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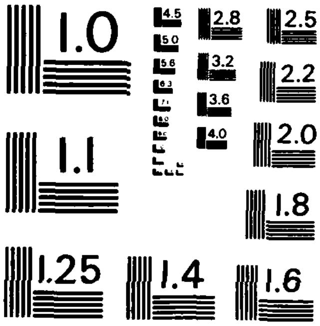

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ESL-TR-85-24

PCB Field Test Kit
Volume I: Field Testing

1LT JAMES R. ALDRICH

USAF ENGINEERING AND SERVICES
LABORATORY (AFESC/RD)
HQ AFESC/RDVW
TYNDALL AIR FORCE BASE
FLORIDA 32403

SEPTEMBER 1985

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This technical report has been prepared in two volumes for two specific audiences. Volume I Field Testing, is intended for persons with no formal laboratory background such as exterior electricians who could perform sampling and testing procedures on transformers, oil circuit breakers, etc., as part of their maintenance duties, and civil engineering personnel who must clean up spill sites. Consequently, Volume I is concerned with how the test is run and how a site is surveyed vs. how the test works and gives cleanup hints and suggested procedures for testing and finding PCB contamination with little emphasis on method development. Only those data necessary to confirm the kit performance are given.

Conversely, Volume II, Method Development/Testing, is intended for use by policy makers who must determine whether or not the kit is appropriate for their organization. As a result, Volume II emphasizes the development of the extraction method, the verification testing for the oil kit, and the data collected during soils testing. The information

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given is meant to serve as a basis for policy decisions with field procedures, spill analysis, and actual cleanup techniques of minor importance.

In either case, Volume I or II, the reports are written to stand alone and need not be read in conjunction with each other.

Soil analysis for polychlorinated biphenyls (PCBs) is a well-established laboratory procedure; however, until recently, the field methods were too complex for nontechnical personnel. Without a simplified test, Air Force cleanup crews working in field situations were seriously hampered. This was the situation with the Alaskan Air Command's efforts to clean up soil inadvertently contaminated with PCBs at the abandoned White Alice Communication System (WACS) sites.

To provide a simplified field test for PCBs, the Air Force Engineering and Services Laboratory (ESL), Air Force Engineering and Services Center, coupled a commercially available analyzer for transformer oils containing PCBs with its own extraction procedure. The result was a PCB field test kit which enabled field teams to perform semiquantitative tests for PCBs in oils or soils, in 5 minutes, for $5 per test. In addition, the test kit can analyze "swipe samples" as well as leaves, grass, etc., by extracting PCB from the sample, measuring the PCB in the extract, and then converting that concentration to a microgram equivalent.

The kit development emphasized finding a field tool for non-laboratory-trained personnel to use in measuring PCB concentrations. The kit is not a replacement for EPA-recognized analytical techniques for PCB measurement in that it cannot differentiate between PCBs and any other organic chloride (e.g., trichloroethylene). To have provided such a level of accuracy and specificity would have defeated the purpose of developing a field method. Instead, the kit compliments standard laboratory techniques by categorizing the contamination in oil or soil samples per the levels set in the EPA regulations.

The kit does have a semiquantitative capability, which adds to its value as a field tool. The ability to approximate contamination levels is useful in mapping a spill area to determine the level of cleanup effort required.

The kit is commercially available as a GSA listed item and the device is being added to Air Force Table of Allowances TA-486.

PREFACE

This technical report was prepared by the Headquarters, Air Force Engineering and Services Center (AFESC), Engineering and Services Laboratory, as an in-house research project under JON 20543046. The objective was to develop a field method for analyzing soils contaminated by polychlorinated biphenyls (PCBs). The research was performed by the Environmental Engineering Branch of the Environics Division (HQ AFESC/RDVW).

The research was performed between January 1983 and March 1984 and included both development and verification of a field analytical method for soil samples and verification testing of a commercially available field test kit for analyzing PCB oil samples. AFESC Project Officer was 1Lt James R. Aldrich.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public including foreign nationals.

This technical report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

OBJECTIVE

This research effort was established to develop a nontechnical, field method to enable field crews to both locate polychlorinated biphenyl (PCB)-contaminated soils and subsequently determine when cleanup efforts were complete.

BACKGROUND

During the Cold War 50s, early warning systems such as the DEWLINE and the White Alice Communications System (WACS) were the basis of our air attack detection capability. Although these ground-based radars were effective, they became obsolete with rapid advances in satellite communications. By the end of the 70s, 69 individual WACS sites had either been shut down or turned over to civilian communications firms such as ALASCOM.

How did this lead to a PCB contamination problem? First, the WACS was, by today's standards, very energy-inefficient with as many as 35 transformers located at any given site. Second, due to the wartime mission, site maintenance requirements were very strict. For example, the dielectric oils used to insulate and cool the electrical equipment were sampled and analyzed regularly for component breakdown and dielectric constant. Unfortunately, many of these coolants were contaminated with PCBs.

When the WACS was operational, PCBs were not recognized as environmental contaminants. They represented the state of the art in dielectric coolants and were used almost exclusively by both the civilian and military industries. As a result, after being tested, the oil samples were often thrown on the ground outside the buildings. By using this "disposal procedure" the problems of clogged plumbing due to the heavier-than-water constituents in the oils were avoided, but it did spread PCB contamination. Hence, the PCB problem was actually caused by standard operating procedures and compounded by the large number of components with dielectric cooling oils. More intricate disposal methods were unnecessary at the time.

PCBs are now a suspected carcinogen and officially banned by the Environmental Protection Agency (EPA). This ban also meant the AAC would have to return to all of these abandoned WACS sites and remove any soil inadvertently contaminated with PCBs.

SCOPE

While PCB spill cleanup is generally a straightforward task, the Alaskan Air Command's (AAC) program was complicated by the remoteness of the WACS sites. The sites on their cleanup list ranged over 6000 miles of Alaskan wilderness and were often accessible only by air. Since the site crews were responsible for maintaining both the landing strips and site access roads, when the sites were in the 70s, maintenance stopped. Major repairs were often necessary just to get the cleanup crews to the sites. In addition, with no laboratory available, finding the contaminated soil and determining when the cleanup was complete were nearly impossible.

The AAC's basic PCB testing requirements were broken into two tasks; first, the required work had to be scoped (where to start digging) and second, the cleanup had to be verified (when to stop digging). During the scoping phase, a small survey team would take soil samples for PCB analysis, log volumes and types of hazardous wastes to be removed (such as leftover PCB oils, solvents, and MOGAS) and record the solid wastes requiring disposal (such as abandoned equipment and empty 55-gallon drums). The soil samples they collected were then brought back to their main base and shipped to a laboratory for analysis. The results were then used to construct a "PCB Map" of the site for the cleanup crews. For example, Figure 1 shows the survey map prepared from the survey of the Fort Yukon WACS site.

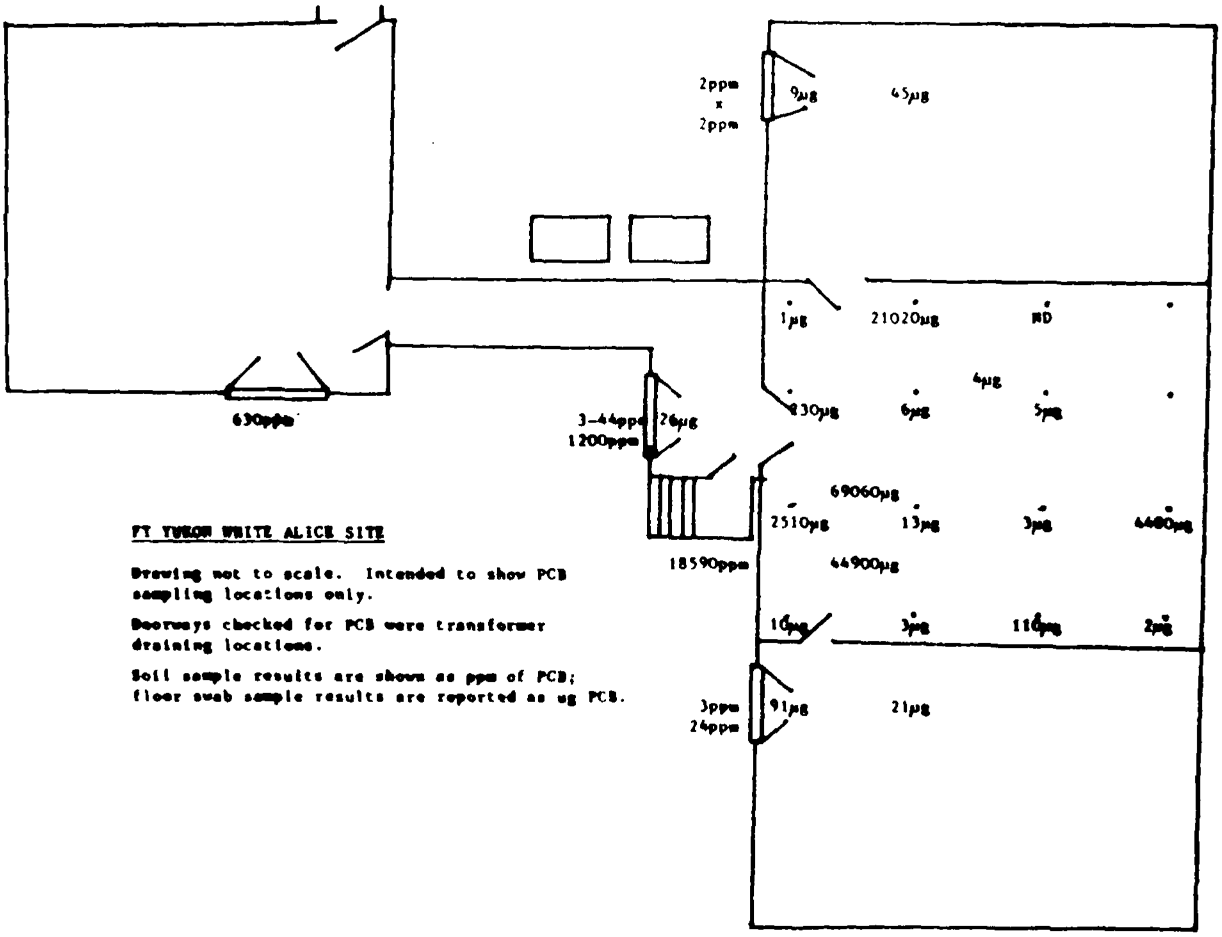

Figure 1. The "PCB Map" of the Fort Yukon WACS Site

The map, along with a listing of onsite hazardous wastes, numbers of empty barrels, etc., would be given to the cleanup crews when they went out to the sites. However, it did not provide the detailed information the cleanup crews needed. The following questions needed to be answered before directing cleanup:

1. Exactly where was each sample taken?

2. Were the samples composited over a 2-foot by 2-foot area? A 6-foot by 6-foot area?

3. Were the samples taken from directly in front of a door? Was the left side of the door composited with soil from the right side?

4. Was the area sampled with depth?

If the map was inadequate, why was it not changed? Given the tools available in the field, it was the best job that could be done. How could the survey crew define a hot spot if their test results were not available until weeks after they had left the site? Because the only laboratory in Alaska performing analyses for PCBs in soils was located in Anchorage, 400 miles from Fort Yukon, a more comprehensive survey was not possible.

In addition, there were two separate PCB test requirements. Even if the survey crews doubled or tripled their sampling to provide a more detailed map for the cleanup teams, there was still a need for a field method to determine when the cleanup was complete. This shortcoming often caused indiscriminate removal of soil to ensure that all the contamination was removed. However, considering that the filled recovery drum (approximately 1300 pounds) had to be airlifted from the sites, this solution was very expensive. Alternatively, a frequent problem was not getting all of it on the first site visit. If this happened, the cleanup crews would have to return to the site for more work. Given the logistics costs of $50,000 to $80,000 to get the crews back to a site, revisiting was even less attractive than indiscriminate digging.

The AAC faced this situation; They had to locate and test the PCB-contaminated soil to determine when could they pull their cleanup crews off the sites. Unless these questions could be answered in the field, the AAC had only the very expensive alternatives of either revisiting sites because of incomplete cleanup or excavating too much soil.

SECTION II

THE EXPERIMENTAL PROGRAM

TEST REQUIREMENTS

The first step was to define exactly what the cleanup crews needed. Obviously, a mobile facility with laboratory extraction and gas chromatographic measurement would provide the analytical capability to determine where to dig and when to stop; however, was that level of complexity realistic or needed? Did the field crews need to measure PCB concentrations or merely categorize the level of soil contamination? The distinction between measuring and categorizing is important.

The EPA does not mandate exact measurements of PCBs such as 98.3 parts per million (ppm). Instead, their cleanup and disposal requirements are based on PCB contamination ranges. For example, the PCB ranges for coolant oils are shown in Figure 2.

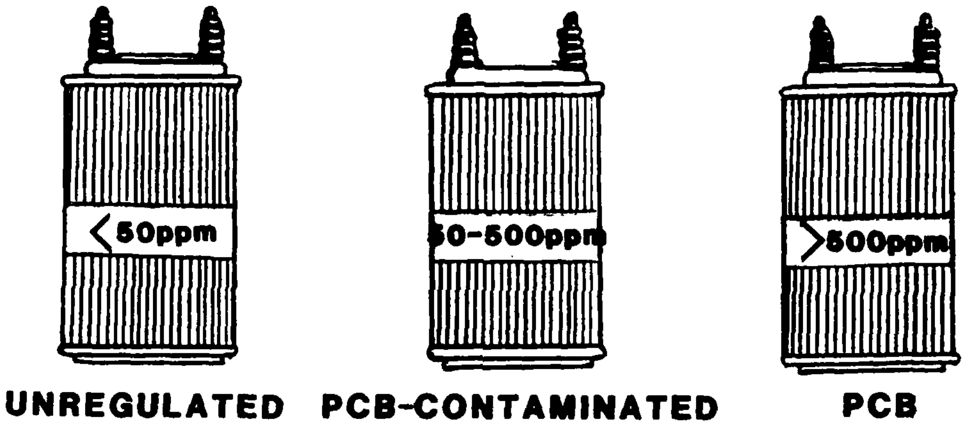

Figure 2. EPA Concentration Ranges for Oil Samples.

Similarly, the AAC's requirements for cleaning up PCB-contaminated soils did not mandate precise analyses. Instead, because PCB concentrations under 50 ppm were unregulated, that level triggered cleanup actions. Any soils containing over 50 ppm PCB would have to be excavated; those containing less than 50 ppm could be left alone.* Although a full laboratory capability would meet the AAC's needs, in view of the regulations, all that was needed was the capability to categorize PCB contamination.

---

*Fifty ppm was selected as the cutoff point for this project because it was the AACs requirement. Given the detection capability of the kit, lower limits could be set and quantified.

The most important requirement for the field test was defined; soil samples needed to be qualified as either contaminated (over 50 ppm PCB) or clean (under 50 ppm). The AAC had other criteria such as portability, power requirements, availability of test reagents, etc., however, the key was the analytical requirement.

ANALYZER SELECTION

Commercially available hardware was surveyed and, although no equipment was found that could test both oils and soils, a number of oil analyzers were available. If an oil analyzer could be used to measure PCB concentrations in a soil extract, the research program would be greatly simplified.

The oil analyzers considered ranged from simple test tube kits to elaborate, portable gas chromatographic (GC) units with dedicated computers. The following criteria were used in evaluating each analyzer.

1. Since the cleanup crews were normally heavy equipment operators, the test method had to be simple enough for personnel with no laboratory training and the equipment could not require a great deal of maintenance or special handling.

2. The device had to yield a simple analytical result with a minimum of data interpretation. Again, an untrained person could not be expected to interpret a GC strip chart.

3. Because PCB extraction efficiency varied with soil type, the analyzer's output would have to be flexible or quantitative rather than a simple qualitative, go/no-go indicator.

4. The device had to accurately categorize PCB concentrations in soils according to the state-imposed criteria.

Because the project became one of adapting an oil analyzer, the analyzer's accuracy in categorizing oils would also be verified.

Except for the GCs, most of the devices evaluated relied upon a chemically induced color change much like the chlorine residual test used for swimming pools. Although these devices were relatively accurate, they were eliminated because they were tied to a specific concentration (generally around 35 ppm PCB) to trigger the color change. This made it impossible to determine the degree of contamination (i.e., over 50 ppm, 500 ppm, or 5000 ppm) in one test and because these analyzers were tied to a preset PCB concentration, it would be difficult to allow for variable extraction efficiencies in different soils. Because cleanup and disposal requirements were tied to the PCB concentration, these colormetric devices were of limited use.

One kit however, quantitatively measured the PCB concentrations in oils and displayed the reading digitally in millivolts. Because this minimized data interpretation and made it easy to incorporate both safety factors and allowances for the variability in soil extraction, it was selected as the measurement device to develop the soil test.

THE ANALYZER MECHANISM

The selected oil analyzer works by relating the amount of organic chloride (on a weight basis) to the concentration of PCB. The first step in analyzing an oil sample is to mix the transformer oil with a strong sodium solution which strips the chloride from the PCB. This mixing combines sodium and chloride ions, forming sodium chloride; an insoluble salt in either the cooling oil, the residual biphenyl, or hexane (the solvent medium).

The next step is to mix the oil/salt suspension with water. When shaken, an emulsion forms and the salt dissolves into free sodium and chloride ions in the water-phase. Then when the emulsion is allowed to stand, the oil and water quickly separate, leaving oil, biphenyl, and hexane in a top layer and saltwater in the bottom layer of the reaction vial. The test then becomes one of simply measuring the chloride concentration in the saltwater layer with a specific ion electrode and relating it to the PCB concentration in the original oil sample. The chloride-PCB relationship developed for the PCB kit is shown in Figure 3.

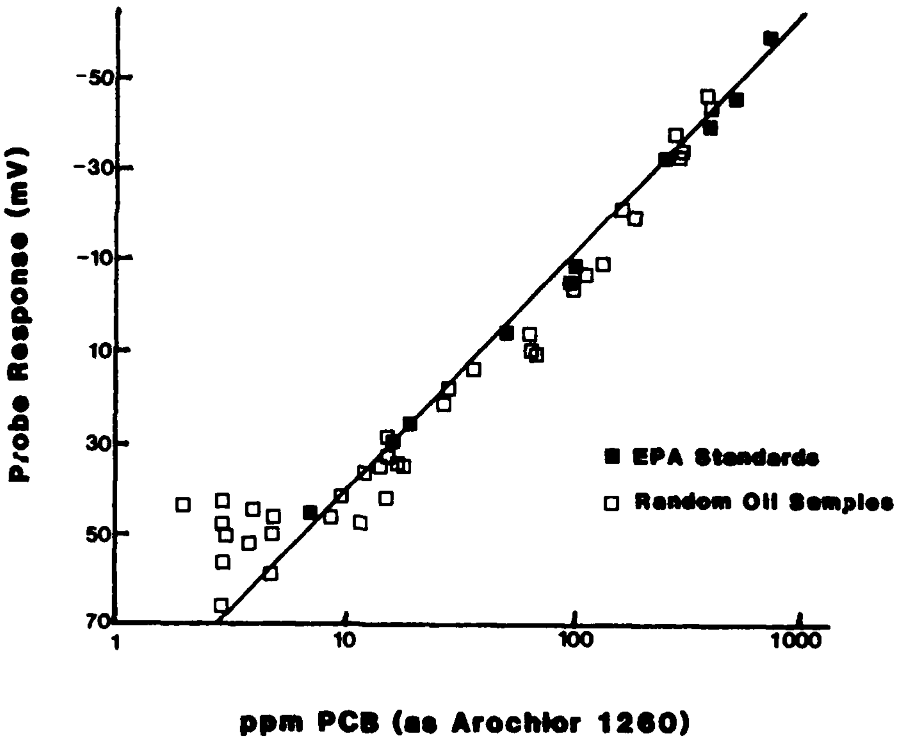

Figure 3. The Chloride/PCB Relationship for Arochlor 1260.
(millivolts vs. ppm)

As shown in the figure, the chloride method can be very accurate at concentrations above 10 ppm. Although an extra test procedure can be added for lower detection limits: such as the 7 ppm California Standard, measuring these very low concentrations was unnecessary for this project. To understand how the PCB/chloride relationship was developed, the chlorinated organics in PCB oil must be defined.

PCB OIL CONSTITUENTS

In general, the amount of bonded chloride in PCB oil varies by brand, and, it can even vary within the oils from one manufacturer. The chloride method used with the selected field kit, is based on the most common transformer oil, Arochlor 1260, or any similarly structured brand such as Askral or Pyranol. The "1260" designator on the Arochlor name indicates that the biphenyl molecules are 60 percent chlorinated (on a weight basis). However, this does not imply that the oils are pure compounds with each biphenyl molecule exactly 60 percent chlorinated. Instead, it refers to a macro relationship. If a large volume of Arochlor 1260 were analyzed, the overall percentage of chloride of the entire sample would be 60 percent. This relationship does not hold on a microscale because of the structure of the PCB molecule itself. As Figure 4 indicates, PCB is made up of two benzene rings (the biphenyl portion) and has 10 possible chlorination sites (the polychlorinated portion).

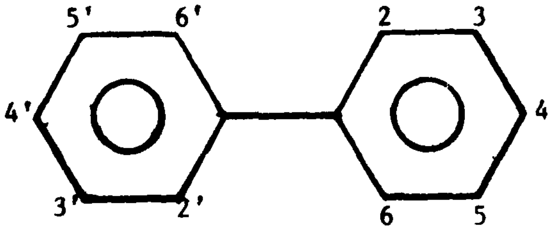

Figure 4. A Biphenyl Molecule Showing the Possible Chlorination Sites.

Since any, or all, of the sites on the biphenyl molecule can be chlorinated, there are 209 possible isomers (called congeners). Because of these many possibilities, determining exactly which congener is present in any given sample is extremely difficult. Consequently, the kit relies on the macro relationship of overall percent chloride.

The various Arochlor types have been analyzed for the various cogeners (i.e., the degree of chlorination) and are described in Table 1.

The cogener type is significant because the greater the number of chlorine atoms carried on a biphenyl molecule, the more persistent the molecule will be in the environment. Generally, environmental stability is broken out with congeners containing one, two or three chlorine atoms classified as readily degradable and those with five or more chlorine atoms as persistent. The tetrachlorinated species are intermediates. This means the less-saturated oils such as 1221 and 1232 can be considered more or less biodegradable and unless the oil spill is relatively recent, there would be no need to have a soil analysis technique based on these congeners. As a result, the AAC's soil analysis method would emphasize the

TABLE 1. APPROXIMATE MOLECULAR COMPOSITION OF THE AROCHLORS

(From the Criteria Document for PCBs, EPA Report PB-255 397)

PERCENT PRESENT IN EACH TYPE

Congener	1221	1232	1242	1248	1254	1260
C_2H_{10}	7	6	-	-	-	-
$C_2H_9Cl_1$	51	26	1	-	-	-
$C_2H_8Cl_2$	38	29	17	1	-	-
$C_2H_7Cl_3$	3	24	40	23	-	-
$C_2H_6Cl_4$	-	15	32	50	16	-
$C_2H_5Cl_5$	-	.5	10	20	60	12
$C_2H_4Cl_6$	-	-	.5	1	23	46
$C_2H_3Cl_7$	-	-	-	-	1	35
$C_2H_2Cl_8$	-	-	-	-	-	6
$C_2H_1Cl_9$	-	-	-	-	-	-
C_2Cl_{10}	-	-	-	-	-	-

-Trace (less than 0.1 percent)

higher-chlorinated oils (Arochlor 1242 - 1260). Also, these higher-chlorinated species are the most common additives for oil-containing electrical equipment such as transformers, oil circuit breakers, and capacitors.

Emphasizing these higher-chlorinated oils brings another factor into consideration. Although the higher-chlorinated congeners are more stable, they are extremely viscous and frequently have very high melting points. For example, one of the pentachlorinated molecules, 2,4,5,3',4' pentachlorobiphenyl, has a melting point of 179°C. If these congeners were mixed with transformer oils at standard temperatures and pressures, they would be solids. Hence, solvents are added to enable these more stable congeners to be used.

In general, tri- and tetrachlorinated benzenes (TCBs) are the most common used solvents. As with PCB, they are chlorinated organic compounds and have many potential isomers; however, the four isomers shown in Figure 5 are most common.

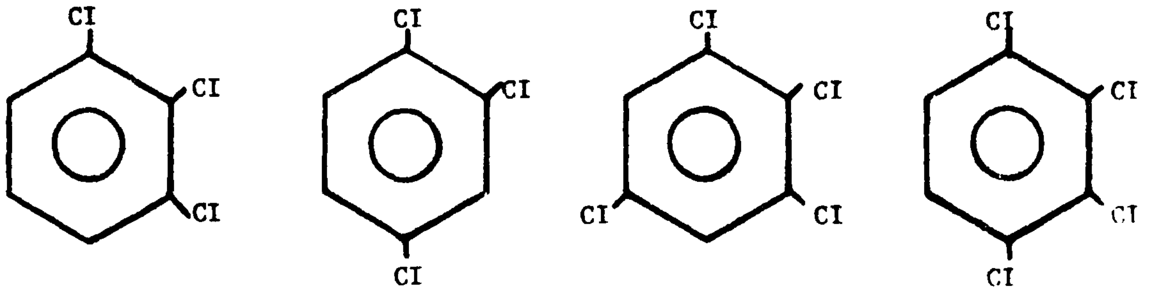

Figure 5. The Major Chlorinated Benzenes Found in Arochlor 1260.

Fortunately, on a weight basis, these TCB isomers are also approximately 60-percent chlorinated and are proportioned in approximately equal parts with the PCB. Hence, the overall 60-percent chloride to biphenyl relationship in the oil is preserved. The presence of these solvents will inflate the chloride/PCB ratio (i.e;, twice as much chloride will be present in the extract because of the TCB contribution); however, because the proportions are consistent, the residual chloride method can still be used with mathematical scaling.

The only other sources of organic chloride in the oil would be contaminants from the manufacturing process such as chlorinated dibenzofurans. Chemically, although very similar to PCB, these contaminant concentrations are very low, typically less than 1 ppm, and because the kit works on a macroscale, they can be ignored.

The concept of measuring PCB indirectly from the chlorinated organics is therefore sound. In fact, the "test tube" kits evaluated also used this type of chemical reaction. With the possible exception of competing chlorinated solvents, the selected test kit can give accurate PCB measurements. (The potential problems from other chlorinated species are addressed in Section VIII of this report.)

SECTION III

SOIL EXTRACTION PROCEDURE

FIELD CONSIDERATIONS

There are two basic laboratory soil extraction methods for PCBs: Soxhlet extraction and agitation. Since the Soxhlet method involves reflux boiling a flammable solvent (normally hexane), it was eliminated for field use because of the inherent dangers to inexperienced personnel. However, because the other method simply involved mixing the soil sample and solvent and agitating them for a given time, there was a good possibility that it could be simplified or "cook-booked" and brought into the purview of the cleanup crews.

To limit the amount of equipment needed in the field, agitation of the sample/solvent by hand was first investigated; however, beyond about 2 minutes, exhaustion makes vigorous shaking and good extraction impossible. This was especially true if multiple analyses were required. In addition to this maximum agitation time, there were other limitations for a field method. Factors such as sample weighing, splitting, and sieving would all have to be addressed. Common laboratory procedures cover these steps, but they would be too cumbersome in the field. At the same time, these sample preparation steps had to be considered or the validity of the field measurement would be questionable.

EXTRACTION METHOD DEVELOPMENT

The initial extraction testing was done at the Environics Division of the Engineering and Services Laboratory (ESL). Standard solutions of transformer type mineral oils were spiked with Arochlor 1260 to approximately 50 ppm. The prepared PCB oil was used to make the following samples:

1. Sample A consisted of PCB oil only.

2. Sample B consisted of PCB oil mixed with an equal mass of hexane.

3. Sample C consisted of PCB oil mixed with Virginia topsoil (characteristics of which will be described later in this report).

4. Sample D consisted of equal masses of PCB oil and hexane mixed with the Virginia topsoil.

All four samples (approximately 5 mls for the oils and 3 grams for the soils) were aged under a drying hood at standard temperature and pressure in 25 ml vials. Each of the samples was periodically checked for PCB, as measured by residual chloride, using the kit. The initial PCB level was unimportant in this phase of the project as long as the concentration in all of the samples was consistent. All that was needed was to establish the variance in the concentrations between the oil-only vs. oil/hexane samples and their soil mixed counterparts. (The hexane was used to help in saturating the soil sample.) To ensure that the hexane did not affect the analysis, the oil-only samples were used as standards.

For these initial tests, equal masses of soil and hexane were mixed and shaken in the 25 ml vial for 30 seconds. The soil extracts were then analyzed with the kit (in the same manner as an oil sample) and the results compared to the oil only (or oil/hexane) results. The oil-only versus the oil-on-soil test results are shown in Figures 6 and 7.

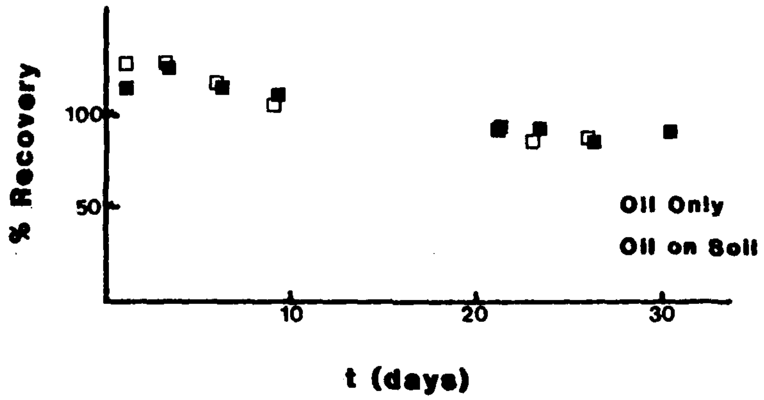

Figure 6. Comparison of Oil-Only vs. Oil-on-Soil Test Results.

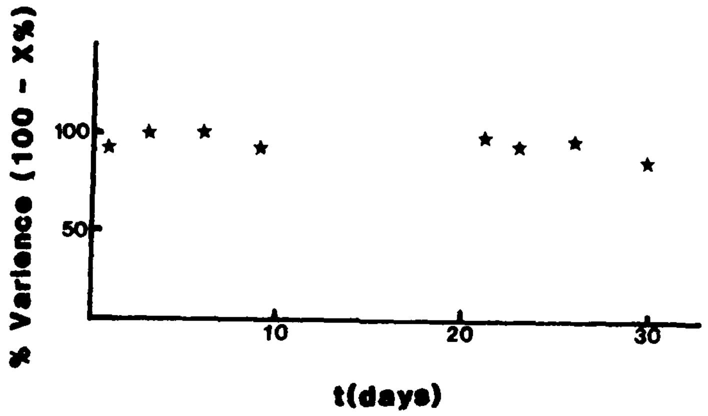

Figure 7. Variance Between Oil-Only and Oil-on-Soil Test Results.

The consistency shown by these two samples was also evident with the oil/hexane counterparts. This indicated the hexane had no effect on the analysis even though the tri- and tetrachlorinated benzenes were relatively volatile when compared to the PCB.

The greater than 100-percent recovery shown in Figure 6 is attributed to errors in measuring the initial PCB stock solution. Again, initial concentration was unimportant compared to consistency. As indicated in Figure 7, the variance between the oil-only and oil-on-soil was nearly zero (note the graph shows 100 - percent variance) indicating good extraction efficiency. There was, however, a noticeable drop in PCB recovery in all samples at approximately 21 days. Whether the apparent decline in PCB concentration was due to adsorption or volatility or some additional factor would be addressed in the next phase of the research program.

SECTION IV

EXTRACTION METHOD VERIFICATION

THE TEST MATRIX

An experimental protocol was established to investigate the new, abbreviated extraction procedure (hereafter referred to as ESL extraction) vs. the standard laboratory method ASTM D3304-77, (hereafter referred to as ASTM extraction). In addition, the oil analyzer (hereafter referred to as either the Field Kit or Kit) would be evaluated for measuring PCB concentrations in the soil extract vs. standard gas chromatographic - electron capture detection (GC-ECD). Figure 8 shows the test matrix developed for this phase of the project.

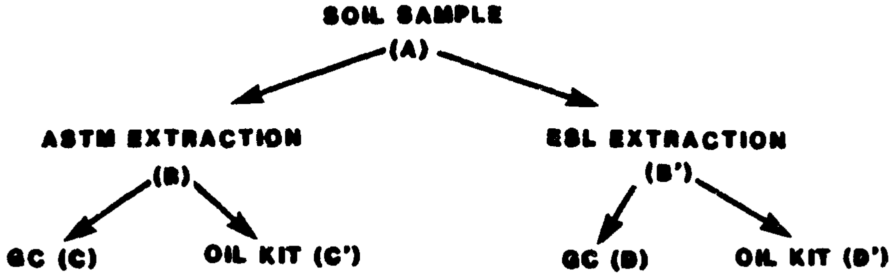

Figure 8. The Soil Method Test Matrix.

Soil samples were tested using this matrix once a week for 8 weeks. By comparing the results from the different pathways, each aspect of the new method, both extraction and measurement, was verified against standard techniques. For example, pathway ABC vs. ABC' compared the kit to GC-ECD; pathway ABC vs. AB'D compared the ESL extraction to ASTM; and pathway ABC vs. AB'D' compared the entire field method to standard techniques.

TEST SOIL TYPES

Next, three separate soil types were selected and contaminated with PCB: Type I, a clay-type subsoil; Type II, a humic topsoil: and Type III, an Alaskan topsoil*. Table 2 shows the characteristics of each soil type.

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* Later in the test program, five additional soil types were added to the experimental program, see appendix A.

TABLE 2. INITIAL SOIL CHARACTERIZATION

SOIL	DESCRIPTION	MOISTURE (%)	ORGANICS (%)	INORGANICS (%)
Type I	Reddish Brown Clay Subsoil (Virginia)	30.1	4.3	65.6
Type II	Black Humic Topsoil (Virginia)	35.5	19.0	45.5
Type III	Black Humic Topsoil (Alaskan)	46.6	26.6	26.7

Note: Organics were measured by TOC using an autoanalyzer. This method was chosen vs. a standard titration technique such as Mebius for convenience; however, comparisons of the two methods showed similar results.

These three types were selected because the particle size range (clay vs. topsoil) and organic carbon content encompass most soil types that would be encountered. The exception would be in coastal areas where the soil type would be very sandy. Because PCB extraction efficiency is largely a function of the organic carbon content of the soil, sandy soils would readily release PCB and were not included in the test program. However, the potential problem with inorganic chloride interferences from these coastal areas will be addressed later in this report.

All three soils were homogenized by successive sieving through and, including a U.S. Standard Number 12 mesh, and gently tumbled prior to spiking. In addition, standard ASTM/GC-ECD analyses for PCBs were done to ensure there was no initial concentration of PCB in the samples. In actual field conditions, bacterial degradation of either the PCB or the tri-tetra-chlorinated benzenes could be a factor. In turn, the soils were neither dried nor sterilized.

Each soil type was then divided into nine fractions of approximately 1 pound each and spiked with PCB. The spiking solution was a standard PCB-free transformer type mineral oil mixed with varying amounts of PCB as Arochlor 1260. This stock oil was then added to the soils to establish the following concentrations (on a mass basis): 0, 15, 30, 50, 75, 250, 500, 750, and 1000 ppm. Procedurally, the spiking consisted of adding a weighed quantity of the PCB stock oil to 20 mls of the PCB-free mineral oil. This was then added drop by drop to the soil as it was stirred in a commercial blender. The residual oil was then transferred to the soil by rinsing with a 5 ml aliquot of PCB-free oil.

INITIAL TEST OBJECTIVES

Five issues concerning the new extraction were addressed before actual matrix testing began:

1. Could the analysis be upset by the presence of inorganic chlorides that would be common to coastal areas?

2. Was there an ideal solvent to soil ratio for the extraction?

3. Was there an ideal soil sample size to optimize the extraction efficiency?

4. Could the 30-second agitation time used in the initial laboratory study be optimized?

5. Was there any effect on extraction efficiency based on the initial concentration of PCB in the soil sample.

TEST RESULTS

Beginning with inorganic chloride interference, the new extraction procedure was based on the solubility of PCB in hexane. Conversely, since inorganic chlorides are relatively insoluble in hexane, these will be eliminated during the hexane extraction step. This was verified by mixing 100 and 1000 ppm of sodium chloride (table salt) with uncontaminated Type I soil and running the ESL extraction. No salt, as measured by chloride concentration, was detected in the extract. Hence, coastal areas could be sampled with no interference from the sea water or salt spray.

Next, solvent/soil ratios and sample size were addressed. To keep the field test as simple as possible, methods that required measuring exact volumes or masses were not considered. Instead, a simple pan balance was used to measure equal masses of solvent and soil. By using equal masses, once the PCB was extracted, the concentration measured in the solvent could be directly correlated to the concentration in the soil. If the study showed that more solvent was needed, multiples of the soil mass (i.e.,2x or 3x) would be measured with the balance. Initially, solvent to soil mass ratios of 1:1 and 2:1 were tested simultaneously with soil sample sizes of 5, 10, and 15 grams. In the laboratory, the amount of soil was weighed using a balance; however, in the field, it would be approximated by specifying the amount of soil to be put in a sample vial (e.g., a "half-full" 25 ml sample vial is approximately 4-5 grams). The results of these tests, using Type I soil at 1000 ppm PCB, are shown in Figure 9.

These results indicate no appreciable advantage was gained in using either extra solvent or larger sample sizes. Although the extraction efficiency shown in Figure 9, was not 100 percent, it was relatively constant. This led to establishing the sample size and solvent/soil ratio for the final ESL method as approximately 5 grams and 1:1, respectively. In addition, minimumizing the solvent ratio and soil sample size would simplify the logistics by lessening the volume of solvent (hexane) that needed to be transported. Since the field test needed only to categorize the PCB concentrations, not quantitatively measure the PCB content of the sample, scaling this consistent extraction efficiency (approximately 90 percent) would pose no problem in calculating the concentration of PCB in soil.

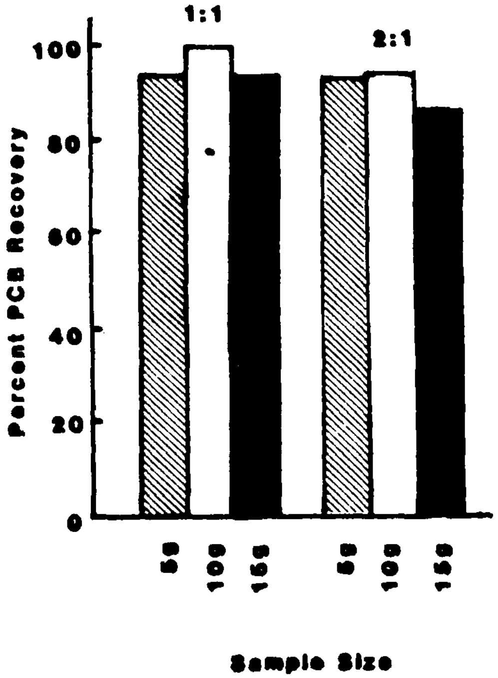


Figure 9. Extraction Efficiency vs Solvent/Soil Mass Ratio and Soil Sample Size

The final issues to be resolved were the optimum agitation time and the potential effects due to the initial PCB concentrations. As determined in the initial studies, 2 minutes was used as the maximum agitation time. Fifteen-gram samples of Type I soil were tested during this phase at concentrations of 50, 250, and 1000 ppm. The results of these tests are shown in Figure 10.

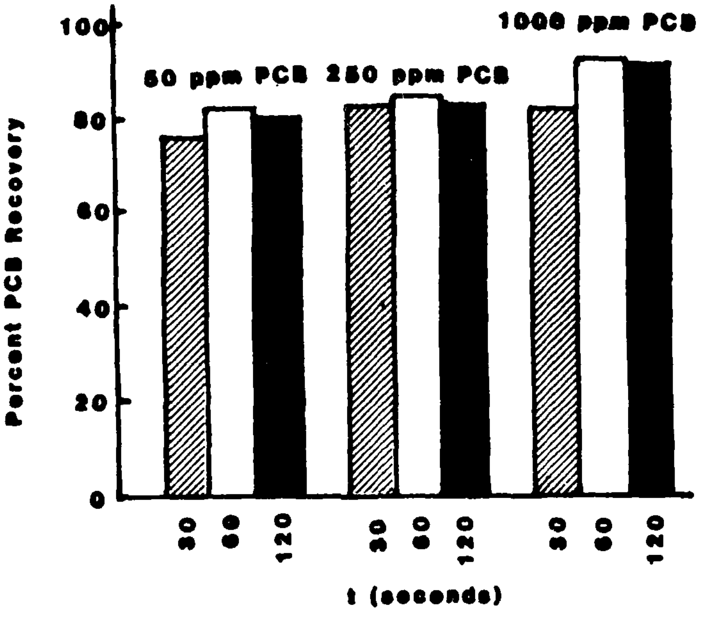


Figure 10. Extraction Efficiency vs. Initial PCB Concentration and Agitation time.

Again, the extraction efficiency of these tests did not reach 100 percent, but at each concentration, there was little advantage in extending the agitation time beyond 30 seconds.

FIELD EXTRACTION METHOD DEFINED

The final ESL field extraction method for PCB soil samples was established as follows:

1. Fill a 25 ml sample bottle approximately one half full with soil.

2. Place the vial and soil in one side of the extraction kit balance and a clean, empty vial in the other side. (Note: caps should not be included with the vials on the balance).

3. Using the eyedropper or squeeze bottle supplied, add solvent to the empty vial until the mass of solvent and its vial is equal to the mass of the soil sample and its vial.

4. Pour the solvent into the soil vial, cap, and vigorously shake the vial for 30 seconds.

5. Using the soil extract as a transformer oil, perform the PCB analysis with the field kit.

With the procedure established and the requirements of the test defined, the matrix testing could begin. Again, the ESL extraction method did not have to be 100 percent efficient nor did the chloride concentrations vs PCB concentrations in the soils need to fit established PCB in oil curves. The key to the success of the project would be if the actual PCB concentrations in the soil could be reliably related to the chloride concentrations measured by the kit in the extract. Problems were anticipated due to factors such as adsorption/absorption of the PCB onto organic carbon and the volatility (relative to PCB) of the TCB which could alter the chloride relationship from that found in the oils. However, a consistent or minimum extraction efficiency was all that would be needed to establish a workable field tool.

SECTION V

MATRIX TESTING RESULTS

TEST OBJECTIVES

Three related issues had to be clarified by the matrix experiments:

1. How did the newly developed ESL extraction procedure compare to standard ASTM techniques.

2. How well would the selected oil analyzer compare to GC-ECD in measuring PCB concentrations in soil extracts.

3. If needed, could the PCB concentrations measured by the new method, ESL extraction and kit measurement, be mathematically adjusted to correlate with concentrations measured by standard laboratory techniques.

EXTRACTION EFFICIENCY

The first issue, the efficiency of the new extraction procedure, was easily checked. Soil samples were extracted by both the ESL and ASTM methods and then both extracts were analyzed for PCB using GC-ECD (i.e., matrix pathway ABC vs AB'D). If the ESL method was equivalent to standard methods, the concentrations in both extracts would be equal. The correlation between the two extraction methods with the Alaskan soil can be easily seen in Figure 11. The data were plotted so that a perfect correlation, as indicated by the dashed line, would be a straight line with a slope of 1.0.

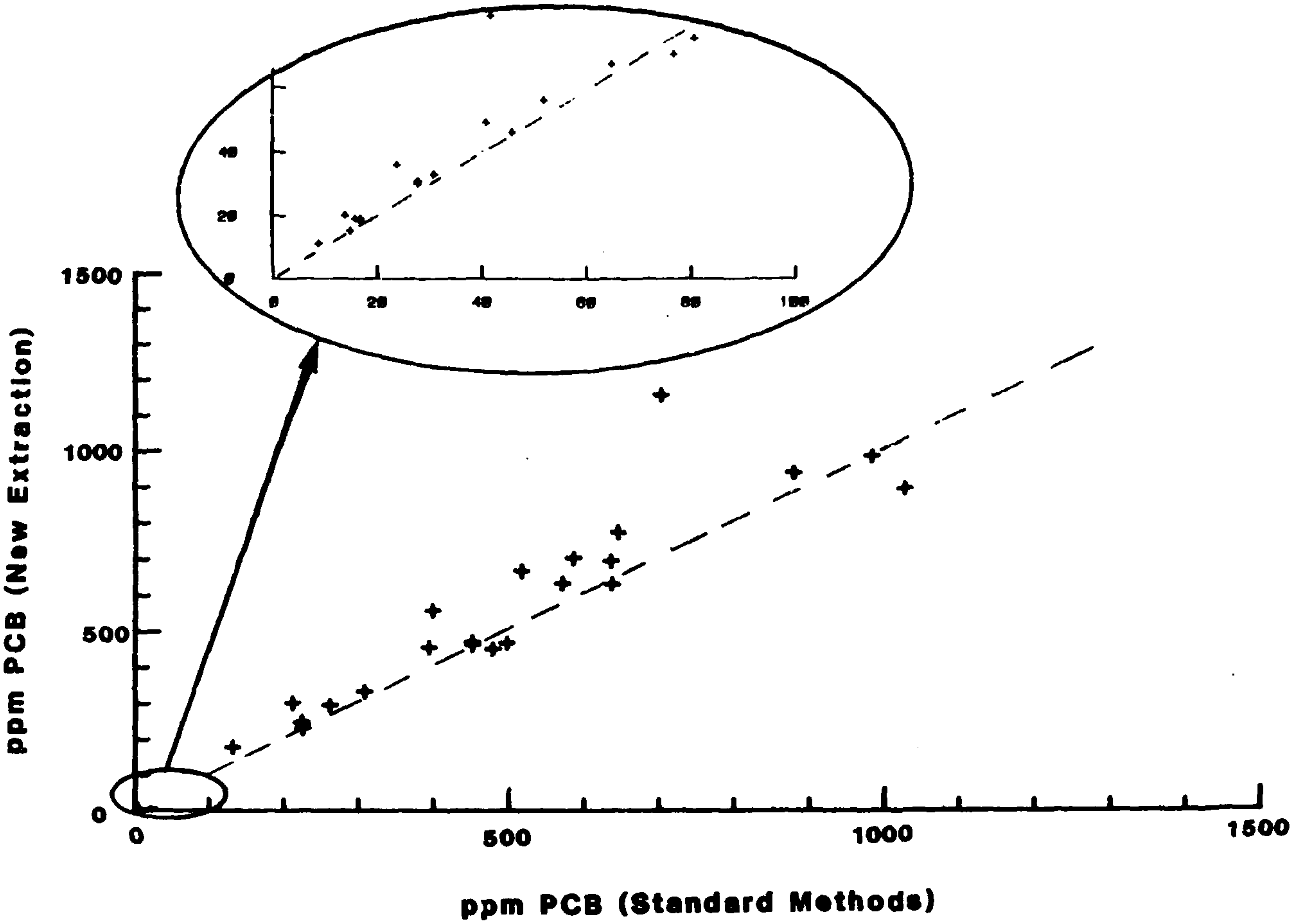


Figure 11. Comparison of the ESL and ASTM Extraction Methods for Type III (Alaskan) Soil.

Accepting minor variations resulting from the soil not being perfectly homogenized, the two methods matched very well. The strong correlation, and the time advantage of the ESL extraction (i.e., 30 seconds vs 24 hours) also makes the new method an attractive alternative for laboratory testing. If a soil sample was extracted using the ESL method and a GC-ECD analysis showed it to be over 50 ppm PCB, unless the customer required a precise quantitative result, there would be no reason to perform a more time-consuming, expensive ASTM extraction. If anything, the ASTM method would be more efficient and only confirm the sample as over 50 ppm.

Similarly, the extraction data from the other two soil types, clay and Virginia topsoil, can be added to the same graph as shown in Figure 12.

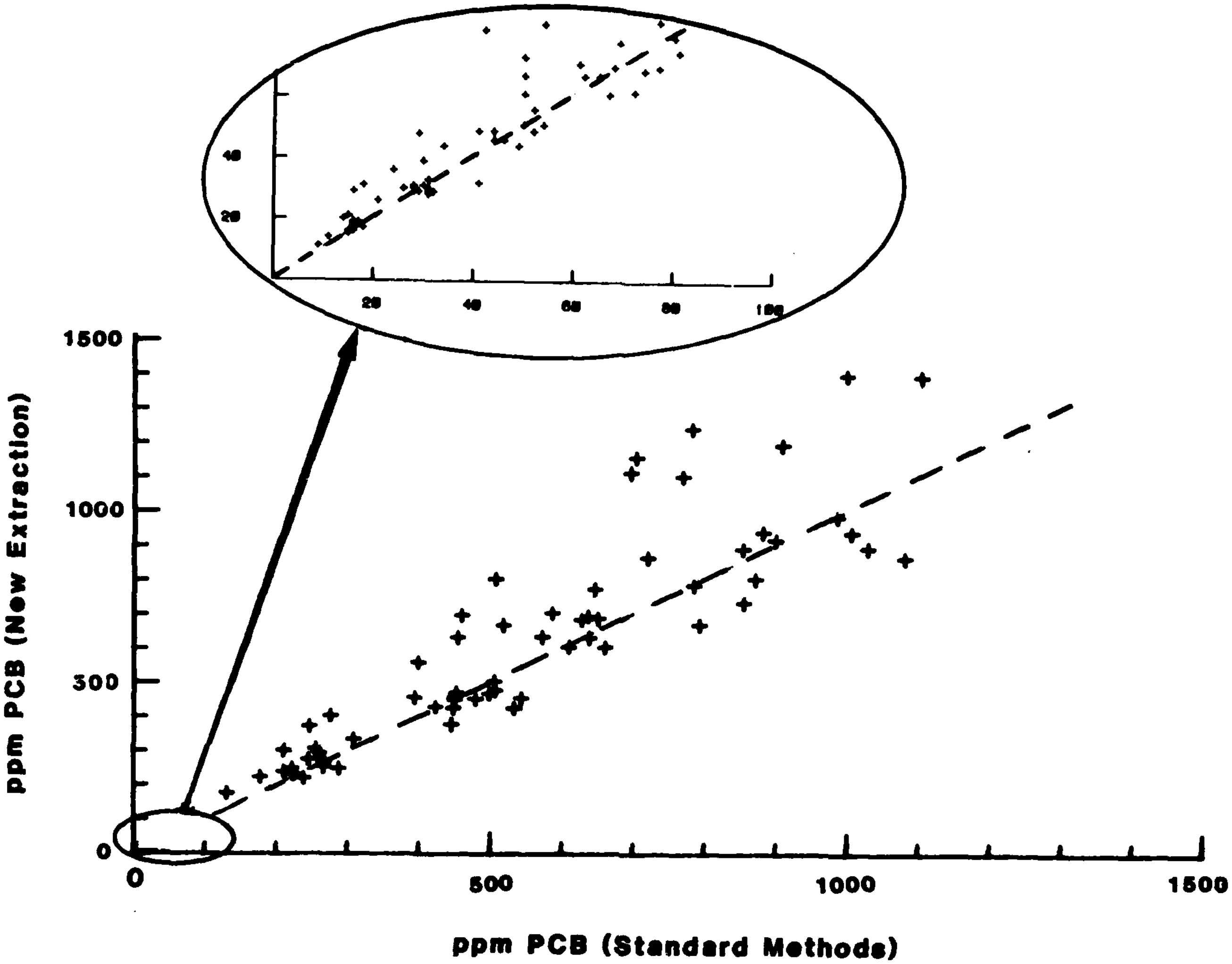


Figure 12. A comparison of the ESL and ASTM Extraction Methods for Soil Types I, II, and III.

Again, the correlation is excellent.

ANALYZER EFFICIENCY

The next issue to address was the reliability and accuracy of the PCB oil kit in measuring the PCB concentration in the extracts from the soil samples. To show this correlation, a similar plot comparing the two measurement methods is presented in Figure 13. Again, the dashed line indicates a 1:1 correlation.

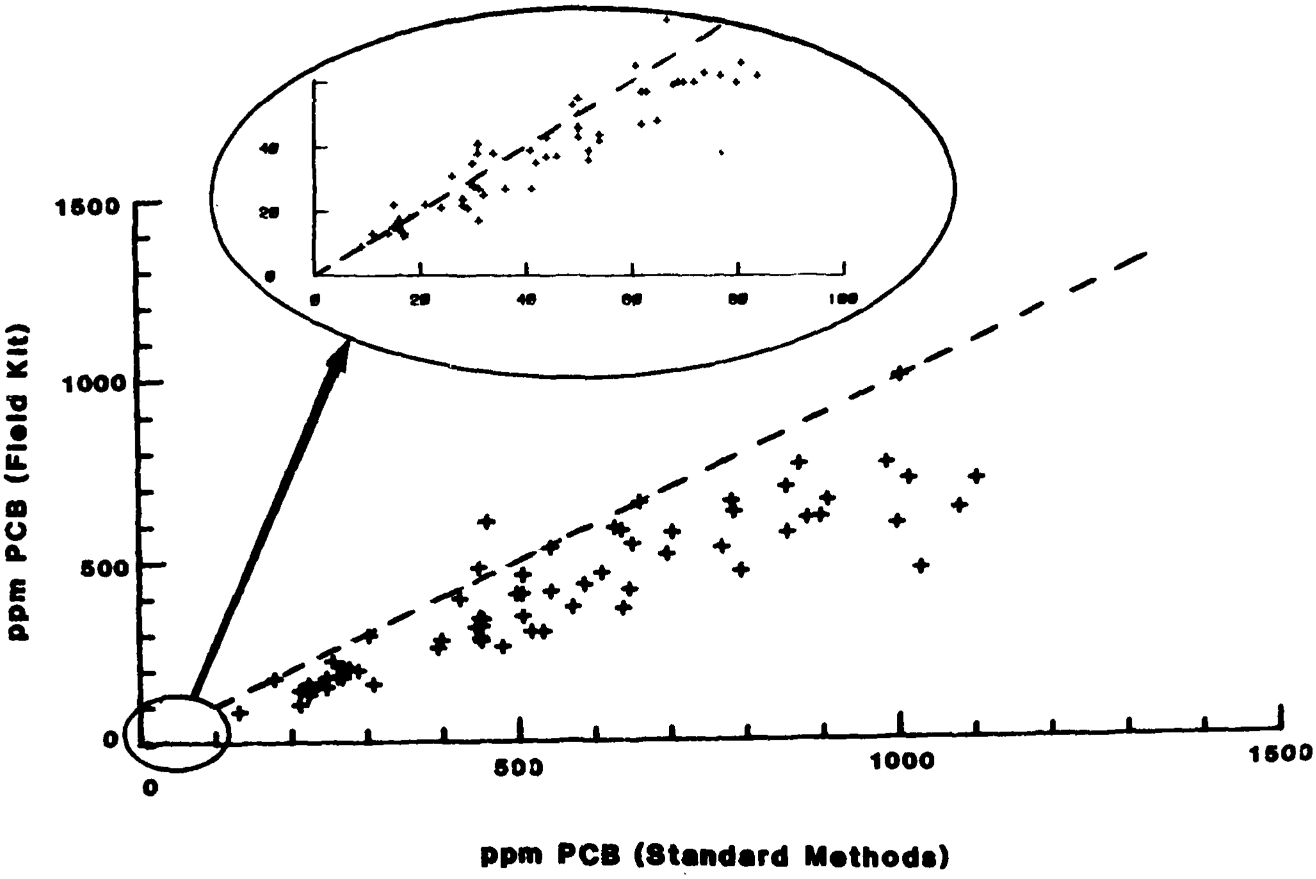


Figure 13. PCB Concentrations Measured in Soil Extracts with the Oil Kit vs. GC-ECD for Soil Types I, II, and III.

Although the correlation is not as good as it was for the extraction method, the graph shows linearity consistent with concentration. Again, the method did not need to be analytically perfect; it only had to be reliable *from a false negative standpoint* (*i.e., the test could not show less PCB than was present in the sample*).

The reliability of the method is better shown in Figure 14 which plots the percent PCB recovered by the field method vs. concentration as measured by standard methods.

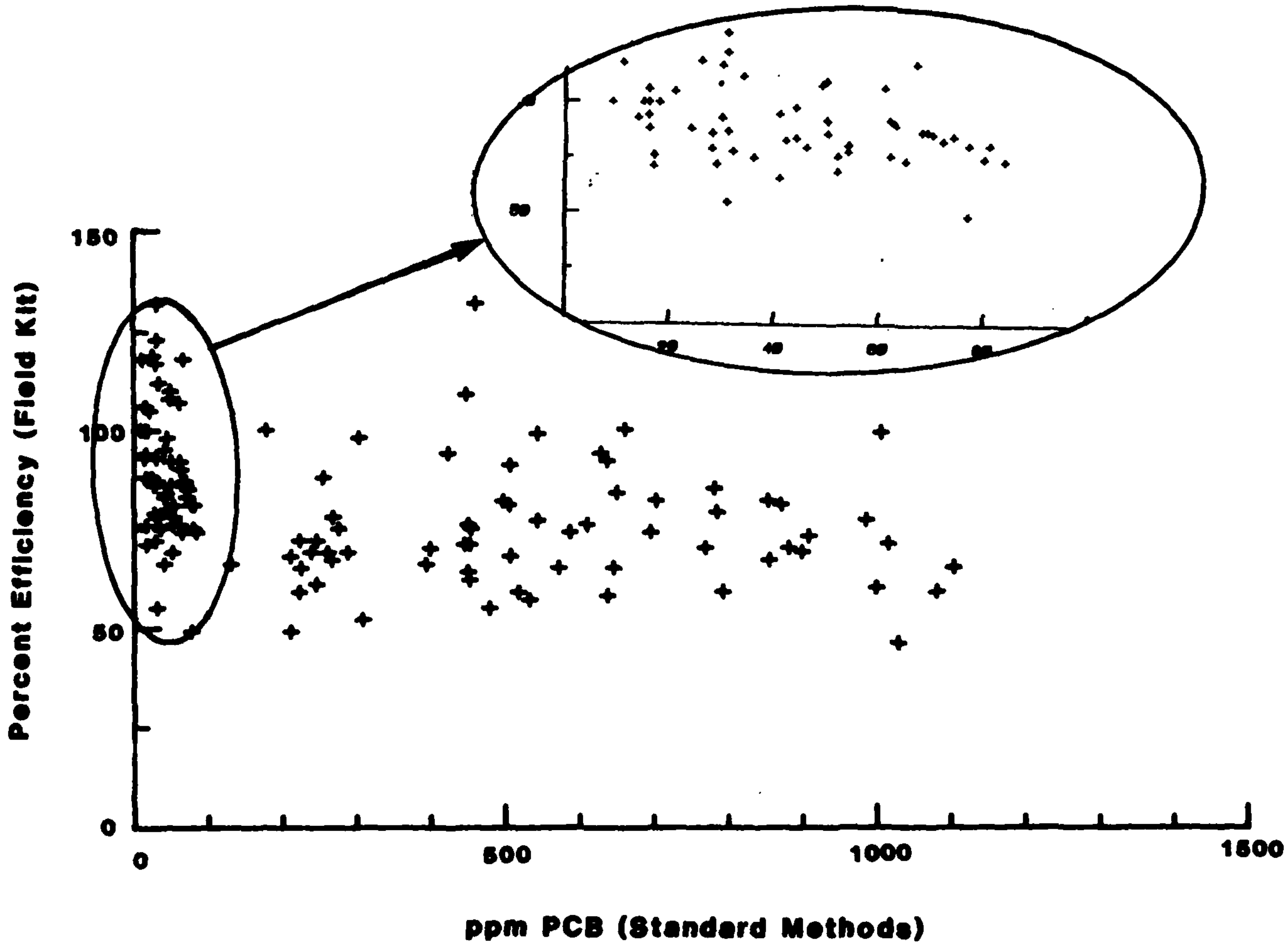


Figure 14. Kit Measurement Efficiency as a Function of Initial PCB Concentration.

Although the "shotgun" correlation shown in Figure 14 at first seemed meaningless, the graph did indicate a minimum efficiency of the measurement. All kit values were at least 50 percent of those measured by GC-ECD. The field data could be scaled up by simply multiplying the measured concentration by two. This approach could cause false positive analyses (i.e., artifically high PCB concentrations), but would eliminate false negatives.

Of even greater importance was the minimum percent of PCB measured in the critical cleanup concentration range of 0 to 100 ppm. In this range, only two data points were less than 65 percent of the GC-ECD value. Analysis of the data in this range led to developing probability estimates/confidence limits.

Hence, on an individual basis, both the extraction and measurement methods were viable; however, the success of the project was how well the entire method correlated to standard ASTM/GC-ECD techniques. Again, Type III soil is presented first because it had the greatest concentration of organic carbon and was considered the "worst case." Figure 15 shows the PCB concentration as measured by the new method vs. the concentration measured by standard methods. As in the previous figures, the dashed line indicates a 1:1 correlation.

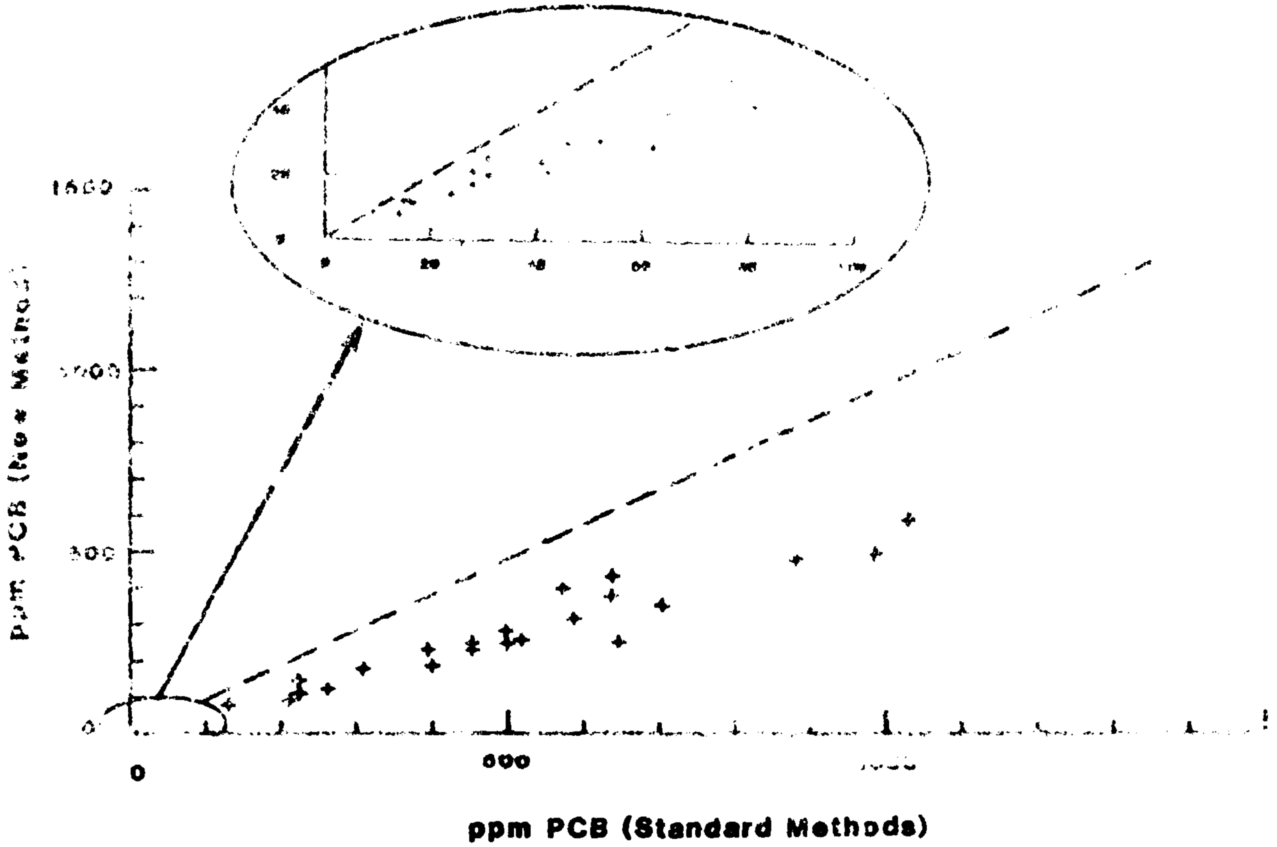


Figure 15. A Comparison of the Entire ESL Method vs. Standard Laboratory Techniques for Type III Soil.

When the data for the two methods were linearized by least squares it resulted in an "r-squared" value of 0.963. While the ESL method underestimated the PCB level, the strong linear relationship gave the consistency required to use a scaling factor to adjust the field test data. If the data from all three soil types are similarly plotted, as shown in Figure 16, this linear relationship is still evident.

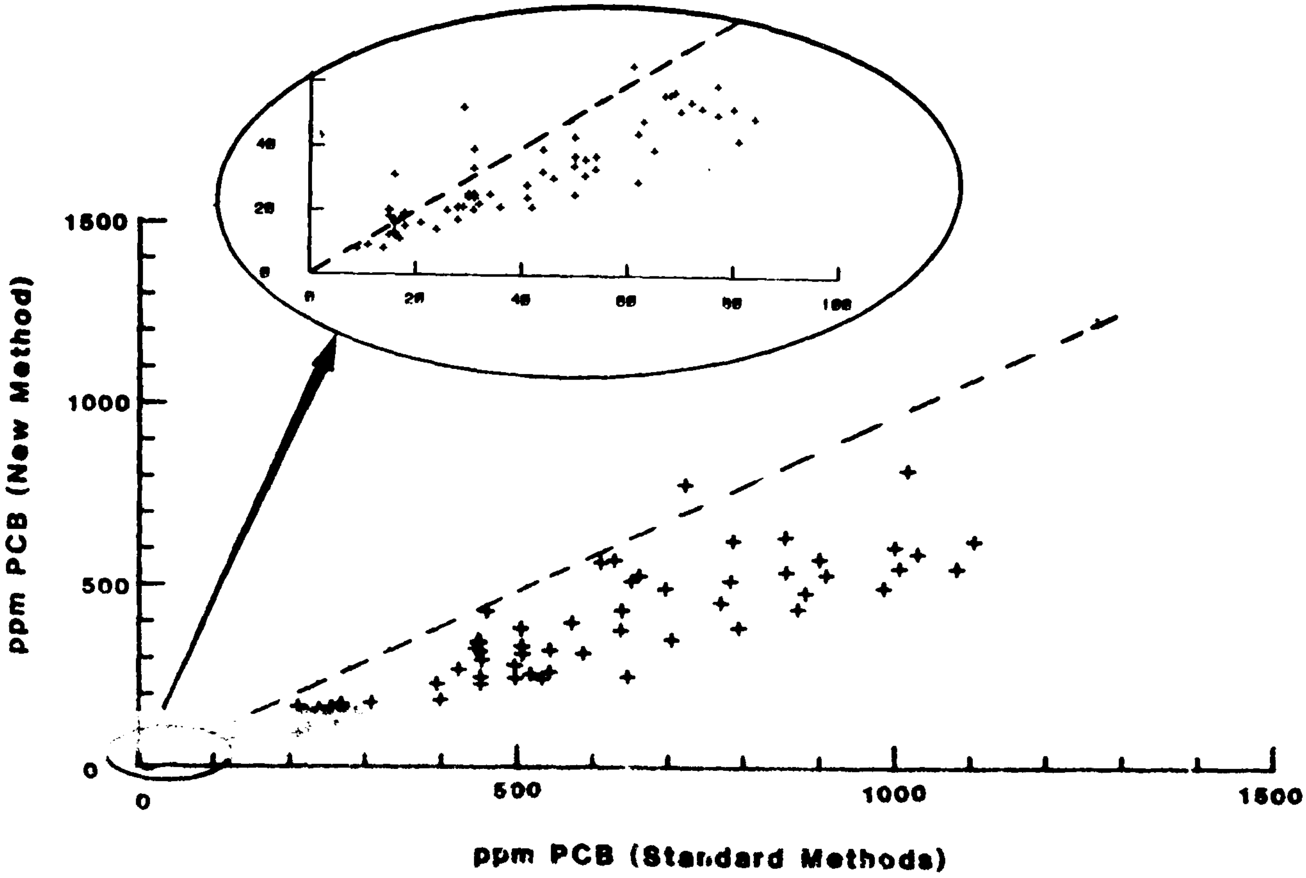


Figure 16. A Comparison of the Entire ESL Method vs Standard Techniques for all Soil Types.

Even though the addition of the other soil types weakened the correlation as compared to the Type III soil alone, the method is still viable because most of the additional data points were in the false positive range relative to the Type III soil. Figure 17 emphasizes this point by indicating the key concentration range, 0 to 100 ppm, vs. percent recovery for the entire ESL/Kit method vs. ASTM/GC-ECD.

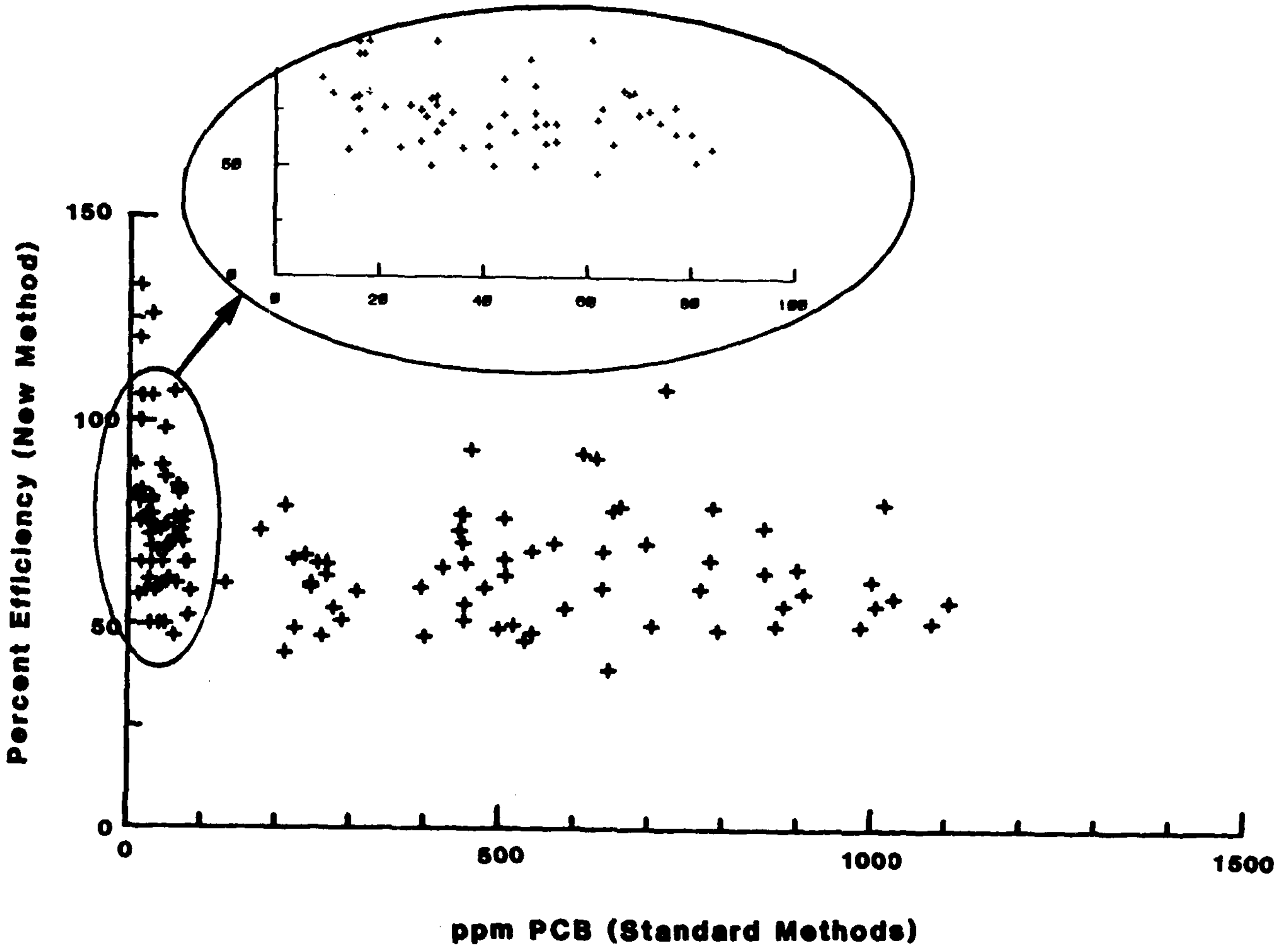


Figure 17. ESL Method Efficiency vs. Concentration of PCB.

Again, a minimum recovery efficiency could be read directly off the plot which could be used in developing a scaling factor for field data.

SECTION VI

OIL TEST RESULTS

TEST ACCURACY CRITERIA

Although the research program was established to develop a soil analyzer for field use in Alaska, there were obvious advantages to having onsite oil testing capabilities. As with the soil test, the accuracy of the oil tester would not be judged by how closely field analysis matched laboratory analysis (e.g., ± "x" percent with small standard deviation). Instead, the merits of the kit would be determined by its ability to accurately categorize PCB concentrations in oils according to the previously mentioned EPA criteria: over 500 ppm, under 50 ppm, or in-between.

Few tests were run by the ESL in verifying the oil kit reliability. Instead, data were collected from five different laboratories who ran nearly 1000 oil tests side-by-side with the field kit and standard laboratory GC-ECD. Four of these laboratories tested random oils (either submitted for analysis, or randomly sampled specifically for kit verification) and one used oil samples spiked to particular PCB concentrations.

DATA INTERPRETATION

Before these test results can be presented, the method to convert the kits readout to PCB concentration must be addressed. The kit measures chloride with a specific ion probe and expresses the concentration as a digital millivolt response in a display such as shown in Figure 18.

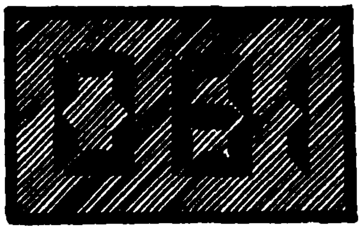


Figure 18. The PCB Kit Digital Millivolt Readout (81 millivolts)

This readout is then converted to a PCB concentration using an equivalency table provided by the manufacture. Because of the differences in the chloride contents of the various oils (Reference Table 1) two PCB oil equivalency tables are supplied, one for Arochlor 1242 and one for Arochlor 1260. The Arochlor 1260 table is reproduced in Figure 19.

Equivalency Table

Probe Response (mV)	ppm PCB (as 1260)	
120	6	
118	6	
116	7	
114	7	
112	8	
110	9	
108	9	
106	10	
104	11	
102	12	
100	13	
98	14	
96	15	
94	16	
92	17	
90	19	
88	20	
86	22	
84	23	
82	25	
80	27	
78	30	
76	32	< 50 Range
74	35	
72	37	
70	40	
68	44	Test 50 Range
66	47	
64	51	
62	55	

(Continued)

Probe Response (mV)	ppm PCB (as 1260)	
60	59	
58	64	
56	69	
54	75	
52	81	
50	88	
48	95	
46	102	
44	111	
42	119	
40	129	
38	139	
36	151	
34	163	
32	176	
30	190	
28	205	
26	222	
24	240	
22	259	
20	280	
18	303	
16	327	50 to 500 Range
14	353	
12	382	
10	413	Test 500 Range
8	446	
6	482	
4	521	
2	563	> 500 Range
0	608	
-2	657	
-4	710	
-6	767	
-8	829	
-10	896	
-12	968	
-14	1046	

Figure 19. The Arochlor 1260 Equivalency Table.

Although the tables are easy to use, it was a potential problem area for the operators. Because two tables were supplied with the kit, operators would have to determine which type oil they were testing (Arochlor 1242 or 1260) to know which chart to use. In addition, if the operator was running soil tests, an additional scaling step would be required. As a result, the Engineering and Services Laboratory developed a wheel, similar to a circular slide rule, to interpret the millivolt response. The wheel, as developed for oil samples, is shown in Figure 20.

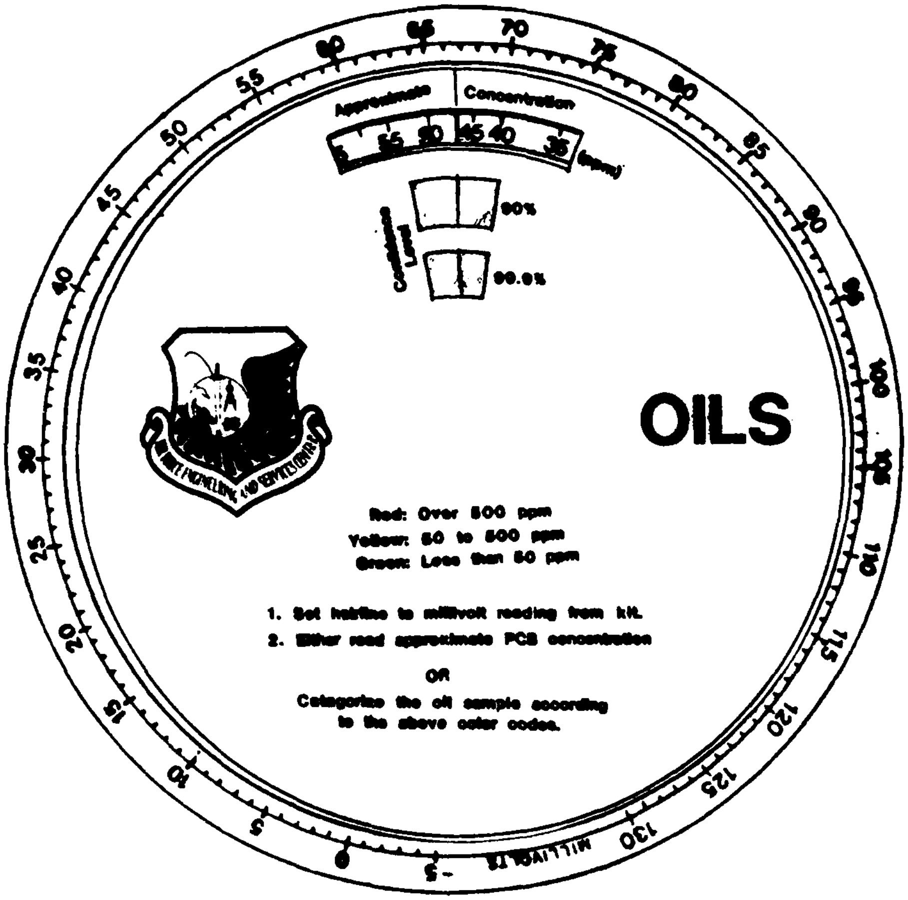


Figure 20: The ESL Wheel for Converting Millivolts to a PCB Concentration

With the wheel, the operator sets the hairline to the millivolt readout from the kit and the PCB level is indicated by the color that shows through the selected confidence limit window. Because the EPA regulations specify categorizing oils, the wheel was based on the same principle; if red showed through the selected window, the concentration was over 500 ppm; if yellow, the concentration was between 50 and 500 ppm; if green, below 50 ppm. The confidence limits were established from the empirical data and corresponded approximately to the two major Arochlors; the 90-percent limit to Arochlor 1260 and the 99.9-percent confidence limit to Arochlor 1242. Again, the difference was based on the chloride concentrations of the two oil types; Arochlor 1242, with no TCB solvents, was the worst case. Deciding which confidence limit to use is a management responsibility and relieves the operator of all interpretations/policy decisions.

OIL TEST KIT RESULTS

Figure 21 shows the results of the oil testing under the criteria of whether or not the kit properly classified the oil samples per EPA requirements.

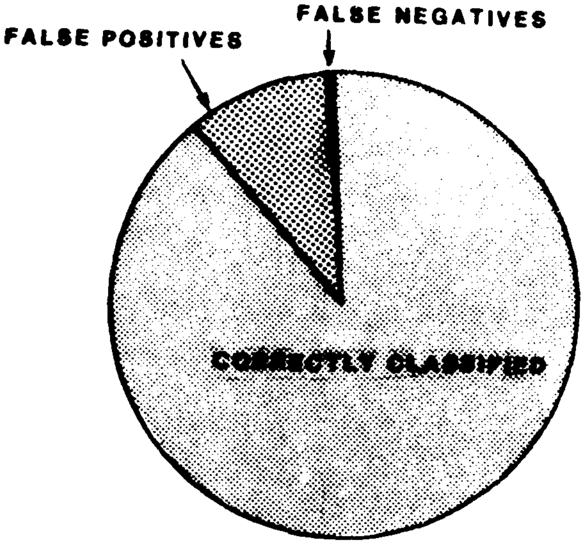


Figure 21. Oil Test Results from the Kit vs. GC (90-Percent Confidence Limit).

Even using the less conservative (90-percent) confidence limit, only 0.5-percent of the samples yielded false negative answers, i.e.,oils classified too low, and these could have been eliminated by simply using the 99.9-percent confidence limit. However, this higher safety factor would also increase the number of false positive (artificially high) answers. Figure 22 shows this increase graphically by showing the same test results as Figure 21, except using the 99.9-percent confidence limit.

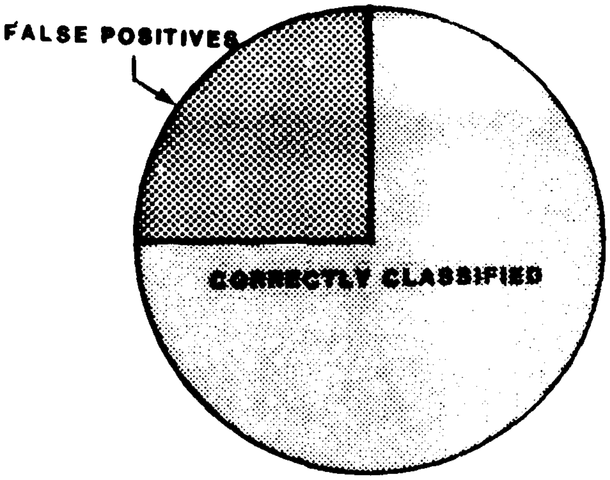


Figure 22: Oil Test Results from the Kit vs. GC (99.9 Percent Confidence Limit)

CONFIDENCE LIMITS

Deciding which confidence limit should be used depends on three factors. First, in general, the Air Force data indicate Arochlor 1260 (the 90-percent confidence limit) was most often used in transformers and Arochlor 1242 (the 99.9-percent confidence limit) in capacitors. In addition, Arochlor 1260 is roughly equivalent to the other common "PCB oils" such as Askral and Pyranol.

Second, as shown in Figure 23, the PCB concentrations found in the electrical equipment can influence the decision. (Note: Only the random samples are included in Figures 23 and 24.)

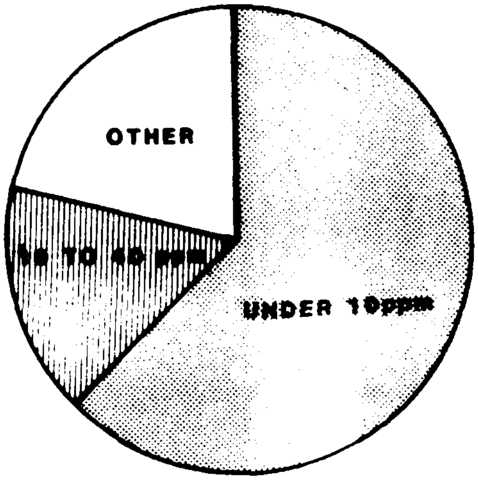


Figure 23. PCB Concentrations from the Random Oil Samples.

Similarly, the percentage of the random oil samples close to the critical cutoff points of 50 and 500 ppm must be considered. Figure 24 shows the same data presented in Figure 23 except the critical ranges within 20 percent of 50 and 500 ppm are emphasized.

Two key conclusions can be drawn from these last two figures. First, over 75 percent of the 700+ random oil samples contained less than 40 ppm PCB; nearly 65 percent were under 10 ppm. Second, very few of the samples fell within ± 20-percent of the critical cutoff points; only 3 percent were in the 40 to 60 ppm range and only 1 percent was in the 400 to 600 ppm range. Hence, the probability of a false negative answer under these conditions became even smaller. This also indicates the value of using the field test kit as a screening device. If the kit were used on all oils and only those samples close to the 50 and 500 ppm cut off concentrations were checked, it would eliminate approximately 95 percent of the laboratory analyses.

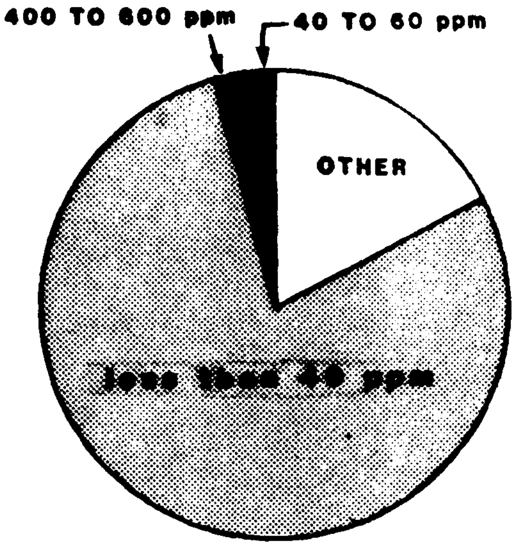


Figure 24. The PCB Concentrations in the Random Oil Samples Near the Critical Ranges

The final consideration in selecting a confidence limit is economics. The PCB regulations allow all oils to be disposed under "worst-case" circumstances (over 500 ppm PCB) without analysis. This is the same concept as using an analyzer with a 100-percent false positive analysis rate. The kit, using the 99.9-or 90.0-percent confidence limits, can reduce this rate to approximately 25- and 10-percent false positives, and conventional laboratory techniques can reduce this even further. The question is then one of how much should be paid for each increment of accuracy.

Even if the advantage of having an analyzer immediately available is ignored, the field kit can be compared to alternative methods based on the cost of testing. Making a conservative assumption that two out of every five test samples are soils vs. oils, a comparison on a cost per analysis can be made. Figure 25 shows the cost of field kit analysis (at $5 per test plus the hardware cost) compared to both standard laboratory techniques (based on $50 for an oil sample and $80 for a soil sample) and one of the "test tube" kits (based on $8 per oil test and $80 for a soil test - i.e., standard laboratory costs).

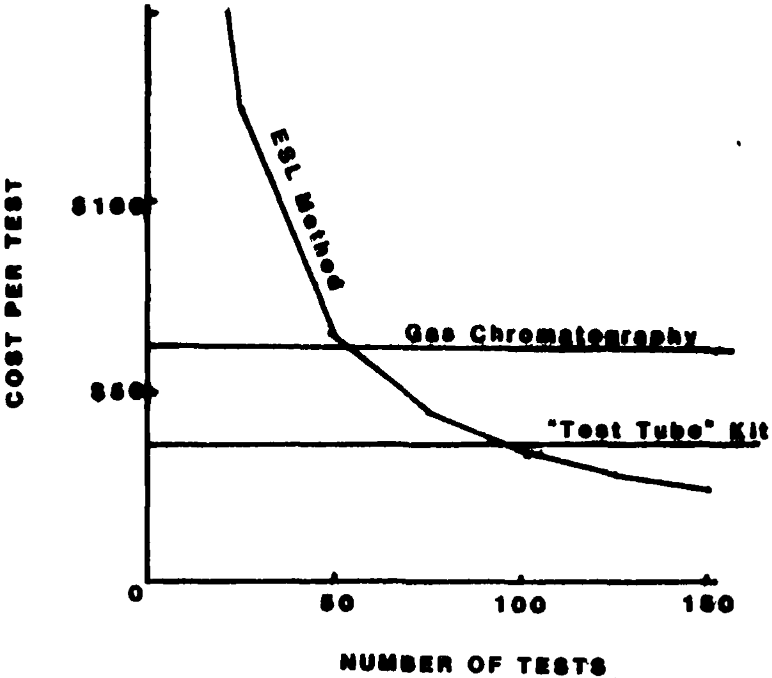


Figure 25. Cost (per test) Comparison of Three PCB Measurement Alternatives.

The breakeven point for 40-percent soil testing (i.e., two out of every five tests) is approximately 100 tests. Similarly, if only one out of every five tests is on soil samples, the breakeven point would be approximately 200 tests.

For bases with a very large number of transformers and oil circuit breakers to analyze, such as those with primary mission involving radar or communications, the same sort of analyses can be made for oil samples only indicating total costs vs. numbers of tests. Figure 26 shows the cost comparison under these circumstances.

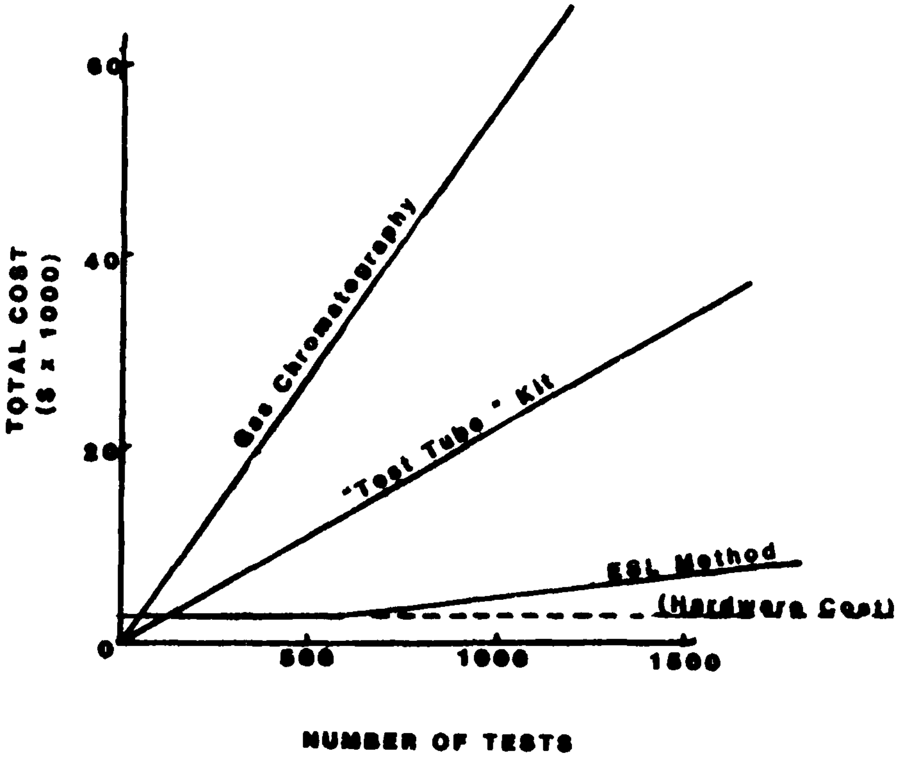


Figure 26. Cost (Total) Comparison of Three PCB Measurement Alternatives.

Again, these cost figures ignore any potential benefit of having an analyzer on hand, not having to ship samples, etc. All of these factors must be considered in determining the appropriate confidence limit or the applicability of the kit in any given situation.

SECTION VII

SOIL TEST RESULTS

READOUT INTERPRETATION

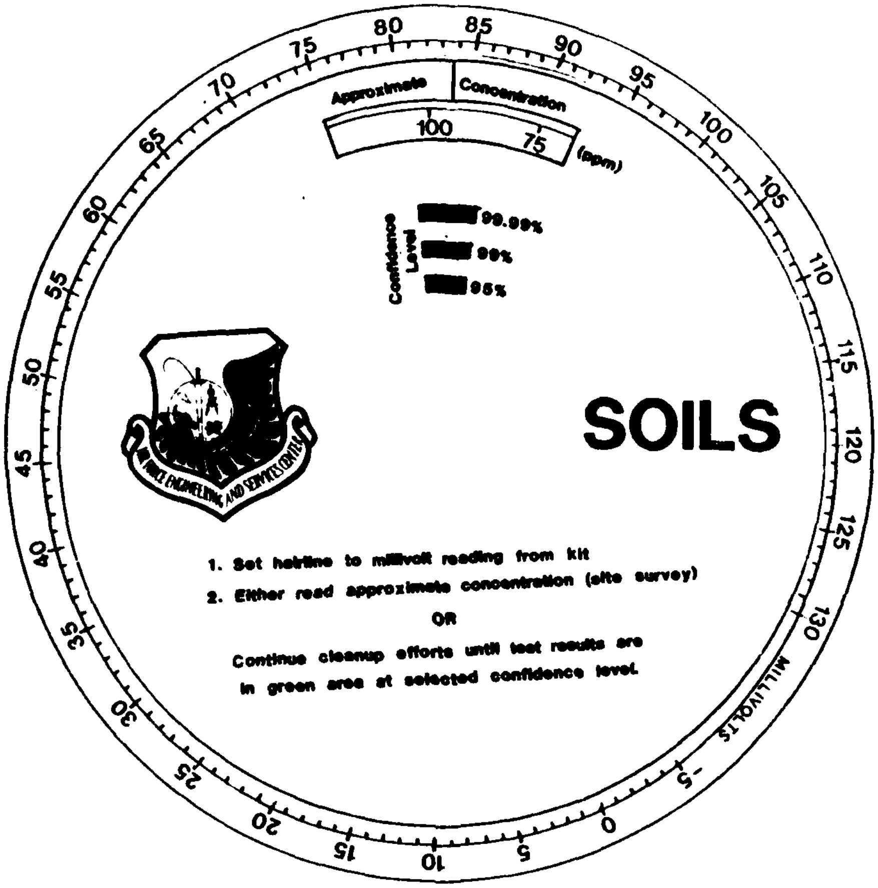
To convert the kit's millivolt readout to a parts per million answer in soils, two factors need to be considered. First, the kit measures PCB concentrations on a volume-to-volume basis and soil concentrations must be expressed on a mass-to-mass basis. This means the data from the kit must be adjusted for the specific gravity of the solvent. Second, the efficiency of the extraction/measurement method must be addressed. With the understanding that false positive answers are acceptable, 40 percent recovery (Figure 17) can be used as a minimum.

Combining these two considerations led to finding a simple empirical factor. Assume an operator has measured the chloride concentration in the soil extract and has an equivalent PCB oil concentration from the Arochlor 1260 equivalency table, "X" mg/l. This volume-to-volume concentration must be divided by the specific weight of hexane to change the answer to a mass-to-mass basis, and then scaled up with an additional factor to allow for the minimum extraction efficiency. This can be expressed mathematically by dividing the ppm answer from the equivalency table by .667 (the specific gravity of hexane) and by 40 percent (the minimum extraction efficiency) as follows:

$$\frac{\text{X ppm PCB (mg/l)}}{(.667 \times 40\%)} = \frac{\text{X ppm PCB (mg/l)}}{(8/30)} = \begin{array}{l}\text{X x 15/4 ppm} \\ \text{PCB (mg/kg)}\end{array}$$

To provide an additional margin of safety, this final factor was rounded to 4.0. Hence, "X" ppm PCB from the equivalency table would be "4X" ppm in a soil sample.

To simplify the conversion for the operator this factor was incorporated into the "wheel." In addition, confidence limits were established for soil testing as previously done for oils. For the operator, the procedure is almost the same as in analyzing oil data. The hairline is set to the millivolt readout from the kit and the color showing through the selected confidence limit window indicates the concentration of PCB on a mass-to-mass basis; red indicating over 50 ppm and green under 50 ppm. The "soil wheel" is shown in Figure 27.



1. Set hairline to millivolt reading from kit
2. Either read approximate concentration (site survey)

OR

Continue cleanup efforts until test results are in green area at selected confidence level.

Figure 27. The ESL Soil Wheel

For example, using the wheel setting in Figure 27, the millivolt reading from the kit would have been 84 mV and the sample would show as above 50 ppm through all three confidence windows. The "approximate concentration" window was included to estimate the degree of contamination in a cleanup scenario. In addition, the approximate concentration window was used in comparing the new ESL method with concentrations measured by standard laboratory techniques. As with the oil wheel, management must decide which confidence limit to use.

Depending upon whether the field team is performing a survey or actually engaged in a PCB cleanup, the soil wheel can be used in two ways. If the kit was being used for a field evaluation or a site survey, in addition to developing a "PCB map" designating hot spots, the approximate concentrations would be useful in determining the degree or extent of contamination. On the other hand, if the kit were used in a cleanup situation, all that would be required would be to categorize the soils. In essence the kit would become a "go/no-go" (or "dig/no-dig") gauge. In this later case, the confidence limits would be unnecessary once the minimum millivolt reading was found. For example, the crew may be directed to clean an area until all samples read at or above 105 millivolts.

SOIL SAMPLING

At this point, the new PCB soil analysis method was within the capabilities of the field crews; however, one area still needed to be addressed. Under the "garbage in garbage out," concept, familiar to computer operators, the field analysis could be no better than the soil sample collected. If the sample were not representative of the area surveyed, the analysis would be worthless. A tool was needed to ensure that inexperienced personnel could collect a representative sample of a given area. After a number of developments, the sampling tool shown in Figure 28 was developed and is now included with the PCB field test kit.

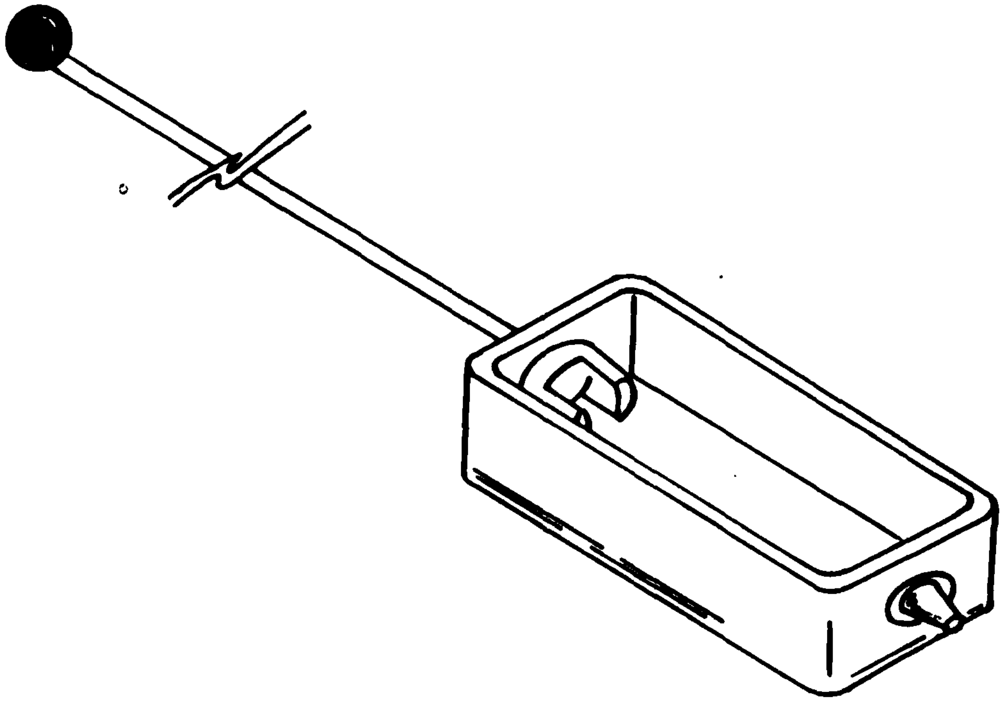


Figure 28. The Composite Soil Sampler

To use the device, a 25 ml sample bottle is inserted into the sampler. Then, holding the sampler like a cane, the device is tamped on the ground, to force a small core of soil into the nozzle of the sampler. Successive tamping forces the individual soil cores up and into the sample bottle, until the bottle is approximately 1/2 full. Figure 29 shows this concept.

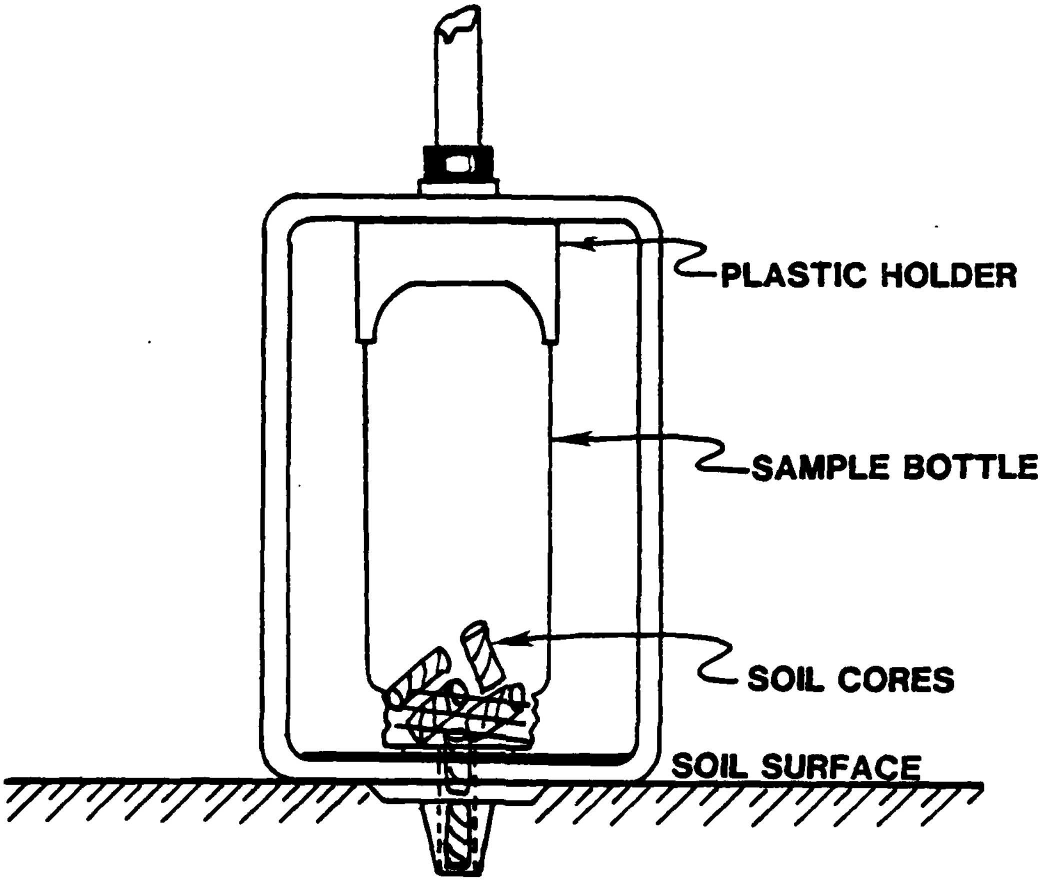


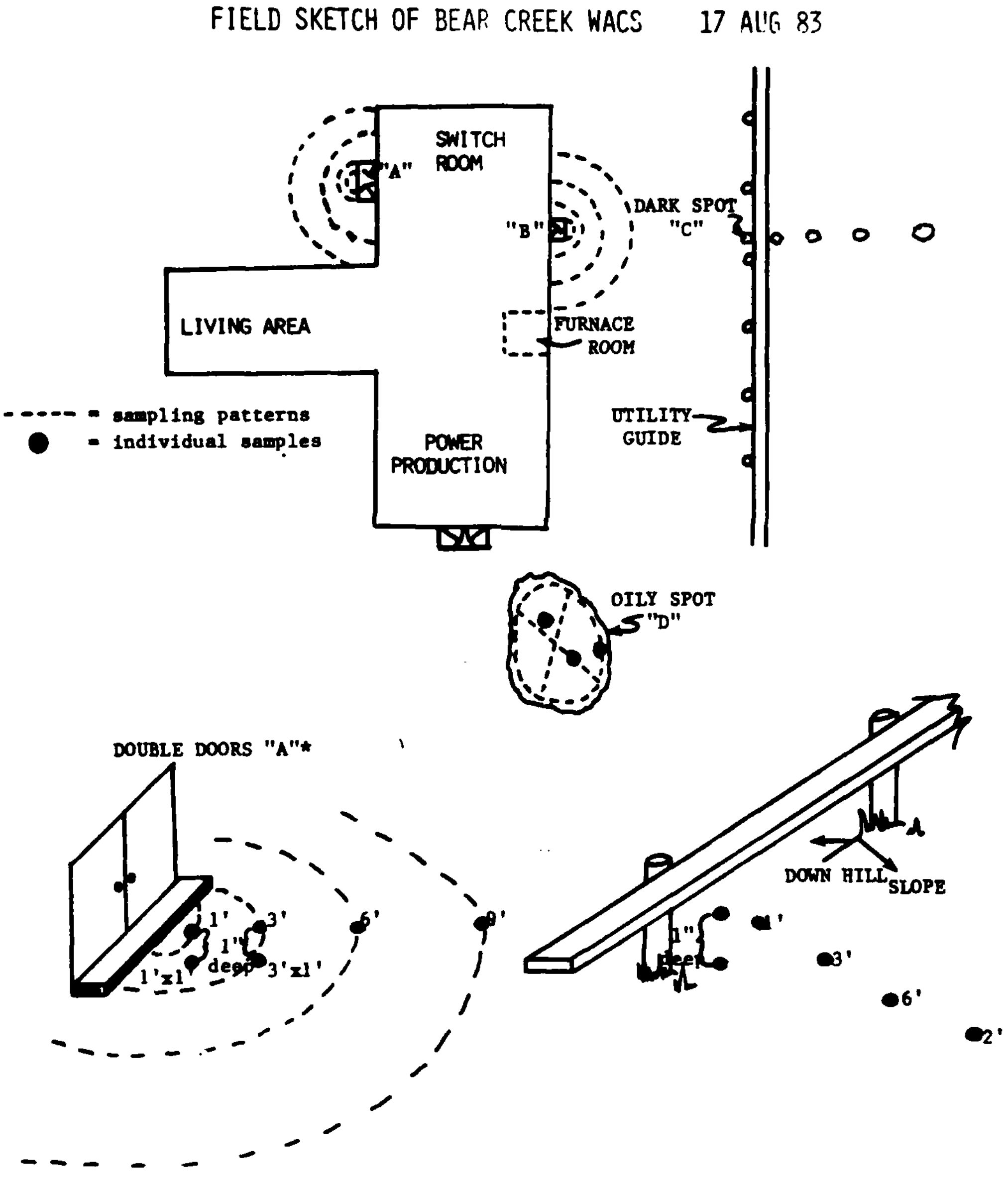
Figure 29. The Mechanics of the Soil Sampler.

After the sample is collected, the soil remaining in the tip is forced into the bottle (a 10-penny nail works very well for this). Then, having been removed from the sampler, the sample bottle is ready for extraction. If the sample is tested immediately, and the test shows negative for PCB, then the only additional cleanup required for the sampler is to wipe the tip with one of the tissues provided with the kit. If the test is positive or if additional samples are to be collected before any analyses are performed, the tip will need to be wiped as before and rinsed with some of the extraction solvent provided with the kit. This step ensures that no residual PCB would be carried over to the next sample. If this is not done, successive samples could be cross-contaminated, giving false positive answers. The tip of the sampler is made of stainless steel so this rinse, and final wiping with a tissue, are sufficient cleanup.

FIELD EVALUATION

The kit was used during two field visits to Alaska with the WACS cleanup teams. The first visit refined the new ESL method and established procedures for site surveys and analyses. The second trip was for technical transfer and training of cleanup personnel. During each trip, duplicate samples were taken to verify the kit results by laboratory analysis.

To show how the kit can help the survey teams in preparing their PCB Map for the cleanup crews, Figure 30 shows the map prepared during the field evaluation at the Bear Creek site.



*NOTE: Door "B" sampled in same manner.

Figure 30. PCB Map of Bear Creek Made with the Kit

Comparing this map with the Fort Yukon WACS site survey shown in Figure 1 shows the value of having PCB test results immediately available. Because the PCB-contaminated areas were defined, the survey teams could "zero in" on hot spots and had more flexibility in survey protocol. This capability was most evident in finding and scoping the area marked "dark spot" in Figure 30 (across from the single door to the switch room). This spot appeared as a darker area in the foliage and was found during a walk-around inspection of the site. It was as if someone had spilled motor oil on the ground; however, it was contaminated by PCBs. Admittedly, this area could have been found and sampled without the kit under the previous survey methods, but the immediate feedback from using the field kit led to an investigation of the area downslope from the dark spot. Without the kit's on-the-spot results, it is doubtful that this extended sampling would have been done and one of the most highly contaminated areas would have been missed.

Again, the kit is of little value unless the field test results are comparable to laboratory analyses. Table 3 compares the field tests to the duplicate laboratory samples from the Bear Creek survey.

TABLE 3. BEAR CREEK ANALYTICAL COMPARISON

Sample	Description	Kit mev	Kit ppm	Lab ppm
A	Switch Room Single Door 1' out	101	48	49
B	Switch Room Single Door 3' out	87	84	99
C	Switch Room Single Door 6' out	90	76	190
D	Switch Room Single Door 9' out	86	88	150
E	Switch Room Single Door 1'x 1'*	NR**	<5	5
F	Switch Room Single Door 3'x 1'	NR	<5	5
G	Switch Room Double Door 1' out	111	32	23
H	Switch Room Double Door 3' out	114	28	16
I	Switch Room Double Door 6' out	76	128	140
J	Switch Room Double Door 9' out	124	<5	2
K	Switch Room Double Door 1'x 1'	NR	<5	1
L	Switch Room Double Door 3'x 1'	NR	<5	1
M	Oily Spot Near Double Door	NR	<5	1
N	Power Room Oily Spot - 2' Dark Circle	117	24	1
O	Power Room Oily Spot - X Thru Center	33	480	560
P	Power Room Oily Spot - Circumference	74	140	4300
Q	Single Door Utility Guide - Dark Spot	-34	4000+	9700
R	Single Door Utility Guide Spot x 1'	38	520	880
S	Single Door Utility Guide Spot x 3'	33	480	15000
T	Single Door Utility Guide Spot x 6'	-10	3600	3100
U	Single Door Utility Guide Spot x 9'	-18	4000	4300

*Indicates distance out from the door x depth of the sample.
**Not Recorded - mev reading too high to be meaningful.

At first glance, the ESL method may appear too inaccurate to be useful. For example, sample "S" tested at 15,000 ppm in the laboratory while the kit indicated only 480 ppm. However, these high concentrations were not the area of concern for soil cleanup situations. The ESL method was only meant to be semiquantitative, especially at these high concentrations. In addition, the kit and the PCB regulations are based on categorizing vs. measuring samples. The true worth of the kit was not in how closely it matched the laboratory results, but in whether or not samples were correctly classified. Precise measurements were not required; the crews had only to remove soil contaminated at over 50 ppm. If the data near that concentration are examined, the correlation is excellent - Sample A tested within 2 percent at 48 ppm and Sample B tested within 15 percent at 100 ppm. The concentrations near 50 ppm are the area of concern for the cleanup crews and in turn, the area of emphasis for the kit.

As more sites were visited and more knowledge was gained, patterns began to develop. Because all of the Air Force communications sites were run by the same personnel (moving from site to site via reassignment), it was logical to assume the survey results from Bear Creek would hold for any of the others. Figure 31 shows the PCB map made during the North River WACS site survey. (Note: Although all doors were surveyed, only door "B" is shown in the figure to indicate sampling protocol. In addition, the dimensions of the areas and sample points have been left off of both Figures 31 and 32 to make them more legible).

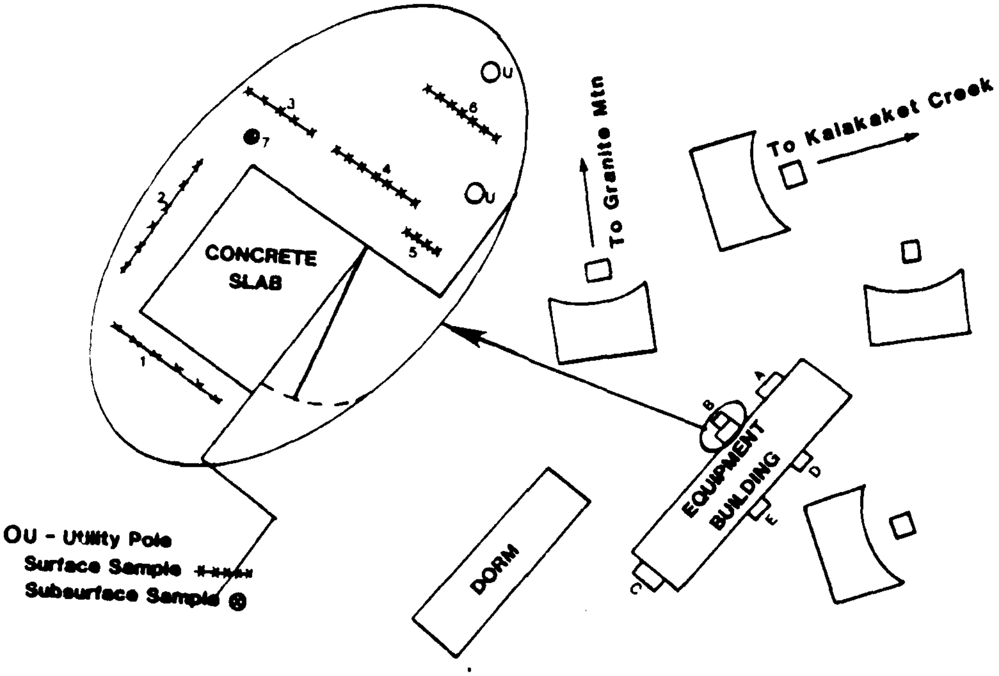


Figure 31. The North River PCB Map

The semicircular sampling pattern used around the doors at Bear Creek was replaced by a left/right/front sampling pattern. In addition, more extensive testing of the individual hot spots was done. The aim of this survey was to provide the cleanup crew with a three-dimensional map of the contaminated area showing the exact locations of soil to be excavated and sufficient detail to compute the volume of soil to be excavated. In the case of North River, the front and left side samples showed no PCB contamination. However, the right side samples indicated concentrations as high as 10,000 ppm. The actual area to be excavated was defined by moving out from the hot spots until contamination levels less than 50 ppm were obtained. In addition, the depth of contamination was determined by simply digging sample holes deeper and deeper until the bottom of the hole tested at less than 50 ppm. Figure 32 shows this extended sampling.

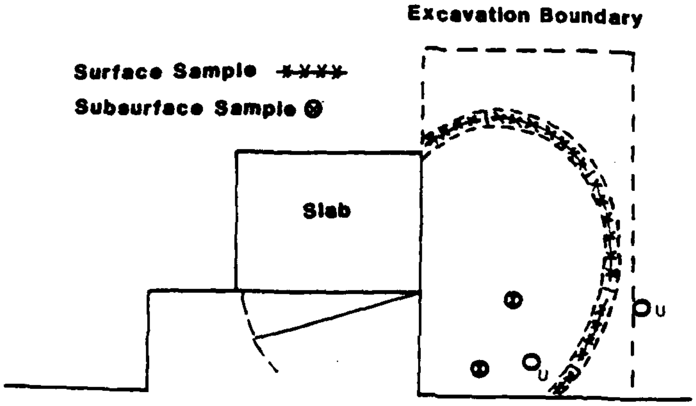


Figure 32. Final Sketch of the North River WACS Site

By locating both the perimeter and the depth of PCB contamination (and, in turn, the volume of soil to be removed), the number of recovery drums required and how much time required for cleanup was defined. In addition, depth sampling indicated the soil/bedrock structure. At this particular site, depth to bedrock varied between 6 inches and 3 feet around door "B" which meant normal cleanup equipment would have been too light to accomplish the excavation. Again, field analysis could prove invaluable in estimating costs and in scheduling cleanup actions.

This extended sampling also exposed a unique phenomenon; summer and winter hot spots. Referring to Figure 31, the area to the right of the door slab and just in front of the doorway (sample numbers 3 and 7) was the winter hot spot and the area behind the door to the right of the building (sample number 5) was the summer hot spot. In general, the winter hot spot had a PCB concentrations in the few thousand ppm range and the summer hot spot had PCB concentrations of approximately 5 to 10 times higher. This same winter/summer spill pattern was identified at every site scoped and became a pattern that the survey crews could search for when investigating a site.

SECTION VIII

CONCLUSIONS

The key to successful analysis with the PCB Field Test Kit is in recognizing what the kit can and cannot do. Familiarization with the limitations imposed by a simplified field method will ensure the best test results.

First, calling the analyzer a PCB Field Test Kit is actually a misnomer. More properly, the kit is a chlorinated organic chemical analyzer which interprets the data as if all of the measured compounds were PCB. Unlike standard laboratory analytical techniques such as gas chromatography, the kit cannot differentiate between the various chlorinated compounds such as trichloroethylene and PCB. If that degree of precision is required, then standard laboratory testing must be done. However, what is the impact of this limitation in a typical cleanup scenario? What do the cleanup crews lose by not being able to identify specific compounds? PCB sampling is not a hit and miss situation. For example, the cleanup program for the WACS sites had well-defined sample areas based on interviews with site personnel and from reconstructing the operational practices when the sites were active.

Even if other chlorinated contaminants were found, the impact on PCB cleanup program must be examined. A variety of chlorinated solvents such as trichloroethylene and carbon tetrachloride were typically used at the sites. Since these solvents are now all classified as priority pollutants, if they were mixed with PCB in soil, there would be no effect on the excavation required.

Two additional factors also affect the probability of encountering problems due to these other solvents. First, the chlorinated solvents are typically more degradable than PCB. Second, relative to an action level of 50 ppm for PCBs, the concentrations of the solvents would probably be very small. If there is still concern whether or not the chlorinated organic compound being measured is PCB or some other solvent, the team can finish its survey in the normal manner, and then send a sample out for laboratory verification. If the sample shows PCBs present, then the cleanup crew can be dispatched. If the sample shows no cleanup is required, then all that is lost is the cost of the extra field analyses (at $5 per test). In view of the logistic costs involved, this is a small price to be sure of the cleanup requirements.

Some of the facilities that can be investigated with the field kit include remote power generation facilities, abandoned and active radar or missile sites, transformer transfer and reconditioning locations, and electrical substations. In general, any area with a high power requirement, having been built and operated before the PCB regulations were promulgated, is a potential PCB spill site.

With this kit, a field team can analyze for PCBs onsite, in 5 minutes, for $5 or less per test. Given the safety factors that must be built into the method, there will be cases where an overestimation of PCB concentration would cause more soil to be excavated than necessary (i.e., false positives); however, the test can eliminate false negative answers which would underestimate the PCB concentration and lead to incomplete cleanup. Even if the kit is only used as an indicator during the sampling and cleanup phases and verification samples are sent to a laboratory, the 60 to 100 soil tests required in surveying and excavating just one spill site can save $4500 to $7500. The kit can pay for itself every time it is used.

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APPENDIX A

SOIL DATA

APPENDIX A

SOIL DATA

This appendix provides an in-depth data presentation in both graphic and tabular formats. Because conclusions and recommendations were presented in the body of this report, no further comment will be made in this section.

The test matrix, reproduced in Figure A1, shows the three critical factors examined in developing the new extraction/measurement method.

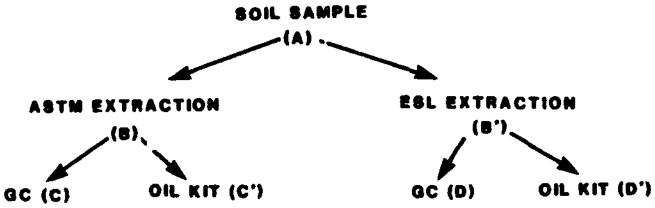


FIGURE A-1. THE SOIL MATRIX

Specifically, pathway ABC vs. AB'C compared the new ESL field extraction method to ASTM Method D3304-77; pathway ABC vs. ABC' compared measurement of the soil extract with the oil test kit to conventional gas chromatography - electron capture detection (GC-ECD); and pathway ABC vs. AB'D' compared the new method (both extraction and measurement) to standard procedures.

Accordingly, this appendix presents the data in the same order. First, the new extraction method shall be compared to the ASTM method with the extracts from both procedures being checked by GC-ECD. Next, the oil kit shall be compared to GC-ECD by comparing the measurement results of a common ASTM extract. Finally, the new method (ESL extraction/kit measurement) shall be compared to standard laboratory techniques (ASTM extraction/GC-ECD measurement).

The soil types used in examining these pathways were those described in the main body of the test (i.e., the clay, the Virginia topsoil and the Alaskan topsoil). Then, after the field method was established, five other soils, specifically blended to various organic carbon contents, were used in verifying the method. Table AI describes the organic carbon content and the percent moisture of all the test soils.

TABLE Al. TEST SOIL CHARACTERISTICS

SOIL NR/TYPE	% ORGANIC CARBON	% PERCENT MOISTURE
I	4.3	30.1
II	19.0	45.5
III	26.6	27.6
A	3.0	7.0
B	7.0	15.0
C	14.0	18.0
D	21.0	24.0
E	29.0	26.0

NOTES: 1. Percent Organic Carbon was measured gravimetrically for convenience. Samples checked by titration (e.g., the Mebius Method) showed good correlation between the two techniques.

2. Samples I, II, and III were those addressed in the main body of this report.

All soil types were homogenized and spiked following the procedure outlined in the body of the text and kept in an atmospheric chamber between analyses.

DATA PRESENTATION - METHOD VERIFICATION

The three critical factors for this method development portion of the study, extraction, measurement, and entire method, shall all be presented in the same manner. When data are presented graphically, the abcissa of the graph shall be the concentration of PCB (in ppm) as measured by ASTM extraction (Method D3304-77) and gas chromatography-electron capture detection (GC-ECD or GC). The ordinate shall show the experimental variable being examined. Figure A2 shows an example graph with fictitious data comparing the oil kit to GC.

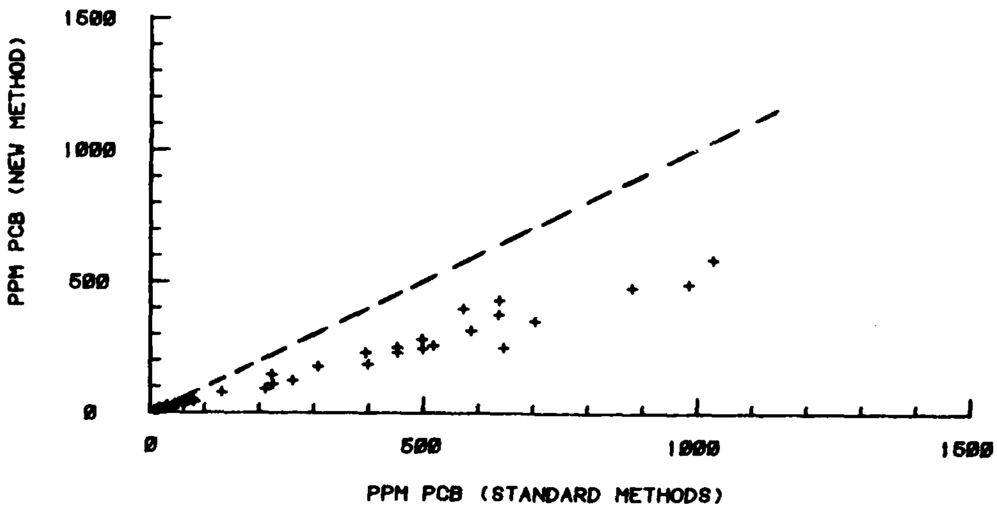


FIGURE A-2. Concentration of PCB as Measured by the New Method vs. Standard Techniques.

As in the body of this report, the dashed line represents a perfect correlation between the two methods. If all data fell on this line it would mean the new method measured the exact same concentrations as standard techniques. Given the inaccuracies of homogenizing the soils, this ideal was never attained; however, by showing this line on the plots, the linearity of the data is easier to see.

Another plot that shall be used throughout this appendix is the concentration as measured by ASTM/GC vs. the percent of PCB measured by the new method shown as a percent error or variance. The percent error was computed so an experimentally high answer would show as a positive answer as follows:

$$\frac{\text{(ppm experimental method) - (ppm standard methods)}}{\text{(ppm standard methods)}} \quad \text{X } 100$$

For example, if a sample contained 500 ppm PCB as measured by standard methods and 450 ppm as measured by experimental methods, the percent recovery would be 100 - [(500-450)/500] x 100 = 90 percent, but the percent error would be [(450 - 500/500] x 100 = -10 percent (i.e., a recovery 10 percent too low.)

Figure A3 shows an example plot on the following hypothetical data set:

TABLE A2. HYPOTHETICAL DATA SET

EXPERIMENTAL VALUE	STANDARD METHODS VALUE	PERCENT VARIANCE
100	90	+11
150	130	+15
80	88	-9
500	460	+9
55	50	+10
25	30	-17
325	375	-13

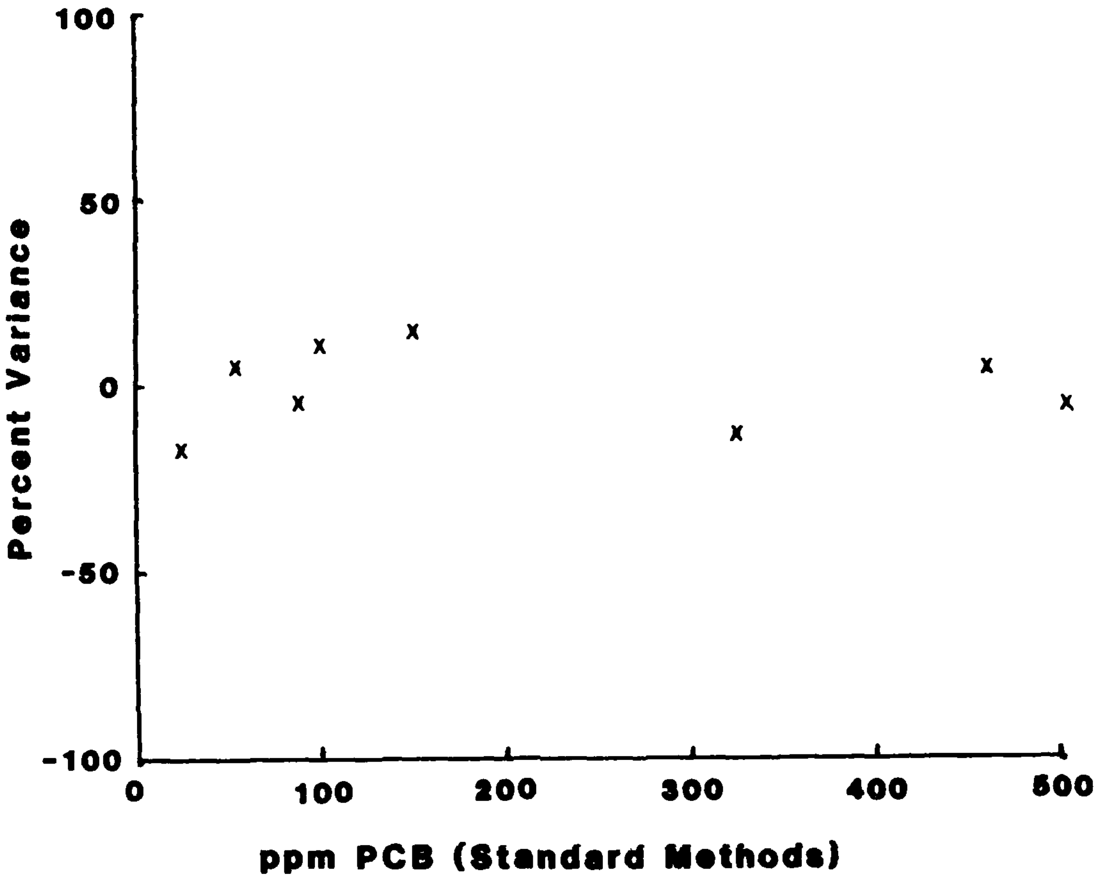


FIGURE A-3. Percent Variance vs. Concentration (in ppm).

This last plot is particularly useful because it is easy to see the minimum PCB recovered by the new procedure. This minimum became the basis for developing the scaling factor discussed in the body of this report. For clarification, histograms for the percent error from ESL extraction method, the development testing, and the verification testing have been included. The data in these histograms are again shown as a percent variance. Hence, a negative 56-percent variance corresponds to a recovery efficiency of 44 percent. The following figures show the results of the testing on Soil Types I, II and III.

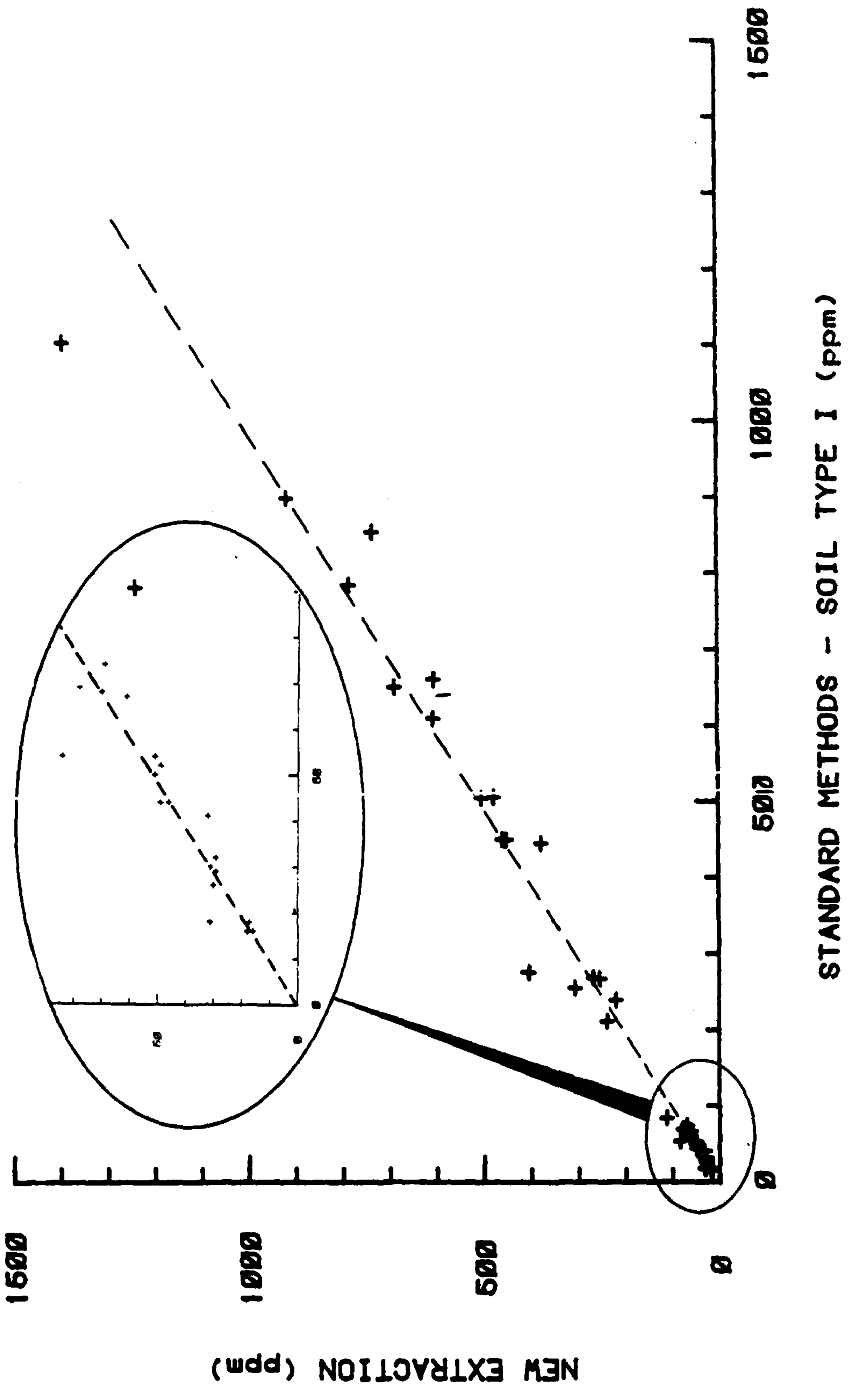


Figure A-4. ASTM vs ESL Extractions From Soil Type I.

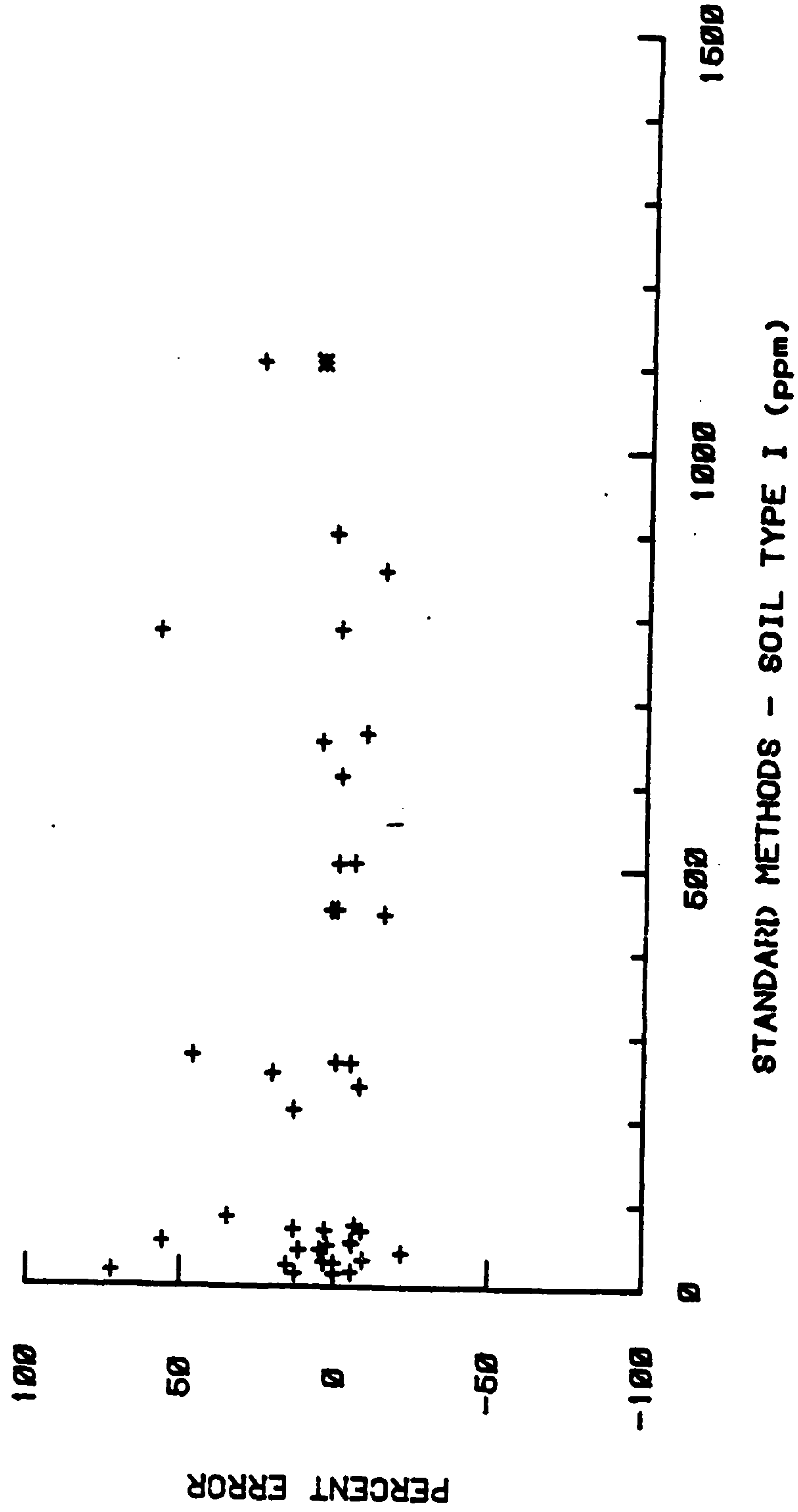


Figure A-5. Percent Error (From Standard Methods) for ESL Extractions on Soil Type I

TABLE A3. DATA FROM ASTM VS ESL EXTRACTION ON SOIL TYPE I

ASTM	ESL	% ERROR
16	16	0
16	16	0
16	18	12
16	16	0
18	17	-5
18	31	72
26	30	15
29	29	0
30	31	3
32	29	-9
41	32	-21
44	49	11
44	46	4
50	51	2
52	49	-5
54	51	-5
54	84	55
67	61	-8
68	70	2
69	78	13
74	69	-6
84	113	34
211	239	13
239	220	-7
255	307	20
267	254	-4
268	288	0
276	404	46
445	378	-15
450	459	2
450	451	0
505	504	-0
506	478	-5
610	605	-0
651	688	5
661	604	-8
782	1240	58
785	785	0
855	735	-14
899	917	26
1104	1394	-26

MEAN ERROR = 6

TABLE A4. DESCRIPTIVE STATISTICS FROM ASTM VS ESL EXTRACTION FROM SOIL TYPE I.

	ASTM	ESL	DIFFERENCES
N =	41		
MEAN =	271	290	-19
VARIANCE	935	120000	8160
STD DEV =	305	347	90.3
DATA MIN =	16	16	-458
DATA MAX =	1100	1390	120
DATA RANGE =	1090	1380	578
STANDARD ERROR OF MEAN =	47.8	54.2	14.1
COEFFICIENT OF VARIATION =	112	119	-475

T-TEST OF MEAN DIFFERENCES = 0 IS - 1.35
WITH 40 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.09
TWO TAIL TEST = 0.19

MEAN DIFFERENCE = -19

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-42.7	4.76)
95%	(-47.5	9.51)
99%	(-57.2	19.2)

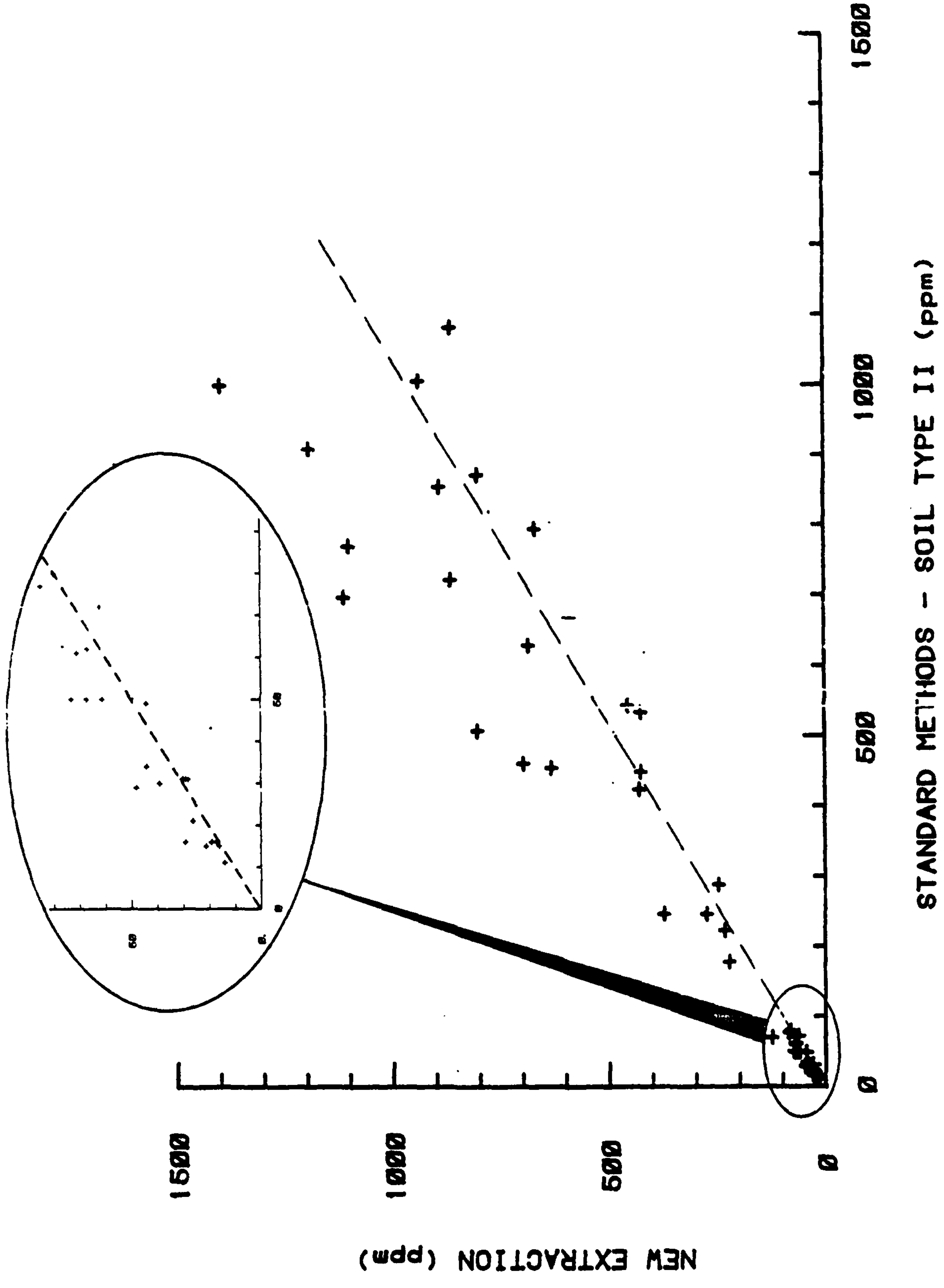


Figure A-6. ASTM vs ESL Extraction From Soil Type II.

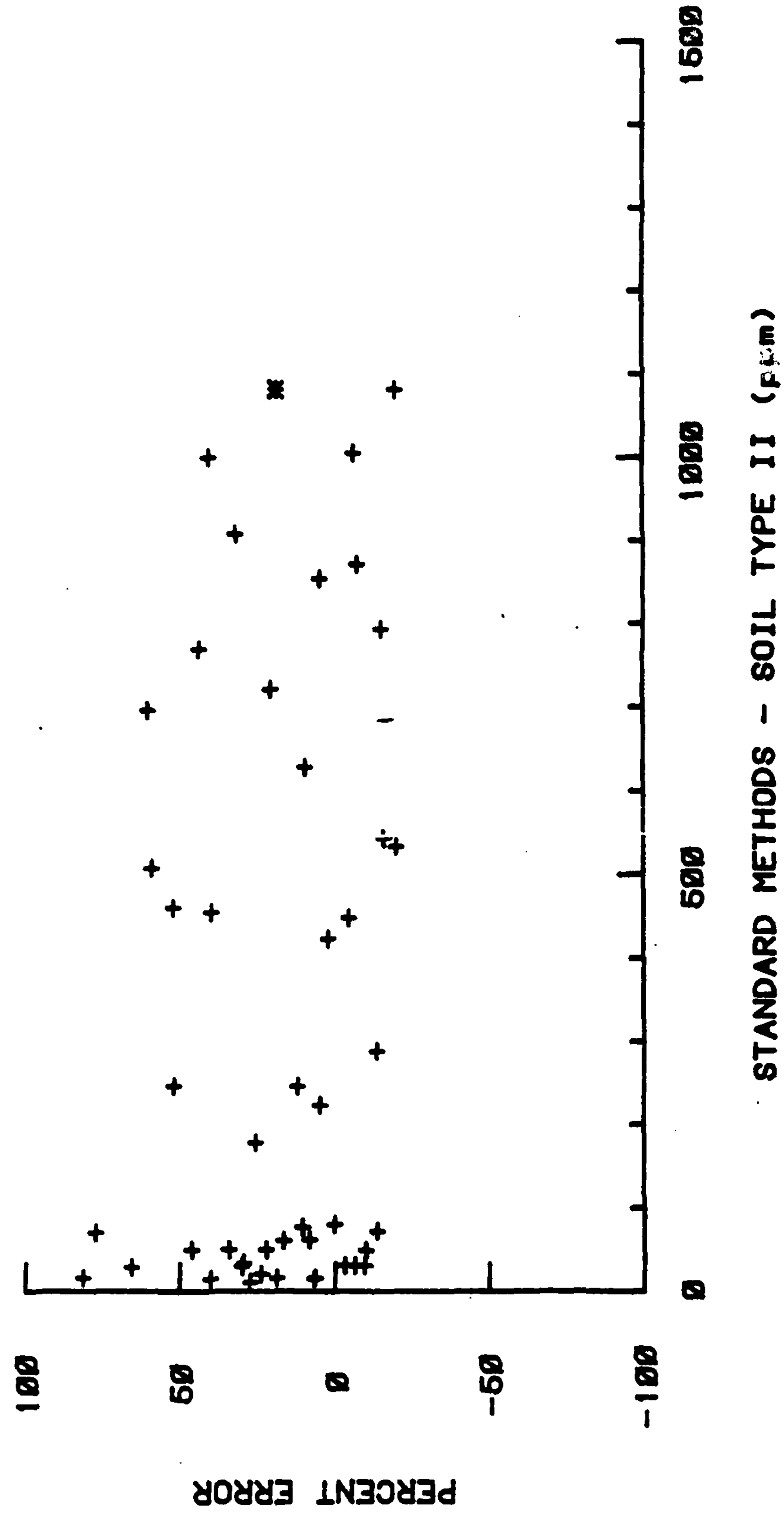


Figure A-7. Percent Error (From Standard Methods) for ESL Extractions on Soil Type II.

TABLE A5. DATA FROM ASTM VS ESL EXTRACTION ON SOIL TYPE II

ASTM	ESL	% ERROR
9	11	22
14	20	42
15	15	0
16	19	18
17	18	5
17	19	11
24	36	50
28	30	7
28	31	10
31	33	6
31	33	6
41	49	19
42	82	95
46	46	0
52	56	7
65	67	3
77	70	-9
81	75	-7
131	177	35
211	302	43
223	249	11
225	231	2
261	295	13
308	334	8
394	457	15
399	560	40
452	472	4
452	464	2
479	453	-5
498	469	-5
518	660	29
572	635	11
587	704	19
637	695	8
638	632	-0
646	774	19
704	1156	64
881	939	6
985	985	0
1029	894	-13

MEAN ERROR = 15.

TABLE A6. DESCRIPTIVE STATISTICS FROM ASTM VS ESL EXTRACTIONS FROM SOIL TYPE II

	ASTM	ESL	DIFFERENCES
N =	46		
MEAN =	321	366	-44.5
VARIANCE =	118000	159000	16700
STD DEV =	343	398	129
DATA MIN =	11	14	-416
DATA MAX =	1080	1400	216
DATA RANGE =	1070	1380	632
STANDARD ERROR OF MEAN =	50.7	58.7	19.1
COEFFICIENT OF VARIATION =	107	109	-290

T-TEST OF MEAN DIFFERENCES = 0 IS -2.34
WITH 45 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.01
TWO TAIL TEST = 0.02

MEAN DIFFERENCE = -44.5

COFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-76.5	-12.5)
95%	(-82.9	-6.16)
99%	(-95.8	6. 71)

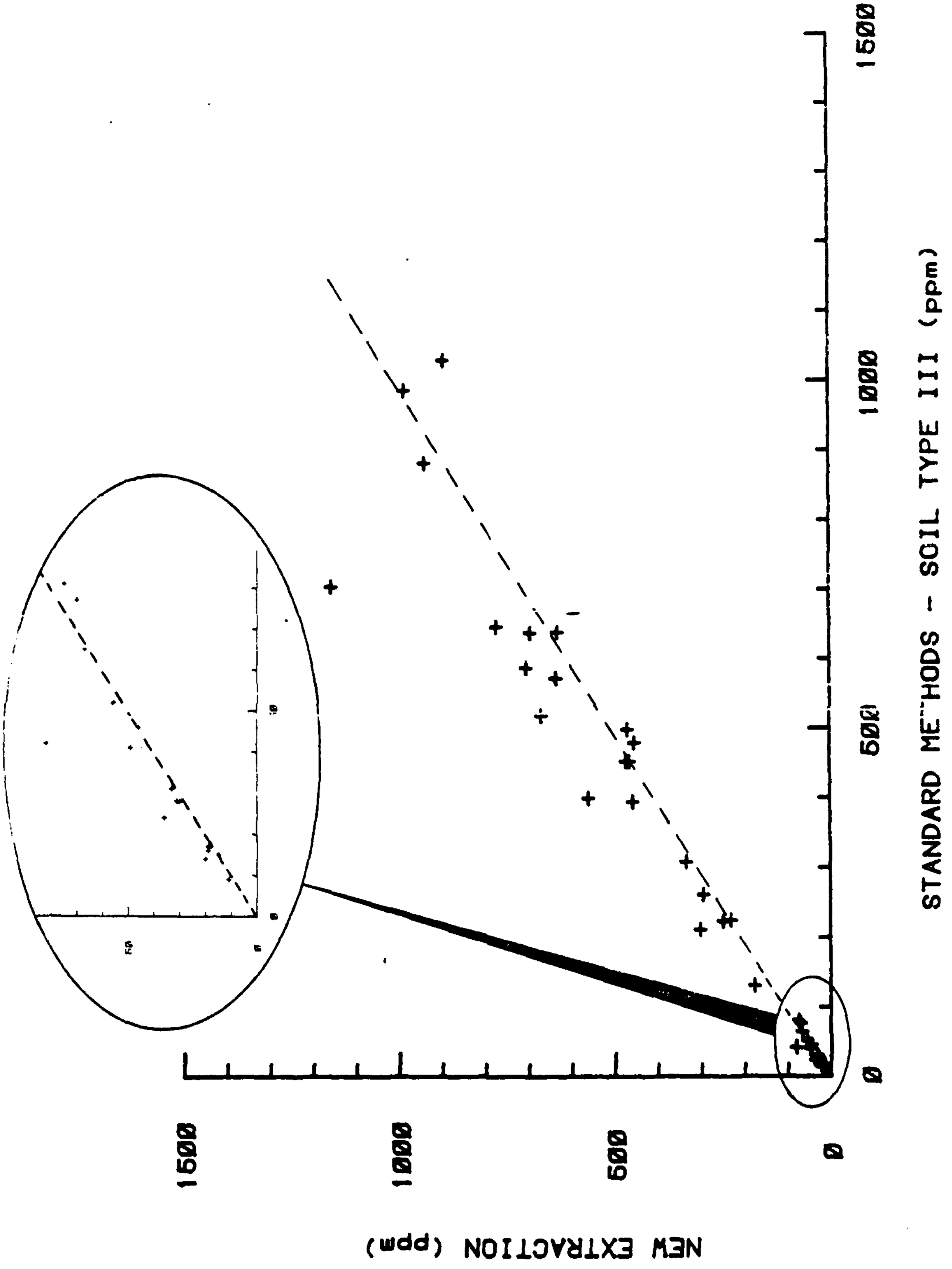


Figure A-8. ASTM vs ESL Extractions From Soil Type III.

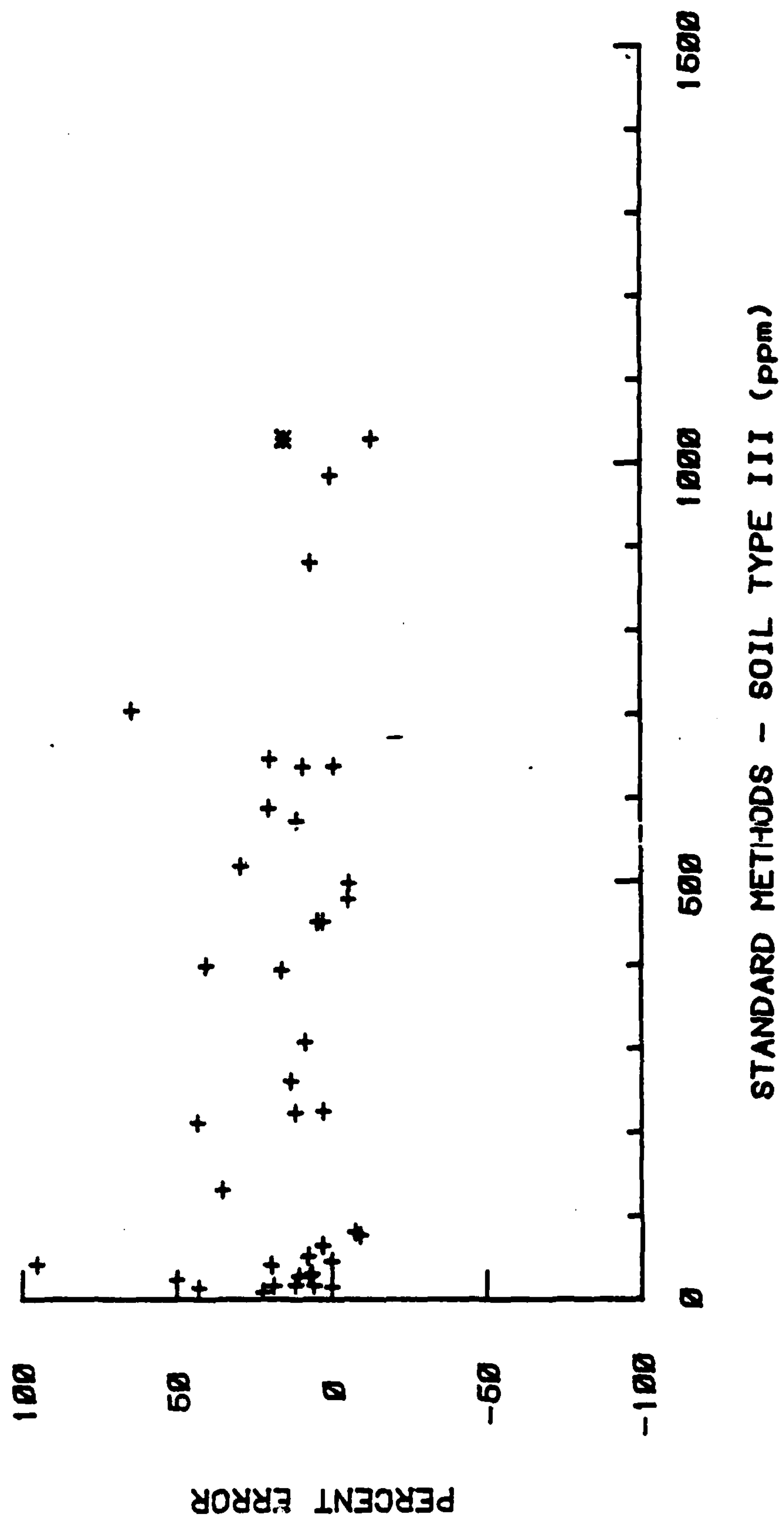


Figure A-9. Percent Error (From Standard Methods) for ESL Extractions on Soil Type III.

TABLE A7. DATA FROM ASTM VS ESL EXTRACTION ON SOIL TYPE III

ASTM	ESL	% ERROR
11	14	27
15	21	40
15	16	6
16	29	81
16	17	6
16	19	18
21	26	23
29	48	65
30	39	30
31	28	-9
31	29	-6
31	30	-3
34	44	29
49	44	-10
50	73	46
50	67	34
50	61	22
61	71	16
62	67	8
70	124	77
72	62	-13
77	85	10
80	80	0
178	223	25
223	233	4
246	275	11
246	373	51
288	248	-13
423	430	1
448	426	-4
454	633	39
460	698	51
507	804	58
533	425	-20
543	455	-16
628	685	9
696	1112	59
721	866	20
769	1101	43
793	670	-15
854	891	4
871	804	-7
908	1193	31
999	1398	39
1005	938	-6
1081	865	-19

MEAN ERROR = 18

TABLE A8. DESCRIPTIVE STATISTICS FROM ASTM VS ESL EXTRACTION OF SOIL TYPE III

	ASTM	ESL	DIFFERENCES
N =	40		
MEAN =	297	331	-34.8
VARIANCE =	90000	110	730
STD DEV =	300	331	85.4
DATA MIN =	9	11	-452
DATA MAX =	1030	1160	135
DATA RANGE =	1020	1150	587
STANDARD ERROR OF MEAN =	47	52.4	13.5
COEFFICIENT OF VARIATION =	101	100	-245

T-TEST OF MEAN DIFFERENCES = 0 IS -2.58
WITH 38 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.01
TWO TAIL TEST = 0.01

MEAN DIFFERENCE = -34.8

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-57.5	-12.0)
95%	(-62.1	-7.47)
99%	(-71.4	1.78)

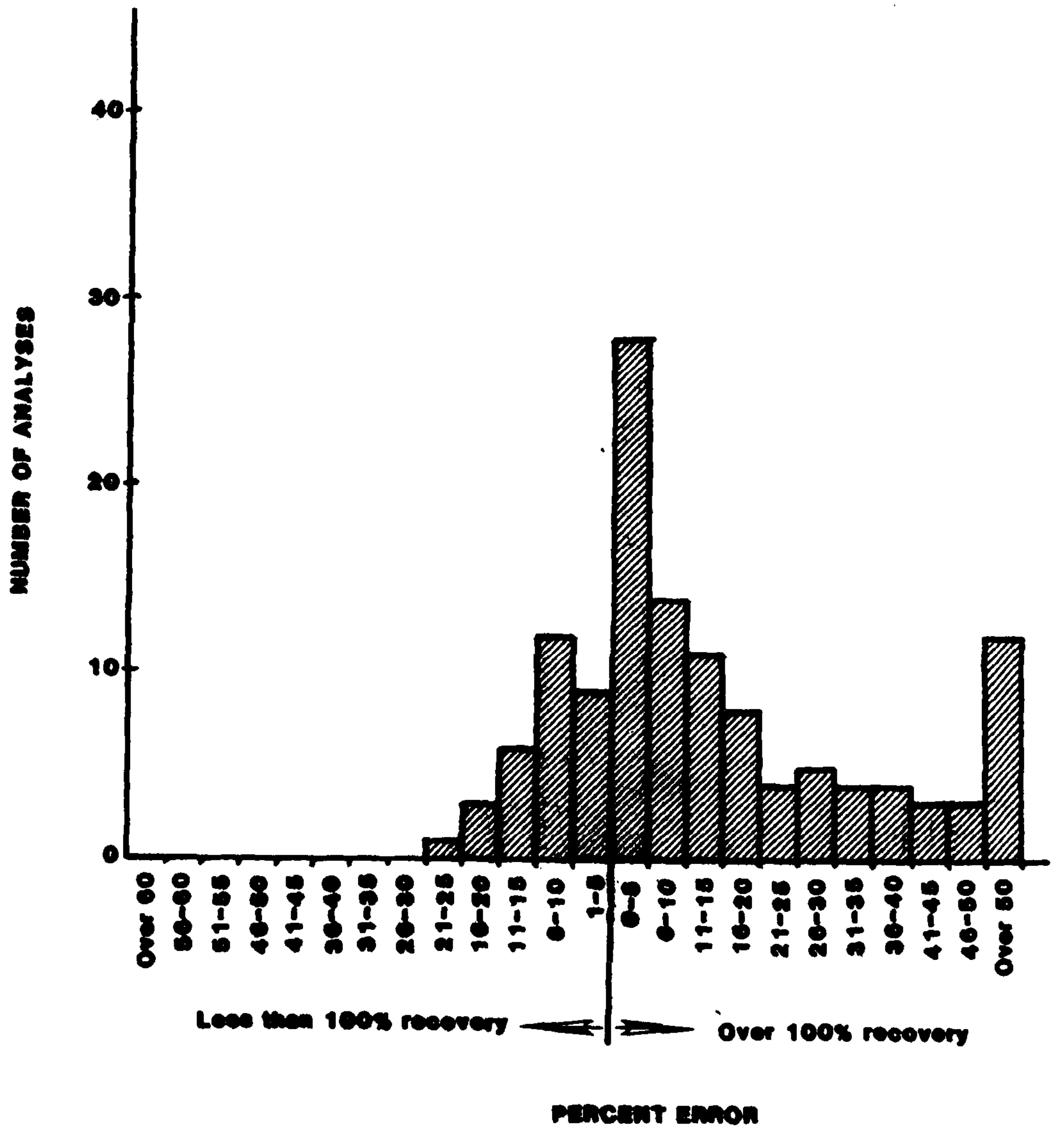


Figure A-10. Histogram of Recovery Data From ESL Extraction.

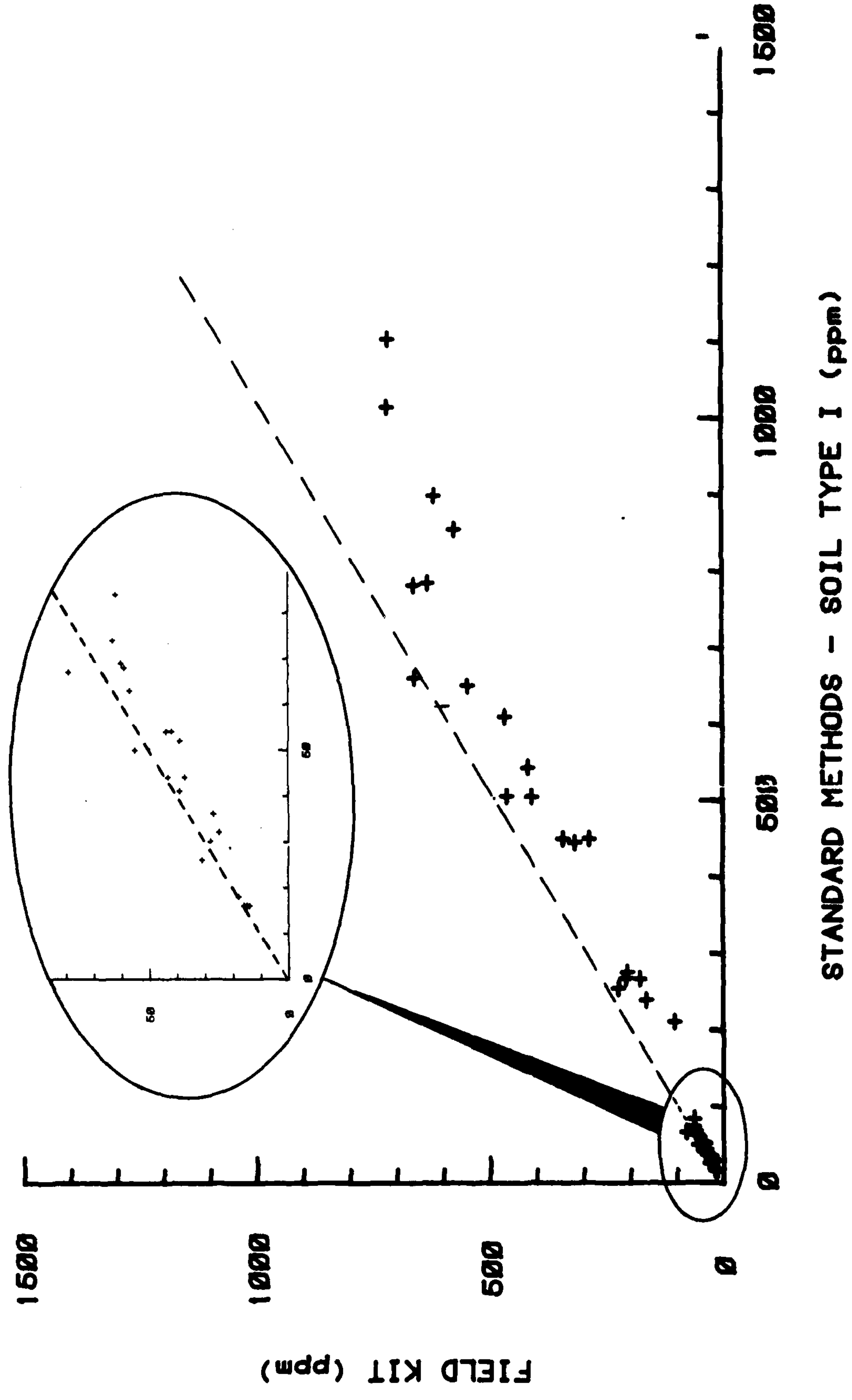


Figure A-11. GC-ECD vs Kit Measurement on Soil Type I Extractions.

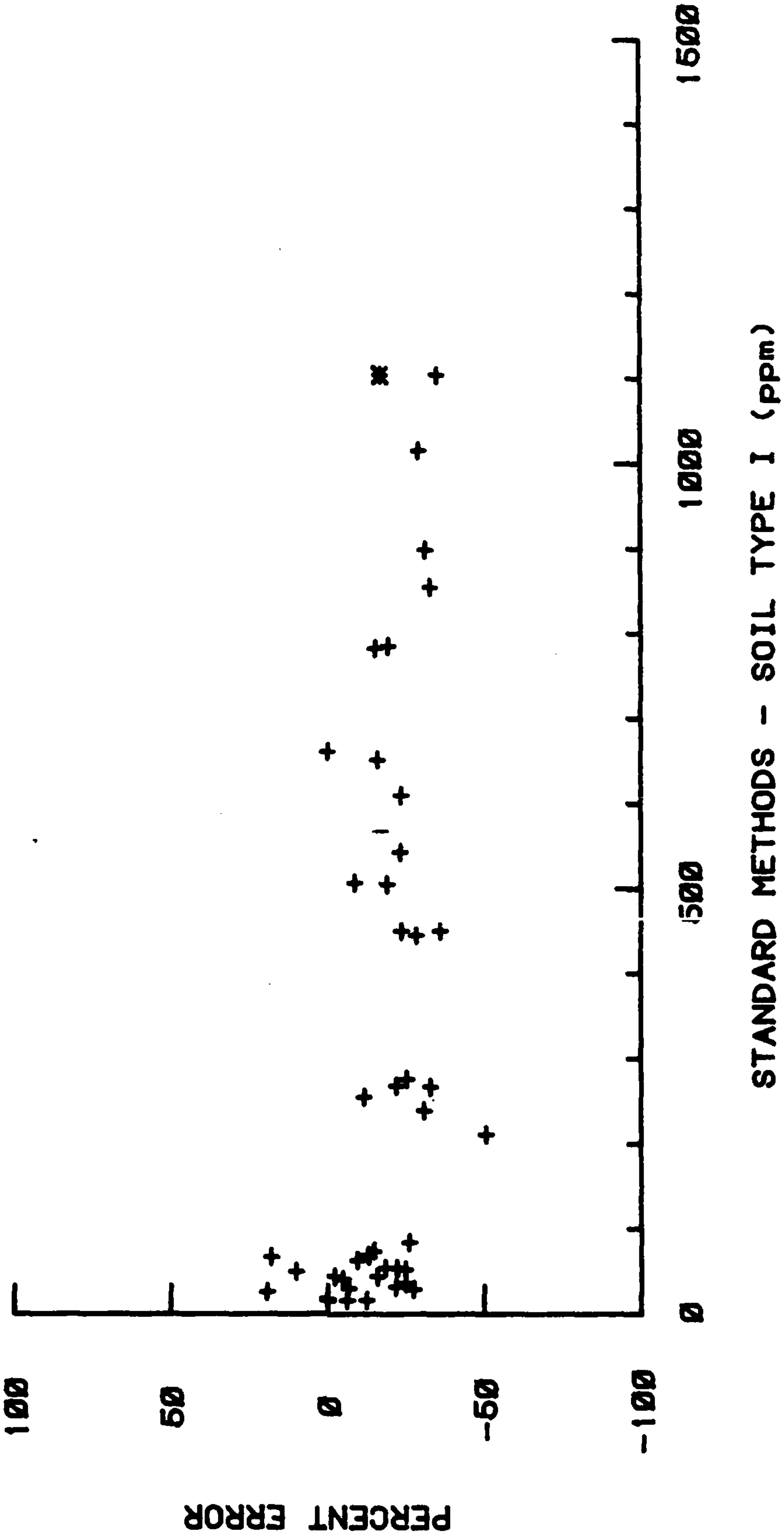


Figure A-12. Percent Error (From Standard Methods) for Kit Measurement on Soil Type

TABLE A9. DATA FROM GC-ECD VS KIT MEASUREMENT ON SOIL TYPE I EXTRACTS

GC-ECD	KIT	% ERROR
16	14	-12
16	16	0
16	15	-6
18	18	0
26	31	19
29	21	-27
30	28	-6
32	25	-21
36	27	-25
41	39	-4
44	37	-15
44	43	-2
50	55	10
52	39	-25
54	42	-22
54	44	-18
63	57	-9
67	79	17
68	59	-13
69	60	-13
74	63	-14
84	62	-26
211	104	-50
239	165	-30
255	225	-11
267	179	-32
268	209	-22
276	206	-25
445	318	-28
450	343	-23
450	287	-36
505	409	-19
506	462	-8
543	416	-23
610	466	-23
651	546	-16
661	660	-0
782	662	-15
785	632	-19
855	574	-32
899	617	-31
1015	718	-29
1104	716	-35

MEAN ERROR = 17

TABLE A10. DESCRIPTIVE STATISTICS FROM GC-ECD VS KIT MEASUREMENT OF SOIL TYPE I

	GC-ECD	KIT	DIFFERENCES
N =	43		
MEAN =	297	228	69.1
VARIANCE =	103000	57200	9010
STD DEV =	320	239	94.9
DATA MIN =	16	14	-12
DATA MAX =	110	718	388
DATA RANGE =	1090	704	400
STANDARD ERROR OF MEAN =	48	36.5	14.5
COEFFICIENT OF VARIATION =	108	105	137

T-TEST OF MEAN DIFFERENCES = 0 IS 4.7
WITH 42 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.01
TWO TAIL TEST = 0.01

MEAN DIFFERENCE = -69.1

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(44.81	93.5)
95%	(39.9	98.3)
99%	(30	108)

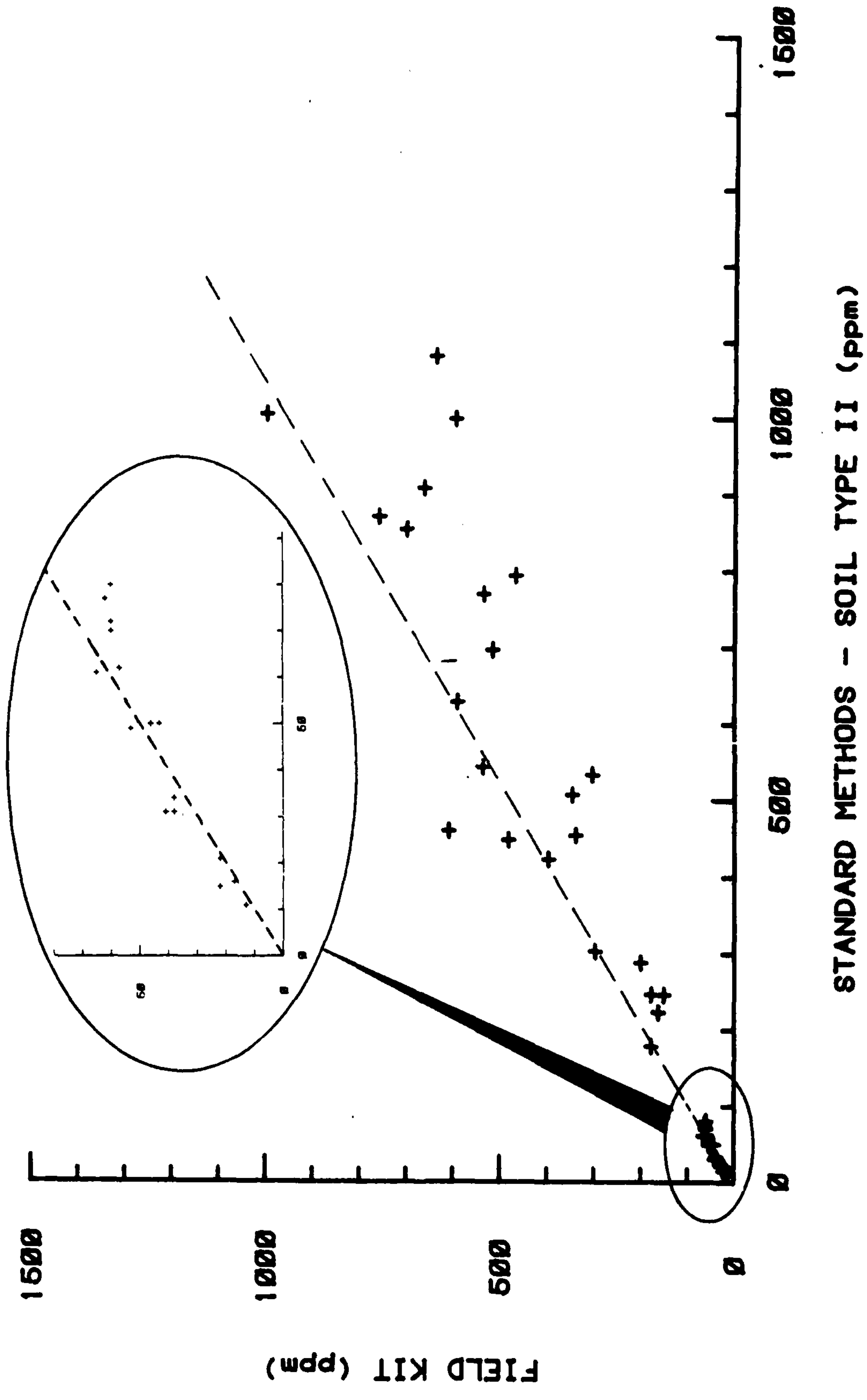


Figure A-13. GC-ECD vs Kit Measurement on Soil Type II Extracts.

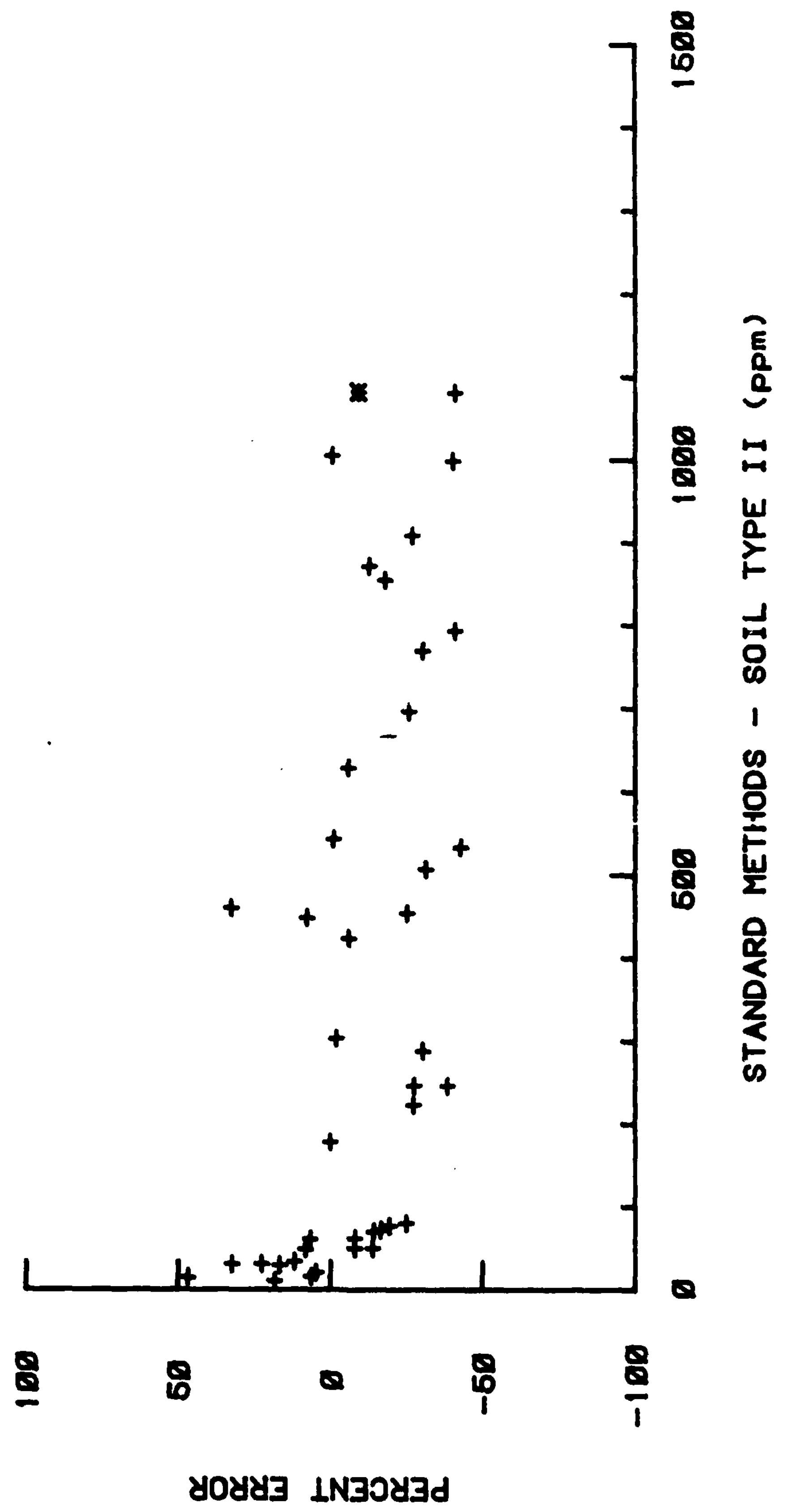


Figure A-14. Percent Error (From Standard Methods) Kit Measurement on Soil Soil Type II Extracts

TABLE A11. DATA FROM GC-ECD VS KIT MEASUREMENT ON SOIL TYPE I EXTRACTS

GC-ECD	KIT	% ERROR
11	13	18
15	22	46
16	17	6
21	22	4
30	35	16
31	41	32
31	38	22
34	38	11
49	53	8
50	46	-8
50	46	-8
50	43	-14
61	65	6
62	57	-8
70	60	-14
72	60	-16
77	62	-19
80	60	-25
178	178	0
223	162	-27
246	151	-38
246	178	-27
288	200	-30
303	297	-1
423	397	-6
448	482	7
454	339	-25
460	609	32
507	347	-3
533	304	-42
543	537	-1
628	591	-5
696	516	-25
769	535	-30
793	468	-40
854	700	-18
871	760	-12
908	663	-26
999	596	-40
1005	999	-0
1081	638	-40

MEAN ERROR = 9

TABLE A12. DESCRIPTIVE STATISTICS FROM GC-ECD VS KIT MEASUREMENT OF SOIL TYPE II

	GC-ECD	KIT	DIFFERENCES
N =	41		
MEAN =	348	279	69.3
VARIANCE =	117000	71500	14800
STD DEV =	342	267	121
DATA MIN =	11	13	-149
DATA MAX =	1080	999	443
DATA RANGE =	1070	986	592
STANDARD ERROR OF MEAN =	53.4	41.8	19.0
COEFFICIENT OF VARIATION =	98.3	96.0	176

T-TEST OF MEAN DIFFERENCES = 0 IS 3.64
WITH 40 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.01
TWO TAIL TEST = 0.01

MEAN DIFFERENCE = -69.3

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(37.2	101)
95%	(30.8	108)
99%	(17.8	121)

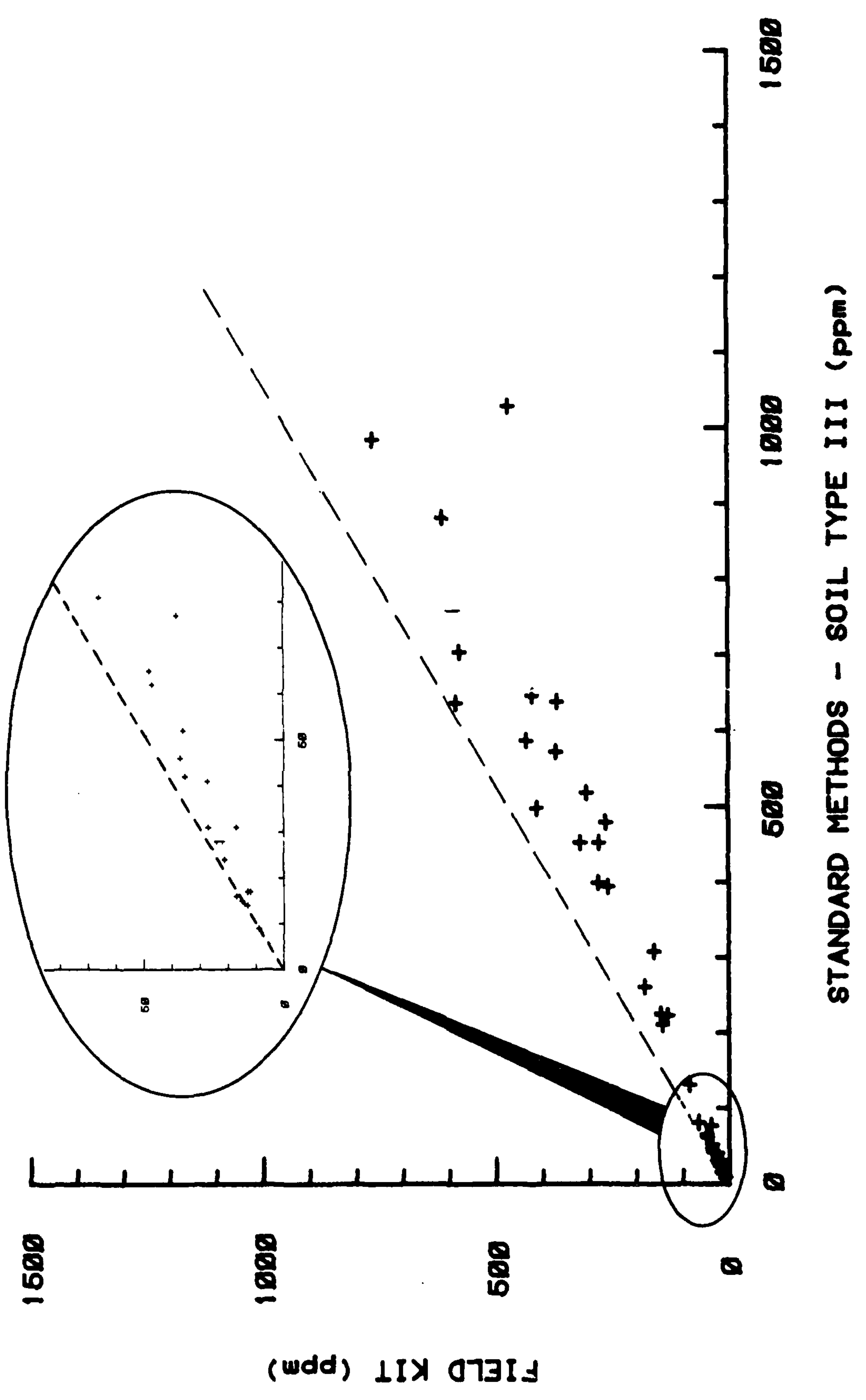


Figure A-15. GC-ECD vs Kit Measurement on Soil Type III Extracts.

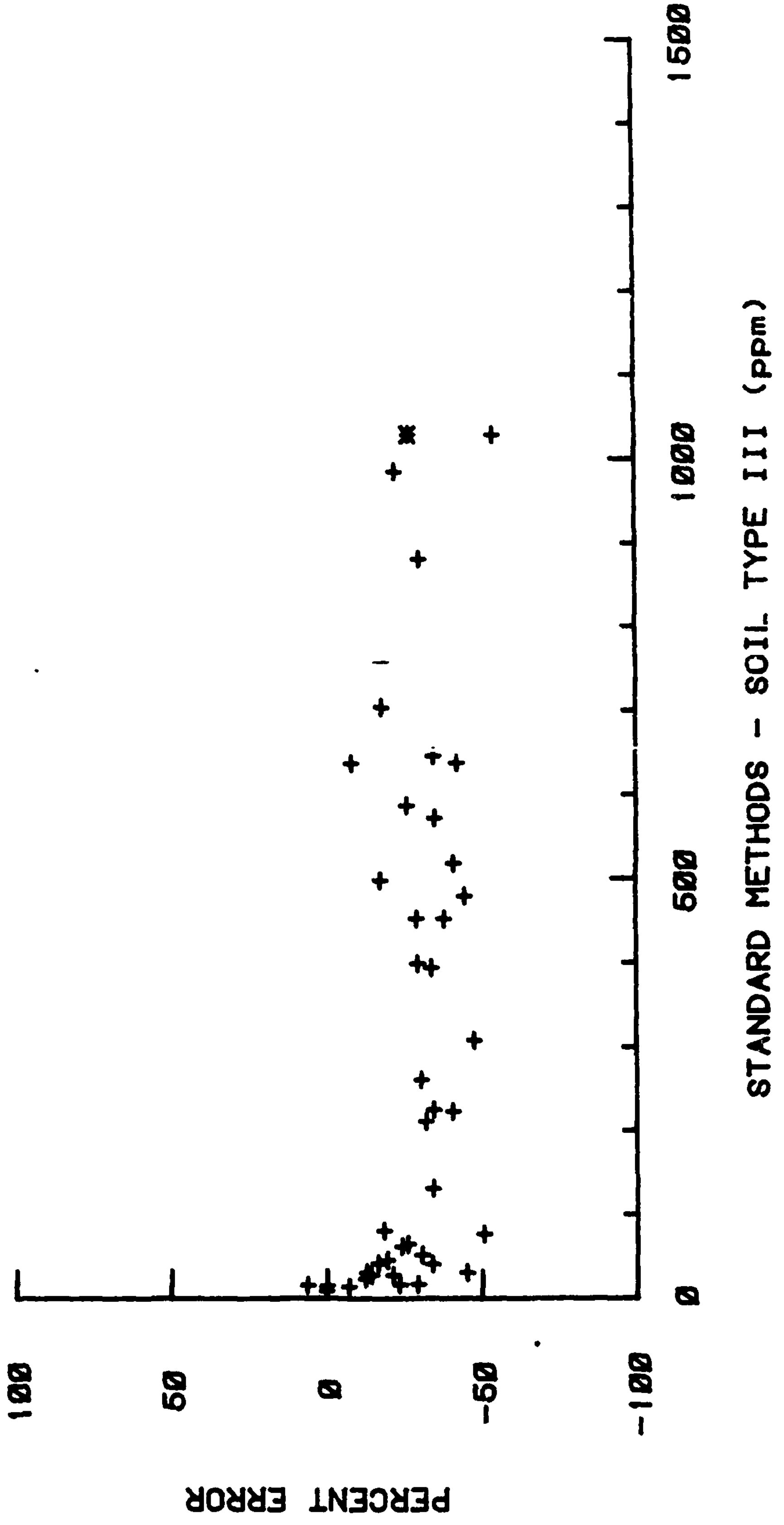


Figure A-16. Percent Error (From Standard Methods) for Kit Measurement on Soil Type III Extracts

TABLE A13. DATA FROM GC-ECD VS KIT MEASUREMENT ON SOIL TYPE III EXTRACTS

GC-ECD	KIT	% ERROR
9	9	0
14	13	-7
15	15	0
16	17	6
17	13	-23
17	12	-29
24	21	-12
28	22	-21
28	24	-14
31	27	-12
31	17	-45
41	27	-34
42	35	-16
46	37	-19
52	36	-30
62	47	-24
65	48	-26
77	38	-50
81	66	-18
131	86	-34
211	143	-32
223	132	-40
225	147	-34
261	181	-30
308	161	-47
394	260	-34
399	281	-29
452	279	-38
452	319	-29
479	264	-44
498	410	-17
518	304	-41
572	371	-35
587	434	-26
637	583	-8
638	367	-42
646	420	-34
704	576	-18
881	613	-30
985	762	-22
1029	472	-54

MEAN ERROR = 27

TABLE A14. DESCRIPTIVE STATISTICS FROM GC-ECD VS KIT MEASUREMENT OF SOIL TYPE III

	GC-ECD	KIT	DIFFERENCES
N =	41		
MEAN =	291	197	93.6
VARIANCE =	89000	42300	12800
STD DEV =	298	206	113
DATA MIN =	9	9	-1
DATA MAX =	1030	762	557
DATA RANGE =	1020	753	558
STANDARD ERROR OF MEAN =	46.6	32.11	17.7
COEFFICIENT OF VARIATION =	103	104	121

T-TEST OF MEAN DIFFERENCES = 0 IS 5.30
WITH 40 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0
TWO TAIL TEST = 0

MEAN DIFFERENCE = 93.6

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(63.8	123)
95%	(57.9	129)
99%	(45.8	141)

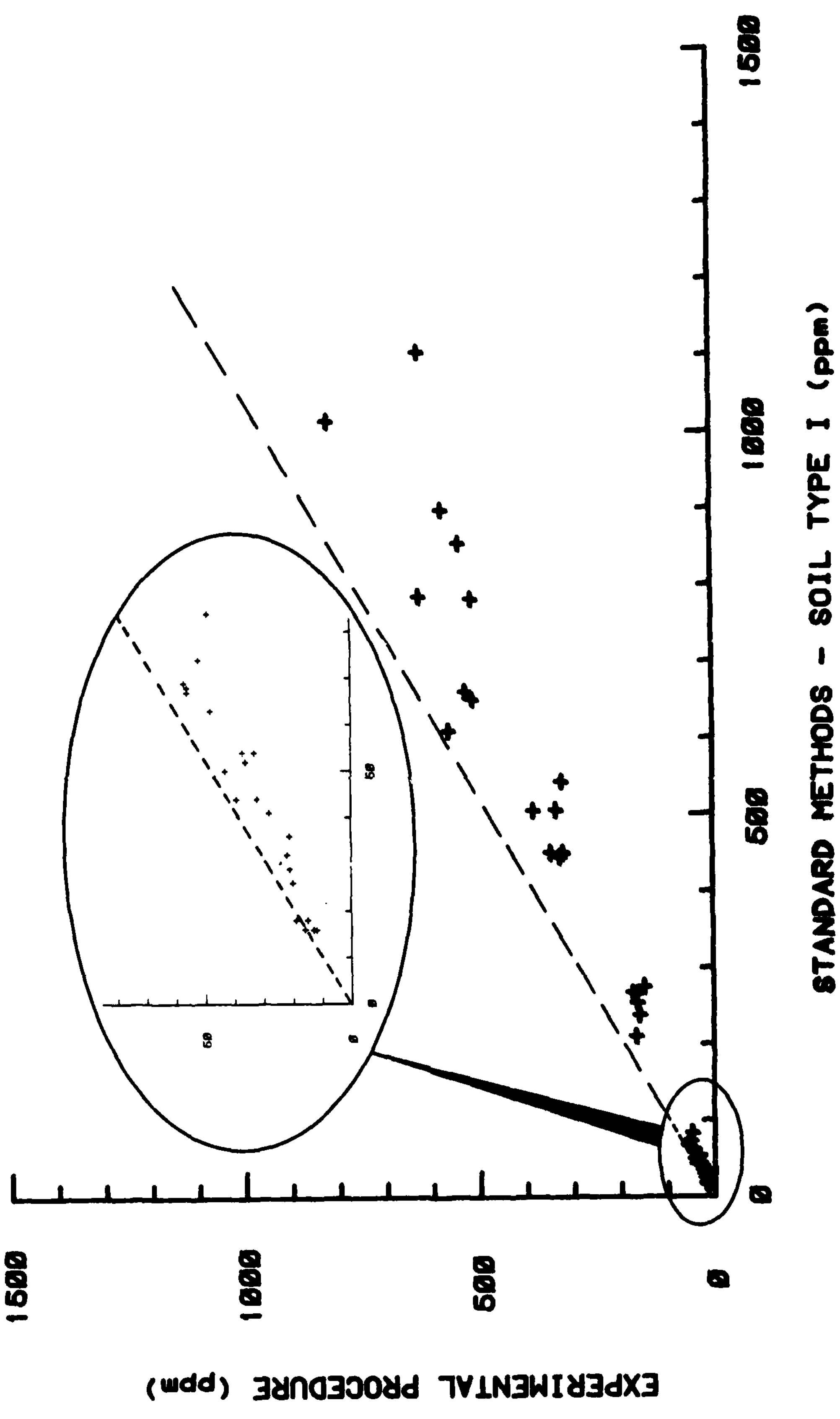


Figure A-17. Standard Methods vs Field Technique for Soil Type I.

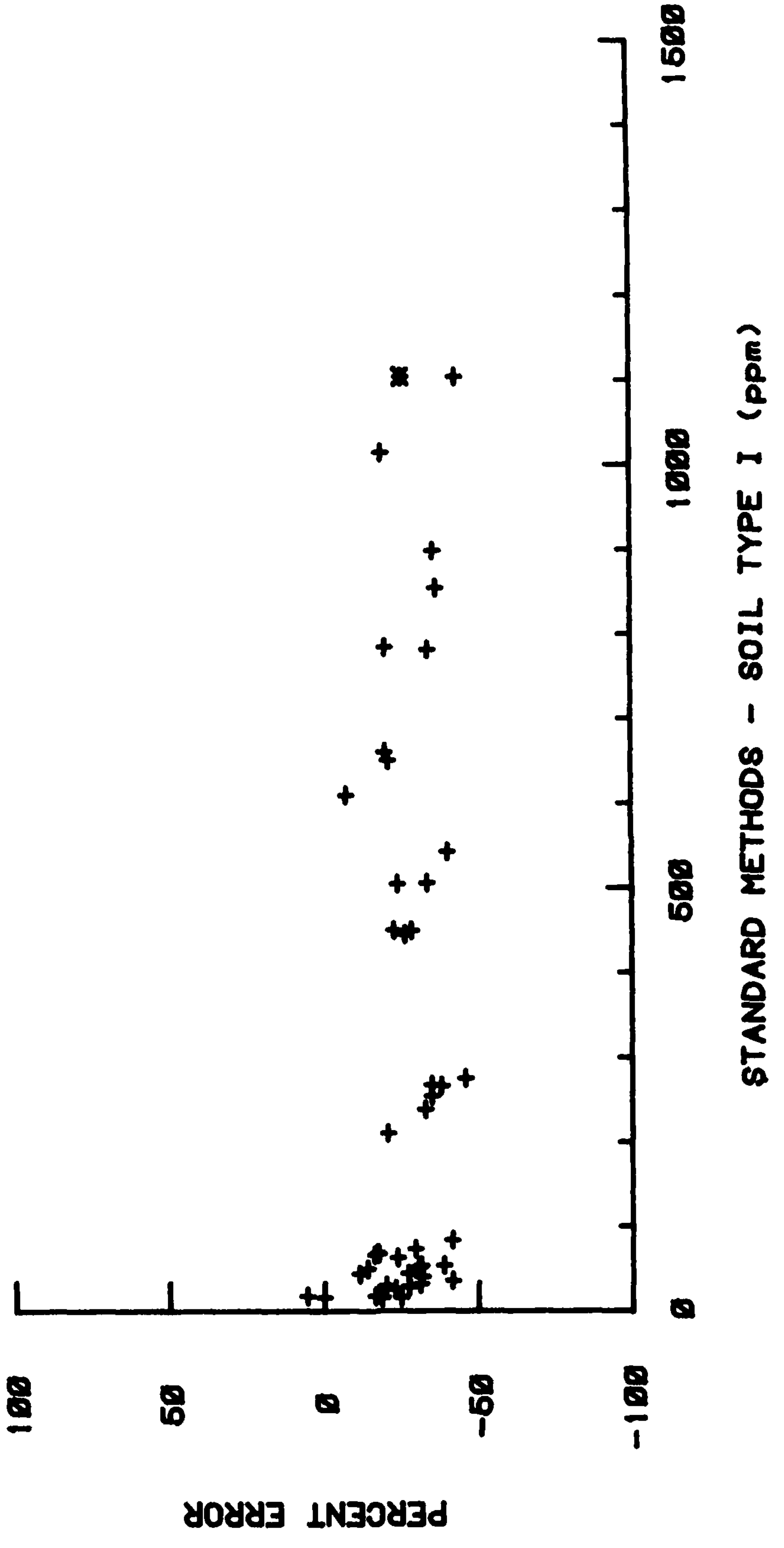


Figure A-18. Percent Error (From Standard Methods) for the Field Technique on Soil Type I.

TABLE A15. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE I.

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
16	16	0
16	12	-25
16	13	-18
16	13	-18
18	19	5
18	15	-16
26	20	-23
29	21	-27
30	24	-20
32	22	-31
36	21	-41
41	28	-31
44	39	-11
44	32	-27
50	43	-14
52	36	-30
54	37	-31
54	33	-38
63	48	-23
67	56	-16
68	56	-17
69	57	-17
74	52	-29
84	49	-41
211	167	-20
239	160	-33
255	165	-35
267	165	-38
268	174	-35
276	149	-46
445	327	-26
450	321	-28
450	347	-22
505	383	-24
506	335	-33
543	323	-40
610	563	-7
651	511	-21
661	526	-20
782	513	-34
785	624	-20
855	538	-37
899	574	-46
1015	818	-19
1104	623	-43

MEAN ERROR = 27

TABLE A16. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE I

	STANDARD METHODS	FIELD TECHNIQUE	DIFFERENCES
N =	45		
MEAN =	284	201	82.8
VARIANCE =	101000	50900	11300
STD DEV =	318	226	106
DATA MIN =	16	12	-1
DATA MAX =	1100	818	481
DATA RANGE =	1090	806	482
STANDARD ERROR OF MEAN =	47.5	33.6	15.8
COEFFICIENT OF VARIATION =	112	112	128

T-TEST OF MEAN DIFFERENCES = 0 IS 5.23
WITH 44 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0
TWO TAIL TEST = 0

MEAN DIFFERENCE = 93.6

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(56.8	109)
95%	(50.9	115)
99%	(40.2	125)

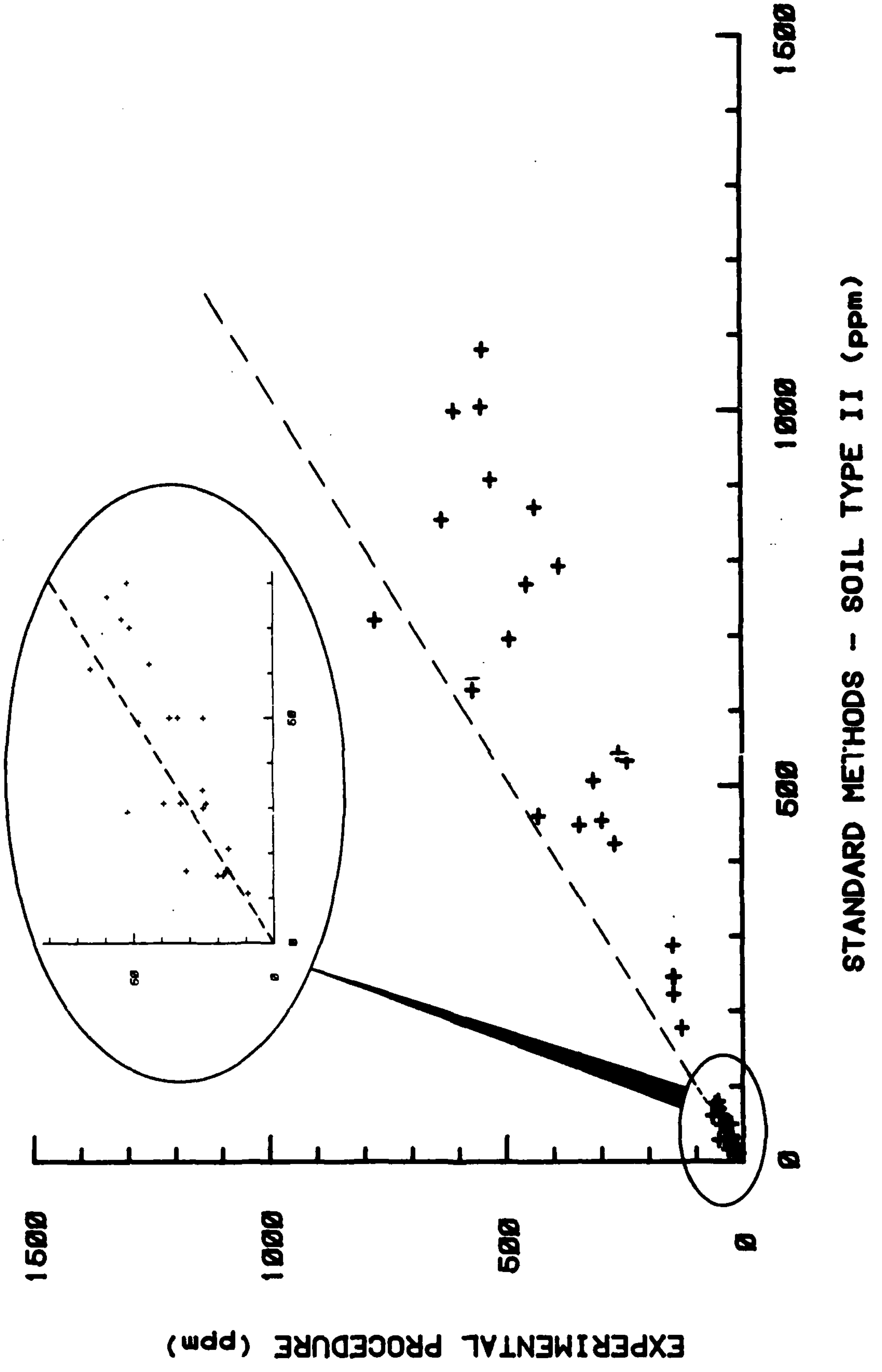


Figure A-19. Standard Methods vs Field Technique for Soil Type II.

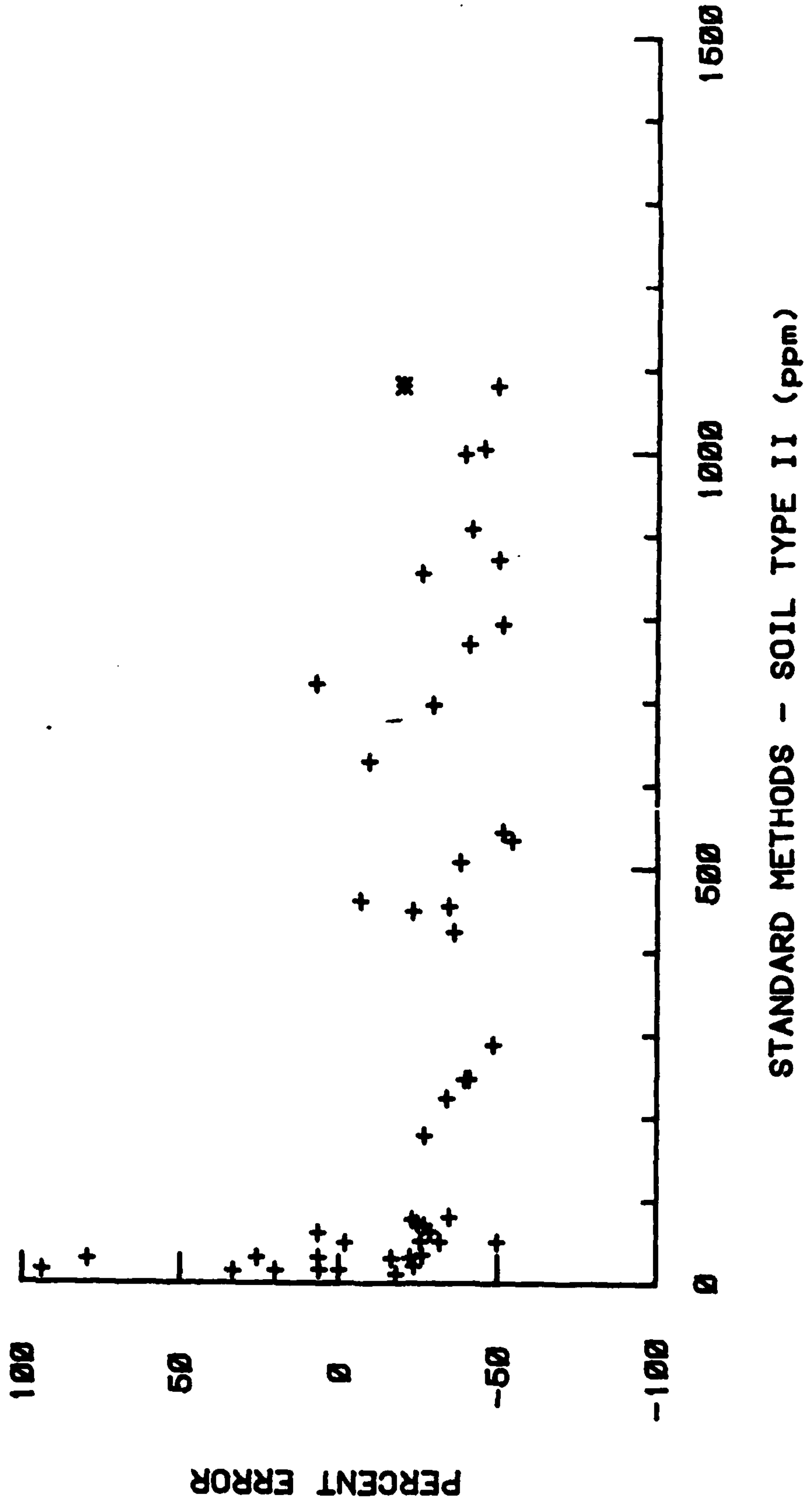


Figure A-20. Percent Error (From Standard Methods) for the Field Technique on Soil Type II.

TABLE A17. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE II

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
11	9	-18
15	20	33
15	18	20
16	16	0
16	31	93
16	17	6
21	16	-23
29	52	79
30	25	-16
31	24	-22
31	33	6
31	39	25
34	25	-26
49	48	-2
50	25	-50
50	34	-32
50	37	-26
61	65	- 6
62	44	-29
70	51	-27
72	54	-25
77	59	-23
80	52	-35
178	130	-26
223	147	-34
246	148	-39
246	145	-41
288	148	-48
423	270	-38
448	344	-23
454	297	-34
460	430	-6
507	314	-38
533	243	-54
543	263	-51
628	569	-9
696	490	-29
721	776	7
769	454	-40
793	386	-51
854	633	-25
871	436	-49
908	530	-41
999	607	-39
1005	549	-45
1081	547	-49

MEAN ERROR = 19

TABLE A18. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE II

	STANDARD METHODS	FIELD TECHNIQUE	DIFFERENCES
N =	46		
MEAN =	322	210	112
VARIANCE =	118000	48100	24000
STD DEV =	343	219	154
DATA MIN =	11	9	-55
DATA MAX =	1080	776	534
DATA RANGE =	1070	767	589
STANDARD ERROR OF MEAN =	50.7	32.3	22.8
COEFFICIENT OF VARIATION =	107	105	139

T-TEST OF MEAN DIFFERENCES = 0 IS 4.90
WITH 44 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 1.0E-5
TWO TAIL TEST = 2.0E-5

MEAN DIFFERENCE = 112

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(73.4	150)
95%	(65.8	158)
99%	(50.7	173)

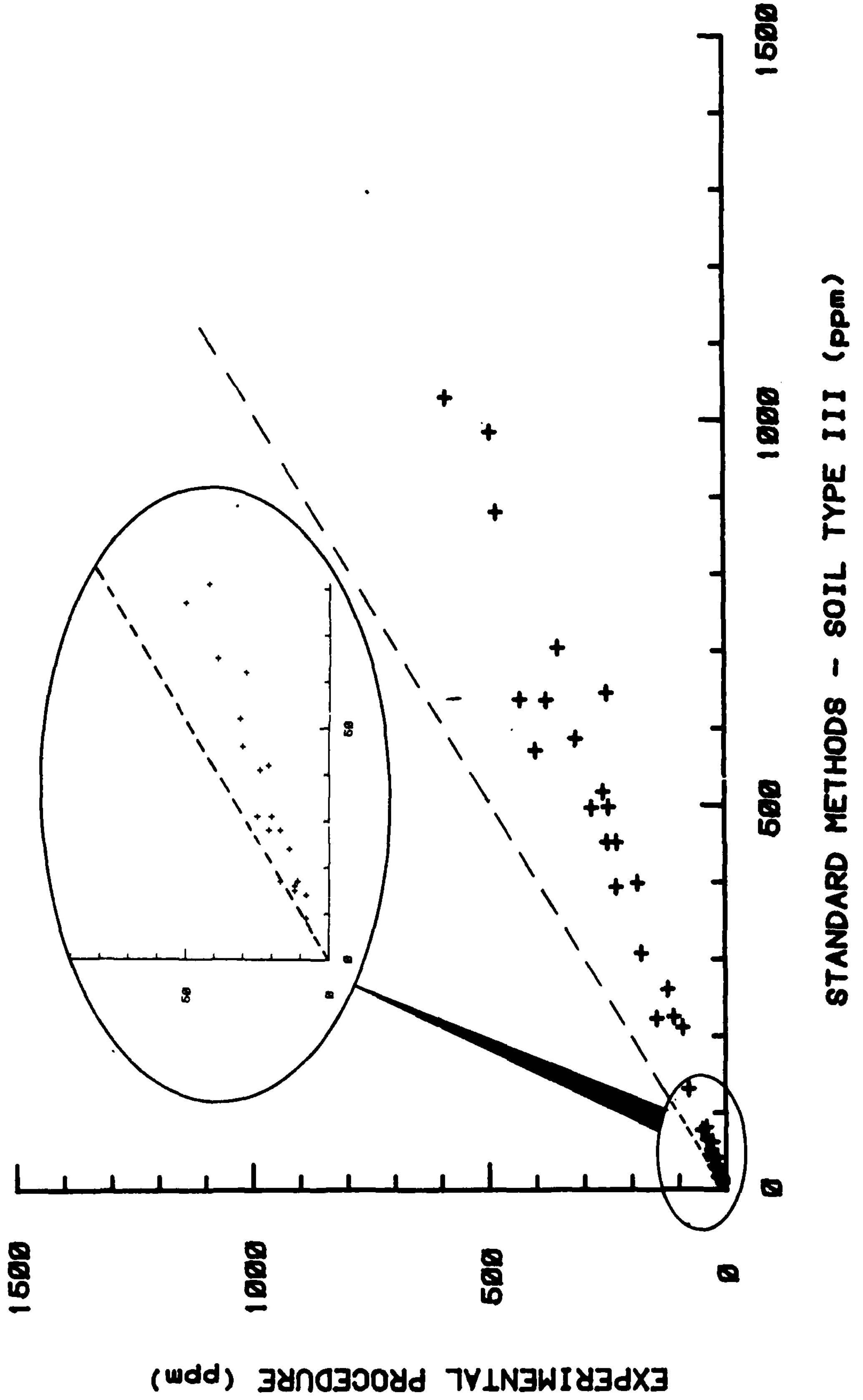


Figure A-21. Standard Methods vs Field Techniques for Soil Type III.

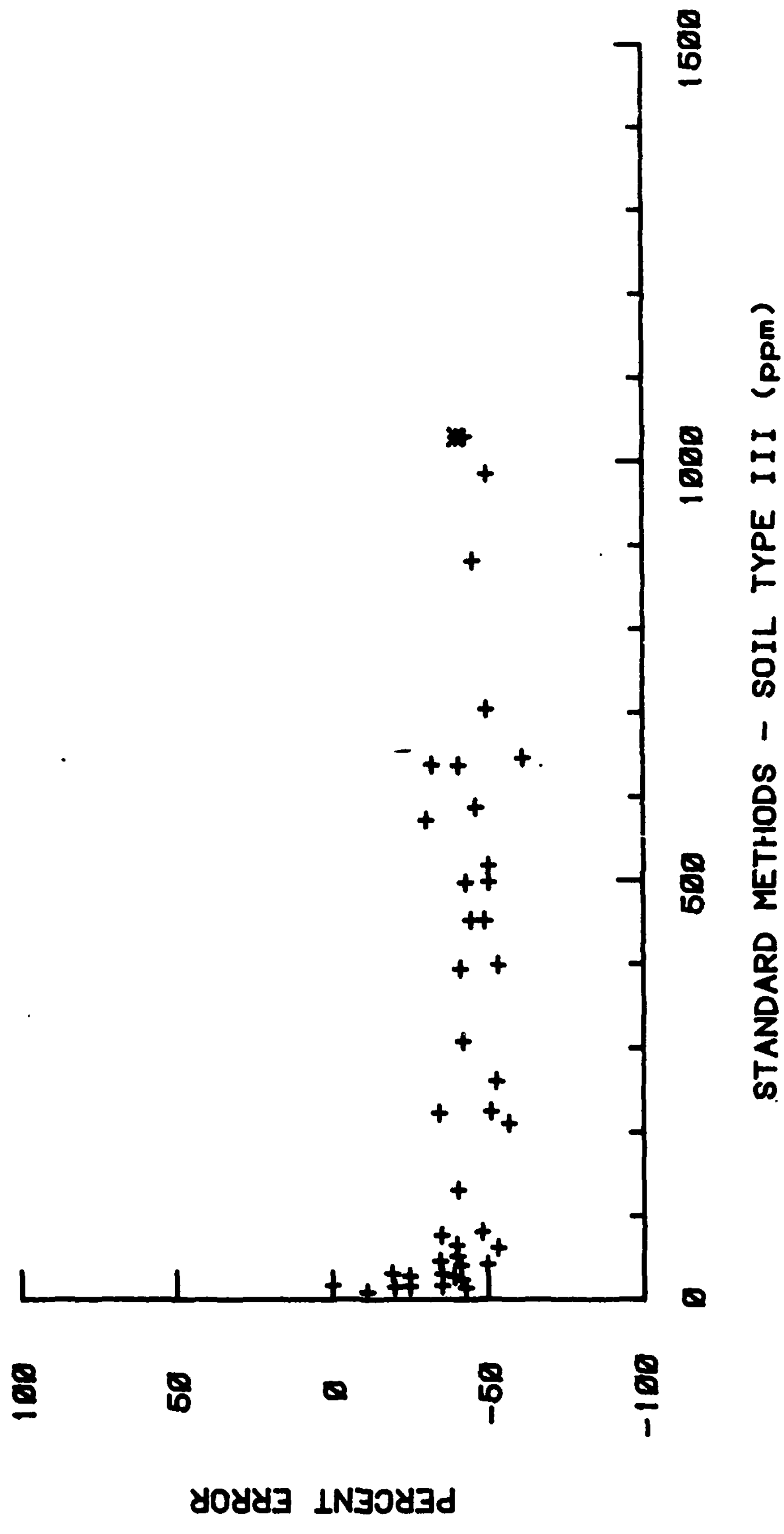


Figure A-22. Percent Error (from Standard Methods)
for the Field Technique in Soil Type III.

TABLE A19. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE III

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
9	8	-11
14	8	-42
15	12	-20
16	12	-25
17	11	-35
17	17	0
24	14	-41
28	17	-39
28	21	-25
31	20	-35
31	25	-19
41	24	-41
42	21	-50
46	30	-34
52	31	-40
62	29	-53
65	39	-40
77	50	-35
81	42	-48
131	78	-40
211	91	-56
223	146	-34
225	123	-51
261	123	-52
308	178	-42
394	231	-41
399	186	-53
452	230	-49
452	250	-44
497	282	-43
498	246	-50
518	258	-50
572	398	-30
587	315	-46
637	377	-40
638	432	-32
646	250	-61
704	353	-49
881	481	-45
985	494	-49
1029	588	-42

MEAN ERROR = 19

TABLE A20. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE III

	STANDARD METHODS	FIELD TECHNIQUE	DIFFERENCES
N =	41		
MEAN =	291	159	132
VARIANCE =	89200	26800	19800
STD DEV =	299	163	141
DATA MIN =	9	8	0
DATA MAX =	1030	588	491
DATA RANGE =	1020	580	491
STANDARD ERROR OF MEAN =	46.6	25.6	22.0
COEFFICIENT OF VARIATION =	103	103	107

T-TEST OF MEAN DIFFERENCES = 0 IS 6.01
WITH 40 DEGREES OF FREEDOM

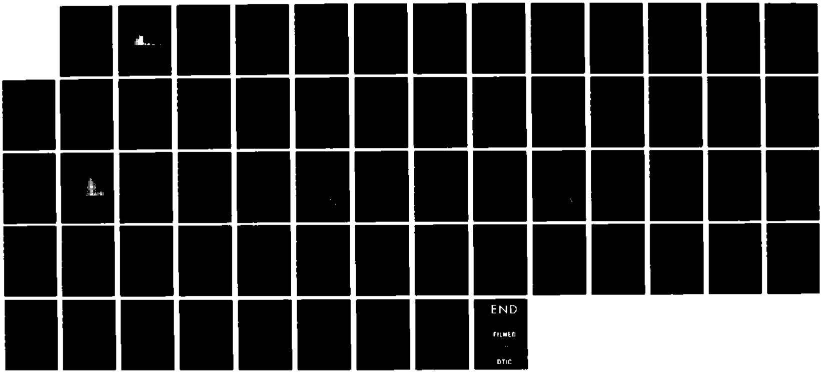
SIGNIFICANCE LEVELS
ONE TAIL TEST = 0
TWO TAIL TEST = 0

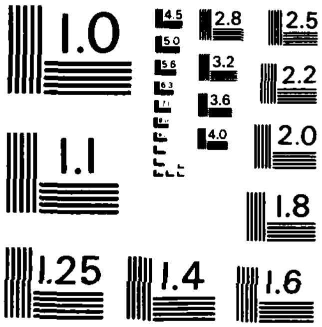
MEAN DIFFERENCE = 132

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(95.1	169)
95%	(87.8	1[illegible]6)
99%	(72.7	192)

AD-A161 386 PCB (POLYCHLORINATED BIPHENYL) FIELD TEST KIT VOLUME 1 2/2
FIELD TESTING(U) AIR FORCE ENGINEERING AND SERVICES
CENTER TYNDALL AFB FL J R ALDRICH SEP 85
UNCLASSIFIED AFESC/ESL-TR-85-24-VOL-1 F/G 13/2 NL




1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

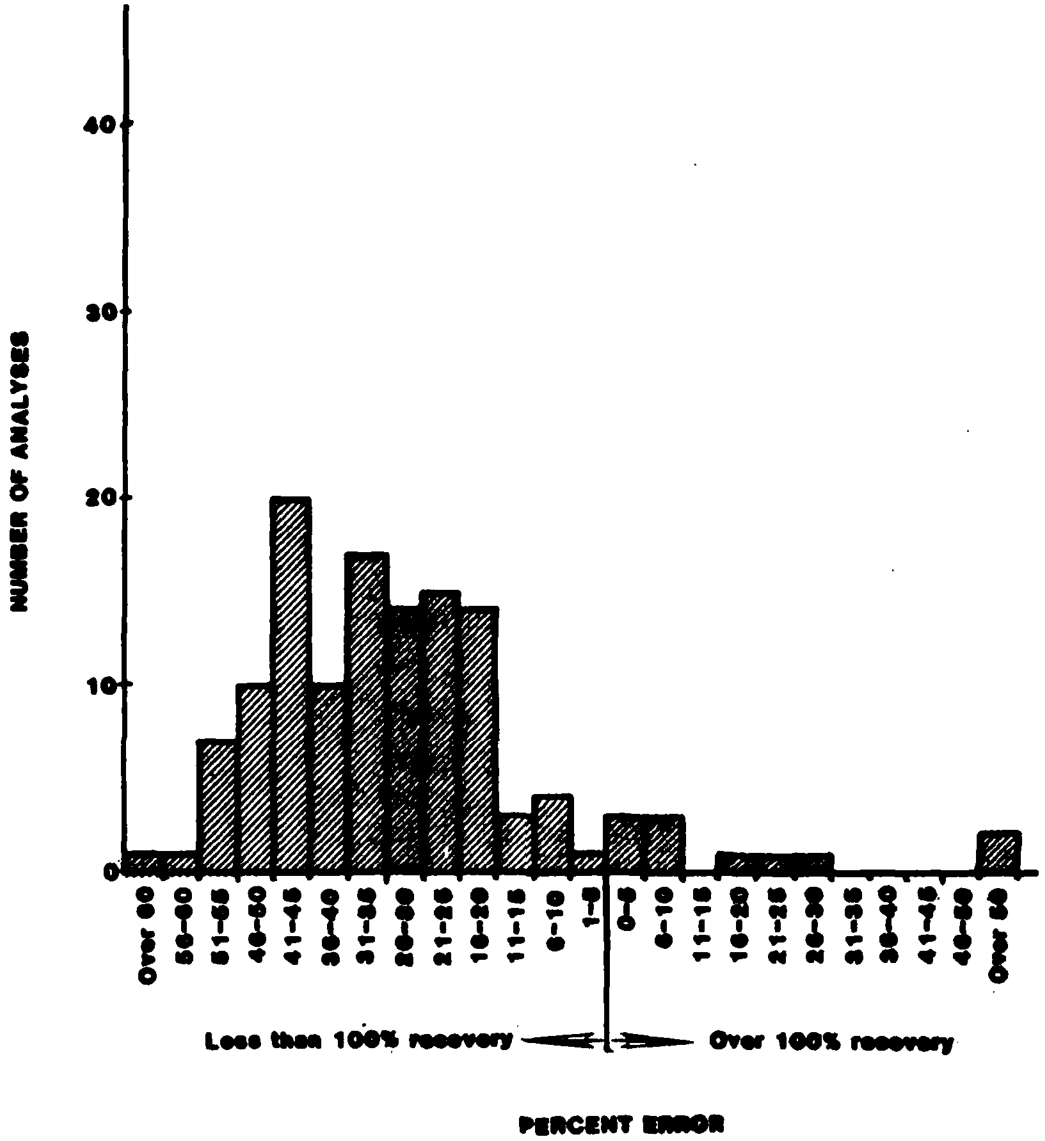


Figure A-23. Histogram of Percent Errors from the Method Development Testing or Soil Types I, II, and III.

VERIFICATION TESTING

With the method established, additional testing was performed on soil types A-E (described in Table A-1) to generate a sufficient data base to verify the new field method. For this verification phase of testing the test methods were not changed; however, the matrix was not used and the range of PCB and contamination was narrowed. Instead of examining the extraction and measurement techniques separately, only the entire field technique was compared to standard methods (i.e., ASTM extraction/GC measurement vs. ESL extraction/Kit measurement). In addition, the narrowing of the contamination range allowed the testing to center on the critical concentrations around typical cutoff points for cleanup. The following figures show the results of the verification testing.

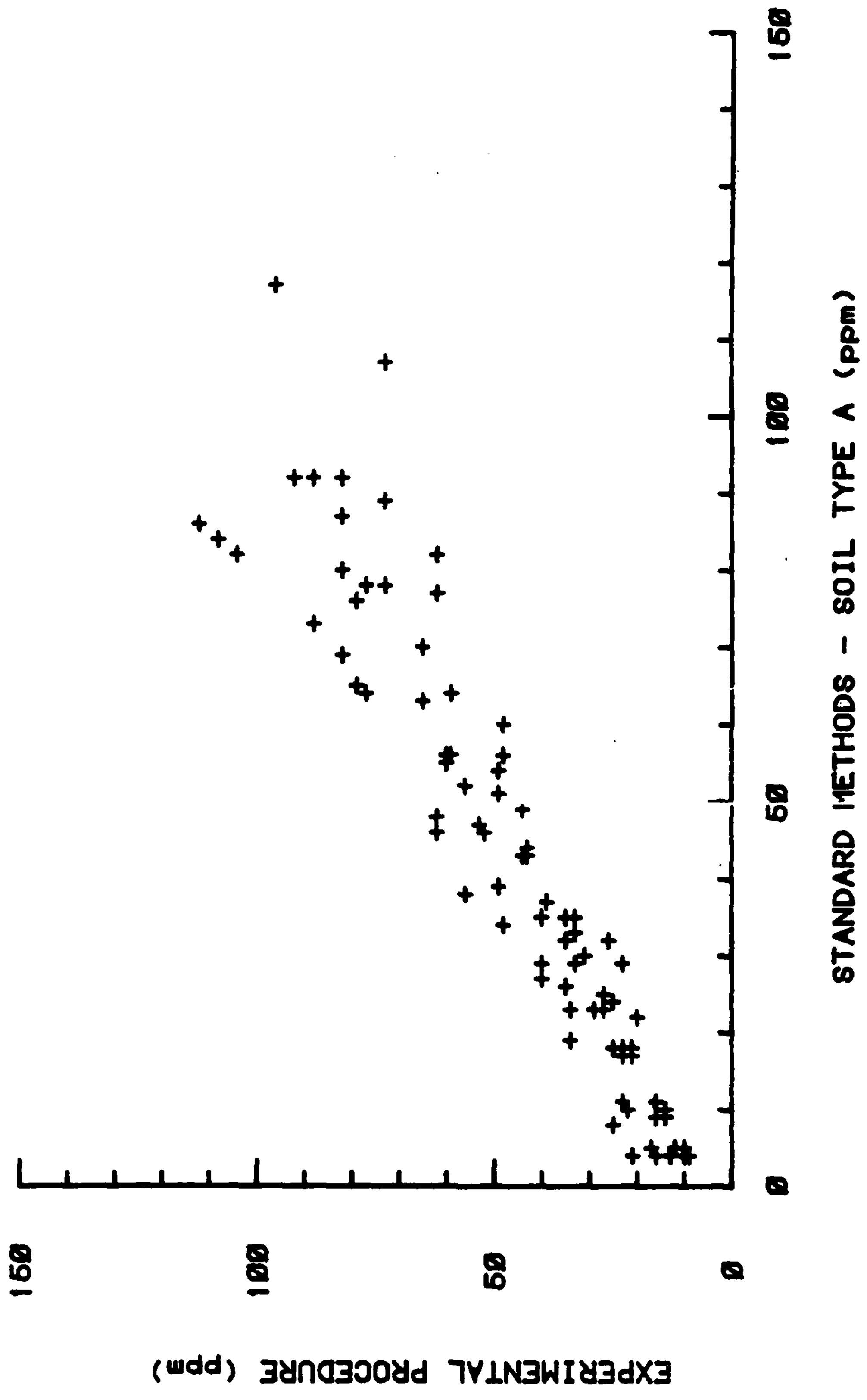


Figure A-24. Standard Methods vs Field Techniques for Soil Type A.

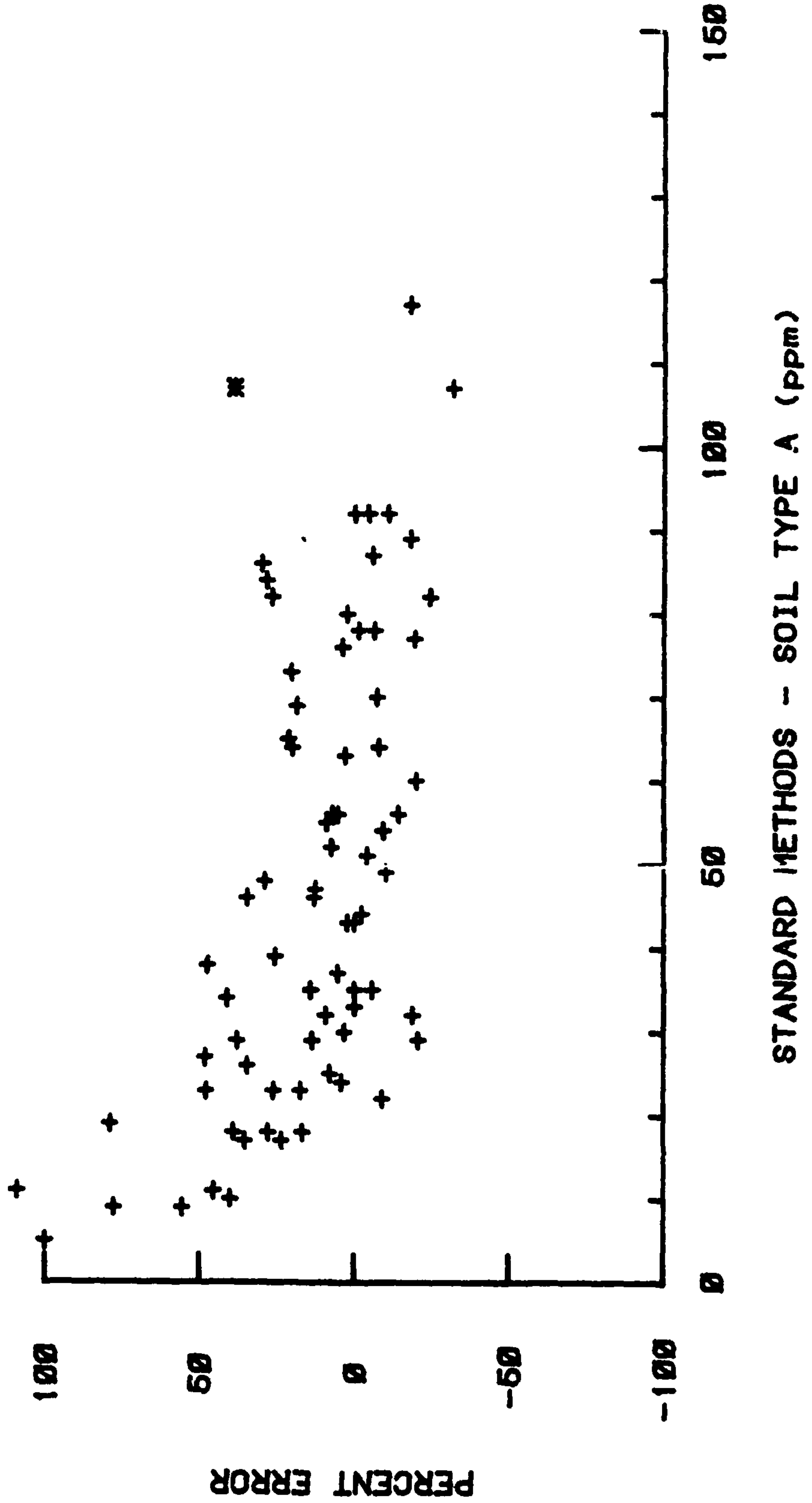


Figure A-25. Percent Error (From Standard Methods) for the Field Technique on Soil Type A.

TABLE A21. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE A

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
4	9	125
4	13	225
4	10	150
4	10	150
4	21	425
4	16	300
5	12	140
5	10	100
5	10	100
9	14	55
5	17	240
9	16	77
9	16	77
9	14	55
8	25	211
10	22	120
10	14	-40
11	16	-45
11	16	-45
24	25	4
11	23	109
18	25	38
18	23	27
23	34	47
19	34	78
17	23	35
17	21	23
22	20	-9
18	21	16
29	33	13
30	31	3
26	35	34
23	29	26
29	40	37
27	40	48
23	27	17
32	26	-18
29	23	-20
25	27	8

TABLE A21. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE A (CONCLUDED)

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
37	39	5
35	40	14
35	40	14
38	56	47
34	48	41
35	35	0
32	35	9
33	33	0
35	33	-5
47	53	12
46	52	13
51	49	-3
39	49	25
48	62	29
46	62	34
43	43	0
43	44	2
49	44	-10
44	43	-2
55	60	9
64	59	-7
56	59	5
56	60	7
64	77	20
63	65	3
52	56	7
54	49	-9
56	48	-14
60	48	-20
69	82	18
92	82	-10
76	79	3
65	79	21
80	82	2
73	88	20
78	73	-6
70	65	-7
77	62	-19
82	62	-24
92	88	-4
117	96	-17
92	92	0
84	108	28
86	112	30
82	104	26
87	82	-5
78	77	-1
89	73	-17
107	73	-31

MEAN ERROR = 35

TABLE A22. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE A

	STANDARD METHODS	FIELD TECHNIQUE	DIFFERENCES
N =	88		
MEAN =	41.1	44.8	-3.69
VARIANCE =	836	697	94.2
STD DEV =	28.9	26.4	9.71
DATA MIN =	4	9	-26
DATA MAX =	117	112	34
DATA RANGE =	113	103	60
STANDARD ERROR OF MEAN =	3.08	2.81	1.03
COEFFICIENT OF VARIATION =	70.4	59.0	-263

T-TEST OF MEAN DIFFERENCES = 0 IS -3.57
WITH 87 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 3E-4
TWO TAIL TEST = 6E-4

MEAN DIFFERENCE = -3.69

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-5.41	1.97)
95%	(-5.75	1.64)
99%	(-6.42	0.97)

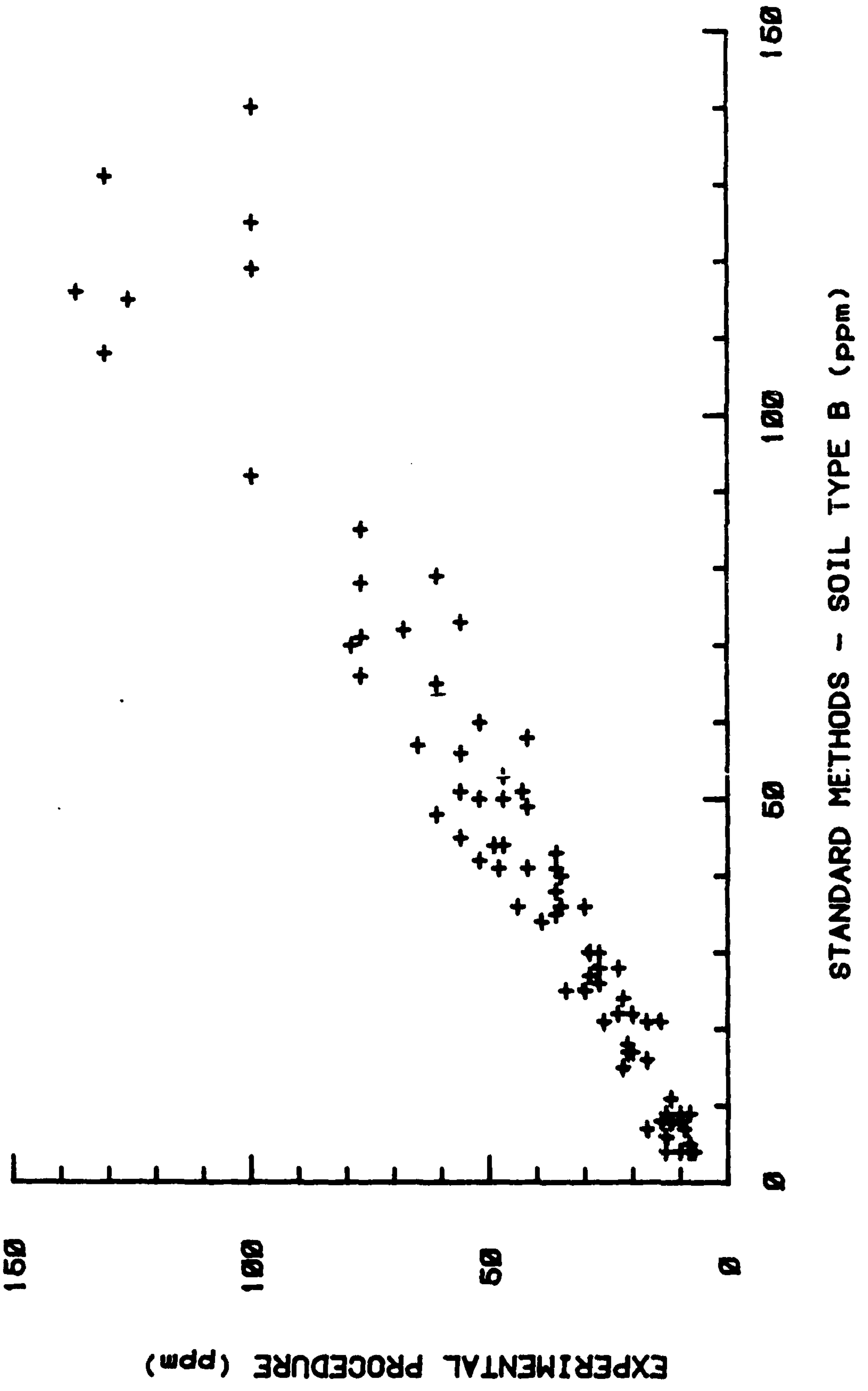


Figure A-26. Standard Methods vs Field Techniques for Soil Type B.

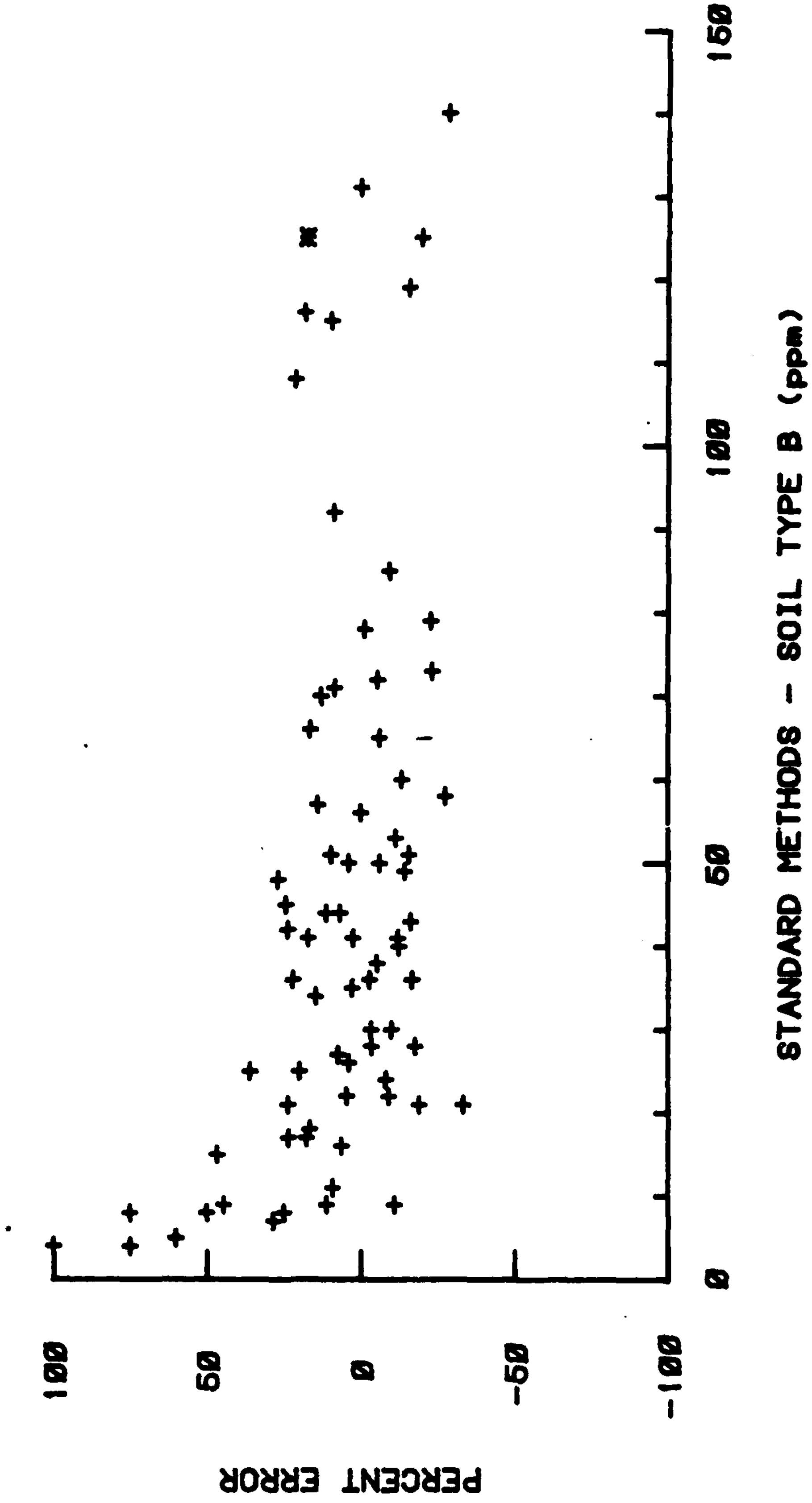


Figure A-27. Percent Error (From Standard Methods) for the Field Technique on Soil Type B.

TABLE A23. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE B

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
4	7	75
5	8	60
9	8	-11
4	8	100
4	7	75
4	13	225
4	10	150
4	8	100
5	8	60
5	8	60
7	9	28
6	13	116
8	12	50
9	13	44
8	10	25
7	17	142
8	14	75
9	10	11
11	12	9
8	12	50
15	22	46
22	20	-9
18	21	16
21	26	23
17	21	23
16	17	6
21	17	-19
21	14	-33
17	20	17
26	27	3
30	29	-3
25	30	20
28	27	-3
27	29	7
25	34	36
22	23	4
22	23	4
24	22	-8
28	23	-17
38	36	-5

TABLE A23. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE B (CONCLUDED)

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
40	35	-12
35	36	2
36	35	-2
36	44	22
34	39	14
27	29	7
30	27	-10
36	30	-16
36	30	-16
44	49	11
53	47	-11
44	47	6
41	48	17
45	56	24
42	52	23
36	35	-2
41	36	-12
41	42	2
43	36	-16
56	56	0
60	52	-13
50	52	4
51	56	9
57	65	14
48	61	27
50	47	-6
49	42	-14
51	43	-15
58	42	-27
66	77	16
85	77	-9
78	77	-1
70	79	12
71	77	8
72	68	-5
65	61	-6
73	56	-23
79	61	-22
115	126	9
166	131	-21
116	137	18
108	131	21
131	131	0
140	100	-28
92	100	8
119	100	15
125	100	20

MEAN ERROR = 15.5

TABLE A24. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE B

	STANDARD METHODS	FIELD TECHNIQUE	DIFFERENCES
N =	87		
MEAN =	41.8	41.9	-0.15
VARIANCE =	1250	1060	93.0
STD DEV =	35.4	32.6	9.64
DATA MIN =	4	7	-23
DATA MAX =	166	137	40
DATA RANGE =	162	130	63
STANDARD ERROR OF MEAN =	3.79	3.49	1.03
COEFFICIENT OF VARIATION =	84.75	77.7	-6450

T-TEST OF MEAN DIFFERENCES = 0 IS -0.14
WITH 86 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.44
TWO TAIL TEST = 0.89

MEAN DIFFERENCE = -0.15

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-1.87	1.57)
95%	(-2.21	1.91)
99%	(-2.87	2.57)

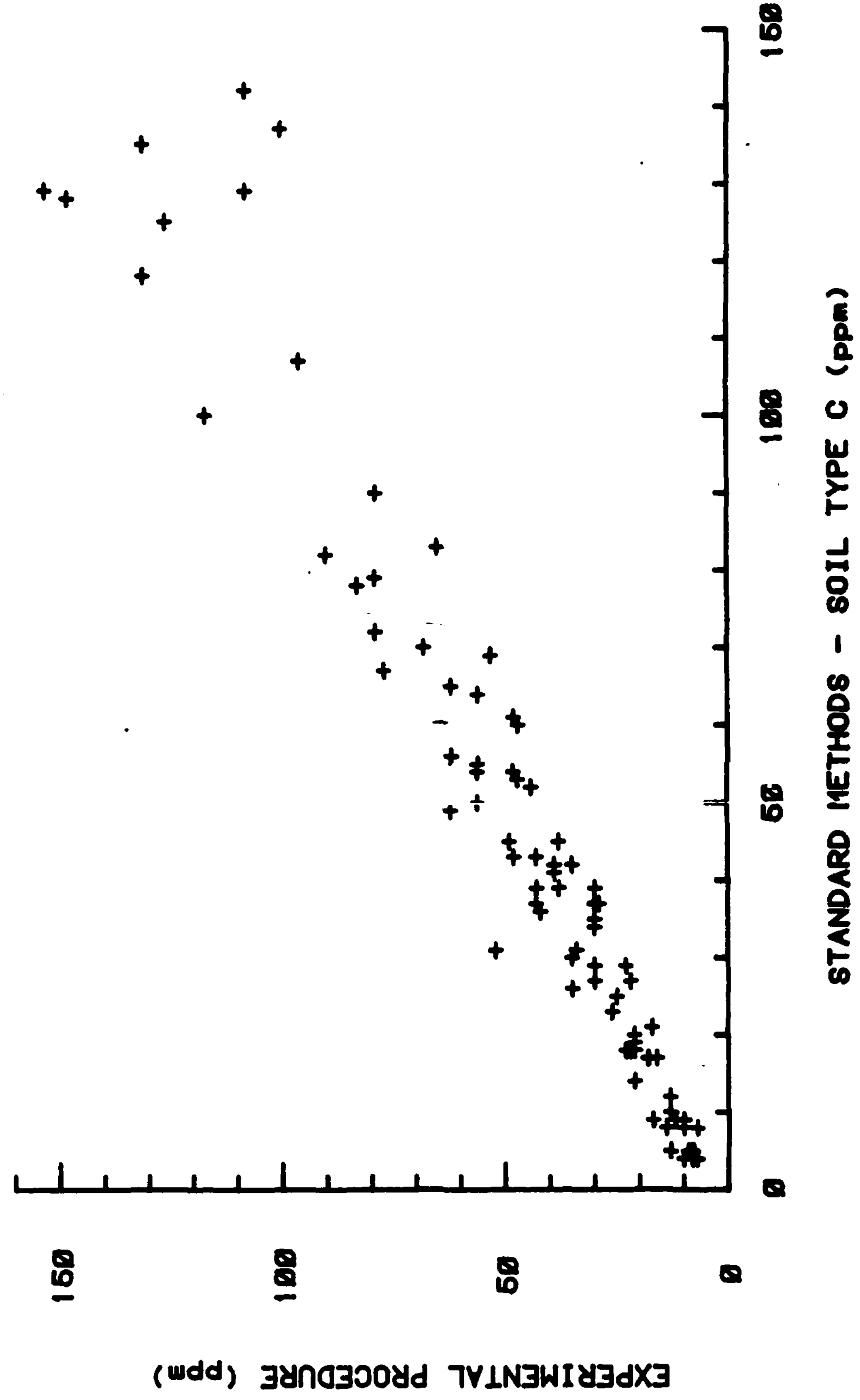


Figure A-28. Standard Methods vs Field Techniques for Soil Type C.

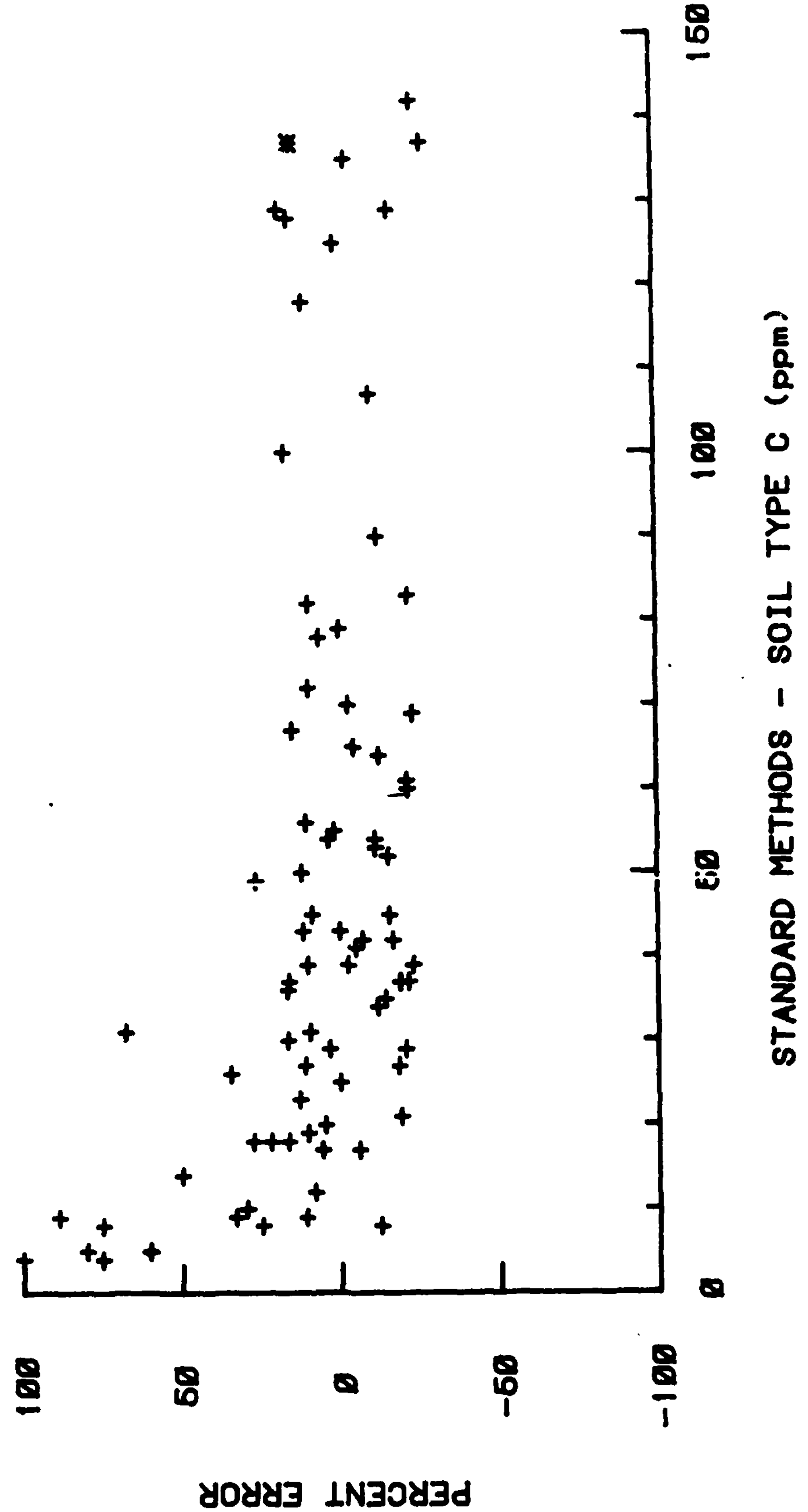


Figure A-29. Percent Error (From Standard Methods) for the Field Technology on Soil Type C.

TABLE A25. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE C

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
4	7	75
5	8	60
5	8	60
4	8	100
4	7	75
5	13	160
4	10	150
5	8	60
5	9	80
5	8	60
8	7	-12
10	13	30
10	13	30
12	13	8
8	10	25
9	17	88
8	14	75
9	10	11
9	12	33
9	12	33
18	22	22
20	21	5
19	21	10
18	21	16
18	23	27
14	21	50
17	16	5
21	17	-19
17	16	-5
17	18	5
29	30	3
35	30	-14
39	30	-23
27	30	11
35	35	16
26	35	34
29	23	-20
23	26	13
27	22	-18
25	25	0

TABLE A25. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE C (CONCLUDED)

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
37	43	16
41	39	-4
36	42	16
37	29	-21
39	43	10
37	30	-18
31	34	9
34	30	-11
37	30	-18
45	49	8
54	48	-11
61	48	-21
43	48	11
31	52	67
42	35	-16
39	38	-2
42	39	-7
39	38	-2
42	39	-7
45	38	-15
55	56	1
64	56	-12
54	56	3
55	56	12
56	62	10
49	62	26
53	47	-11
43	43	0
52	44	-15
60	47	-21
78	83	6
90	79	-12
79	79	0
67	77	14
82	90	9
72	79	9
70	68	-2
65	62	-4
69	53	-23
83	65	-21
125	126	0
135	131	-2
129	153	18
118	131	11
128	148	15
100	117	17
129	108	-16
107	96	10
142	109	-23
137	100	-27

MEAN ERROR = 13

TABLE A26. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE C

	STANDARD METHODS	FIELD TECHNIQUE	DIFFERENCES
N =	88		
MEAN =	44.1	44.2	-0
VARIANCE =	1350	1240	90.6
STD DEV =	36.7	35.2	9.52
DATA MIN =	4	7	-24
DATA MAX =	142	153	37
DATA RANGE =	138	146	61
STANDARD ERROR OF MEAN =	3.91	3.75	1.02
COEFFICIENT OF VARIATION =	83.2	79.6	-9310

T-TEST OF MEAN DIFFERENCES = 0 IS -0.10
WITH 87 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.46
TWO TAIL TEST = 0.92

MEAN DIFFERENCE = -0.10

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-1.79	1.58)
95%	(-2.12	1.92)
99%	(-2.78	2.57)

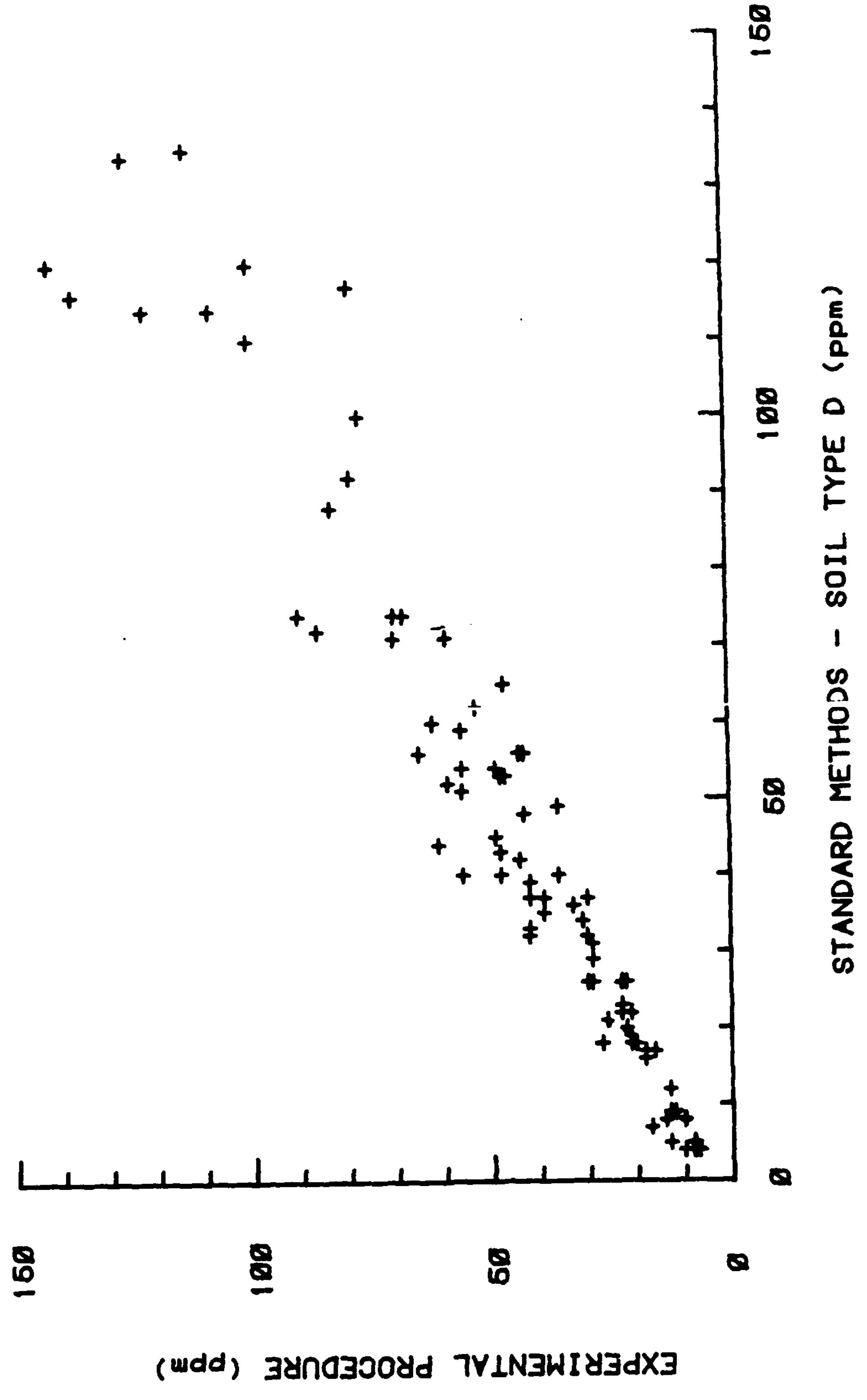


Figure A-30. Standard Methods vs Field Techniques for Soil Type D.

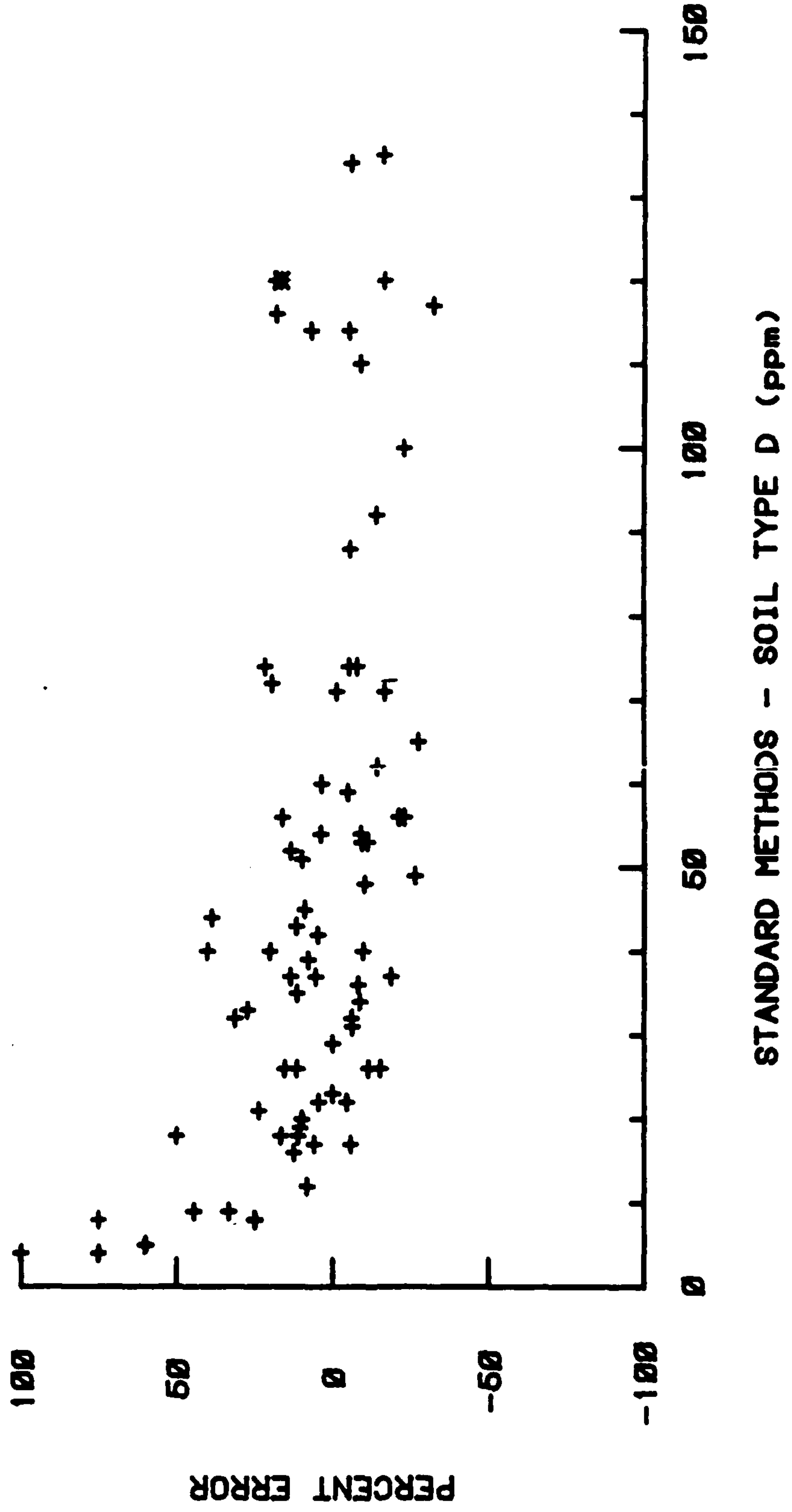


Figure A-31. Percent Error (from Standard Methods) for the Field Technology on Soil Type D.

TABLE A27. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE D

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
4	7	75
5	8	60
4	8	100
5	8	60
4	7	75
5	13	160
4	10	150
4	8	100
5	8	60
4	8	100
5	8	60
8	10	25
9	13	44
9	13	44
12	13	8
8	10	25
7	17	142
8	14	75
8	10	25
9	12	33
9	12	33
20	22	10
22	21	-4
18	21	16
19	21	10
21	26	23
18	27	50
18	20	11
16	18	12
17	16	-5
17	18	5
26	29	11
29	29	0
37	30	-18
26	30	15
23	23	0
22	23	4
26	22	-15
33	42	27
37	39	5

TABLE A27. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE D (CONCLUDED)

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
37	42	13
35	39	11
42	44	4
32	42	31
32	30	-6
34	31	-8
31	29	-6
36	33	-8
45	49	8
53	48	-9
65	47	-27
40	48	20
52	59	13
40	56	40
40	36	-10
39	42	7
43	48	11
49	36	-26
54	56	3
62	53	-14
54	49	-9
51	56	9
56	63	16
44	61	38
53	47	-11
48	43	-10
56	43	-23
56	44	-21
74	70	-5
88	83	-5
92	79	-14
72	86	19
74	90	21
74	68	-8
71	70	-1
60	62	3
59	56	-5
71	59	-16
114	122	7
134	126	-5
116	137	18
110	100	-9
120	142	18
135	113	-16
114	108	-5
100	77	-23
117	79	-32
120	100	-16

MEAN ERROR = 15

TABLE A28. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE D

	STANDARD METHODS	FIELD TECHNIQUE	DIFFERENCES
N =	88		
MEAN =	43.1	43.3	-0.17
VARIANCE =	1210	1040	87.4
STD DEV =	34.8	32.3	9.35
DATA MIN =	4	7	-22
DATA MAX =	135	142	38
DATA RANGE =	131	135	60
STANDARD ERROR OF MEAN =	3.71	3.45	1.00
COEFFICIENT OF VARIATION =	80.6	74.6	-5490

T-TEST OF MEAN DIFFERENCES = 0 IS -0.17
WITH 87 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.43
TWO TAIL TEST = 0.86

MEAN DIFFERENCE = -0.17

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-1.82	1.49)
95%	(-2.15	1.81)
99%	(-2.80	2.45)

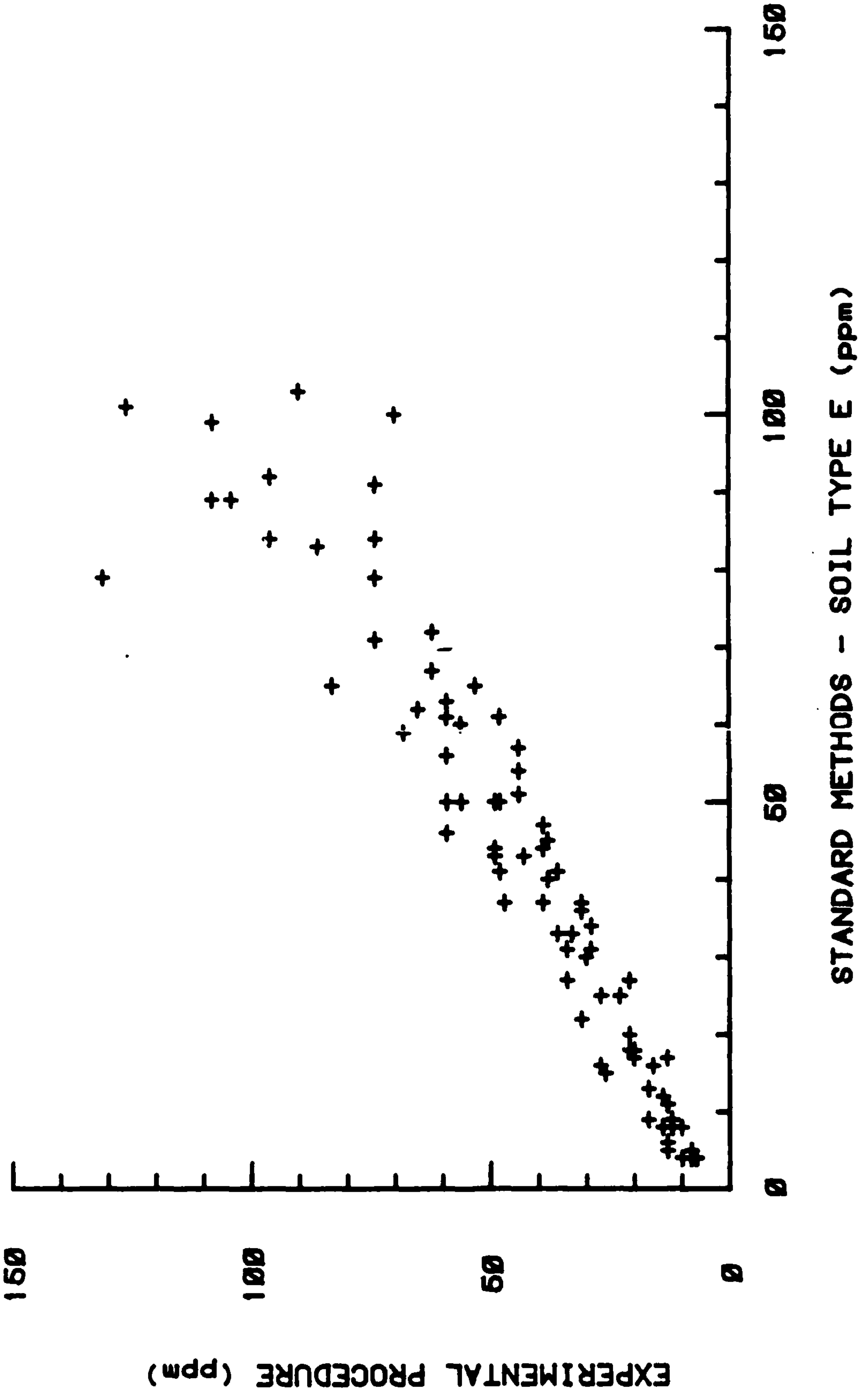


Figure A-32. Standard Methods vs Field Techniques for Soil Type E.

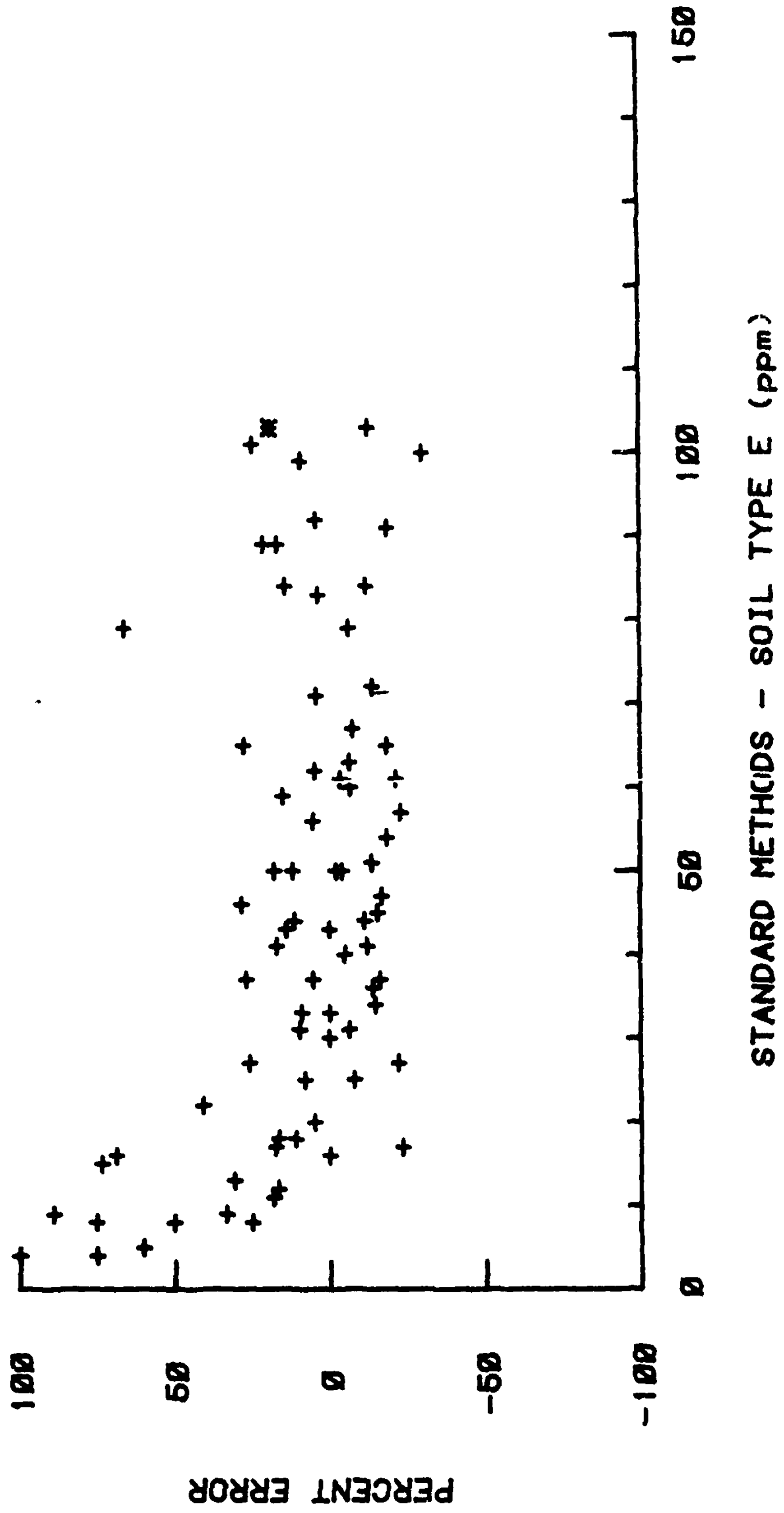


Figure A-33. Percent Error (From Standard Methods) for the Field Technique on Soil Type E.

TABLE A29. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE E

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
4	7	75
5	8	60
4	8	100
4	8	100
4	7	75
5	13	160
4	10	150
4	8	100
5	8	60
8	12	50
6	13	116
11	13	18
12	14	16
8	12	50
9	17	88
8	14	75
8	10	25
9	12	33
11	13	18
20	21	5
18	21	16
17	20	17
16	27	68
15	26	73
16	16	0
13	17	30
17	13	-23
18	20	11
22	31	40
31	34	9
37	31	-16
27	34	25
25	23	-8
25	27	8
27	21	-22
27	21	-22
43	43	0
40	38	-5
37	39	5
33	36	9

TABLE A29. DATA FROM STANDARD METHODS VS FIELD TECHNIQUE ON SOIL TYPE E (CONCLUDED)

STANDARD METHODS	FIELD TECHNIQUE	% ERROR
37	47	27
33	33	0
34	29	-14
30	30	0
31	29	-6
36	31	-13
44	49	11
50	48	-4
61	48	-21
41	48	17
50	56	12
43	49	13
41	36	-12
45	38	-15
44	39	-11
47	39	-17
61	59	-3
63	59	-6
56	59	5
46	59	28
59	68	15
50	59	18
50	49	-2
51	44	-13
57	44	-22
54	44	-18
71	74	4
84	74	-11
100	70	-30
65	83	27
83	86	3
62	65	4
72	62	-13
60	56	-6
65	53	-18
67	62	-7
92	96	4
101	126	24
89	108	21
79	131	65
99	108	9
89	104	16
79	74	-6
84	96	14
91	74	-18
103	90	-12

MEAN ERROR = 17

TABLE A30. DESCRIPTIVE STATISTICS FROM STANDARD METHODS VS FIELD TECHNIQUES ON SOIL TYPE E

	STANDARD METHOD	FIELD TECHNIQUE	DIFFERENCES
N =	86		
MEAN =	40	42.5	-1.73
VARIANCE =	816	871	97
STD DEV =	28.6	29.5	9.88
DATA MIN =	4	7	-52
DATA MAX =	103	131	30
DATA RANGE =	99	124	82
STANDARD ERROR OF MEAN =	3.08	3.18	1.06
COEFFICIENT OF VARIATION =	70.2	69	-570

T-TEST OF MEAN DIFFERENCES = 0 IS -1.63
WITH 85 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.05
TWO TAIL TEST = 0.11

MEAN DIFFERENCE = -1.73

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-3.50	0.039)
95%	(-3.85	0.39)
99%	(-4.54	1.07)

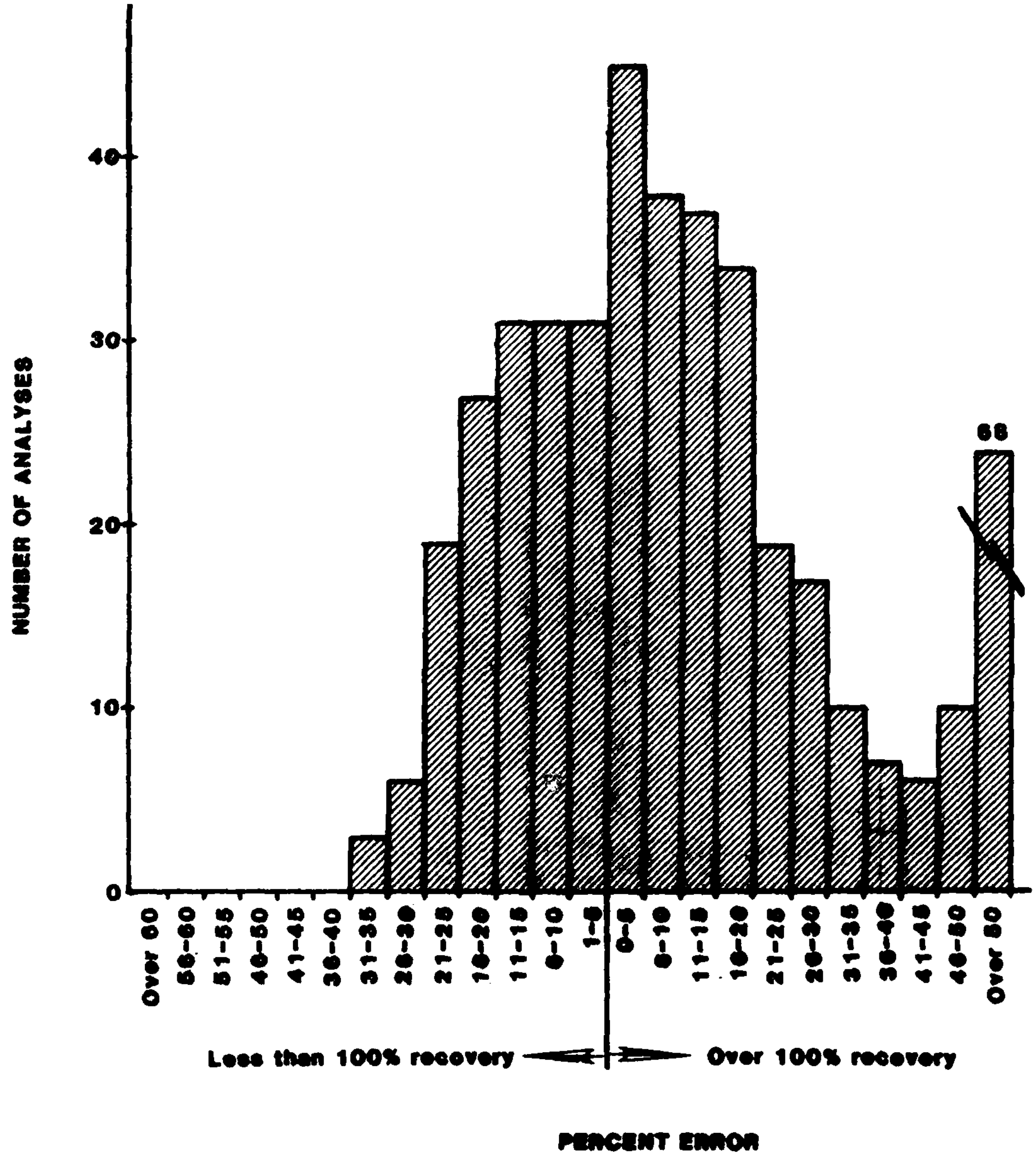


Figure A-34. Histogram of Percent Errors From the Verification Testing on Soil Types A & E.

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APPENDIX B
SOIL TESTING

APPENDIX B

OIL TESTING

Although this project was not established to develop or verify the accuracy of the oil portion of the field test kit, data were collected from a number of different laboratories. In addition to verifying the kit's accuracy, the data were used to develop an oil wheel similar to that used for soils. Test results from a "did the kit properly classify the oil" standpoint were given in the body of this report, hence, this appendix presents actual test results in ppm as measured by gas chromatography vs. the field test kit. The data presentation is similar to the soil appendix except that it has been separated by laboratory vs. by soil type. All of the laboratories tested samples submitted at random for GC analyses except the USAF Occupational and Environmental Health Laboratory (OEHL) and the USA Environmental Hygiene Agency (AEHA). The OEHL sampled transformers at random and the AEHA spiked oils to specific target values.

With the exception of the AEHA data, the following figures present the oil testing data. The AEHA data has been omitted because it has been previously published: NO. 17-44-0609-83, January -July 1983, United States Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD.

In reviewing the data, it is important to remember that the value of a field method is not in how closely the field method matches laboratory techniques. Instead, it is in how accurately the field method classified the oil samples. All data are presented as Arochlor 1260.

TABLE B1. ANALYSES PERFORMED BY CENTEC ANALYTICAL SERVICES, SALEM VA
(Selected Oils for Developing "1260" Equivalency Table)

GC-ECD	KIT	% ERROR
1	5	400
1	7	600
1	1	0
2	12	500
3	7	133
3	10	233
3	11	266
3	6	100
3	15	400
3	18	500
4	10	150
4	14	250
5	10	100
5	12	140
5	9	80
9	13	44
10	15	50
12	14	16
15	21	40
15	22	46
16	21	31
16	22	37
16	15	-6
16	23	43
16	24	50
17	18	5
19	18	-5
27	35	29
29	36	24
66	58	-12
66	61	-7
70	50	-28
96	93	-3
96	110	14
98	94	-4
98	120	22
100	110	10
100	89	-11
100	98	-2
290	300	3
300	280	-6
300	240	-20
410	430	4

MEAN ERROR = 98 Percent

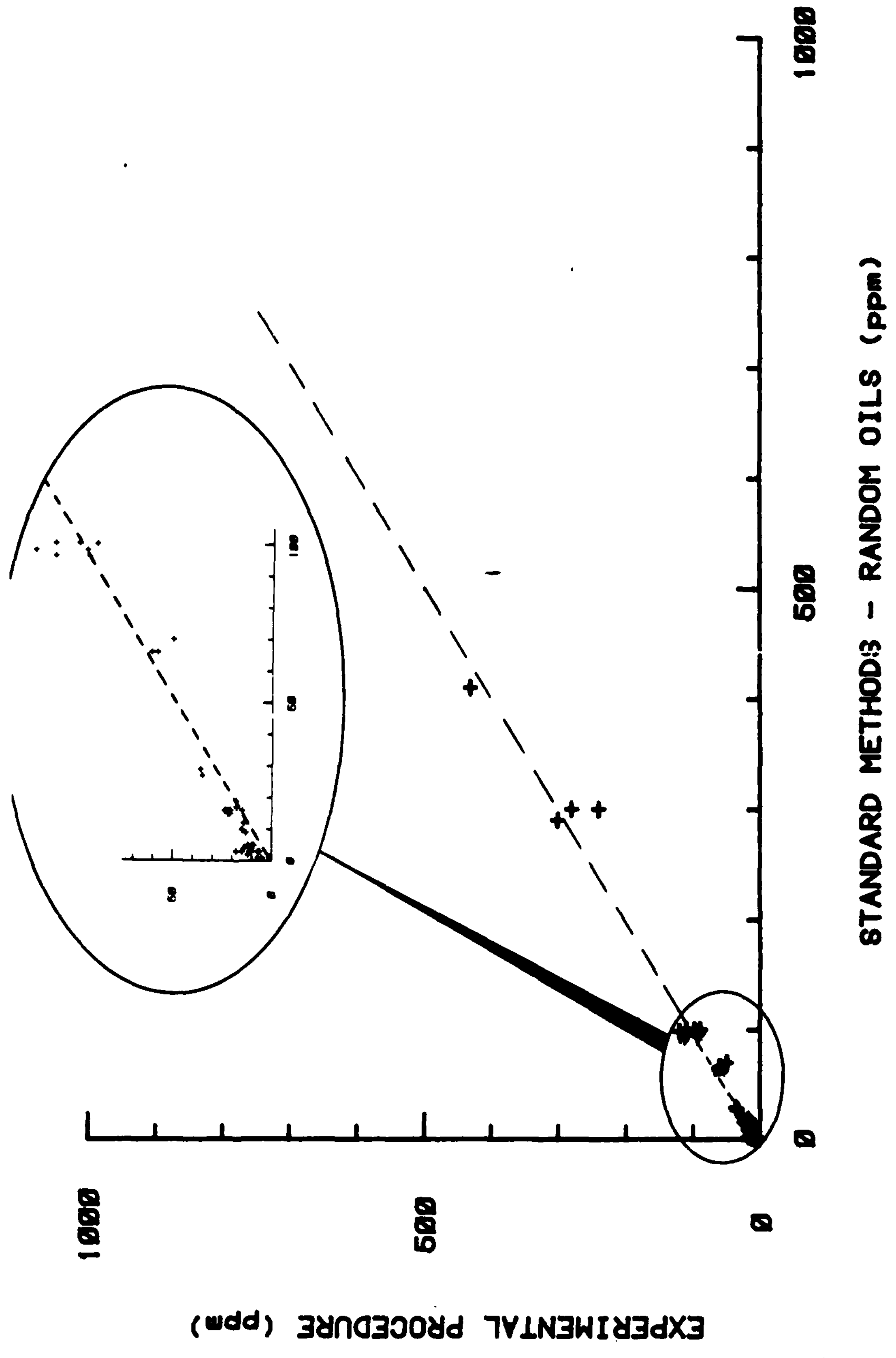

Figure B-1. Method Comparison (Stand Methods Vs Field Kit) on Selected CENTEC Samples.

TABLE B2. DESCRIPTIVE STATISTICS

```
                           GC-ECD           FIELD KIT          DIFFERENCES

N =                          43

MEAN =                       57.4              59.9               -2.51

VARIANCE =                 8960              8290                166

STD DEV =                    94.6              91.1               12.9

DATA MIN =                    1                 1                -22

DATA MAX =                  410               430                 60

DATA RANGE =                409               429                 82

  STANDARD
ERR OF MEAN =                14.4              13.9                1.96

 COEFFICIENT
OF VARIATION =              165               152               -512

T-TEST OF MEAN DIFFERENCES = 0 IS -1.28
   WITH 42 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
                   ONE TAIL TEST = 0.104
                   TWO TAIL TEST = 0.208

MEAN DIFFERENCE = -2.51

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

                 LEVEL     LOWER LIMIT     UPPER LIMIT
                 90%         (-5.81            0.79)
                 95%         (-6.47            1.45)
                 99%         (-7.81            2.78)
```

TABLE B3. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS, FRANKSVILLE, WI (Selected Oils for Developing "1242" Equivalency Table)

GC-ECD	KIT	% ERROR
12	16	33
12	16	33
12	17	41
12	18	50
12	17	41
12	16	33
12	13	8
12	18	50
12	16	33
12	14	16
15	22	46
15	23	53
15	25	66
15	18	20
15	18	20
15	20	33
15	19	26
15	18	20
15	15	0
15	16	6
23	29	26
23	28	21
23	29	26
23	25	8
23	23	0
23	24	4
23	26	13
23	23	0
23	21	-8
23	20	-13
33	40	21
33	38	15
33	38	15
33	33	0
33	33	0
33	32	-3
33	34	3
33	30	-9
33	30	-9
33	30	-9
39	52	33
39	45	15
39	47	20
39	42	7
39	34	-12
39	39	0
39	38	-2
39	36	-7
39	34	-12

TABLE B3. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS, FRANKSVILLE, WI
(Selected Oils for Developing "1242" Equivalency Table)
(Concluded)

GC-ECD	KIT	% ERROR
39	33	-15
46	56	21
46	61	32
46	56	21
46	49	6
46	44	-4
46	47	2
46	54	17
46	52	13
46	40	-13
46	39	-15
77	87	12
77	84	9
77	81	5
77	74	-3
77	68	-11
77	78	1
77	58	-24
77	66	-14
77	63	-18
77	60	-22
88	54	-38
88	95	7
88	91	3
88	87	-1
88	84	-4
88	87	-1
88	66	-25
88	84	-4
88	78	-11
88	66	-25
276	244	-11
276	221	-19
276	244	-11
276	198	-28
480	489	1
480	531	10
480	489	1
480	470	-2
666	800	20
666	708	6
666	625	-6
666	652	-2
630	800	26
630	768	21
630	652	3
630	576	-8

MEAN ERROR = 7 Percent

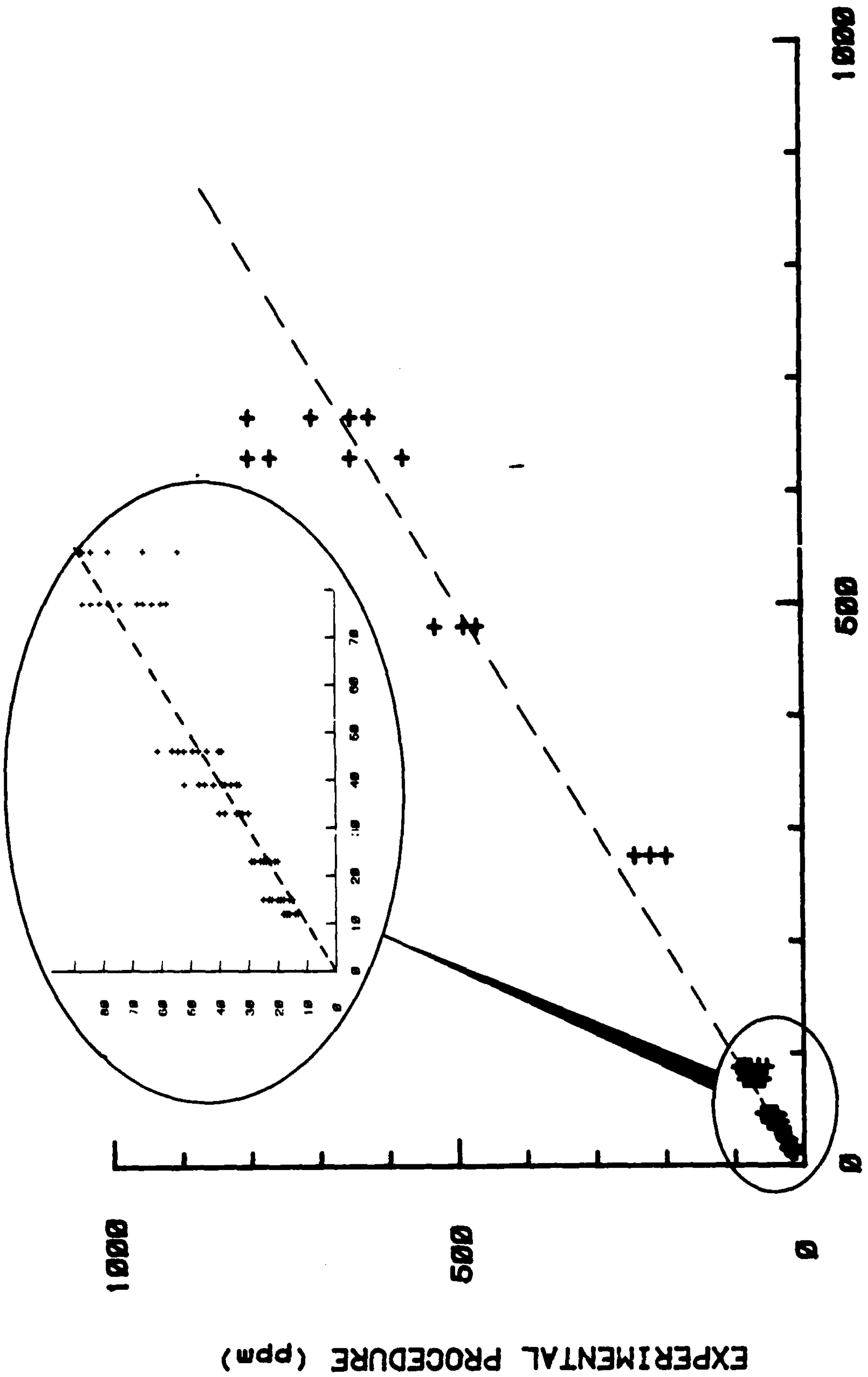

Figure B2. Method Comparison (Standard Methods vs. Field Kit) on Selected McGraw Edison Samples

TABLE B4. DESCRIPTIVE STATISTICS

	GC-ECD	FIELD KIT	DIFFERENCES
N =	96		
MEAN =	120	123	-2.91
VARIANCE =	35700	40600	962
STD DEV =	189	202	31
DATA MIN =	12	13	-170
DATA MAX =	666	800	78
DATA RANGE =	654	787	248
STANDARD ERR OF MEAN =	19.3	20.6	3.17
COEFFICIENT OF VARIATION =	157	164	-1070

T-TEST OF MEAN DIFFERENCES = 0 IS -0.918
WITH 95 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.18
TWO TAIL TEST = 0.36

MEAN DIFFERENCE = -2.91

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-8.17	2.35)
95%	(-9.19	3.38)
99%	(-11.2	5.42)

TABLE B5. ANALYSES PERFORMED BY CENTEC ANALYTICAL SERVICES
(Randomly Submitted Oil Samples)

GC-ECD	KIT	% ERROR
10	9	-10
5	4	-20
5	9	80
1	1	0
3	6	100
3	11	266
3	15	400
4	14	250
5	12	140
4	10	150
9	13	44
10	15	50
2	12	500
3	7	133
3	17	466
5	10	100
3	10	233
1	5	400
1	1	0
1	3	200
2	3	50
1	3	200
2	12	500
4	11	175
6	11	83
4	11	175
6	14	133
1	3	200
5	14	180
5	6	20
1	5	400
1	5	400
1	10	900
1	2	100
1	6	500
4	7	75
4	6	50
10	7	-30
9	7	-22
8	7	-12
8	7	-12
10	7	-30
1	5	400
1	5	400
9	5	-44
7	29	314
3	8	166

TABLE B5. ANALYSES PERFORMED BY CENTEC ANALYTICAL SERVICES
(Randomly Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
5	8	60
9	14	55
10	12	20
8	11	37
10	11	10
9	12	33
10	11	10
10	11	10
8	8	0
8	7	-12
9	9	0
10	12	20
1	3	200
2	3	50
1	3	200
2	12	500
4	11	175
6	11	83
4	11	175
6	14	133
1	7	600
1	12	1100
1	3	200
5	14	180
5	6	20
1	5	400
1	5	400
1	10	900
1	2	100
1	6	500
10	10	0
4	7	75
4	6	50
1	1	0
1	1	0
1	6	500
1	1	0
1	2	100
1	1	0
1	1	0
2	3	50
2	3	50
2	3	50
2	1	-50
2	5	150
2	1	-50

TABLE B5. ANALYSES PERFORMED BY CENTEC ANALYTICAL SERVICES
(Randomly Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
2	3	50
4	4	0
4	5	25
4	6	50
4	4	0
4	4	0
4	4	0
4	6	50
6	9	50
6	10	66
6	5	-16
6	6	0
6	6	0
6	7	16
6	9	50
8	10	25
8	5	-37
8	8	0
8	8	0
8	10	25
8	8	0
8	8	0
10	10	0
10	10	0
10	8	-20
10	12	20
10	12	20
10	13	30
10	8	-20
1	7	600
3	6	100
5	12	140
4	10	150
9	13	44
10	15	50
2	13	550
3	21	600
4	19	375
4	13	225
4	28	600
3	31	933
4	20	400
3	30	900
3	18	500
5	13	160
4	10	150

TABLE B5. ANALYSES PERFORMED BY CENTEC ANALYTICAL SERVICES
(Randomly Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
2	12	500
2	14	600
8	14	75
2	8	300
2	21	950
2	20	900
1	4	300
3	7	133
5	10	100
3	10	233
1	5	400
1	1	0
5	9	80
1	7	600
1	7	600
9	7	-22
7	15	114
3	12	300
4	14	250
1	7	600
1	10	900
1	3	200
1	3	200
2	8	300
3	11	266
6	7	16
5	11	120
9	9	0
1	8	700
1	4	300
3	9	200
3	10	233
9	10	11
10	7	-30
2	4	100
1	7	600
1	5	400
1	4	300
1	4	300
1	5	400
8	10	25
8	10	25
6	8	33
5	11	120
14	7	-50
19	7	-63

TABLE B5. ANALYSES PERFORMED BY CENTEC ANALYTICAL SERVICES
(Randomly Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
6	7	16
14	7	-50
1	7	600
1	7	600
1	7	600
16	7	-56
1	7	600
1	7	600
1	7	600
7	7	0
1	7	600
1	7	600
1	7	600
1	7	600
1	7	600
1	7	600
1	1	0
1	1	0
1	1	0
1	1	0
1	1	0
1	1	0
1	1	0
5	7	40
6	7	16
2	20	900
10	15	50
8	7	-12
7	7	0
4	7	75
1	1	0
9	1	-88
1	1	0
1	1	0
1	1	0
1	1	0
2	18	800
1	1	0
1	1	0
1	1	0
1	1	0
1	1	0
1	1	0
1	1	0
1	7	600
1	7	600

TABLE B5. ANALYSES PERFORMED BY CENTEC ANALYTICAL SERVICES
(Randomly Submitted Oil Samples)
(Concluded)

GC-ECD	KIT	% ERROR
1	7	600
1	7	600
1	16	1500
3	7	133
1	28	2700
1	17	1600
2	23	1050
1	19	1800
3	21	600
3	14	366
1	28	2700
2	10	400

MEAN ERROR = 244 Percent

TABLE B6. DESCRIPTIVE STATISTICS

```
                          GC-ECD               FIELD KIT              DIFFERENCES

N =                        243

MEAN =                       4.06                 8.40                  -4.34

VARIANCE =                 11.7                 32.9                   36.0

STD DEV =                    3.42                 5.73                   6.0

DATA MIN =                 1                    1                     -28

DATA MAX =                 19                   31                     12

DATA RANGE =               18                   30                     40

  STANDARD
ERR OF MEAN =                0.22                 0.37                   0.38

 COEFFICIENT
OF VARIATION =             84.3                 68.3                  -138

T-TEST OF MEAN DIFFERENCES = 0 IS -11.3
   WITH 242 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
                   ONE TAIL TEST = 0
                   TWO TAIL TEST = 0

MEAN DIFFERENCE = -4.34

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

               LEVEL      LOWER LIMIT     UPPER LIMIT
               90%         (-4.97           -3.70)
               95%         (-5.60           -3.56)
               99%         (-5.34           -3.34)
```

TABLE B7. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS
(Random Submitted Oil Samples)

GC-ECD	KIT	% ERROR
38	38	0
3	4	33
32	35	9
37	22	-40
146	106	-27
35	28	-20
3	4	33
6	7	16
95	106	11
45	37	-17
3	4	33
35	40	14
17	14	-17
181	64	-64
4	30	650
69	139	101
576	190	-67
292	141	-51
84	64	-23
259	129	-50
422	502	18
94	95	1
20	16	-20
37	32	-13
46	42	-8
44	37	-15
7	7	0
3	6	100
3	23	666
3	7	133
15	16	6
3	16	433
69	64	-7
369	145	-60
10	7	-30
3	4	33
3	4	33
22	33	50
18	20	11
22	382	1636
18	111	516
3	49	1533
3	129	4200
17	20	17
9	19	111
80	30	-62

TABLE B7. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS
(Random Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
32	20	-37
34	23	-32
8	6	-25
33	20	-39
3	5	66
20	1046	5130
3	4	33
3	4	33
14	12	-14
110	40	-63
11	16	45
22	31	40
6	7	16
13	14	7
3	25	733
59	57	-3
66	69	4
26	20	-23
22	16	-27
629	710	12
3	7	133
620	684	10
17	16	-5
171	116	-32
112	37	-66
172	303	76
3	8	166
16	33	106
3	9	200
993	482	-51
3	12	300
10	7	-30
4	6	50
4	5	25
4	6	50
3	7	133
3	22	633
443	542	22
472	501	6
25	30	20
75	59	-21
843	446	-47
7	22	214
90	55	-38
820	446	-45
52	49	-5

TABLE B7. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS
(Random Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
48	49	2
127	124	-2
780	446	-42
21	29	38
80	51	-36
12	91	658
3	4	33
3	7	133
3	9	200
3	8	166
2	6	200
46	12	-73
27	25	-7
32	35	9
132	157	18
567	862	52
56	59	5
11	17	54
6	10	66
149	163	9
1046	1046	0
53	34	-35
340	446	31
437	413	-5
7	10	42
337	291	-13
52	64	23
59	37	-37
11	16	45
30	382	1173
20	44	120
143	124	-13
64	49	-23
12	18	50
4	84	20000
72	34	-52
201	92	-54
207	84	-59
188	66	-64
3	6	100
2204	1046	-52
25	124	396
28	124	342
26	25	-3
497	240	-51
300	134	-55

TABLE B7. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS
(Random Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
6721	1046	-84
8312	968	-88
8472	1046	-87
84	72	-14
252	222	-11
106	99	-6
130	107	-17
45	59	31
20	25	25
49	32	-34
25	20	-20
510	482	-5
154	134	-12
361	413	14
237	240	1
26	27	3
28	36	28
19	13	-31
29	20	-31
45	44	-2
30	36	20
31	30	-3
3	12	300
9	16	77
3	8	166
9	15	66
3	4	33
3	633	21000
10	1046	10360
258	250	-3
3	5	66
139	111	-20
13	16	20
15	25	66
3	9	200
3	5	66
26	27	3
28	36	28
45	44	-2
30	36	20
31	30	-3
3	18	500
3	14	366
139	222	59
13	35	169
62	95	53

TABLE B7. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS
(Random Submitted Oil Samples)
(Continued)

GC-ECD	KIT	% ERROR
28	34	21
132	163	23
107	102	-4
67	84	25
172	78	-54
91	51	-43
38	36	-5
24	9	-62
145	95	-34
156	102	-34
145	107	-26
794	863	8
38	13	-65
8	9	12
3	31	933
1	5	400
11	12	9
3	145	4733
36	119	230
431	157	-63
1	4	300
5	7	40
3	4	33
3	5	66
218	340	55
3	9	200
194	315	62
252	563	123
3	19	533
3	9	200
3	1815	60400
35	157	348
57	31	-45
3	8	166
36	291	708
13	157	1107
16	115	618
32	55	71
172	303	76
60	259	331
16	44	175
3	-4	33
2	4	100
19	9	-52
12	4	-66
36	968	2588

TABLE B7. ANALYSES PERFORMED BY MCGRAW EDISON POWER SYSTEMS
(Random Submitted Oil Samples)
(Concluded)

GC-ECD	KIT	% ERROR
17	11	-35
21	14	-33
14	13	-7

MEAN ERROR = 558 Percent

TABLE B8. DESCRIPTIVE STATISTICS

	GC-ECD	FIELD KIT	DIFFERENCES
N =	233		
MEAN =	206	137	69.5
VARIANCE =	821000	64100	647000
STD DEV =	906	253	805
DATA MIN =	1	4	-1810
DATA MAX =	8470	1820	7430
DATA RANGE =	8470	1810	9240
STANDARD ERR OF MEAN =	59.4	16.6	52.7
COEFFICIENT OF VARIATION =	439	185	1160

T-TEST OF MEAN DIFFERENCES = 0 IS 1.32
WITH 232 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.09
TWO TAIL TEST = 0.19

MEAN DIFFERENCE = 69.5

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-17.6	157)
95%	(-34.4	173)
99%	(-67.4	206)

TABLE B9. ANALYSES PERFORMED BY USAF OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY (Random Submitted Oil Samples)

GC-CD	KIT
40	15
0	21
0	15
0	30
0	25
0	13
0	19
0	18
13	0
34	33
45	45
47	161
65	87
82	36
88	65
95	165
208	45
27	68
0	0
0	0
81	69
0	22
0	0
0	0
0	0
218	88
230	115
0	11
19	24
36	23
0	0
33	15

NOTE: Percent error not computed due to large number of samples with no PCB by GC-ECD.

TABLE B10. DESCRIPTIVE STATISTICS

	GC-ECD	FIELD KIT	DIFFERENCES
N =	32		
MEAN =	42.5	38.4	4.16
VARIANCE =	4220	1930	2710
STD DEV =	64.9	43.9	52.0
DATA MIN =	0	0	-114
DATA MAX =	230	165	163
DATA RANGE =	230	165	277
STANDARD ERR OF MEAN =	11.5	7.76	9.20
COEFFICIENT OF VARIATION =	153	114	1250

T-TEST OF MEAN DIFFERENCES = 0 IS 0.45
WITH 31 DEGREES OF FREEDOM

SIGNIFICANCE LEVELS
ONE TAIL TEST = 0.33
TWO TAIL TEST = 0.65

MEAN DIFFERENCE = 4.15625

CONFIDENCE INTERVALS FOR MEAN DIFFERENCE

LEVEL	LOWER LIMIT	UPPER LIMIT
90%	(-11.4	19.8)
95%	(-14.6	22.9)
99%	(-21.1	29.4)

TABLE B11. SUMMARY OF ALL OIL TESTS

Number of samples: 615

Average Error: +315%

Average Error in 40 - 60 ppm Range: +9%

Average Error in 400 - 600 ppm Range: -8%

APPENDIX C

TRI- AND TETRA-CHLORINATED BENZENE TESTING

APPENDIX C

TRI- TETRA-CHLORINATED BENZENE TESTING

A portion of this effort was devoted to examining the relationship between the concentrations of the benzene solvents (both tri- and tetrachlorinated species - TCBs) and the PCB in Arochlor 1260 type dielectric oils. Because the selected test kit keys on any chlorinated organic compound in the oil sample, establishing this relationship would add credibility to the oil test by proving the predicability of the TCB concentrations.

Soil Types A - E (as previously described) were used for this phase of testing. The total TCB present in the samples (i.e., 1,2,4- and 1,2,3-trichlorinated benzenes and 1,2,3,5- and 1,2,3,4-tetrachlorinated benzenes combined) is shown in Table C1.

TABLE C1. TRI- AND TETRA-CHLORINATED BENZENE AGING DATA

				DAY	OF	TEST				
SOIL TYPE/CONCENTRAT	1	2	3	4	5	8	13	16	20	25
TYPE A/0 ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TYPE A/5 ppm	3.4	2.9	2.6	2.7	3.1	3.2	3.0	3.3	3.5	2.8
TYPE A/10 ppm	6.5	5.4	5.5	5.9	6.3	5.4	6.4	5.9	7.2	6.0
TYPE A/20 ppm	16.4	*	11.7	12.0	13.2	13.4	13.5	12.8	13.6	12.6
TYPE A/30 ppm	18.8	19.2	18.4	17.3	23.6	21.8	19.6	18.7	20.8	17.2
TYPE A/40 ppm	29.4	26.8	21.9	21.7	28.8	32.5	27.9	24.4	25.3	26.1
TYPE A/50 ppm	30.2	31.2	35.4	37.7	36.9	31.9	32.1	27.0	27.0	30.6
TYPE A/60 ppm	*	40.9	34.8	*	42.2	40.3	42.1	39.6	35.5	39.8
TYPE A/80 ppm	44.3	45.3	57.6	48.8	51.7	58.9	28.5	45.7	50.8	54.6
TYPE A/100 ppm	65.2	63.1	81.2	51.4	58.5	63.4	61.9	55.7	61.2	63.5
TYPE B/0 ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TYPE B/5 ppm	3.4	2.9	2.7	2.8	3.1	3.4	3.0	2.5	3.1	2.8
TYPE B/10 ppm	5.6	*	5.2	6.1	6.2	6.5	6.3	5.6	6.2	4.8
TYPE B/20 ppm	12.6	12.6	12.9	12.7	16.6	14.3	14.1	10.0	13.2	12.6
TYPE B/30 ppm	19.8	18.8	20.2	17.5	19.3	20.4	18.6	16.7	16.7	19.0
TYPE B/40 ppm	26.4	24.1	23.9	23.6	28.4	26.7	23.1	21.1	26.3	26.9
TYPE B/50 ppm	27.9	28.7	28.7	34.3	33.2	27.8	31.7	29.3	17.0	28.5
TYPE B/60 ppm	39.9	39.8	32.6	40.7	40.4	38.3	42.8	34.4	33.8	36.8
TYPE B/80 ppm	45.8	48.0	60.7	48.0	54.1	53.5	49.8	50.1	50.4	53.3
TYPE B/100 ppm	78.7	74.5	90.7	93.6	76.7	91.5	83.8	66.0	43.7	81.7
TYPE C/0 ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TYPE C/5 ppm	3.9	2.9	3.0	2.6	3.1	3.4	3.2	2.9	2.8	2.9
TYPE C/10 ppm	6.5	6.5	5.9	5.3	6.3	5.9	6.1	5.5	5.5	5.5
TYPE C/20 ppm	13.8	12.4	12.2	10.8	14.7	15.2	14.8	12.2	13.9	13.7
TYPE C/30 ppm	18.6	18.9	19.5	15.6	25.7	19.8	23.8	16.7	18.0	20.1
TYPE C/40 ppm	27.9	28.3	24.4	22.1	28.6	26.7	27.1	24.1	23.6	26.7
TYPE C/50 ppm	32.4	37.3	30.4	32.0	*	29.8	33.7	27.3	30.4	29.0
TYPE C/60 ppm	39.6	43.3	36.3	34.7	42.6	*	43.5	35.0	37.4	37.3
TYPE C/80 ppm	*	53.4	65.0	52.8	58.4	59.7	51.2	42.2	42.5	56.9
TYPE C/100 ppm	85.8	79.6	102.6	71.2	84.8	90.5	82.8	69.1	*	82.0
TYPE D/0 ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TYPE D/5 ppm	3.6	2.8	2.8	2.8	3.3	3.4	3.2	2.8	2.9	2.9
TYPE D/10 ppm	6.2	*	5.7	4.9	6.2	6.2	6.2	5.5	5.1	5.8
TYPE D/20 ppm	14.4	15.2	14.3	11.7	12.4	14.1	14.1	11.2	11.2	11.9
TYPE D/30 ppm	19.3	18.7	17.9	17.4	20.3	18.8	19.0	17.7	20.1	18.9
TYPE D/40 ppm	30.0	23.0	25.9	22.1	31.9	26.9	25.0	21.0	18.7	23.3
TYPE D/50 ppm	29.5	31.0	34.4	33.4	37.7	36.3	42.6	29.9	28.0	34.5
TYPE D/60 ppm	38.7	37.3	36.2	35.0	40.2	*	45.9	33.2	35.7	38.0
TYPE D/80 ppm	49.3	51.0	65.6	48.3	55.9	58.4	50.2	47.0	43.2	48.3
TYPE D/100 ppm	80.5	80.9	98.2	71.1	80.5	92.6	76.6	66.9	68.0	78.2

TABLE C1. TRI- AND TETRA-CHLORINATED BENZENE AGING DATA

(concluded)

TYPE E/0 ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TYPE E/5 ppm	3.5	2.7	2.8	2.9	3.1	3.3	3.3	*	2.9	3.2
TYPE E/10 ppm	6.4	5.5	6.1	5.1	6.2	6.1	6.2	5.1	5.5	6.8
TYPE E/20 ppm	12.9	14.1	11.8	11.5	12.7	14.1	13.9	11.3	12.0	13.4
TYPE E/30 ppm	17.6	19.9	18.9	16.8	17.5	19.3	20.2	18.2	20.0	18.4
TYPE E/40 ppm	25.5	23.9	23.4	22.1	30.4	27.0	26.1	24.4	32.0	23.4
TYPE E/50 ppm	27.1	29.2	32.0	36.4	32.1	28.9	41.1	26.4	32.4	33.5
TYPE E/60 ppm	42.7	39.4	47.0	36.6	39.7	*	41.9	36.8	38.4	41.3
TYPE E/80 ppm	*	47.8	56.3	43.9	52.0	55.4	51.7	39.7	50.0	44.0
TYPE E/100 ppm	*	57.8	83.9	54.6	62.4	75.1	59.5	59.7	*	69.9

*Data unavailable.

Considering the problems inherent in precisely homogenizing a soil sample, the data are consistent with soil type (i.e.,[TCB] in soil type "A" at 5 ppm PCB is equivalent to type "B" at 5 ppm PCB). This was consistent with the initial field extraction studies which showed the shortened procedure to be relatively consistant with soil type. Hence, the first data reduction was to average the values from the different soil types and reduce the matrix to TCB concentration vs. time. This was then further reduced by expressing the concentration of TCB as a function of PCB as follows: ([TCB]/[PCB]) x (100) = percent TCB. Table C2 shows the data resulting from this matrix and Figure C1 shows the same data graphically.

TABLE C2. TCB CONCENTRATIONS (AND PERCENT OF PCB) AVERAGED OVER ALL SOIL TYPES

Day	1	2	3	4	5	8	13	16	20	25
AVE ALL 5PPM	3.5	2.8	2.7	2.7	3.1	3.3	3.1	2.8	3.0	2.9
SOIL TYPES	(70)	(56)	(54)	(54)	(62)	(66)	(62)	(56)	(60)	(58)
AVE ALL 10 PPM	6.2	5.8	5.6	5.4	6.2	6.0	6.2	5.5	5.9	5.7
SOIL TYPES	(62)	(58)	(56)	(54)	(62)	(60)	(62)	(55)	(59)	(57)
AVE ALL 20 PPM	14.0	10.8	12.5	11.7	13.9	14.2	14.0	11.5	12.7	12.8
SOIL TYPES	(70)	(54)	(63)	(59)	(70)	(71)	(70)	(58)	(64)	(64)
AVE ALL 30 PPM	18.8	19.1	18.9	16.9	21.2	20.0	20.2	17.6	19.1	18.7
SOIL TYPES	(63)	(64)	(63)	(56)	(71)	(67)	(67)	(59)	(64)	(62)
AVE ALL 40 PPM	27.8	25.2	23.9	22.3	26.0	27.9	25.8	23.0	25.1	25.2
SOIL TYPES	(70)	(63)	(60)	(56)	(65)	(70)	(65)	(58)	(63)	(63)
AVE ALL 50 PPM	29.4	31.4	32.1	34.7	34.9	30.9	36.2	27.9	26.9	31.2
SOIL TYPES	(59)	(63)	(64)	(60)	(70)	(62)	(72)	(56)	(54)	(62)
AVE ALL 60 PPM	40.2	40.1	37.3	36.7	41.0	39.3	43.2	35.8	36.1	38.6
SOIL TYPES	(67)	(67)	(62)	(61)	(68)	(66)	(72)	(60)	(60)	(64)
AVE ALL 80 PPM	46.4	49.1	61.0	48.3	54.4	57.1	46.2	44.9	47.3	51.4
SOIL TYPES	(58)	(61)	(76)	(60)	(68)	(71)	(58)	(56)	(59)	(64)
AVE ALL 100 PPM	77.5	71.1	91.3	68.3	72.5	82.6	72.9	63.4	57.6	75.0
SOIL TYPES	(78)	(71)	(91)	(68)	(73)	(83)	(73)	(63)	(58)	(75)

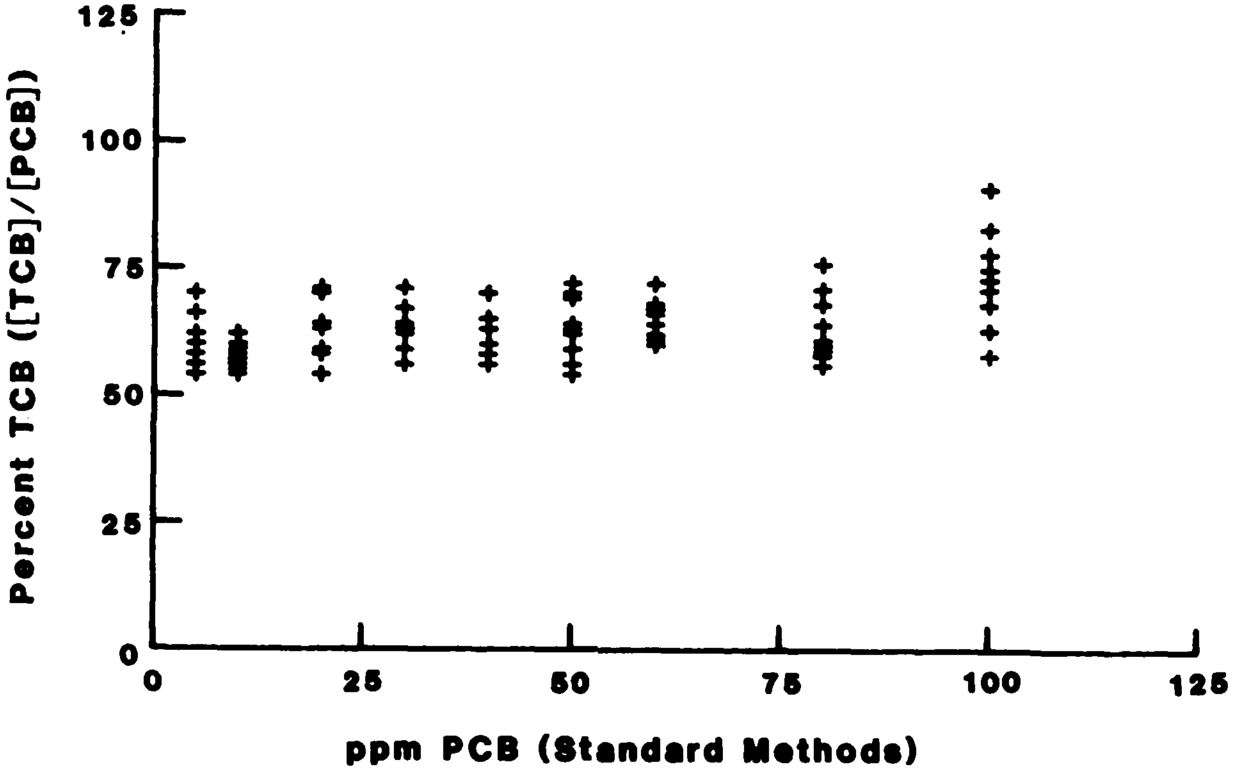

Figure C1. The Relationship of PCB Concentration (ppm) vs. TCB (as a percent of PCB).

Again, the data are relatively constant with time. Hence, the final data reduction was to show the TCB concentration (i.e., a percent of PCB) as a function of the PCB concentration (in ppm). This relationship is shown in Table C3.

TABLE C3. AVERAGE TCB CONCENTRATION VS. PCB CONCENTRATION

AVERAGE OVER TIME	PPM TCB	% OF PCB	lnTCB
5 PPM	3.0	60.0	1.10
10 PPM	5.8	58.0	1.77
20 PPM	12.8	64.0	2.55
30 PPM	19.0	63.3	2.95
40 PPM	25.2	63.0	3.23
50 PPM	31.6	63.2	3.45
60 PPM	38.8	64.6	3.66
80 PPM	50.6	63.2	3.92
100 PPM	73.2	73.2	4.29

The Table C3 data was then graphed in Figure C2 with the "best fit" curve established by least squares analysis.

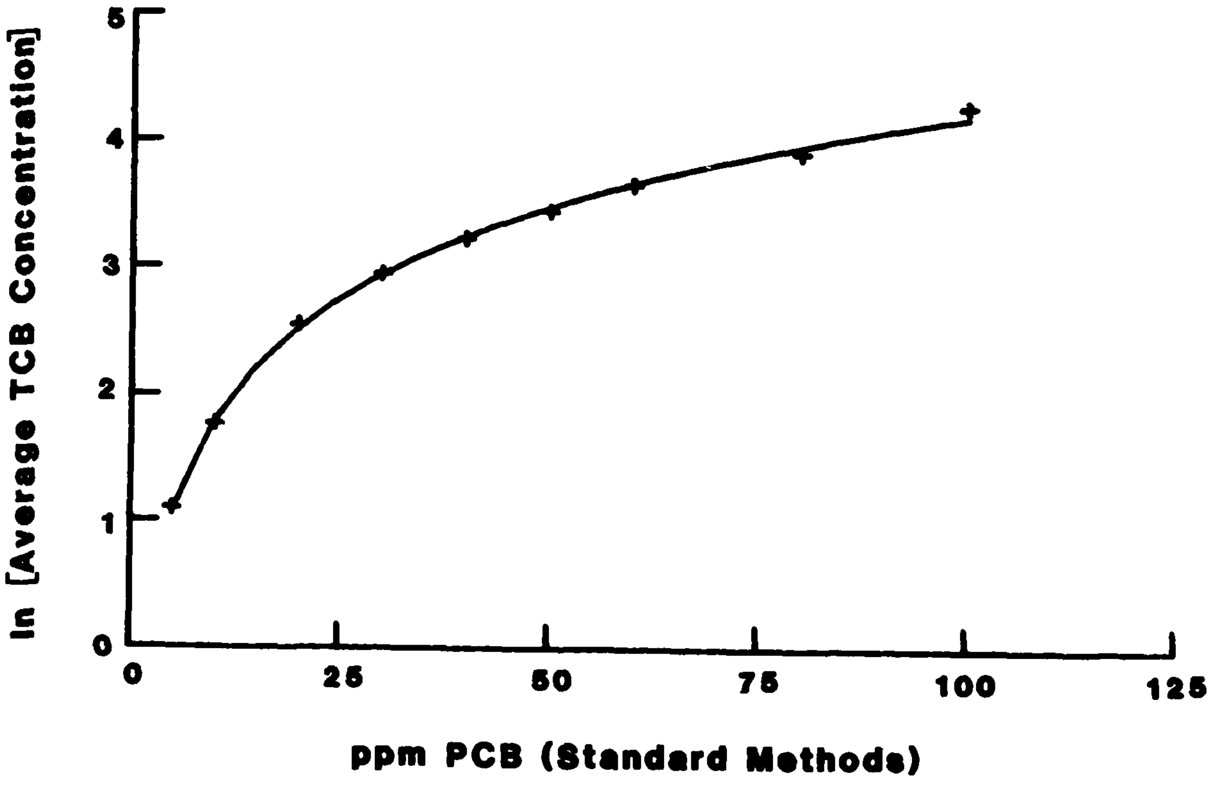

Figure C2. Average TCB Concentration vs. PCB.

The data correlation is excellent ("r-squared" value = .9984) indicating a strong, predictable relationship of the TCB solvent to the PCB concentation in these 1260 type oils. This type of correlation is the basis of predicting PCB concentration by measuring the chlorinated organic compounds in the oil.