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Standard Guide for Investigation of Equipment Problems and Releases for Petroleum Underground Storage Tank Systems[1]

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INTRODUCTION

This guide provides a framework for the development of procedures and directions for the investigation of equipment problems associated with petroleum underground storage tank (UST) systems and releases. It gives the user practical suggestions of how to investigate equipment and installation problems, document findings, and in some cases prepare samples of failed equipment for laboratory analysis. Use of this guide may result in the identification of equipment and installation problems that can be corrected in future tank system designs and equipment maintenance programs to prevent releases to the environment.

1. Scope

1.1 *Overview*—This guide is an organized collection of information and series of options for industry, regulators, consultants and the public, intended to assist with the development of investigation protocols for underground storage tank facilities in the United States. While the guide does not recommend a specific course of action, it establishes an investigation framework, and it provides a series of techniques that may be employed to: identify equipment problems; in some cases prepare samples of failed equipment for laboratory analysis; and document the investigation. The guide includes information on methods of investigation, documentation, taking samples of problem equipment; preservation of equipment samples; chain of custody; storage; shipping; working with equipment manufacturers; and notification of regulators and listing laboratories. The goal in using the guide is to identify the appropriate level of investigation and to gather and preserve information in an organized manner, which could be used in the future to improve system design or performance. While this guide may act as a starting point for users with limited experience in failure investigation, the user is encouraged to consult with failure analysis experts for specific investigation procedures that may be needed for certain equipment and the investigation should be conducted by a qualified professional. As users develop their specific investigation protocols, they may find that the investigations can be streamlined for certain types of facilities.

1.2 *Limitations of This Guide:*

1.2.1 Given the variability of the different investigators that may wish to use this guide and the different types of facilities and failures that will be investigated, it is not possible to address all the relevant standards that might apply to a particular investigation. This guide uses generalized language and examples to guide the user. If it is not clear to the user how to apply standards to their specific circumstances, it is recommended that users seek assistance from qualified professionals.

1.2.2 This guide does not address safety issues associated with the investigation, taking samples and storing equipment. users are cautioned to exercise proper care in handling equipment that was in contact with flammable and combustible liquids and vapors. Some of the activities described in this guide may be subject to OSHA (Occupational Safety and Health Administration) regulations or may only be conducted by individuals with appropriate HAZWOPER (Hazardous Waste Operations and Emergency Response) training certifications recognized by federal and state regulatory authorities, such as HAZWOPER training.

1.2.3 This guide does not address laboratory investigations of material properties and detailed failure analysis.

1.2.4 This guide does not cover underground storage tank systems storing liquefied petroleum gas (LPG).

1.2.5 This guide does not replace state-required closure assessments and investigations. Requirements vary from state to state and often include specific sampling requirements.

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1.3 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1188 Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator

F1127 Guide for Containment of Hazardous Material Spills by Emergency Response Personnel

2.2 *Other Standards:*

STD 2015 Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks, 6th Edition—August 2001[3]

RP 2016 Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks, 1st Edition—August 2001[3]

PEI/RP 100 Recommended Practices for Installation of Underground Liquid Petroleum Storage Systems, Petroleum Equipment Institute (PEI)[4]

NFPA 30 Flammable and Combustible Liquids Code[5]

2.3 *Federal Regulations:*[6]

49 CFR 172 Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements

29 CFR 1910.146 Occupational Safety and Health Standards, Subpart J, General Environmental Controls, Permit-required Confined Spaces

3. Terminology

3.1 *Definitions:*

3.1.1 *equipment problems or problem equipment*—any failure, malfunction, or other issue that has resulted in abnormal equipment condition or operation or that has resulted in a release or suspected release.

3.1.2 *release prevention*—activities that reduce the risk of human and environmental exposure to petroleum or hazardous substances. In the United States, underground storage tank and toxic use reduction regulations are examples of such requirements.

3.1.3 *underground storage tank*—a tank and any underground piping connected to the tank that has at least 10 % of its combined volume underground.

3.1.4 *waste*—discarded solid or liquid materials that may be hazardous to public health or the environment. Solid and hazardous waste require controls on handling, transport, storage treatment, and disposal.

4. Significance and Use

4.1 This guide may be used in the investigation of underground storage tank systems for equipment problems in a wide variety of applications. Use of this guide is voluntary. It is intended to assist users who want to investigate equipment failures and malfunctions.

4.2 The following groups of users may find the guide particularly helpful:

4.2.1 Storage tank system designers;

4.2.2 Storage tank installers;

4.2.3 Storage tank maintenance contractors;

4.2.4 Storage tank removal contractors;

4.2.5 Storage tank inspectors;

4.2.6 Federal, state or local regulators, including departments of health, departments of environmental protection, and fire departments;

4.2.7 Storage tank release detection installers;

4.2.8 Storage tank testers;

4.2.9 Petroleum release remediation consultants;

4.2.10 Storage tank equipment manufacturers;

4.2.11 Insurance adjusters;

4.2.12 Storage tank owners and operators;

4.2.12.1 Retail fuel service station owners and operators;

4.2.12.2 Small businesses or enterprises;

4.2.12.3 Service industries;

4.2.12.4 Waste managers, including liquid and solid waste haulers, treatment, recycling, disposal and transfer;

4.2.12.5 Non-regulatory government agencies, such as the military;

4.2.12.6 Specific industrial sectors such as dry cleaners, printers, photo processors, laboratories; and

4.2.13 Consultants, auditors, inspectors, and compliance assistance personnel.

4.3 This guide is intended to assist in the development of protocols for the investigation of a malfunction or failure of storage tank systems and the implementation of said protocols. This guide outlines steps that may be necessary and include, but are not limited to initial evaluation of the UST system to determine the malfunction(s); preparation of samples of failed equipment for laboratory analysis; and document the investigation. The guide provides a series of investigation options on which the user may design failure investigation protocols. The guide describes common investigation techniques in the order in which they might be employed in an investigation.

4.4 A user may elect to utilize this guide for a number of reasons, which include, but are not limited to:

4.4.1 To differentiate new releases from new discovery of old releases;

4.4.2 To establish malfunction and failure rates of various storage tank equipment components;

4.4.3 To determine expected life spans of various storage tank equipment components;

4.4.4 To identify opportunities for improving the performance and reliability of storage tank equipment;

4.4.5 To focus inspection and maintenance efforts on those portions of the tank system that are most prone to malfunction and failure;

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

[4] Available from Petroleum Equipment Institute (PEI), P. O. Box 2380, Tulsa, OK 74101-2380, http://www.pei.org.

[5] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[6] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

4.4.6 To identify those components of the storage tank system that require more frequent maintenance;

4.4.7 To reduce remediation and equipment replacement costs;

4.4.8 To prevent petroleum releases;

4.4.9 To identify those conditions that may cause or contribute to the deterioration or cause the malfunction and failure of various components of the UST system; and

4.4.10 To comply with environmental regulations that require the investigation of release detection alarms and the source of releases.

4.5 This guide may be used to establish a framework, which pulls together the common approaches to investigation. The framework will allow the user to establish an investigation protocol to meet their specific requirements. Specific user requirements will vary depending upon the purposes of the data collection and the decisions that the investigation is intended to support. This guide does not provide methods to establish specific user investigation requirements nor does it establish minimum levels of documentation.

4.6 This guide is not intended to require the user to conduct a failure investigation.

4.7 This guide is focused on the identification, documentation, and preservation of underground storage tank system equipment problems. It does not provide guidance on establishing root causes of malfunction or failure. The identification of root causes of malfunction or failure may require further expert analysis of the data and equipment collected during the failure investigation.

4.8 This guide does not address all the safety measures that must be taken when removing and disassembling underground storage tank systems. Because most underground storage tank systems have contained flammable or combustible liquids special precautions should be taken to prevent fire, explosions and exposure to toxic vapors. API standard STD 2015 and RP 2016 address some of the safety considerations as do many of the procedures available from fire departments.

5. Elements of Failure Investigation

5.1 The guide will acquaint users with methods and tools that may be used in investigations of equipment problems associated with petroleum underground storage tanks and releases. The user may include a subset of the methods described in this guide in their investigation. The user may consider a variety of factors in determining which combination of the methods to employ. For example, the manner of discovering a release may influence the methods employed. If there is an indication of a release from release detection or off site impacts, the user may select failure investigation methods that rely on records reviews and non-destructive tests. If the release is discovered during tank removal, some equipment tests may not be possible, and the user may choose visual examination techniques. If there are no indications of a release, the user may choose to employ visual examination techniques to check on the site assessment information that indicated that no release occurred.

5.2 *General Records*—Gathering and reviewing records prior to the physical investigation may help focus the investigation and make the investigation run smoothly. Reviewing records from the following categories may help inform the user what types of equipment to expect, where the equipment can be found, the repair and maintenance history and prior releases. These records may be in the possession of the owner(s) of the petroleum underground storage tank system; a third party consultant or maintenance contractor; or one or more regulatory entities. The user may find that it is beneficial to organize the records and bring them to the field investigation for reference.

5.2.1 Equipment purchase records.

5.2.2 Installation records:

5.2.2.1 "Record" or "as-built" drawings andor site plans;

5.2.2.2 Installation check lists;

5.2.2.3 Pre-operation leak checks;

5.2.2.4 Regulatory registration data;

5.2.2.5 Warranty registration data; and

5.2.2.6 Photos and videos of the original installation.

5.2.3 *Operating and Maintenance Manuals*—Some equipment manufacturers make copies of operation and maintenance manuals available in printed or electronic form. The user can check the manufacturers' web sites for ordering or downloading manuals.

5.2.4 Repair records;

5.2.5 Inventory control records;

5.2.6 Release detection records;

5.2.7 Equipment alarm histories;

5.2.8 Tightness testing records; and

5.2.9 Prior monitoring well, site assessment and remediation records.

5.3 *Pinpointing The Source of a Release and Malfunctioning Equipment in an Operating or Undisturbed Tank System:*

5.3.1 *Visual*—Careful observation of the equipment may reveal misalignment of equipment and malfunctioning components. While not always the case, generally underground storage tank equipment is installed in alignment and should remain in alignment throughout the life of the system. Poor alignment of the installed equipment may indicate shifting, settling, creep, expansion or failure of components. Installation photos when compared to the current conditions may help determine if the condition of the underground storage tank system has deteriorated. Visual indicators of potential problems in the underground storage tank system include, but are not limited to:

5.3.1.1 Misalignment;

5.3.1.2 Equipment not performing to original specifications, for example loose, rattling or intermittent operation;

5.3.1.3 Indications of prior repairs;

5.3.1.4 Water intrusion into primary containment;

5.3.1.5 Drips and staining in sumps and beneath dispensers;

5.3.1.6 Stored product, water intrusion, stains and sheens in secondary containment;

5.3.1.7 Dead vegetation and staining of surface soil and pavement; and

5.3.1.8 Unusual system operation (that is, slow discharge of product from pumps), which may indicate a leak or a component failure in the system.

5.3.2 Inventory records may indicate if there is a significant loss in one or more stored products. Inventory records are often not accurate, and should not be relied upon alone to indicate that a release did or did not occur.

5.3.3 Release detection alarms may indicate that a system is leaking. They can also indicate that the release detection equipment is malfunctioning. Some state regulations require that the owner or operator determine the source of a suspected release following a release detection alarm.

5.3.4 Tightness testing may detect breaches in the underground storage tank system. A variety of methods are available with various degrees of accuracy and sensitivity. Some tightness testing methods detect breaches in specific portions of the underground storage tank system. The user should consider the characteristics of the tightness test when selecting a test method and evaluating the results of the test.

5.3.5 Tracer testing can be conducted using a variety of gases. Some tracers, such as helium can permeate through some materials that are liquid tight and even some materials that are impermeable to most vapor components of motor fuel. The user should consider the characteristics of the tracer when selecting a test method and evaluating the results of the test.

5.3.6 Soil and groundwater contamination testing conducted prior to removing an underground storage tank system may help identify releases and in some cases indicate the proximity of the release. It is important to identify the presence of older releases and to determine if the release came from the the equipment currently in place or from older equipment that has been removed.

5.4 *Pinpointing the Source of a Release and Identifying Equipment Problems During Excavation, Prior to Equipment Removal*—Careful observation and tests during the removal of underground storage tank systems may yield valuable information on the proximity of a release, whether the release came from the equipment at the site and conditions that may have contributed to equipment failure. The following observations and tests can be conducted during the excavation of underground storage tank equipment:

5.4.1 *Soil Staining*—Most motor fuels can stain soils and backfill materials when released from an underground storage tank system. In many cases, careful excavation in stained areas will help pinpoint sources of release. Soil staining can also provide a rough indication of how long the released product has been in the ground, although this age indication is highly dependent on the product released and specific conditions at the location being examined. The soil color change is due, in large part, to changes in soil redoximorphology and geochemistry from degradation of the fuel. Colors can be recorded using a standard chart system such as Munsel and stratum colors at the point of the release. Documenting soil colors away from the point of release can be useful for comparison and to further document the cause of the staining. The user is cautioned that some soils are naturally mottled and that there are other sources of staining besides releases from underground storage tank systems, thus the user should investigate the source of the stain to determine if in fact it is the result of a release from the underground storage tank system.

5.4.2 *Visual Assessment of Equipment*—Careful examination of the underground storage tank system may help identify equipment problems.

5.4.2.1 Staining and discoloration may be caused by product releases;

5.4.2.2 Damage such as fractures and breaches;

5.4.2.3 Corrosion; and

5.4.2.4 Improper alignment.

5.4.3 *Backfill Conditions*—Improper backfill can lead to many types of equipment failure. Excessive settlement in the backfill can lead to inadequate support for tanks. Signs of settlement and inadequate compaction may be observed during excavation. Settlement may also result from finer surrounding soil migrating into coarse backfills such as pea stone. Some types of equipment can be damaged by sharp backfill or backfill that contains trash, clumps of clay or large rocks. Unclean or varied backfill can lead to accelerated corrosion of metallic components. Backfill that is not adequate when compared to the equipment manufacturer's installation requirements may indicate that there is an increased likelihood of failure in the component.

5.4.4 Soap tests can be conducted on piping, tank connections and bungs after they have been exposed. In a soap test the pressure is raised inside the equipment to be tested and the outside is sprayed with a soap solution. Bubbles forming in the soap solution may indicate the location of a leak. Users of this guide are cautioned to use safe procedures when introducing pressurized gasses into an underground tank system that may still contain vapors. Inert gas may be required to safely conduct a soap test on an underground tank system that has contained petroleum.

5.4.5 Similarly to testing of an operating or undisturbed system, tracer tests can be conducted during and after removal using a variety of gases. Some tracers permeate through materials that are liquid tight and even some materials that are impermeable to most vapor components of motor fuel. The user should consider the characteristics of the tracer when selecting a test method and evaluating the results of the test.

5.4.6 *Age of Fuel*—In some cases, the age of the petroleum can be estimated. There are a variety of techniques that can be used on free product, soil, and groundwater that might be sampled during excavation. Estimating the age of the petroleum may help determine if more than one release has occurred or if the release occurred prior to a repair or replacement date. One of the techniques, "fingerprinting" attempts to estimate the age by relating the characteristics of the petroleum in the investigation to known changes in formulations of fuels, refining practices and additives.

5.5 *Pinpointing the Source of a Release and Identifying Equipment Problems During and After Equipment Removal*—A number of observations can be made as the underground storage tank system is removed. Many of these are similar to the observations and tests described in 5.4 above. The user may conduct additional observations and tests on equipment as described below, Most of these observations can be made after the equipment is uncovered and before it is removed from the ground, although some of the items indicated below, such as 5.5.3 may be more appropriate after removal.

5.5.1 Soil staining.

5.5.2 Equipment Condition:

5.5.2.1 Staining;

5.5.2.2 Damage;

5.5.2.3 Corrosion;

5.5.2.4 Improper alignment;

5.5.2.5 Loose Ffittings can be observed as equipment is disassembled;

5.5.2.6 Softening of plastic materials may indicate that strength properties of the equipment have deteriorated. For example, soft and spongy pipe may indicate chemical attack and weakening; and

5.5.2.7 Excessive microbial growth on system components can indicate deterioration of plastics or rubber materials.

5.5.3 *Stored Product Trapped in Secondary Containment*—Product can build up in the secondary containment system if the primary containment is leaking faster than the secondary containment system. This can be detected by creating a small hole in the secondary containment system with a pocket knife or an awl. In some cases, particularly in certain models of thermoplastic pipe where the secondary containment pipe is in intimate contact with the primary pipe, the product can become trapped in the secondary containment and build up pressure. Trapped product can indicate that there is a breach in the primary containment in that section. This investigation technique may not be reliable if the secondary containment system is open to migration of releases from sumps unless the product trapped in the secondary is under pressure. The user should assess the potential quantity of product that could be trapped in the secondary containment and be prepared to capture the released product with absorbent pads and containers such as those described in Guide F1127.

5.5.4 *Soap Test*—Soap tests can be conducted using the manufacturer's recommended practice or standard industry methods such as those described in PEI and API installation guides (PEI/RP 100).

5.5.5 Groundwater and soil testing can be used to confirm that a release has occurred and to determine what product was released and when it occurred. There are a variety of field and laboratory techniques for assessing soil and groundwater constituent concentrations. The user should consult with an contamination assessment professional to determine which techniques to employ and the skills and equipment needed.

5.5.5.1 *Source Area Identification*—Concentrations from several sample locations can be plotted on a map to indicate the likely area of highest concentration. The area of highest concentration is also often the area of the release. A three-dimensional plot method such as a box diagram may be helpful, particularly for analyzing the tank excavation area.

5.5.5.2 *Age of Fuel*—In some cases the age of the petroleum can be estimated. There are a variety of techniques that can be used on free product, contaminated soil, and groundwater. Estimating the age of the petroleum may help determine if more than one release has occurred or if the release occurred prior to a repair or replacement date. One of the techniques, "finger printing" attempts to estimate the age by relating the characteristics of the petroleum in the investigation to known changes in formulations of fuels, refining practices and additives.

5.6 *Identification of Suspected Equipment Problems*—Underground storage tank equipment has changed considerably over the years. Manufacturers are constantly introducing new equipment and making changes to older equipment designs. Manufacturing defects are often isolated to one model or even one lot of a particular type of equipment. Complete identification of equipment problems from many sites can help the user identify trends in malfunctions and failures informing preventive maintenance programs and preventing future malfunctions and failures and improving tank system design practices.

5.6.1 *Make, Model and Serial Number*—The make and model number can help identify equipment design, manufacturing technologies used, general installation requirements, possible age, and so forth. The serial number can help identify manufacturing date, materials and manufacturing technologies used, age, and so forth.

5.6.2 *UL Listing*—Many underground storage tank system components carry a UL mark. The Underwriters Laboratory (UL) mark often includes lot numbers and date of manufacture. UL has a system for investigating malfunctions and failures of listed equipment that can aid in the improvement of their standards. A UL reporting form for underground piping is contained in X1.3. Contact UL at the number listed in the Underground Piping Field Report form to report other malfunctions and failures of listed petroleum equipment.

5.6.3 *Documentation*—Pictures and field notes of equipment model numbers, serial numbers and any other identifying marks can be valuable to inform later analysis of equipment problems.

5.6.4 *Working with Equipment Manufacturers*—Equipment manufacturers are often keenly interested in investigating equipment failures. They should be consulted as soon as possible when a piece of equipment is suspected of failing or malfunctioning. They may have specific removal and sample preparation recommendations. In some cases, the equipment manufacturer will send a representative to the site to observe or participate in the investigation.

5.7 *Removing Suspected Problem Equipment*—In some cases, the user may choose to prepare failed equipment for laboratory analysis. Laboratory analysis may be warranted if there is uncertainty in the mode of failure or the reason for the equipment problem. In preparing equipment for laboratory analysis, it is important that equipment be removed in a way that does not cause further damage and allows for further testing. The following are some general guidelines for removing equipment that is intended to be subjected to laboratory tests and analysis. For some laboratory tests, samples of product, backfill, and equipment should be preserved in their as-removed condition as much as possible to more closely represent actual use conditions. For example, drying the hydrocarbons out of a plastic can cause dramatic changes in its physical properties. In some cases, this type of preservation is not practical due to packaging, storage and shipping constraints. The user should consult with the testing expert for specific removal requirements to meet the user's goals.

NOTE 1—User(s) should never attempt to cut samples from any tank or equipment that has not been thoroughly degassed or inerted. User(s) should never attempt to enter deactivated fuel tanks or contaminated sumps without proper confined space entry training. See 29 CFR 1910.146. Many states require special certifications for individuals to remove or repair petroleum storage tank equipment.

5.7.1 *Preparing Samples or Documenting the Equipment Problems*—The equipment should be removed carefully, and care should be taken to not damage or disturb it further. For example the equipment should not be wiped off. Equipment connected to pipes should be removed by cutting the pipe on either side of the problem equipment, if possible rather than unscrewing the pipe connections. In many cases it is helpful to prepare samples of similar, but properly functioning equipment at the site for benchmarking by the expert. Photographs and field notes are often used by experts to analyze the failure when it is not possible to preserve the equipment.

5.7.2 *Preparing Samples of Stored, Trapped, Released Product*—As discussed above chemical analysis of the released product can help estimate the date of the release. Chemical analysis of the product can also identify the mode of the malfunction or failure. For example the presence of plasticizers in released product can indicate that the product has attacked particular plastics or gaskets. It may be helpful to preserve stored product, product trapped in the secondary containment, as well as released product to make a complete analysis of the failure. The user should consult with the testing expert for specific sampling and preservation requirements to meet the user's goals. Generally chemical preservation of liquid product is not required for most analyses.

5.7.3 *Documentation*—Field notes, photos, and videos can all be used to show the condition of the equipment and released product. It is often important to document the removal and sample preparation process so the experts who conduct later analysis can trace the condition of the equipment.

5.8 *Removing Sections of Suspected Problem Equipment*—The user may sometimes need to save sections of equipment such as tanks, piping, and sumps because they are too large to store or ship. It is important to take the sections in a way that allows them to be useful in later analysis. Careful documentation of the sectioning process may help experts who conduct later analysis to trace the condition of the equipment.

NOTE 2—User(s) should never attempt to cut samples from any tank or equipment that has not been thoroughly degassed and inerted. User(s) should never attempt to enter deactivated fuel tanks or contaminated sumps without proper confined space entry training. See 29 CFR1910.146. Many states require special certifications for individuals to remove or repair petroleum storage tank equipment.

5.8.1 *Preparing Samples or Documenting the Malfunction or Failure*—Most laboratory analysis can be conducted on sections as described below. However, some types of analysis need larger sections or special sample preparation techniques. The user should consult with the testing expert for specific sectioning and preservation requirements to meet the user's goals. Samples of the product, residue or backfill that was in contact with the equipment section of interest may be needed for the testing expert to make a complete analysis. This is particularly true when investigating corrosion-related failures as certain chemicals and bacteria have been reported to accelerate corrosion,

5.8.1.1 *Tanks*—In many investigations of tank failures, both the exterior and interior of the tank is examined for signs of failure. Careful visual inspection of the tank may help identify areas of suspected corrosion or flaws. These areas may then be removed for laboratory analysis. Failed or flawed tank sections should be cut out using carbide, Carborundum, or diamond-tipped tools. Typically tank sections are at least 40 by 40 in. and include the jacket material on composite tanks and two ribs on fiberglass tanks when structural testing is planned. Smaller, 12 by 18 in. sections are generally sufficient for visual examination and compatibility testing. Sections should be taken where there is visual evidence of flaws or failures. In analyzing fiberglass tank failures, additional tank samples are often taken at the bottom of the tank (6:00) or near the bottom and at 3:00 or 9:00 positions. Samples at the top of fiberglass tanks (12:00) are sometimes taken for comparison purposes. Internal corrosion of steel tanks is generally most severe in the bottom of the tank near the striker plate and at the sludge line. However, in some cases internal corrosion occurs at the top of the tank. Documenting the suspected corrosion or flaws in the tank with notes, diagrams, measurements and pictures may help experts who were not present at the investigation analyze the failure when it is not practical or desirable to remove sections of the tank.

5.8.1.2 *Pipe*—Typically, failed or flawed pipe sections are cut with 2 to 3 diameters of pipe before and after the failed or flawed section, or about ten (10) diameters overall to allow for test plugs to be inserted in the pipe during later mechanical testing. Pipe sections can be cut shorter if mechanical testing is not going to be conducted.

5.8.2 *Documentation*—Field notes, photos, and videos can all be used to show the condition of the equipment. It is often important to document the removal and preservation process so the experts who conduct later analysis can trace the condition of the equipment. The field notes should include a description of any fluid in the secondary containment.

5.9 *Documenting the Progress of the Failure Investigation*—As discussed in the above sections, documentation is important for experts to trace the condition of the equipment. Documentation is also important to help put together the pieces of an investigation and to substantiate the conditions that were observed during component removal through analysis of the preserved equipment. The following documentation is typically conducted at failure investigations. The user may collect additional documentation to meet specific goals. Practice E1188 provides guidelines for the collection and preservation of information and physical items by any technical investigator.

5.9.1 Notes should be kept to document the progress of the investigation. Notes that are taken in a way that can not be altered, such as in bound books or time-stamped electronic files may allow more reliable determinations of the sequence of events in the investigation.