RESEARCH REPORT

External Research Program

Corrosion of Domestic Oil Tanks

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CORROSION OF DOMESTIC OIL TANKS

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February 2000

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This project was carried out with the assistance of a grant from Canada Mortgage and Housing Corporation under the terms of the External Research Program (CMHC File 6585-M123-2). The views expressed are those of the author and do not represent the official views of the Corporation.

PURPOSE

The scope and objective of the research covered by this report was to investigate the corrosion of domestic oil tanks. Based on the examination of the corrosion process predictive/preventive maintenance techniques as well as changes to tank fabrication, were explored.

ACKNOWLEDGEMENTS

The writer would like to acknowledge the assistance and support of Mr. Richard Hale, P.Eng. of Professional Project Engineering Limited in Halifax. Mr. Hale's help with research and in the testing of tanks is much appreciated.

EXECUTIVE SUMMARY

This report covers a research project to find the reason why domestic fuel oil tanks corrode. After an introductory statement the first section gives a background of the problem of leaking home oil tanks in the Maritime Provinces. The next section explains how tank data was collected from homeowners and presents the results of this data collection. The corrosion process is defined. Following this is a description of the process of collecting and analysing oil, sludge and tank shell samples along with the associated results. An interpretation of the sampling results is presented followed by the closing section outlining conclusions and recommendations.

RÉSUMÉ

Le présent rapport traite d'un projet de recherche visant à découvrir pourquoi les réservoirs à mazout domestiques sont sujets à la corrosion. Après une brève introduction, la première section donne un historique du problème des réservoirs à mazout domestiques non étanches dans les provinces de l'Atlantique. La section suivante explique comment les données relatives aux réservoirs ont été recueillies auprès des propriétaires-occupants et présente les résultats de cette collecte de données. On définit le processus de corrosion. On donne ensuite une description du processus de collecte et d'analyse des échantillons de mazout, de boue et de paroi des réservoirs, avec les résultats correspondants. On présente l'interprétation des résultats de l'analyse des échantillons, suivie de la section finale qui renferme les conclusions et les recommandations.

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1.0 INTRODUCTION

After a period of time in-service domestic oil tanks generally start to corrode from the inside. Sometimes a new tank will hole through from within and begin to leak after less than two years in use. In other cases a tank that has been operational for thirty years, upon internal inspection, will show no signs of corrosion. Why is this? What is the difference? What is the cause of corrosion? Can corrosion or accelerated corrosion be predicted? Are there preventive maintenance procedures that a homeowner or service technician can carry out? Will some type of coating or change in tank material or fabrication specification deter corrosion? The following report endeavours to answer these questions.

2.0 BACKGROUND

There were approximately 860,000 households in the Atlantic Provinces in 1997 and of these more than 400,000 were heated by furnace fuel oil[i]. Associated with each of these heating systems is a steel tank storing 700 to 1200 litres of oil. Tanks can be installed above ground outside the dwelling or inside, generally in the basement. Every year a number of the tanks leak and spill petroleum product into the environment. In the vast majority of cases this leakage is caused by corrosion from the inside of the tank

Some of the incidents are minor in nature but others result in major spills and cleanup costs. Provincial Environmental Department officials contacted were not able to offer meaningful statistics concerning the number of major or minor spills. One jurisdiction indicated that there was a reported major or minor leak in approximately 1 of 150 in-service tanks in a typical year. This would translate into more than 2,600 major and minor incidents during a particular year in the Atlantic Provinces.

Insurance industry spokespersons stated that clean-up expenditures in the Atlantic Provinces were approximately $6 million per year and represent one of the most expensive types of claim in the region. Of thirty incidents handled by one company in a year, the average cost of a spill was approximately $20,000. If this average is considered to be a major spill and is applied to the total expenditures, i.e., $6 million, this would indicate that approximately 300 major spills could occur each year in Atlantic Canada. Incident expenditures in some instances, reached well over $100,000. The preceding costs do not of course include any charges borne by the householder, oil supplier or installation contractor not covered under homeowners insurance.

The various regulatory bodies do not collect pertinent statistics and could not give estimates of the service life of tanks. One oil company states in a handout to customers, that the average life span of a tank is 12 years. Other estimates range from 18 years to 30 years[ii]. Some tanks are still in good condition after more than 30 years in service while others fail after less than three years.

3.0 HOMEOWNER QUESTIONNAIRE

3.1 Form of Questionnaire and Identification of Recipients

To obtain historical data and material for the research project it was necessary to approach homeowners that used oil to heat their residence and had an associated storage tank. For the purposes of the research the Halifax Regional Municipality was considered a representative region. Several methods of surveying this target market were investigated. Telephone solicitations, personal interviews and mail inquires were all considered. It was felt that a mail drop along with a "Business Reply" card, while relatively expensive, would be the most effective means to ensure a representative and significant response. This method would also allow personal contact with the respondents if required. Several Canada Post letter carrier "walks" were analysed to achieve the highest percentage of homes with oil tanks. For example neighbourhoods with a minimum of industrial facilities, apartment units or rental properties were selected. A sample "Business Reply" card is enclosed as Appendix "A"

An incentive was offered to the householder in the form of a free inspection of their oil tank so as to guarantee a meaningful number of responses. These subsequent examinations, based upon a detailed investigation, proved to be somewhat time consuming but gave a valuable insight into various domestic tank installations. As well the inspections allowed a chance to obtain samples of tank sludge and shell material, in conjunction with tank installers, when two of the tanks were replaced at later dates.

Appendix "B" is the questionnaire that the homeowner was asked to respond to. The questions were developed in conjunction with CMHC.

3.2 Questionnaire Results

A total of 977 "Business Reply" cards were dropped by carriers along various postal routes in the cities of Halifax and Dartmouth resulting in 74 responses. This represents a rate of 7.5%, considered very good, particularly in the summer, for this form of survey and indicative of the interest in potential leaking domestic oil tanks. Questionnaires and inspections were subsequently completed at twenty-eight locations. Although the completion of more questionnaires could have been accomplished it was concluded after a number of tank examinations and the review of the returned cards, that substantial additional time requirements for further investigations would prove to be a duplication of effort. It was felt that the results obtained represented a meaningful sampling.

Following are some of the results of the questionnaires (note that not all homeowners surveyed, responded to all questions, consequently answers do not total twenty-eight in every case):

- 12 tanks were located outside the house and 16 were inside, in the basement
- 11 homeowners had an oil leak problem in the past and this leak was generally identified by themselves (these leaks were all of a minor nature)
- 15 respondents did not know whether their household insurance covered an oil spill and 12 did not realise that a spill could cost over $100,000 to clean up
- 19 individuals checked for oil droplets on the underside of their tank and 5 considered the addition of a supplementary spill collection system
- even though the survey was carried out in the summer (August and early September) 23 out of 28 kept the tank nearly full
- one person had sludge and water regularly pumped out of their tank
- the age of 17 of the tanks was definitely established and the average was 9 years, with the oldest estimated at 44 years (only recently have ULC regulations required that the date of manufacture be stamped on a nameplate on the tank, older tanks have only an identifying serial number and the oldest have no identification)
- 20 householders did not know how long their tank was warranted for
- the fabricator was determined for 20 of the tanks and there were 6 different fabricators
- of the 18 tank shell thickness' identified, 1 was 13 gauge (2.28 mm), 6 were 14 gauge (1.90 mm) and 11 were 2 mm thick (see discussion on thickness in Section 6.2)
- homeowners replaced 2 tanks with new tanks following the questionnaire completion
- 3 tanks of 8 inspected had evidence of internal water

As noted in the last item above, included as part of the inspection was an investigation to determine the presence of water in a tank. The test could be completed only if there was easy access to the interior of the tank through an existing opening and consisted of inserting a dipstick through this opening. Water indicating paste (alkanolamine a dye, in clay as manufactured by Kolor Kut Products, Houston, TX) was applied to the end of the dipstick. If present, water being heavier than oil, sits on the bottom of the tank and is detected by a colour change in the paste. Eight such tests were performed and water was recorded in three instances. (See Figure 1)

Appendix "C" is a summary of the results of the completed questionnaires.

Typical tank installations, inside and outside the home, are shown in the accompanying photographs (Figures 2 and 3).

4.0 THE CORROSION PROCESS

Corrosion can be defined as follows:

> *The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties*[iii].

Chemical corrosion, resulting from a reaction between metal surfaces and gases, occurs at temperatures well above ambient and for this reason was not considered to be pertinent to the subject research.

Electrochemical, the most common, is corrosion that is accompanied by a flow of electrons between cathodic and anodic areas on metallic surfaces. Such corrosion occurs when a liquid electrolyte comes in contact with the metal. Electrolytes, for example salts or oxides, separate into ions and conduct electricity when dissolved in a solvent such as water. The electrochemical corrosion process involves two reactions, an anodic reaction where a metal dissolves, releasing electrons and a cathodic reaction in which the electrons formed are removed[ii]. Anaerobic corrosion or biocorrosion is also a form of electrochemical corrosion based on sulphur-reducing bacteria which produce acidic organic materials [iii]. Electrochemical corrosion including biocorrosion were considered to be applicable to the research under this report

5.0 SAMPLING REQUIREMENTS, COLLECTION AND LABORATORY REPORTS

5.1 Initial Set of Samples (one oil test and one sludge test}

The research project initially identified three elements that would be analysed for their contribution to the corrosion process namely; tank sludge, fuel oil and tank shell material. It was not clear at the commencement of the research what sort of testing would be most applicable to the determination of the presence and progress of tank corrosion. Hence several local chemical testing companies were contacted to ascertain the types of chemical and biological testing that could be carried out on oil and sludge samples. Armed with this information a former refinery chief chemist was consulted to determine which of the various test procedures would be the most relevant to determination of tank corrosion as defined in Section 4. Based on these discussions it was felt that acidity and the presence of water were major contributing factors. Accordingly while the questionnaire and tank inspections were being carried out, and as an experiment, the following tests were identified for initial analysis of tank sludge, and furnace fuel oil:

Sludge

- Copper strip corrosion
- Acid number
- Water, %

Furnace Fuel Oil

- Copper strip corrosion
- Sulphur content
- Acid number
- Water, mg/kg
- pH

A sample of sludge of approximately 500ml and a similarly sized sample of fuel oil were obtained in association with a tank replacement contractor. These samples were secured prior to the questionnaire and inspection procedures outlined in section 3. The laboratory was also asked to test a further sample of what was thought to be residual water and which turned out to be in fact fuel oil. No analysis was carried out on this latter specimen.

Appendix "D" is a laboratory report covering the foregoing.

5.2 Second Set of Samples (2 steel tests, 1 chemical sludge test and 1 biological sludge test)

The next set of samples was obtained from one of the tanks taken out of service following the questionnaire completion and inspection outlined in Section 3. The tank was located inside in the basement of the dwelling. It was not determined exactly when the tank was made but in discussions with the homeowner it was determined that it was more than 30 years old. Specimens were obtained when the contractor was replacing the old tank with a new one. Although the old tank was not leaking there proved to be a fair number of significant interior pits. Figure 4 shows tank interior, sludge and section of the bottom removed for testing. A metallurgist was consulted prior to submitting the samples for analysis and the resulting test requirements are listed below:

Tank Sludge (chemical and biological)

- pH determination
- chloride content
- sulphide content
- iron content
- microbiological evaluation

Section of steel from the bottom of the tank

- full metallurgical scan
- hardness measurement
- microstructural investigation

Fuel oil from the tank was analysed under the third set of samples as noted below.

The testing laboratory also had a relatively new tank on hand that had corroded through in less than two years of service. For comparison purposes the same tests were carried out on a piece of steel from this tank as for the 30-year-old tank. Unfortunately there were no associated sludge or oil samples from this tank. It would have been interesting to have analyses carried out to attempt to determine the reasons for the accelerated corrosion.

Appendix "E" is the laboratory report covering this series of tests.

5.3 Third Set of Samples (1 steel test, 1 chemical sludge test, 2 biological sludge tests and 4 furnace oil tests)

The third set of samples were obtained and tested as follows:

Section of steel from bottom of tank manufactured prior to 1962

- metallurgical scan
- hardness measurement
- microstructural investigation

This tank was determined to be leaking during an inspection carried out under Section 3. Samples were taken after the tank was taken out of service and replaced with a new tank. Figure 5 show the tank installation and the bottom leak.

Sludge from the above tank (chemical test)

- chloride content
- iron content

Sludge from a different tank that was taken out of service (chemical test and biological test)

- pH
- chloride content
- iron content
- microbiological evaluation

The age of this tank was unknown. The new owner of a recently purchased residence was removing it for peace of mind.

Four furnace oil samples from three different branded suppliers manufactured by two regional refineries

- sulphur content
- water
- sediment
- iron content

The first two samples were taken from filters at the tank outlet running to the furnace burner. The third sample was taken at the discharge nozzle from a fuel oil delivery truck and the fourth sample was taken from an operational oil tank. The samples were obtained randomly and their intended use for research, unannounced to the suppliers.

Appendix "F" is an outline of the results of this testing.

5.4 Fourth Set of Samples (1 chemical sludge test and 1 biological sludge test)

The fourth sample was an oil/water mixture taken from a 7-year-old tank in service at a residence and the testing was as follows:

- microbiological
- pH
- chloride content

- solids
- iron content

The result of the sample tests is shown in Appendix "G".

6.0 INTERPRETATION OF RESULTS

6.1 General

The sample testing was done on a progressive basis. If the completion of one analysis did not prove to be meaningful it was not repeated and more pertinent items would be focused on for the next series of tests. An example would be the copper strip corrosion trial called for in the initial investigation. Perhaps this would be significant under a longer time frame but for the subject research it did not prove of any value.

6.2 Metallurgical Analysis

During the survey part of the project, variations of the phrases: "the steel that the new tanks are made of is not as good as the old steel", "the tank should be made of thicker steel" or "the tank is made of recycled steel", were heard from a number of homeowners. These views have not been supported by the research findings.

The chemical compositions of the two old tanks were similar to the new tank and within present day CSA specifications. The testing metallurgist stated that steel has to meet composition specifications and while it may be fabricated using scrap steel the manufacturing process removes contaminants that would adversely affect its service properties. There were some minor differences in hardness and grain structure between tanks but the testing laboratory indicated that these would not have a significant effect on corrosion.

The shell thickness of the one old tank measured was greater than the new tank (2.1mm compared to 1.8mm). This is likely due to modifications in steel specifications over the years, for instance changing from thickness gauge to nominal metric measurements. It is interesting to note that the new tank "holed through" in less than two years. To withstand this corrosion rate (1 mm per year) for thirty years, the steel of the tank shell would have to have been 30mm thick. On the other hand the apparent corrosion rate for the old tank based on measured pit depths, is something less than .03 mm per year. The new tank would have lasted 60 years at this corrosion rate. It is obvious that thicker steel is not the answer to the corrosion problem. As the chemical and mechanical properties of the steel in the new and old tanks are similar there must be some other reason for the accelerated corrosion found in the new tank.

6.3 Microbiological Analysis

The results of the microbiological testing of the tank sludge do not support bacteria as the cause of corrosion. As was mentioned earlier under Section 4 anaerobic corrosion is caused by sulphur reducing bacteria and the consequent production of acidic compounds. The laboratory reports indicate that there are sulphates in the sludge but there are only minor levels of sulphur reducing bacteria in any of the samples. Further while this bacteria is present in the specimens, the pH of the sludge is generally nearly neutral or only slightly acidic, indicating that bacterial contamination has not caused the corrosion seen in the tanks.

It should be noted that the level of aerobic bacteria in one of the sludge samples was 120,000 per gram. The testing laboratory advise that this would only be of concern as a potential corrosion source if the level exceeded 1 million.

6.4 Fuel Oil Analysis

Five samples of fuel oil were tested. There was nothing to indicate corrosive elements in any. The various water contents, ranging from 50 to 70 mg/kg (combined water as opposed to free water) were deemed to be acceptable by the analytical laboratory personnel. It is understood, from the laboratory, that chlorides are not present in fuel oil. A difference in sulphur levels was noted, in that three of the samples supplied by one refinery had considerably less sulphur than those supplied by the other. This variance was presumably due to differences in the crude mix or processing procedures at the respective refineries. Two of the samples were taken at filters, in lines exiting the tanks, and as expected contained sediment. The samples taken directly from the storage tanks and from the oil delivery truck did not have sediment.

6.5 Analytical and Environmental Analysis

These proved to be the most enlightening of the tests carried out. For ease of reference the important results of the sludge analyses are tabulated below.

Sample No.	pH	Chloride mg/kg	Iron %(w)	Remarks
S2T	7.2	1870	4.8	From tank > 30 years old
SC	5.8	2300	20.0	Tank removed due to age
B7	*	15900	26.0	Leaking tank > 30 years old
S41	6-7	86	47.0	Operational tank

* Sample too small for analysis

As was mentioned previously the sludge is relatively neutral as reflected in the above pH numbers. The iron content left after the ignition test indicates that there is a corrosion process occurring.

According to the testing laboratory the significant finding is the high chloride content in three of the samples. Chlorides accelerate the pitting process seen in a tank. The examinations indicate that there was chloride-laden or salt water at the bottom of the tank.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

There is no significant difference in the composition or properties of the steel used to manufacture tanks more than 30 years ago and that used to fabricate tanks relatively recently. The thickness of the steel plate of current tanks is less than that used in old tanks but additional thickness would not significantly increase the life of a tank subjected to accelerated corrosion.

Microbiological testing of sludge does not substantiate bacteria as a cause of either anaerobic or aerobic corrosion in tanks. Tank sludge is relatively, chemically neutral. There was nothing found in the fuel oil sampled that would lead to premature tank corrosion.

The primary cause of accelerated corrosion based on the sampling and subsequent testing covered by this project appears to be chloride-laden water. There are a number of sources of water and chloride entry. Water can form from atmospheric moist air drawn into the tank during the day then cooled and condensed overnight. Warm fuel oil, from a refinery for instance, can hold dissolved water and as the fuel cools the water can precipitate out. Free water can get into the fuel in a further number of ways during distribution between the refinery and the home oil tank. It may be the result of leakage into the bulk storage system or as contamination from tanker ballast water. Leakage of water or snow into the home oil tank can take place at the fill pipe, vent pipe or level gauge opening. Chlorides may be included in the atmosphere as salt-water fog. They may also be present in the previously mentioned tanker ballast as seawater contamination. Water and chlorides can be transferred from an old tank into a new tank during replacement. Nothing in the fuel oil analyses carried out as part of this research project indicated that any of the fuel oil samples were contaminated by seawater. However it should be noted that only one contaminated filling allowed to act over an extended period of time would have a detrimental effect on the corrosion resistance of a storage tank.

7.2 Recommendations

A change in tank materials or fabrication methods is one possibility to prevent internal corrosion. There are presently stainless steel, double walled and internal bladder tanks on the market. Fibreglass tanks could be approved for use in Canada similar to those in use in Europe. Maybe a change in fabrication process is required such as lining the interior bottom of the tank with a corrosion resistant coating, such as fibreglass or epoxy paint. These alterations could be legislated into the present ULC fabrication code and ultimately would result in higher costs to the homeowner. Several of the changes would prove to be relatively expensive in comparison to the use of plain unlined carbon steel tanks favoured by the vast majority of householders now. Their widespread adoption might also present new issues and uncertainties.

Based on the research covered by this report a more economical and sensible approach to the problem is to remove the corroding medium. Water appears to be this medium, contributing, particularly in conjunction with chlorides to the corrosion process. It is necessary to identify and eliminate the electrolytic solution. The Environmental Departments of all three Maritime Provinces distribute guides outlining oil tank installation and maintenance procedures [iv]. Included in these guides is a suggestion to have the storage tank checked annually for water. However this is something that is not required as maintenance under the present governing federal *Installation Code for Oil Burning Equipment, CAN/CSA-B139-M91* and generally is not done as part of an oil burner technician's annual inspection. The homeowner can not easily do it. A water indicating paste or a sample is required to determine if there is water at the bottom of the tank. The interior of a tank, particularly one inside in the basement may not always be easily accessible through a tank opening. There is further the requirement to pump out and dispose of any water and sludge if found in the bottom of the tank. (It should be noted that there are proprietary chemicals that can be added to a residential oil tank to remove or put into suspension water and sludge found on the bottom. At least one tank installation contractor questioned the effectiveness of such compounds. The scope of this research report did not allow for an investigation of their capability.)

The test for and subsequent removal of water ought to be made more critical. Water investigation should be added to the CSA standard or perhaps be included in a new standard developed covering heating system maintenance. Because of the relative ease that it can be tested for, water rather than chloride would be the compound to search for. The test could be made part of a periodic mandatory system examination where oil suppliers would not be allowed to deliver product without a valid inspection sticker on the tank fill pipe. Insurance and lending agencies could use the results of such an inspection to renew or issue insurance or mortgages similar to what is now done in the case of wood stoves or private wells.

To implement the above there would have to be co-ordination between federal, provincial and municipal regulatory agencies. Maintenance procedures would have to be developed in conjunction with tank installation contractors and tank fabricators. Inputs from parties at interest such as the insurance and banking industries would have to be solicited. Obviously there are costs associated with these changes but they would be relatively small compared to the potential savings in environmental clean-up costs.

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[i] Statistics Canada

[ii] Proceedings of the Above Ground Fuel Oil Storage Systems Workshop, North River PEI, September 1994

[iii] Metals Handbook, Ninth Edition, Volume 13, Corrosion. American Society for Metals, 1987, Metals Park, Ohio

[iii] Encyclopaedia of Chemical Technology, Fourth Edition, John Wiley & Sons, Volume 7, 1993, New York

[iv] Testing of Domestic Oil Tanks, October 1998, Canada Mortgage and Housing Corporation

Appendix "A"

"Business Reply Card"

PROFESSIONAL PROJECT ENGINEERING LIMITED

CONSULTING ENGINEERS

Tel: 902-477-3964 Halifax, N. S. B3J 3E4 P. O. Box 2401 Fax: 902-479-3036

July, 1999

Dear Householder:

We invite you to participate in our research study to find out what causes home oil storage tanks to corrode.

Recently there has been much publicity when a tank leaked and created a very expensive environmental problem. The Nova Scotia Department of Environment requires that any leak over 100 litres be reported to the department. The clean up of a spill (sometimes the responsibility of the homeowner) can cost many thousands of dollars.

We would like to send or deliver to you a short questionnaire seeking some answers to very basic questions about your furnace oil storage tank. This is not a sales promotion and your name and address will not appear in our final report or be used by others.

For your participation in the study we will make a visual inspection of your furnace oil tank and pass along any comments we can suggest to you about its appearance and location in or near your house. There is no further obligation on your part and there is no fee for our inspection. Your furnace oil tank will not be disturbed.

Our study is limited to fifty participants, so reply soon.

Please fill out, tear off and mail the bottom portion of this letter if you'd like to participate and we will contact you and come to your house at a time convenient to you.

Dear Sir:

I am interested in helping to find out what causes home furnace oil tanks to corrode and would like to receive a questionnaire to complete and have a free visual inspection of my tank. Please contact me.

Name: ______________________ Telephone Number: ____________

Address: ______________________________ Postal Code: ________

Note: Professional Project Engineering Company is an accredited Engineering Consultant registered by the Association of Professional Engineers of Nova Scotia

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PO BOX 2401 STN CENTRAL
HALIFAX NS B3J 9Z9

Appendix "B"

Homeowner Questionnaire

SURVEY QUESTIONNAIRE - DOMESTIC HOME OIL STORAGE TANKS

OWNER OF HOUSING UNIT AND TANK________________________DATE_________

ADDRESS___________________________________TELEPHONE NUMBER__________

1. Is your furnace fuel oil tank: a). outside your house? ☐Yes ☐No
   b). inside your basement? ☐Yes ☐No
   If inside, have you noticed oil smells in the basement? ☐Yes ☐No

2. Have you ever had an oil leak problem? ☐Yes ☐No
   If yes, how old was the tank at the time of the leak? _________(years)

3. Was the leak identified: a). by you? ☐Yes ☐No
   b). by others? ☐Yes ☐No
   c). by an oil company rep? ☐Yes ☐No
   d) .by a professional person? ☐Yes ☐ No

4. Where was the leak? a). In the tank itself? ☐Yes ☐No
   b). In the oil line? ☐Yes ☐No
   c). In the filter? ☐Yes ☐No
   d). Don't know? ☐Yes ☐No

5. Do you have insurance to cover the cost to clean up the leak on your property or on another property? ☐Yes ☐No ☐Don't know

6. Do you know it could cost $100,000 or more to clean up after a leak and that you may be responsible for the cost? ☐ Yes ☐No

7. Do you do maintenance yourself on the tank?
   a). Paint the tank? ☐Yes ☐No
   b). Change the filter? ☐Yes ☐ No
   c). Check the underside for oil droplets? ☐Yes ☐No
   d). Do nothing? ☐Yes ☐No

8. At this time is your tank: a). nearly full? ☐Yes ☐No
   b). nearly empty? ☐ Yes ☐No
   c). Don't know? ☐ Yes ☐No

9. Who supplies your furnace oil? ____
   Do you have a standing order with your supplier to have the tank filled when oil is needed? ☐Yes ☐No
   If they fail to do so, and you run out of oil will they give you a free tank of oil or some other perk? ☐Yes ☐No

10. Have you considered the purchase of an additional containment system (concrete or oil proof surround) in case of a spill? ☐ Yes ☐ No

11. Most tanks have a name plate on them with a date of manufacture.
    a). What year is shown on your tank? ________
    b). When was it installed? _______ (year)
    c). Was it installed by your oil company? ☐ Yes ☐ No
    d). By others? ☐ Yes ☐ No
    e). For how many years is your tank guaranteed to last? ________

12 Have you had sludge or water removed from your tank periodically? ☐ Yes ☐ No

13. If you had a tank replaced, were the existing contents pumped back into the new tank? ☐ Yes ☐ No

14 . Would you consider upgrading your tank at a cost of $800 for a tank with a 10-year warranty against leaking? ☐ Yes ☐ No

15. Would you consider paying for a test by an expert to see if your tank needs replacing? ☐ Yes ☐ No If yes, would a price tag of $75 be reasonable? ☐ Yes ☐ No

16. Do you think the government or insurance companies should require periodic testing or inspection of tanks? ☐ Yes ☐ No

Thank you for participating in our research study

Appendix "C"

Summary of Survey Questionnaires

Following is a summary of the results of the Survey Questionnaire, Domestic Home Oil Storage Tanks, numbered as per the questionnaire. Twenty-eight forms were completed however not all homeowners responded to all questions consequently answers do not total twenty-eight in every case. Responses are stated in Italics.

1. Is the furnace fuel oil tank?
   - *Outside your house 12*
   - *Inside your house 16*

   If inside have you noticed oil smells in your basement? *Yes 2*

2. Have you ever had an oil leak problem? *Yes 11* *No 17*

   If yes how old was the tank at the time of the leak in years?

   29, 15-20, 16, 6, 10, 27, 7, 3, 7 and two unknown

3. How was the leak identified?
   - *By you 9*
   - *By others nil*
   - *By an oil company representative 1*
   - *By a professional person 1*

4. Where was the leak?
   - *In the tank 10*
   - *In the oil line 1*
   - *In the filter nil*
   - *Don't know nil*

5. Do you have insurance to cover the cost to clean up the leak on your property or on another property?
   - *Yes 8*
   - *No 3*
   - *Don't know 15*

6. Do you know it could cost $100,000 or more to clean up after a leak and that you may be responsible for the cost?
   - *Yes 16*
   - *No 12*

7. Do you do maintenance on the tank yourself?
   - *Paint the tank 10*
   - *Change the filter 2*
   - *Check the underside for oil droplets 19*
   - *Do nothing 7*

8 At this time is your tank?

- ***Nearly full 23***
- ***Nearly empty 2***
- ***Don't know 2***

9. Who supplies your furnace fuel?

- ***Cunard 7***
- ***Irving 3***
- ***Scotia Fuels 4***
- ***Ultramar 2***
- ***BuyerTran 1***
- ***ESSO 8***
- ***Shell 3***

Do you have a standing order with your supplier to have the tank filled when oil is needed? ***Yes 27*** ***No 1***
If they fail to do so and you run out of oil will they give you a free tank of oil or some other perk? ***Yes 9*** ***No 3*** ***Don't Know 11***

10. Have you considered the purchase of an additional oil containment system (concrete or oil proof surround) in case of a spill? ***Yes 5*** ***No 23***

11 Most tanks have a nameplate on them with the date marked when manufactured.

- Year of manufacturer established on 17 out of 28 and ***average age of these was 9 years***
- Average ***age of installation 9 years***
- ***17 tanks installed by Oil company, 1 by others and 10 did not know***
- the ***one other installation was by a independent heating contractor***
- ***20 did not know how long their tank was guaranteed for, 2 said 5 years, 2 said 3 years, 1 said 15-20 years, 1 said "not very long" and 2 said none***

12. Have you ever had sludge or water removed from your tank periodically? ***Yes 1*** ***No 25*** ***Don't know 2***

13. If the tank was replaced were the existing contents pumped back into the new tank?
Yes 4 ***No 6*** ***Don't know 1***

14. Would you consider upgrading your tank at a cost of $800 for a tank with a 10 year warranty against leaking? ***Yes 9*** ***No 7*** ***Not sure 9***

15. Would you consider paying for a test by an expert to see if your tank needs replacing? ***Yes 10*** ***No 12***
If yes would a price tag of $75 be reasonable? ***Yes 8*** ***No 2*** ***Not sure 2*** ***A bit high 1***

16. Do you think the government or insurance companies should require periodic testing or inspection of tanks? ***Yes 12*** ***No 12*** ***Don't know 1***

Appendix "D"

Initial Laboratory Report

NOVA SCOTIA INNOVATION CORPORATION
innovacorp

ANALYTICAL & ENVIRONMENTAL CHEMISTRY
LABORATORY REPORT

CLIENT: Moody Engineering
71 Newcastle Street
Dartmouth NS B2Y 3M8

DATE SUBMITTED: August 12, 1999

ATTENTION: Bill Moody
FAX: 463-4111

MATERIAL: Oil Water Sludge
SUBMITTED BY: Moody Engineering

DATE REPORTED: August 30, 1999

Lab No.	Description	Copper Strip Corrosion 3 hrs @ 50 °C	Sulphur % (w)	Water by Karl Fischer Titration mg/kg	Total Acid Number mg KOH/g	Water by Distillation % (v/w)	pH
99-1166/1	Furnace Oil	Freshly Polished	0.067	70	<0.05	-	6.8
99-1166/2	Tank Sludge	Freshly Polished	-	-	4.34 (4.25)	18	-

NOTE: Sample 99-1166/3 (client sample W1) was noted to be primarily fuel oil.

Mike Robicheau, M.A.Sc.
Lab Manager

Certificate No. 003407

Appendix "E"

Second Laboratory Report

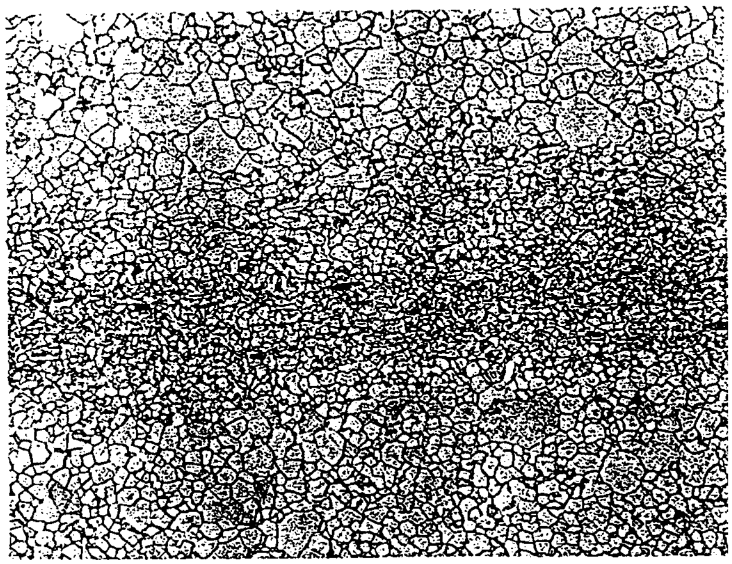


Figure 1: Ferritic Grain Structure in Older Steel Oil Tank 100X

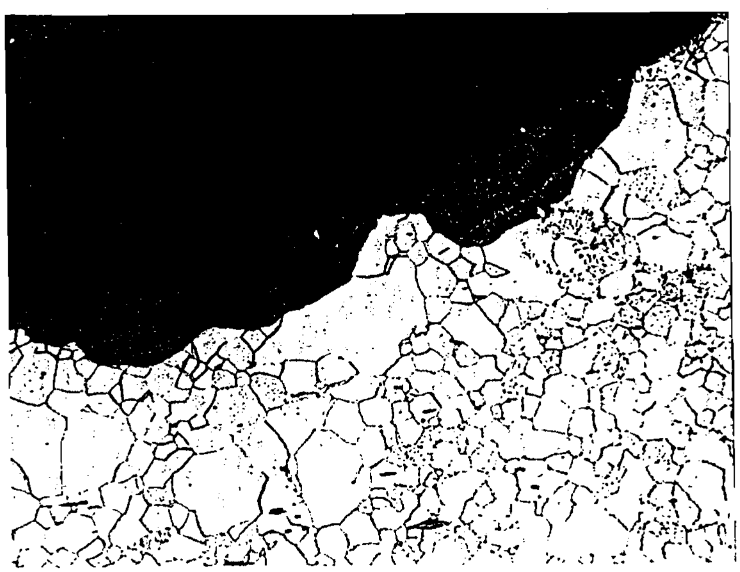


Figure 2: Pitting Action Initiated at Inner Surface of Oil Tank 200X

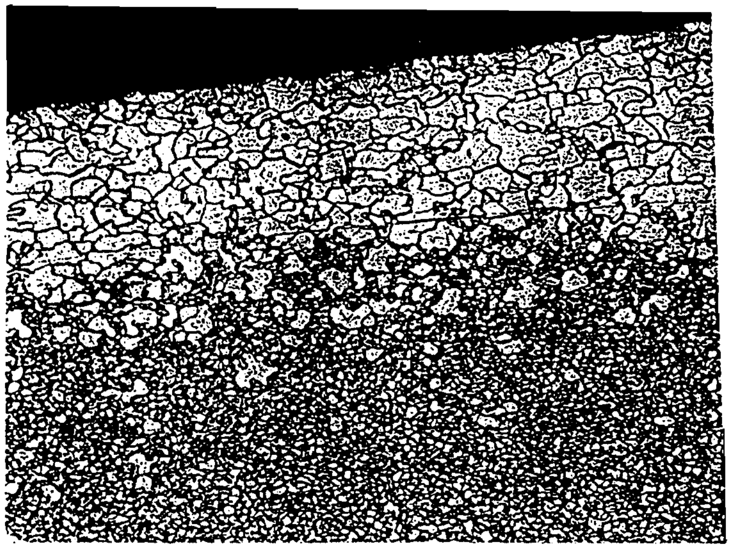


Figure 3: Ferritic Grain Structure in Newer Steel Oil Tank 100X

PHILIP SERVICES

99/00-786 Moody Engineering Consultants **22-Oct-99**
Oil Tank Analysis

Chemical Composition of Steel

Element	Old Tank	New Tank	CSA G40.21 230G
C	0.1	0.03	0.26 max
Mo	<0.01	<0.01	
P	<0.05	<0.05	.05 max
Al	<0.01	0.041	0.10 max
Ni	<0.01	0.018	
Co	<0.01	<0.01	
Si	0.013	0.018	0.04 max
Mn	0.37	0.18	1.2 max
Cr	0.013	0.033	
V	<0.01	<0.01	
Zn	<0.01	0.011	
Cu	0.04	0.039	
Pb	<0.02	<0.02	
Cd	<0.01	<0.01	
S	0.04	0.01	0.05 max

Average Hardness Vickers

Old Tank	New Tank
108	123

Thickness of Steel (mm)

Old Tank	New Tank
2 nominal	2 nominal
2.1 actual	1.8 actual

Depth of Pitting (mm)

Old Tank	New Tank
0.8	2 (failure)

PHILIP ANALYTICAL SERVICES CORPORATION
101 RESEARCH DRIVE, P.O. BOX 790, DARTMOUTH, NOVA SCOTIA, CANADA B2Y 3Z7 TEL. (902) 424-8670 FAX (902) 424-4679

PHILIP SERVICES

ANALYTICAL & ENVIRONMENTAL CHEMISTRY
LABORATORY REPORT

CLIENT: Materials Group
InNOVAcorp
PO Box 790
Dartmouth NS B2Y 3Z7

DATE SUBMITTED: Oct 4, 1999

ATTENTION: Doug MacDonald

MATERIAL: Sludge
SUBMITTED BY: Materials Group

DATE REPORTED: Oct 14, 1999

Lab No.	**99-1486/1**
Description	**99/00-786 sludge from fuel oil tank S2T**
pH	7.2
Fe %(w)	4.8
Loss on Ignition @500^{0}C %(w)	91.6
Water Extractable Cl^- mg/kg	1870
Water Extractable SO_4^{-4} mg/kg	3730

Note All results reported on an as received basis.

Mike Robicheau, M.A.Sc.
Lab Manager

PHILIP SERVICES

MICROBIOLOGY LABORATORY REPORT

CLIENT: Materials Group
Philip Analytical Services Corp.
101 Research Dr., PO Box 790
Dartmouth NS B2Y 3Z7

DATE REPORTED: October 12, 1999

LAB NUMBER: 8361

DATE REVISED: October 18, 1999

ATTENTION: Doug MacDonald

MATERIAL: Sludge from fuel oil tank received September 30, 1999
Job # 99/00-786

RESULTS:

Sample	Description	Aerobic Bacteria /gram	Anaerobic Bacteria /gram
99/00-786 S2T	Sludge from fuel oil tank	present 120,000	present 400

Annette Clarke
Microbiologist

Patti Densmore
Microbiologist

Appendix "F"

Third Laboratory Report

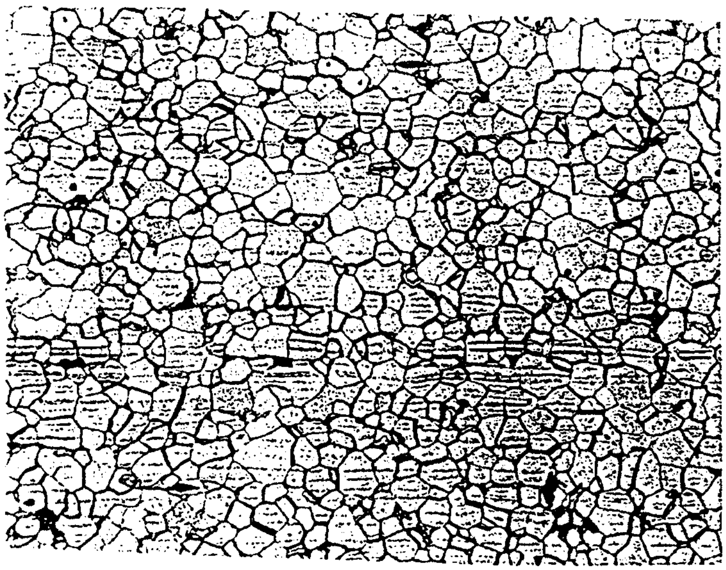


Figure 1: Ferritic Grain Structure in Steel Sample B7 at 200X

PHILIP SERVICES

ANALYTICAL & ENVIRONMENTAL CHEMISTRY
LABORATORY REPORT

CLIENT: Materials Group

DATE SUBMITTED: Nov 5,1999

ATTENTION: Doug Mac Donald

MATERIAL: Drillings

FAX:

SUBMITTED BY: Materials Group

DATE REPORTED: Nov 12, 1999

Lab No.		99-1677/1
Description		E834
C	% (w)	0.10 (0.10)
Sn	% (w)	<0.05
Mo	% (w)	<0.01
P	% (w)	<0.03
Al	% (w)	<0.01
Ni	% (w)	0.031
Co	% (w)	<0.01
Si	% (w)	<0.01
Mn	% (w)	0.32
Cr	% (w)	0.027
Ti	% (w)	<0.005
V	% (w)	<0.01
Zn	% (w)	<0.01
Cu	% (w)	0.047
Pb	% (w)	<0.03
Cd	% (w)	<0.01
S	% (w)	0.037

Mike Robicheau, M.A.Sc.
Lab Manager

PHILIP ANALYTICAL SERVICES CORPORATION
101 RESEARCH DRIVE, P.O. BOX 790, DARTMOUTH, NOVA SCOTIA, CANADA B2Y 3Z7 TEL. (902) 466-0370 FAX (902) 434-3592

PHILIP SERVICES

ANALYTICAL & ENVIRONMENTAL CHEMISTRY LABORATORY REPORT

CLIENT: Philip Analytical
101 Research Drive
Dartmouth NS B2Y 3Z7

DATE SUBMITTED: November 5, 1999

ATTENTION: Doug MacDonald
FAX: 424-4679

MATERIAL: Sludge

SUBMITTED BY: Philip Analytical

DATE REPORTED: November 15, 1999

Lab No.	Description	pH	Cl^- mg /kg	Fe % (w)	Loss on Ignition @ 500°C % (w)
99-1686/1	SC Sludge E 834	5.8	2300	20	71.1
99-1686/2	B7 Sludge 9900-834	-	15900	26	45.5

Note: All results are reported on an as-received basis.

Mike Robicheau, M.A.Sc.
Lab Manager

PHILIP SERVICES

MICROBIOLOGY LABORATORY REPORT

CLIENT: Materials Group
Philip Analytical Services Corp.
101 Research Dr., PO Box 790
Dartmouth NS B2Y 3Z7

DATE REPORTED: November 10, 1999

LAB NUMBER: 8449

ATTENTION: Doug MacDonald

MATERIAL: "SC" Sludge

RESULTS:

Sample	Description	Aerobic Bacteria /mL	Anaerobic Bacteria /mL
9900-834	"SC" Sludge	<25	<25

Annette Clarke
Microbiologist

Patti Densmore
Microbiologist

PHILIP SERVICES

ANALYTICAL & ENVIRONMENTAL CHEMISTRY LABORATORY REPORT

CLIENT: Philip Analytical
101 Research Drive
Dartmouth NS B2Y 3Z7

DATE SUBMITTED: November 5, 1999

ATTENTION: Doug MacDonald

MATERIAL: Fuel

FAX: 424-4679

SUBMITTED BY: Philip Analytical

DATE REPORTED: November 15, 1999

Lab No.	Description	Sulfur % (w)	Water by Karl Fischer Titration mg / kg	Sediment mg / L	Fe (Sediment Analysis) % (w)
99-1678/1	F2T Sept. 1/99	0.20	50	510	41
99-1678/2	F7 Aug. 31/99	0.094	40	200	1.7
99-1678/3	FULT. Nov. 1/99	0.064	30	-	-
99-1678/4	FIRV. Nov. 4/99	0.21	40	-	-

Mike Robicheau, M.A.Sc.
Lab Manager

Appendix “G”

Fourth Laboratory Report

PHILIP SERVICES

ANALYTICAL & ENVIRONMENTAL CHEMISTRY
LABORATORY REPORT

CLIENT: Philip Analytical
101 Research Drive
Dartmouth, NS B2Y 3Z7

DATE SUBMITTED: December 15,1999

ATTENTION: Doug MacDonald

MATERIAL: Sludge

FAX: 424-4679

SUBMITTED BY: Materials Group
For Moody Engineering

DATE REPORTED: December 22, 1999

Lab No.		99-1947/1
Description		Fuel Sludge 541
pH		6-7
Cl^-	**mg/L**	86
Solids	**mg/L**	184 (2980)*
[+]Fe	**% (w)**	47

*"Top" layer of sample.
+ Fe result based on portion of residue scraped off filter.

Mike Robicheau, M.A.Sc.
Lab Manager

PHILIP SERVICES

MICROBIOLOGY LABORATORY REPORT

CLIENT: Materials Group
Philip Analytical Services Corp.
101 Research Dr., PO Box 790
Dartmouth NS B2Y 3Z7

DATE REPORTED: December 14, 1999

LAB NUMBER: 8542

ATTENTION: Doug MacDonald

MATERIAL: Fuel/Sludge (Moody Engineering)
Job # 99/00-834

RESULTS:

Sample	Description	Aerobic Bacteria /ml	Anaerobic Bacteria /ml
99/00-834 S41	Fuel/Sludge	5	10

Annette Clarke
Microbiologist

Patti Densmore
Microbiologist

Figure 1 - Test using "Water Finding" paste

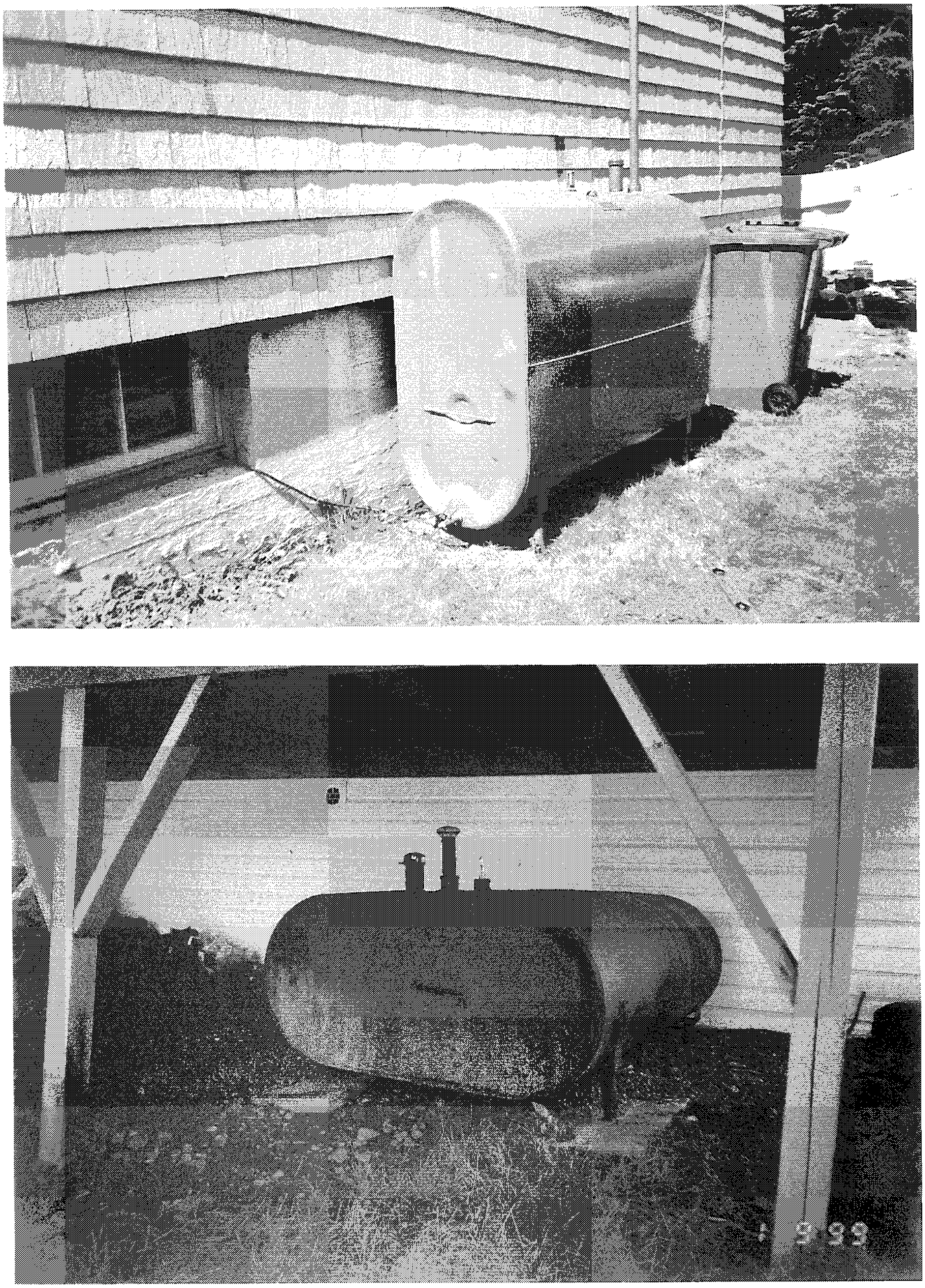


Figure 2 - Typical outdoor tank installations

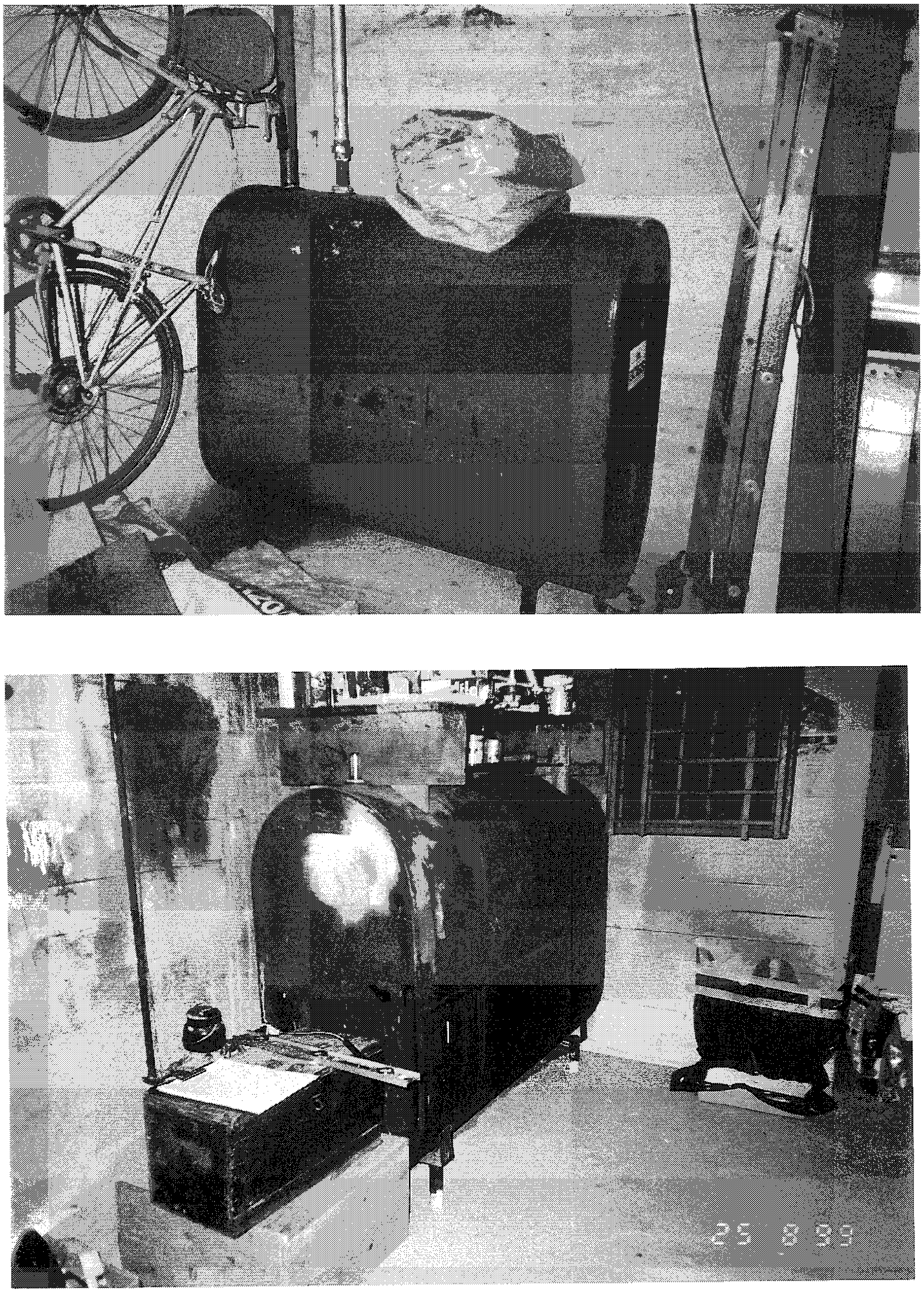
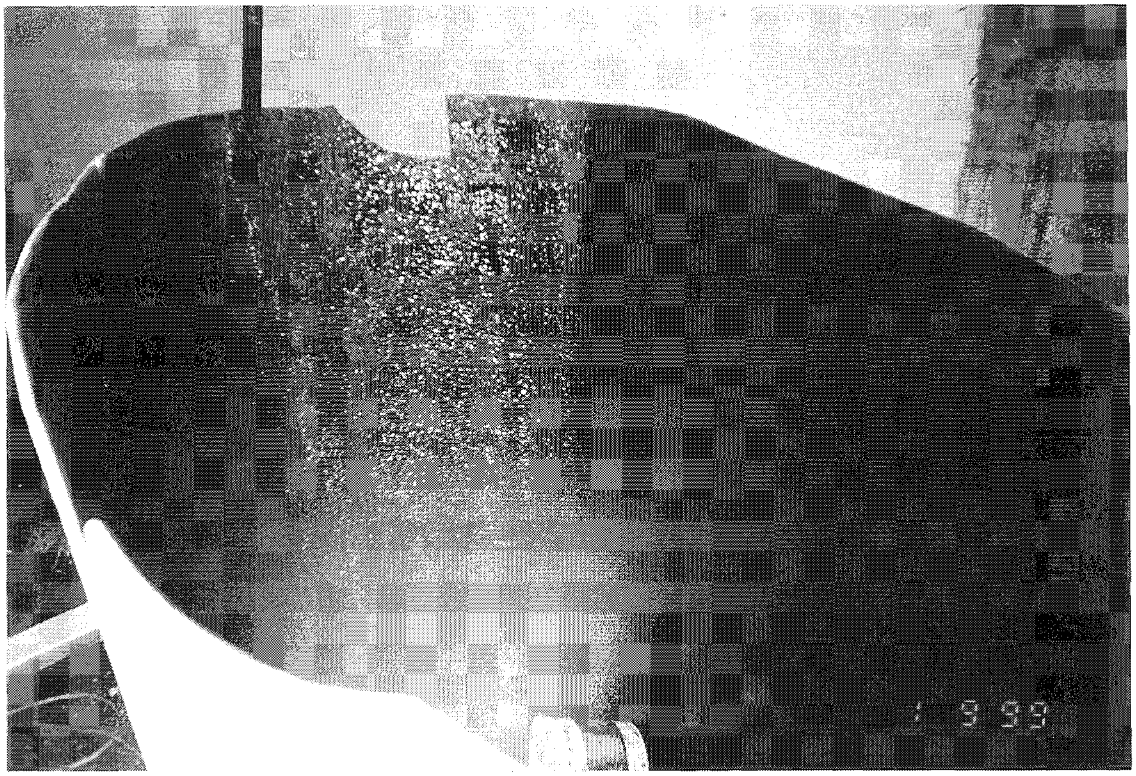


Figure 3 - Typical indoor tank installations



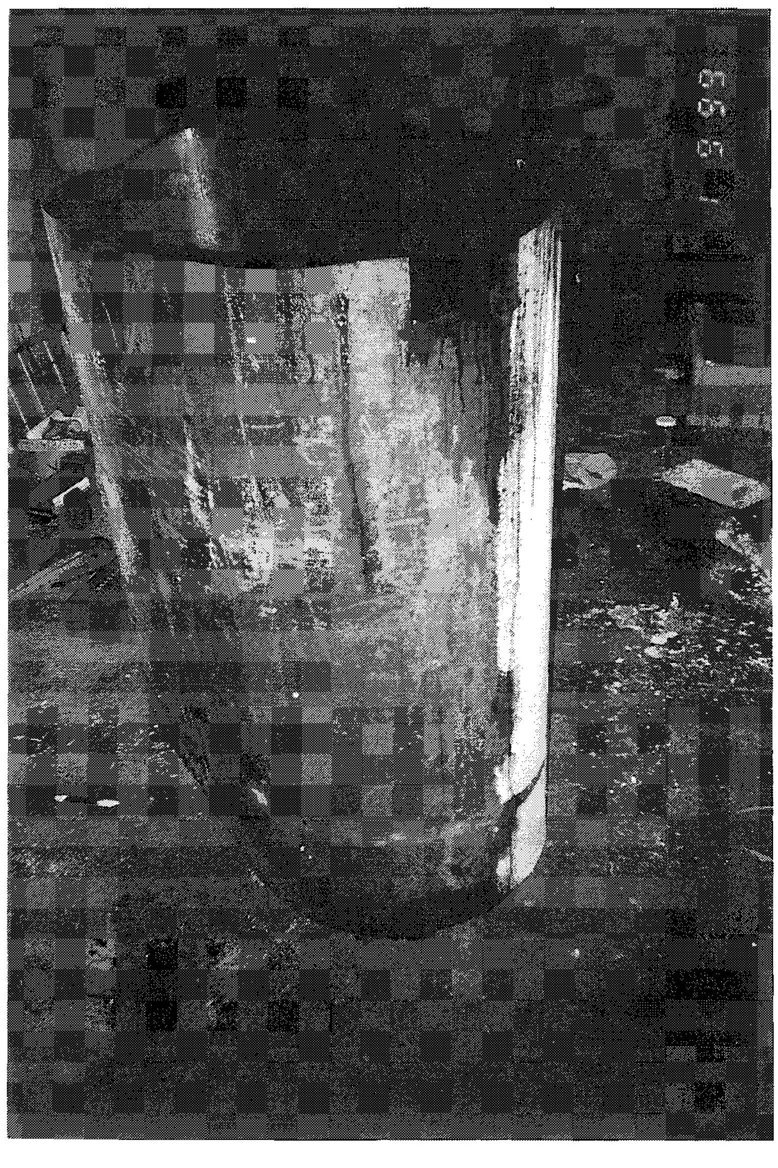


Figure 4 - Interior tank sludge and shell test sample

Figure 5 - Leaking tank installation