and accurate only can locate tanks that are actively leaking product. The study proved that tanks can rust through completely long before they begin to leak product. In fact, the number of tanks found to have holes was nearly twice the number that showed evidence of having leaked.

6) **Tanks do not always leak immediately upon perforation.** As stated in the preceding paragraph, only a little over half the tanks with holes actually showed evidence of leakage. It was frequently observed that the corrosion products were still tightly adhered to tanks at the points of corrosion and had to be forcibly knocked off before the holes were revealed. At sights such as these, product had not yet succeeded in seeping through the plug of corrosion products. There was no way of determining through this study at what point a corrosion hole would finally turn into a leak.

7) **Tank testing can not be relied upon to locate tanks with holes.** Even if functioning accurately, tank testing can only locate tanks that are leaking and there are many tanks with holes that are not yet leaking.

8) **The study, though not conclusive, throws some doubt on the reliability of tank testing.** There were 29 tanks found with perforations that had passed a tightness test within the two years prior to removal. Of these, 11 actually had leaked into the soil and therefore should not have passed. Clear conclusions cannot be drawn from this however because of unknown factors. The tanks could have started leaking after testing was completed or seepage could have been too slow to be detected by testing. The database regarding this particular subject is too small to provide reliable information, however as an indication, the numbers are perhaps sufficient to suggest the need for further investigation.

9) **On tanks constructed of plates of more than one thickness, perforations can usually be expected to occur first in the thinnest plates regardless of where they are located on the tanks.**

10) **Non-uniform backfill increases somewhat the likelihood of tank perforations, but the rate is not dramatically different than that for uniform backfill.**

11) **The findings of this study are conservative and should be applicable elsewhere.** Because Suffolk County soils fall generally in a low corrosivity classification and because many of the worst tanks had already been removed before the study began, it can be reasonably assumed that the occurrence of tank corrosion and perforation at most other locations in this country can be expected to be at least as bad as that indicated by the statistics in this report.

In addition, only perforations that were large enough to be easily observed visually were recorded. There were undoubtedly other, smaller perforations that went undetected that could only have been found by careful air testing and soaping of the tanks. This would have been a tedious task that was beyond the scope of the study. Therfore the actual number of perforated tanks was certainly larger than the number observed.

Figure 1 - Tank Contents
See chart, page 11

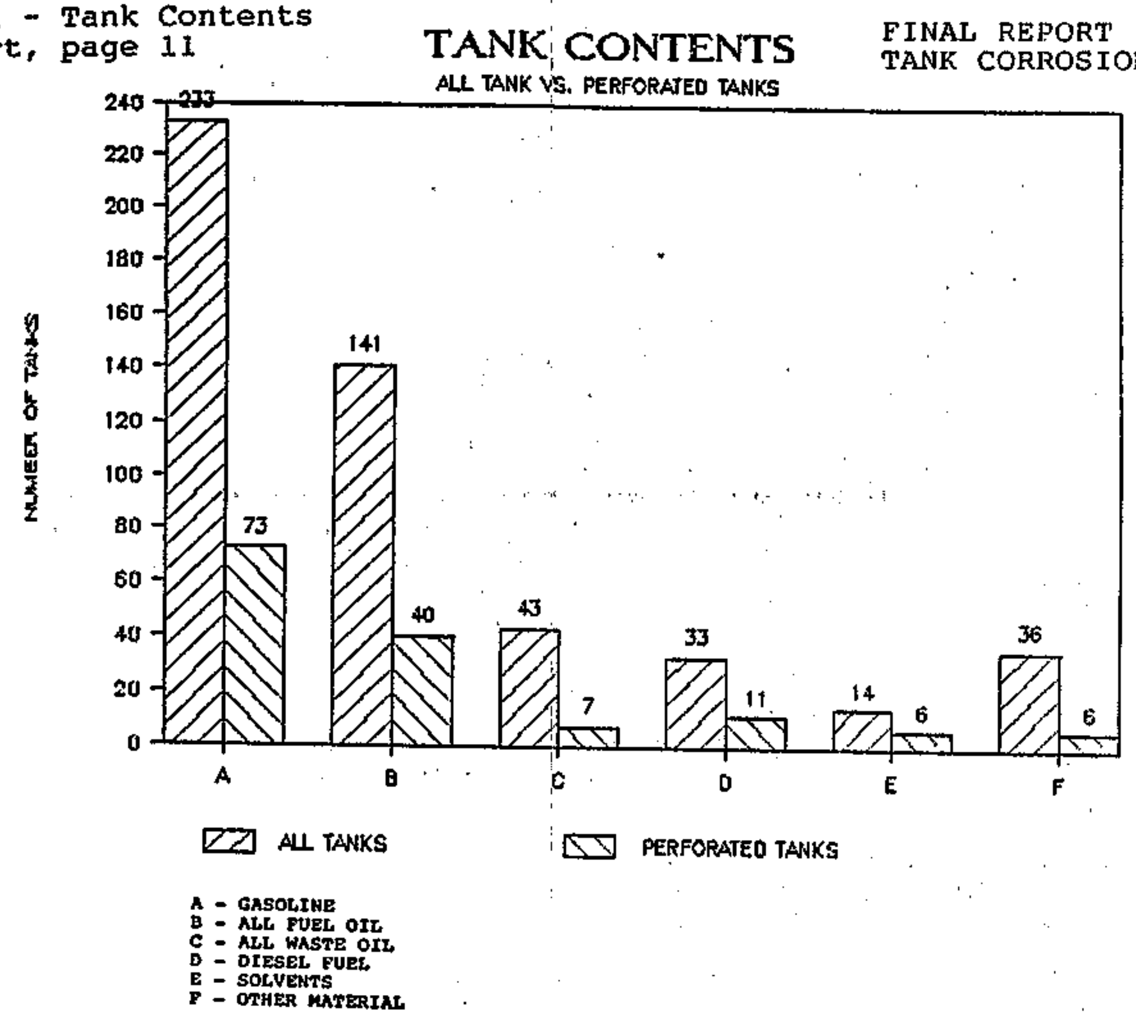


Figure 2 - Age of Tanks
See chart, page 15

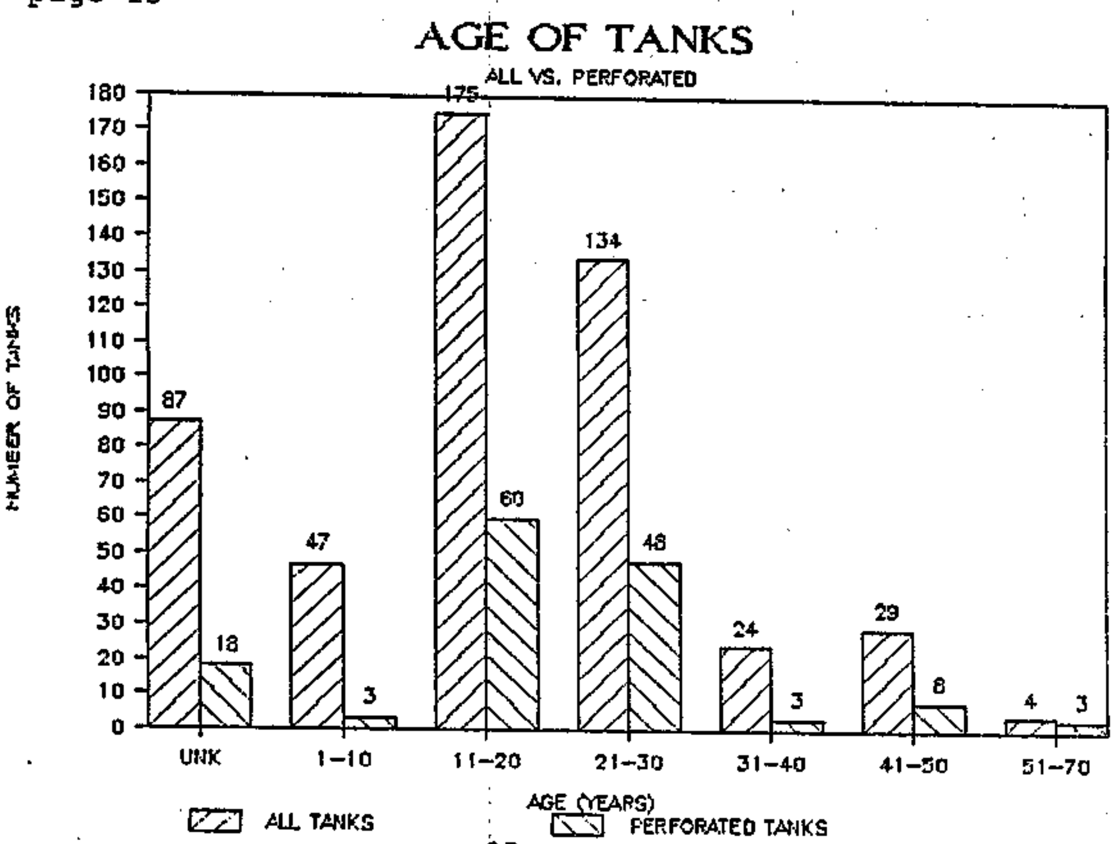


Figure 3 - All Gasoline
See chart, page 20

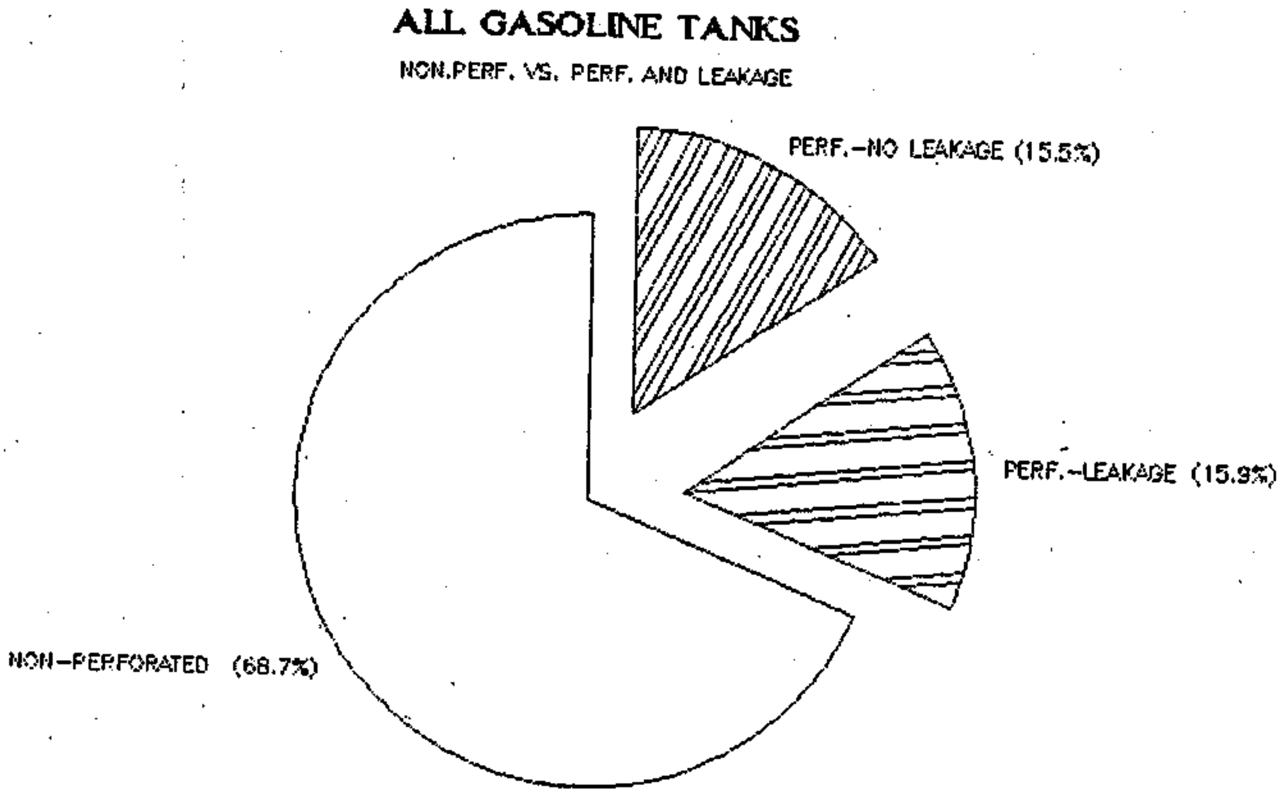


Figure 4 - All Fuel Oil
See chart, page 20

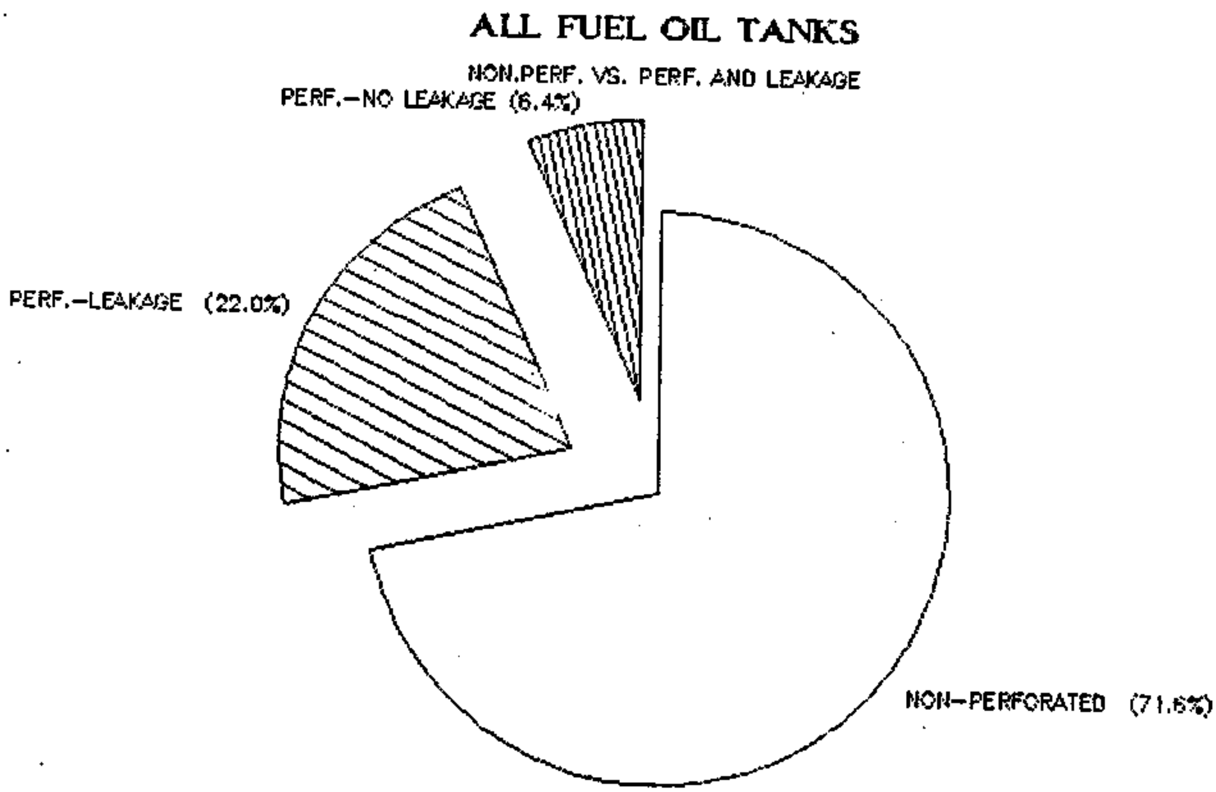


Figure 5 - Average Plate Thickness

See chart, page 14

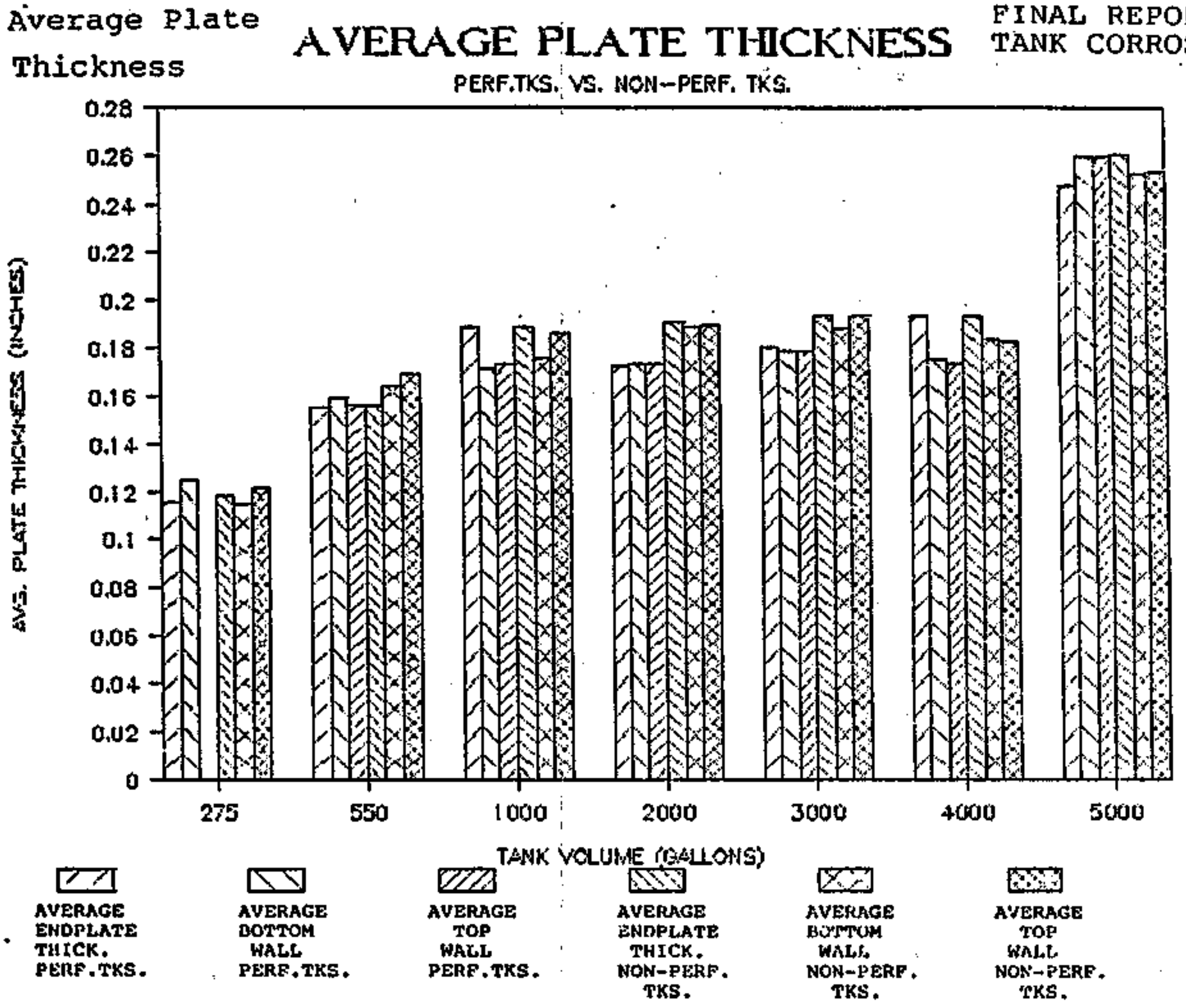
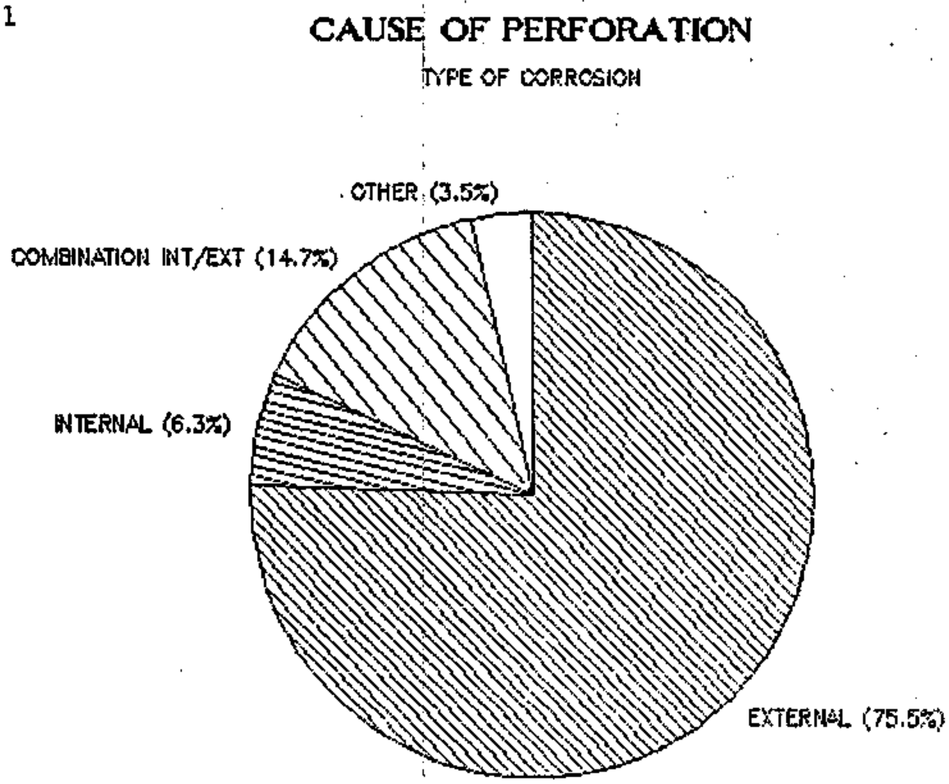


Figure 6 - Cause of Perforation

See chart, page 11



APPENDIX A
Exerpt Portions of Article XII
of the
Suffolk County Sanitary Code

Section 1210. Underground Storage Facilities

a. New Storage Facilities

1. All new storage facilities used or to be used for the underground storage of toxic or hazardous materials shall be designed and constructed in a manner which will, in the opinion of the commissioner, provide the maximum reasonable protection available against leakage or spillage from the facility due to corrosion, breakage, structural failure, or other means. Double-walled or equivalent facilities are required for all toxic or hazardous materials except those with a specific gravity of less than one and which are only slightly soluble in water such as oils and gasoline. For these floatable materials, acceptable designs for tank construction include cathodically protected steel; glass fibre reinforced plastic; steel clad with glass fiber reinforced plastic; double-walled steel or plastic; or other equivalent design approved by the commissioner.

2. Approval of design by the commissioner is required before installation, and the determination of equivalency or adequacy lies with the commissioner.

3. Design, construction, fabrication, and installation of new underground storage facilities shall be in accordance with regulations and standards as they may be adopted by the commissioner under this article from time to time.

4. A new storage facility for all facilities not previously covered by this section is one for which construction actually begins on or after November 1, 1982; subject however to the exemptions contained in Section 1208(a).

5. It shall be unlawful for any person to sell for use in Suffolk County, install, use, put into service or maintain the existence of any new underground storage facility or part thereof after November 1, 1982, if said new storage facility or part thereof fails to conform to all of the provisions of subsections (1), (2), and (3) above, and all regulations and standards promulgated thereunder; subject however to the exemptions contained in Section 1208(a).

b. Existing Storage Facilities

1. An existing underground storage facility is one for which construction actually begins prior to November 1, 1982.

2. It shall be unlawful for any person to substantially modify or cause the substantial modification of any existing underground storage facility or part thereof without complying with the provisions of subdivision (a) above and all regulations and standards promulgated thereunder.

3. It shall be unlawful to use, or maintain the existence of any existing underground storage facility beyond January 1, 1990, which is intended for use with toxic or hazardous materials with a specific gravity of less than one and which are only slightly soluble in water such as oils and gasoline, without modifying said storage facility so as to comply with all of the provisions of subdivision (a) above and all regulations and standards promulgated thereunder.

4. It shall be unlawful to use or maintain the existence of any existing underground storage facility beyond January 1, 1987, which is intended for use with any toxic or hazardous materials other than those with a specific gravity of less than one and which are only slightly soluble in water such as oils and gasoline, without modifying said storage facility so as to comply with all of the provisions of subdivision (a) above and all regulations and standards promulgated thereunder.

c. Abandonment

1. It shall be unlawful for any person to use or maintain the existence of an abandoned underground storage facility or part thereof.

2. It shall be unlawful for anyone to sell or transfer to another an improperly abandoned underground storage facility or land containing an improperly abandoned underground storage facility if there exists any reasonable evidence of the existence of such a facility, unless the purchasing party has been made fully aware of the presence of such facility or evidence.

3. It shall be unlawful for any person to repair, alter or prepare for use any abandoned storage facility without first obtaining a permit to construct from the commissioner.

4. It shall be unlawful for the owner or other person in possession or control of any real property, building or place or vehicle to fail to immediately empty of all toxic or hazardous materials and to completely fill with sand or concrete or permanently remove an abandoned storage facility or part thereof within ninety (90) days of the discovery thereof on or in said real property, building or place pursuant to the provisions of subdivision (h) below unless approval is granted by the commissioner to do otherwise.

5. For the purposes of this section, an abandoned storage facility or part thereof means one which has remained out of service for two (2) years or more, or which has been declared by the owner to be abandoned.

6. For the purposes of this section, out of service means substantially empty, meaning five (5%) percent or less

filled; or not in use, meaning no regular filling or drawing; or not being maintained, meaning lacking adherence to the requirements of this article; or uncontrolled, meaning not attended or secured; or any combination thereof.

7. For the purposes of this section, discovery means either actual discovery or knowledge of the existence of the abandoned storage facility or part thereof or possession of sufficient knowledge of the facts and circumstances involved so that the existence of the abandoned storage facility or part thereof should have been discovered or known of.

d. Testing and Inspection

1. All existing underground storage facilities or parts thereof which do not meet the construction standards in subdivision (a) above, must be tested and inspected in accordance with the schedule set forth below. It shall be unlawful for any existing underground storage facility owner, operator or lessee to fail to test his tanks and file an acceptable certificate of test completion with the commissioner in accordance with the following schedule:

TESTING SCHEDULE FOR EXISTING UNDERGROUND TANKS
AGE OF SYSTEM BY 1980
(in years)

	1 - 4	5 - 9	10 - 14	15 - 19	20 or more
1980					
1981					X
1982				X	
1983			X		X
1984		X			
1985	X			X	X
1986			X		

ALL TANKS COVERED BY SECTION 1208(b) BY VIRTUE OF THE 1986 AMENDMENT SHALL BE INITIALLY TESTED IN 1986 IF THE TANK IS TEN (10) YEARS OR OLDER, AND/OR ALL TANKS SHALL BE TESTED ON THEIR TENTH ANNIVERSARY AND EVERY FIVE (5) YEARS THEREAFTER UNTIL PERMANENTLY CLOSED.

FULL COMPLIANCE FOR ALL FACILITIES EXCEPT THOSE DESCRIBED IN 1210(b)(3)

	1 - 4	5 - 9	10 - 14	15 - 19	20 or more
1987				X	X
1988		X			
1989					
1990	FULL COMPLIANCE FOR ALL FACILITIES				

2. If for any reason testing satisfactory to the commissioner cannot be performed, the tank must be removed from service or brought up to the standards of subsection (a) by the first scheduled test date.

3. The Final Test of the National Fire Protection Association (NFPA), Recommended Practice No. 329 or other test of equivalent or superior accuracy as approved by the commissioner must be used to comply with the testing and inspection requirement of Section 1210(d)(1).

4. Any test and inspection as required by this subdivision shall be performed by a person whose qualifications are acceptable to the commissioner, pursuant to Department standards, for performing such tests. Certificates of test completion containing the results of such tests as performed shall be prepared by the tester and shall be filed with the commissioner within thirty (30) days after completion of the testing of the storage facility. No certificate of test completion shall be acceptable to the commissioner to indicate satisfactory compliance with the testing requirements of this subdivision if the qualifications of the tester have not been accepted by the commissioner prior to the test. No certificate of test completion shall be acceptable to the commissioner, pursuant to Department standards, if the test and inspection were not performed in accordance with subsection (3) of this subdivision and in accordance with any regulations and standards which may be promulgated pursuant thereto.

5. The Certificate of Test Completion shall be filed on a form provided by the commissioner and a copy of such form, completed, shall be kept by the storage facility owner, operator or lessee and by the tester for a period of not less than five (5) years from the date of its issuance. It shall be unlawful for the storage facility owner, operator or lessee and for the tester thereof to fail to keep a copy of the Certificate of Test Completion for the required five (5) year period.

6. Certificates of Test Completion shall contain a legally authorized form notice to the effect that false statements made knowingly therein are punishable pursuant to Section 210.45 of the Penal Law.

7. A Certificate of Test Completion not properly completed and/or not subscribed by the tester shall not be acceptable to the commissioner.

e. General Provisions and Requirements

1. When an underground storage facility or part thereof is found to be leaking, the portion containing the leak must be immediately emptied of all contents therein and removed from service. It shall be unlawful to cause or permit a leaking

underground storage facility or part thereof to remain in service or to continue to retain its toxic or hazardous contents after the owner, operator or lessee of said storage facility or part thereof knows or should have known of the existence of the leak therein.

2. It shall be unlawful for any person to repair or to permit the repair, in place, of any underground storage facility or part thereof which has leaked or has otherwise failed, for the purpose of reusing said storage facility, unless:

i. such repair will result in the storage facility or part thereof complying with the requirements of subdivision (a) above and all regulations and standards promulgated thereunder; and unless

ii. such repair occurs pursuant to plans therefor previously submitted to and approved by the commissioner.

3. It shall be unlawful for any person to replace or cause the replacement of any underground storage facility or part thereof for any reason if the replacement facility does not meet the requirements of subdivision (a) above and all regulations and standards promulgated thereunder.

4. It shall be unlawful for any person to use, maintain, or put into service any underground storage facility or part thereof without first complying with the testing and inspection requirements of subdivision (d) above and regulations and standards promulgated thereunder.

APPENDIX B
Suffolk County Tank Removal Standard

SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES

BUREAU OF HAZARDOUS MATERIALS

STANDARDS FOR THE ADMINISTRATION

OF ARTICLE 12

OF THE SUFFOLK COUNTY SANITARY CODE

"REMOVAL OF UNDERGROUND STORAGE FACILITIES FROM SERVICE"

1.0 General

1.1 Article 12, Section 1210.h provides for two methods of decommissioning underground tanks: either complete removal, or abandonment in place if local town ordinances permit. Complete removal is preferred since a tank left buried creates a major obstacle for future construction.

1.2 Upon removal or abandonment of an underground hazardous/toxic material storage facility, every effort must be made to determine if the tank has leaked into the ground. If the tank is removed, this can usually be accomplished by examination of the tank and the bottom of the excavation. For tanks abandoned in place, monitoring wells must be installed to the satisfaction of the Department or a satisfactory system tightness test must have been performed within 6 months prior to the abandonment.

1.3 Proper notification of facility removal or abandonment must be provided to the Bureau of Hazardous Materials. Notification must include, but is not limited to a minimum of forty eight hours verbal notification prior to the scheduled decommissioning to schedule the required inspection.

1.4 Failure to comply with the forty eight hour notice requirement will subject the contractor and the owner or any other person in possession or control of the land where the tank was removed or abandoned without notice, to a fine of up to $500 and an order to restore the land to its' condition at the time of tank removal or abandonment so that an appropriate inspection may be undertaken to determine whether pollution was created by the storage facility.

1.5 This Standard shall apply to all underground hazardous/toxic material storage facilities located within Suffolk County.

2.0 Procedures for Tank Removal

2.1 Prior to removal, the tank must be pumped as empty as possible using a portable pump to scavenge the bottom of all liquid that can be removed.

2.2 The excavation must remain open and the bottom left exposed and undisturbed until the Health Department inspector has examined it. The hole should be refilled with clean soil as quickly as possible thereafter to minimize the hazard of an open hole.

2.3 After excavation of the tank is completed, holes, at least 48" in diameter must be cut in each end of the tank to allow quick venting and to facilitate sludge removal and internal inspection.

2.3.1 Care must be taken in cutting holes to avoid sparks that could ignite flammable fumes. Only non-sparking pneumatic tools may be used.

2.3.2 All sludge must be removed from the tank by shoveling and brushing and be collected in properly labeled drums for removal as a toxic waste. The tank interior shall have all major scale knocked loose and be in a "brush clean" condition before removal from the site. Proper protective breathing appartatus and protective clothing should be worn since the sludge is likely to contain lead and other toxic materials.

2.3.3 The sludge may not be removed from the site until a Health Department inspector has noted the volume of sludge and inspected the tank.

2.4 The tank can not be removed from the site until it has been inspected by a Health Department inspector or otherwise released by the Health Department.

2.5 All piping such as fill and vapor recovery lines must be removed to at least 12" below grade.

3.0 Procedure for Tank Abandonment

3.1 Prior to abandonment, the tank must be pumped as empty as possible using a portable pump to scavenge the bottom of all liquids that can be removed. In addition, the tank must be cleaned and freed of all residual toxic/hazardous materials.

3.1.1 All waste must be removed from the tank and be collected in properly labeled drums for removal as a toxic waste. Proper protective breathing appartatus and protective clothing should be worn since the sludge is likely to contain lead and other toxic materials.

3.1.2 The sludge and waste may not be removed from the site until a Health Department inspector has noted the volume of sludge and inspected the tank.

3.2 After the tank has been inspected and determined to be clean by a Health Department inspector, it must be completely filled with a clean inert material such as sand or concrete.

3.3 All piping such as fill and vapor recovery lines must be removed to at least 12" below grade. Remaining underground piping must be completely filled with the inert material.

3.4 In the absence of a satsisfactory systems tightness test within the last 6 months, groundwater monitoring wells must be installed.

3.4.1 Wells must be 4" diameter Schedule 40 PVC with a slot size of .020" . The slotted portion of the wells must extend 5 ft. above and below the groundwater elevation. Each well must be brought to grade and all covers at grade must be liquid tight and labeled monitoring well. A minimum of two wells , one upstream and one downstream of groundwater flow at the tank location, must be installed.

3.4.2 Groundwater monitoring wells must be sampled and analyzed as directed by New York State Department of Environmental Conservation and/or the Suffolk County Department of Health.

APPENDIX C
Tank Corrosion Study Inspection Sheet

SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES

FIELD INSPECTION FORM

FIRST DRAFT

Inspection Date ________
Time Start ________
Time End ________
Time Spent ________ Min.

Facility ID: ________ Tank No. ________ Prop.Tax No. ____ ____ ____ ____

Facility Name: ________________________________

Facility Address: ________________________________

Type of Facility: Gas Sta.___ Car dealer__ Commercial__ Residential__

Industrial__ Other__(describe)________________________

Type of Tank: Plain steel__ Asphalt or coal tar coated steel__

STIP3__ Other induced current cat.prot.steel___ Imposed current cat.

prot.steel__ Bufhide__ Other fiberglas coated steel__ Owen Corning

fiberglas__ Xerxes fiberglas__ Other fiberglas__ Other material___

(describe)________________________

Contents(Observed): Gasoline__ Fuel oil #2__ Fuel oil #4__ Fuel

oil #5__ Fuel oil #6__ Kerosene__ Diesel__ Gasahol__ (% mixture)__

Jet fuel__ Av.gas__ Solvents__ (Describe)________________________

Waste oil__ Other oil__ (Describe)________________________

Other material __ (Describe)________________________

Dimensions: Diameter(x)_____' Diameter(y)_____' Length_____'

Width_____' Height_____' Volume_____cu', _____gal.(Calculated from dimensions)

Date Installed:________ Present age _____

End plate thickness ________" (mic,)_____" (Ultrasonic)

Wall thickness ______" (Ultrasonic)

Holes: Yes__ No__ Total No. observed___ Leak confirmed before removal____ Dia. largest_____" Dia. smallest_____" Average dia._____" (Es

Hole locations Bottom below fill__ Bottom below gage hole__ Elsewhere along bottom__________ Multiple along bottom __________ Top around fittings ___ Eleshere on top___ Along groundwater line__ On side__ On end__ Multiple on sides and/or ends___

Cause of holes: Point corrosion internal__ Point corrosion external__ General Corrosion internal__ General corrosion external__ Combination internal and external corrosion____ Weld failure__ Mechanical damage internal__ Mechanical damage external__

Sludge: Volume_____ gal. Wt.___.___!

Exterior coating: Yes__ No__ Completely intact__ Minor flaws__ Many failed areas__ Completely failed__ ____% Remaining

Interior coating: Yes__ No__ Fiberglas lining__ Other__ Completely intact__ Minor flaws__ Many failed areas___. Completely failed__ ____%Remaining

Natural Soil Conditions: Clean sand or gravel__ Clay__ Bog__ Loam__ Sand w/some clay__ Other__ (describe)____________________________ Can't tell _____

Backfill Conditions: Clean sand or gravel__ Same as natural soil__ Concrete, asphalt, stones or rubble against tank___ Other ____ (describe)____

Groundwater level: Always in contact with tank__ Sometimes in contact with tank __ Never in contact with tank__

Groundwater Quality: Salinity (if near shore)_____ pH_____ Floating product in observation wells__ In excavation dissolved product ____

Closest estimate of total product leaked: Ogal__ 10 Gal.__ 50 Gal.__ 100 Gal.__ 500 Gal__ 1,000 Gal.__ 2,000 Gal.__ 5,000 Gal.__ 10,000 Gal

50,000 Gal.__ 100,000 Gal. or more __ No idea__.

Approximate Burial Depth Below Grade: ________'

Buried Tank Deflection: total length:___'______"
(minus) to tank top:___'______" BURIED
A. tank diameter:___'________

total length:_______'_______"
(minus) to tank top:_______'_______" REMOVED
B. tank diameter:__________'_______"

Diameter A.:____'____"
(minus) Diameter B.:____'____"
Deflection :____'____"

Description of Tank EXTERIOR Corrosion:

Point Corrosion:___nominal___mild___moderate___severe

General Corrosion:___nominal___mild___moderate___severe

Description of Tank INTERIOR Corrosion:

Point Corrosion:___nominal___mild___moderate___severe

General Corrosion:___nominal___mild___moderate___severe

APPENDIX D
Non-corrodible Tanks

During the course of the study, twelve non-corrodible tanks were removed from service for a variety of reasons. Though these were not included in the statistics, an investigation similar to that performed on each of the 500 unprotected steel tanks was performed on each of these. A synopsis of that investigation follows.

Of the 12 non-corrodible tanks removed, two were fiberglass, two were fiberglass coated steel, and the remaining eight were some type of cathodically protected tanks. None of these had perforations.

Fiberglass

The two tanks in this category were both single-walled tanks. One was 8 years old and the other was 10 years old. For discussion here, the 8 year old will be tank A and the 10 year old will be tank B. Tank A contained gasoline and tank B contained caustic soda. Tank A was 6000 gallons and B was 4000 gallons.

Although no holes were immediately evident on either tank, tank A showed evidence of leakage and had product oozing from its ribs. This could have been due to leaky fittings or gasket failure causing product to leak around the outside of the tank. However, the tank had failed three tank tightness tests prior to removal. This tank was sometimes in groundwater and had rubble in the hole. Tank B had several areas where crystallization had begun on the outside of the tank. The areas were soft when pressure was applied, indicating that the fiberglass was beginning to breakdown under the effects of the caustic. This tank was never in groundwater and was in a natural (sand/clay) backfill. The interior resin liner was intact and appeared to have held up well, but the exterior of the tank was badly deteriorated, apparently from caustic that had leaked down around the outside surface of the tank.

Fiberglass Coated Steel

Two tanks of this type were removed. Tank A was 16 years old and tank B was 12 years old. Tank A was 1000 gallons, tank B was 2000 gallons. Both were in good shape with 100 % of the exterior coating (fiberglass) intact. They were both in natural soil backfill (sand, clay, loam) and buried approximately 18 inches below the surface. Both contained #2 fuel oil. The tank interiors were also in good shape with very little corrosion (in both the general and point category). Tank A had thickness measurements taken: the steel was .180 inches and the fiberglass coat was .128 inches. Neither tank was in contact with the groundwater and there was no evidence of leakage.

Cathodically Protected Tanks

Eight cathodically protected tanks were removed. Four were STIP-3 type tanks and four were other type.

Of the four STIP-3 type tanks, two were 8 years old and two were 9 years old. The 8 year old tanks were used as oil-water seperators. Both were 2000 gallons and had average wall thicknesses as follows: endplate - .1790 inches; top wall - .1773 inches; bottom wall - .1753 inches. Both had minor flaws in the exterior coating, but 90 % was still intact. They were backfilled in natural backfill (sand, clay, loam) and were never in contact with the groundwater. No evidence of leakage was found. The tanks did not have perforations. The only corrosion problem was the interior of the tanks. Both were very scaly and were classified as having moderate general corrosion. In the area of the exterior flaws, the coating was brittle and peeled off readily. It appeared as though corrosion had begun. There may have been some installation damage to the tanks.

The 9 year old tanks were used to hold a solvent material. These tanks were also backfilled with natural soil and were never in contact with groundwater. The coating was completely intact and there was only minor corrosion associated with the interior of the tank.

None of these four tanks had perforations.

Of the four 'other' types, two were made by one manufacturer (A) and two by another manufacturer (B). None of these tanks were of the STIP-3 type.

Manufacturer A's tanks were 5 and 6 years old. Both contained #2 fuel oil, and had a capacity of 10,000 gallons and 2,000 gallons respectively. Both were in a natural backfill and never in contact with the groundwater. Neither leaked any product. While corrosion was only nominal, it was apparent that the coating was bubbling and beginning to peel. The coating was very thin and corrosion was beginning to take place under many areas of the bubbled coating.

Manufacturer B's tanks appear to have been custom built. They were of unknown age. Both contained chemicals used in the plastics industry and were 10,000 gallons and 20,000 gallons in capacity. Each of the tanks had baffles on the interior. The 10K tank had its baffles reinforced while the 20K tank did not. Each tank had two anodes attached by wires to three locations on each tank. The exterior coating was 90 % intact on the 20K tank and 80 % intact on the 10K tank. The 10K tank had some severe exterior pitting on the bottom of one endplate. No leakage was evident on either tank.

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2. USDA - Soil Conservation Service, Publication 430-VI-NSH, Pages 603-38 and 603-39, July 1983 (no publication title).