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Workshop Report: Identification of Performance Parameters for Portable X-Ray Fluorescence Measurement of Lead in Paint

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WORKSHOP REPORT: IDENTIFICATION OF PERFORMANCE PARAMETERS FOR PORTABLE X-RAY FLUORESCENCE MEASUREMENT OF LEAD IN PAINT

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DISCLAIMER

The Workshop described in these proceedings was sponsored by the United States Environmental Protection Agency. The opinions, conclusions and recommendations are solely those of the various participants and therefore, the contents of this document do not necessarily reflect the views of the Agency. No official endorsement should be inferred.

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EXECUTIVE SUMMARY

The potential impact on health from environmental lead has resulted in increased interest in lead exposure by Federal, State and local government agencies. As a result, programs committed to sampling and analysis of lead are increasing nationwide. Public housing authorities are required, by 1994, to randomly inspect all their housing projects for lead-based paint [Lead-Based Paint Poisoning Prevention Act, 42, U.S.C. 4:22 (d)(2)(A), 1971]. Currently, the most common approach to screening housing for the presence of lead in paint is the use of the portable X-ray fluorescence (XRF) detector, which gives rapid results and is non-destructive. More than six different portable XRF instruments are commercially available. The EPA has sponsored studies of the performance of each of several of these instruments.

To review the status of portable XRF technology, the U.S. Environmental Protection Agency sponsored a 1-1/2 day workshop limited to Federal and State government personnel and government contractors. The goal of the workshop was to identify problems and limitations that could result in measurement error and to develop a set of performance parameters to generate or verify figures of merit that are comparable across the technology.

The workshop was attended by 32 persons with experience in portable XRF measurements. The morning session of the workshop began with a brief overview of the purpose and goals of the workshop and was followed by presentations on the following topics:

- fundamentals
- specific studies
- future needs
- a proposed test design
- manufacturer's input

In the afternoon, the attendees discussed spectral and physical problems and limitations of portable XRF and began to identify specific parameters or areas that need

to be evaluated. On the second day, the attendees continued to identify parameters that are experimentally verifiable and to discuss general approaches to the experimental measurement of these parameters that would allow direct comparisons of portable XRF instruments. Details of the experiments were not determined and will require consultation with a statistician. The parameters judged to be the most important by consensus of the workshop participants are the manufacturer's calibration, precision, accuracy, detection limit, substrate effects and other interferences, and ruggedness. Other parameters that should be considered in evaluating a portable XRF but are difficult to measure experimentally include training, cost, safety features, physical configuration, portability, data retention/storage capabilities, and manufacturer's support.

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SECTION 1
INTRODUCTION

1.1 Goals of the Workshop

Numerous programs involving research on the toxicity and bioavailability of lead, the environmental monitoring of lead, and the abatement of lead in and clearance testing of housing are currently active. Examples of past projects include the Housing and Urban Development (HUD) National Survey, the Three City Study and method evaluation studies sponsored by the U.S. Environmental Protection Agency (EPA), and abatement programs carried out by Maryland, Massachusetts, and many other active groups.

Public housing authorities are required, by 1994, to randomly inspect all their housing projects for lead-based paint [Lead-Based Paint Poisoning Prevention Act, 42, U.S.C. 4:22 (d)(2)(A), 1971]. That statute specifies the use of an on-site X-ray fluorescence (XRF) analyzer for measurement of lead and denominates a reading of 1.0 mg/cm^2 as a positive finding of lead-based paint. The HUD Interim Guidelines (September 1990) use the XRF analyzer and the 1.0 mg/cm^2 standard, but also specify that atomic absorption analysis (AAS) or another comparable testing technique will be used as a backup or confirmatory test when the XRF reading is inconclusive. Alternatively, AAS may be used without first using on-site XRF. The HUD Guidelines set the level of hazard for lead as 1.0 mg/cm^2 (area basis) or 5000 µg/g (weight basis).

Currently, the most common approach to screening housing for the presence of lead in paint is the use of the portable X-ray fluorescence (XRF) detector, which gives rapid results and is non-destructive. More than six different portable XRF instruments are commercially available. The EPA has sponsored studies of the performance of each of several of these instruments.

The U.S. Environmental Protection Agency sponsored a 1-1/2 day workshop limited to Federal and State government personnel and government contractors to review the status of portable XRF technology. The goal of the workshop was to identify problems and limitations that could result in measurement error and to develop a set of performance parameters to generate or verify figures of merit that are comparable across

the technology. Parameters to be included are detection limits, precision, bias, interferences, productivity, safety, and use or generation of hazardous materials.

1.2 Structure of the Workshop

Following planning efforts by EPA and EPA-contractor staff, letters of invitation were mailed to representatives from Federal and State governmental agencies and a number of EPA contractors with experience in the use of portable XRF methods for measurement of lead in paint. The intent was to invite recognized experts in the field, while keeping the size of the workshop manageable and productive. Manufacturers of portable XRF instruments were not invited to the workshop but were asked to complete a questionnaire and to supply any additional information that they judged to be of value to the workshop.

Thirty-two representatives accepted the invitation to attend the workshop (see Appendix C for list). Upon arrival, attendees received a notebook containing the following information:

- Workshop Program
  - Agenda
  - List of Attendees
- XRF Reports
  - "First Preliminary Draft Recommendation on Portable and Transportable X-Ray Fluorescence Spectrometers for Field Measurements of Hazardous Elemental Pollutants (International Organization of Legal Metrology, OIML Reporting Secretariat PS17/RS5: USA, October, 1992)
  - "Evaluation of Portable X-Ray Fluorescence Spectrometer for Measurement of Lead in Paint, Soil and Dust," Hardison, D. L., C. O. Whitaker, J. D. Neefus, E. D. Estes and W. F. Gutknecht, Proceedings of 1992 EPA and AWMA International Symposium on Measurement of Toxic and Other Related Air Pollutants, Durham, NC, May 1992.

The workshop began with a morning session of presentations on the current status of portable XRF technology including fundamentals, specific studies, future needs, a proposed test design, and manufacturers' input (see workshop agenda presented on page 4). In the afternoon, the attendees discussed spectral and physical problems and limitations of portable XRF and began to identify specific parameters or areas that need to be evaluated. On the second day, the attendees continued to identify parameters that are experimentally verifiable and to suggest experiments that would allow evaluation and direct comparisons of portable XRF instruments.

AGENDA

FOR
PORTABLE XRF SPECTROMETER WORKSHOP
JANUARY 11 - 12, 1993
EPA Environmental Research Center, RTP, NC

Time	Topic	Speaker
Day 1 - January 11		
9:00 a.m.	Welcome and Overview	M. Beard/S. Harper
9:15 a.m.	Presentation by Attendees	B. Gutknecht
9:30 a.m.		B. Clickner
9:45 a.m.		S. Weitz/M. McKnight
10:00 a.m.		J. Pesce
10:15 a.m.		J. Zilka
10:30 a.m.	Break	
10:50 a.m.	Presentation by Attendees	R. Petre
11:05 a.m.		C. Papanicolopoulos
11:20 a.m.		T. Spittler
11:35 a.m.		Open
11:50 a.m.	Lunch	
1:00 p.m.	Manufacturers' Input	B. Gutknecht
1:15 p.m.	Discussion of spectral and physical problems/limitations	Attendees

Time	Topic	Speaker
Day 1 - January 11		
2:40 p.m.	Break	
3:00 p.m.	Development of prototype performance tests (spectral, physical and statistical aspects)	Attendees
4:30 p.m.	Adjourn	
Day 2 - January 12		
9:00 a.m.	Discussion/revision of performance tests	Attendees
10:30 a.m.	Break	
10:50 a.m.	Continuation of discussion/ revision of performance tests	Attendees
12:00 p.m.	Adjourn	

Section 2
SUMMARY OF PRESENTATIONS

Presentations were made to provide a background for the development of a set of performance parameters that would be used to generate or verify figures of merit that are comparable across portable XRF technology. The presentations covered the fundamentals of the XRF method, specific studies and comparisons, future needs, and manufacturers' input. Summaries are given below.

William Gutknecht/RTI - "A Comparison of the Scitec, Warrington and Princeton Gamma-Tech Portable XRFs"

The preliminary (draft) results of a limited evaluation of three portable XRF instruments (Scitec MAP-3, Warrington Microlead 1, and Princeton Gamma-Tech XK-3) were presented. The evaluation was carried out using standard films prepared from oil-based paint spiked with white lead and verified by acid digestion/atomic absorption analysis. The lead concentration of the standard films ranged from 0 to 6 mg/cm^2. The films were placed on eight different substrates and analyzed by portable XRF, using the manufacturer's calibration and following the manufacturer's instructions. The substrates tested were 3/4" plasterboard, 3/4" plywood, 5" concrete, 4" cinderblock, 1/8" aluminum, 1/8" steel, brick and solid cinderblock. According to the manufacturer, no substrate correction is necessary for the Scitec. Warrington and Princeton Gamma-Tech (PGT) data were substrate corrected.

The Scitec was evaluated using two different "universal" calibrations installed by the manufacturer. The first calibration covered the range 0.6 to 2.64 mg/cm^2. The standard paint films yielded correlation coefficients of 0.98 to 0.99 and standard errors of estimate of x from y of ~0.5 mg/cm^2 for the five substrates tested (plasterboard, plywood, 4" cinderblock, aluminum and brick). Biases ranged from + 0.13 mg/cm^2 for 3/4" plasterboard to -0.29 mg/cm^2 for 3/4" plywood. The second calibration covered the range from 0 to 6 mg/cm^2. The standard films yielded correlation coefficients ranging from 0.93

for solid cinderblock to 0.995 for steel. The standard error of the estimate ranged from 0.30 mg/cm^2 for steel to 1.1 mg/cm^2 for solid cinderblock. The bias ranged from 0.1 mg/cm^2 for plasterboard to 4.4 mg/cm^2 for solid cinderblock. The bias was found to be concentration dependent for plasterboard, aluminum, and concrete (i.e., there is a change in the value of the bias with a change in the value of the concentration) and constant for plywood, steel, brick and 4" and solid cinderblock.

The Warrington was evaluated with all eight substrates. Correlation coefficients were consistent, ranging from 0.990 for concrete to 0.998 for plasterboard, plywood and steel. The standard error of estimate ranged from 0.2 mg/cm^2 for plasterboard, plywood and steel to 0.4 mg/cm^2 for concrete. The bias ranged from -0.04 mg/cm^2 (at 1.6 mg/cm^2) for plasterboard to 1.2 mg/cm^2 (at 0.3 - 0.8 mg/cm^2) for concrete and was found to be concentration dependent for all substrates.

The PGT also was evaluated with all eight substrates. The correlation coefficients were consistent, ranging from 0.977 for brick to 0.988 for 4" cinderblock. The standard error of estimate ranged from 0.39 mg/cm^2 for 4" cinderblock to 0.63 mg/cm^2 for brick. The bias ranged from 0.1 mg/cm^2 (at 0.3 mg/cm^2) for plasterboard and cinderblock to -1.0 to -1.1 mg/cm^2 (at 1.6 mg/cm^2) for concrete, aluminum and steel. Bias was found to be concentration dependent for all substrates, with the greatest dependency found for concrete and 4" cinderblock.

To determine whether Scitec results could be improved by applying a substrate correction, the Scitec was used to measure the substrate only for wood, sheetrock, 4" cinderblock, brick, aluminum siding and steel. All substrates gave readings very close to 0 mg/cm^2 (0.00 to 0.03 mg/cm^2). When real-world painted boards were measured before and after scraping, however, a different result was obtained. A board that measured 13 to 15 mg Pb/cm^2 before scraping appeared to contain 1 to 3 mg Pb/cm^2 after scraping; a board that measured 6 to 7 mg Pb/cm^2 before scraping yielded results of 0.1 to 3 mg Pb/cm^2 after scraping; and a board that measured 1.7 to 2.2 mg Pb/cm^2 before scraping measured 0.0 to 0.1 mg Pb/cm^2 after scraping. One explanation for these observations is that lead migrates or is driven into the substrate by the removal process. Variables that must be considered in evaluating a portable XRF are the calibration, substrate

correction, lead in the substrate, and paint variability.

Robert Clickner/WESTAT - "On the Performance of the Scitec MAP/XRF in the National Survey of Lead-Based Paint in Housing"

Dr. Clickner discussed the performance of the Scitec MAP-3 XRF used in the National Survey of Lead-Based Paint in Housing from January to March, 1990. Scitec delivered eight nominally identical MAPs, each containing a fresh 40 mCi Co^{57} radioactive source and the "universal automatic substrate correction" software. Each MAP was calibrated by the manufacturer over the range 0.0 to 2.64 mg/cm^2. During the survey, 381 housing units across the United States were tested and thousands of 60-second XRF measurements were made on dozens of different substrates.

Shims (standard paint films) from NIST with lead paint levels of 0.6 $\pm$ 0.02 and 2.99 $\pm$ 0.3 mg/cm^2 and four substrates (wood, drywall, steel and concrete) were used to continually check the MAPs' performance. Daily validation measurements were made for each MAP/shim/substrate combination. Regression analyses on the validation data were performed to estimate the precision and accuracy of the readings and to relate readings to substrate and lead loading level. A different equation was obtained for each machine/substrate.

For a wood substrate, readings generally were lower than the actual lead levels (NIST certified levels) when the levels were <2.0 mg/cm^2 and higher than the actual levels when the levels were >2.0 mg/cm^2. Eighty-eight percent of the validation readings of the 0.6 mg/cm^2 shim on wood were <0.6 mg/cm^2 and 52 percent were equal to 0.0 mg/cm^2. (The MAP will not give a negative reading.) For the 2.99 mg/cm^2 shim, 60 percent of the readings were >3.0 mg/cm^2. The standard deviation of repeated readings was 0.25 mg/cm^2.

The performance of the MAP on drywall or plaster was similar to the performance on wood, with readings lower than the actual levels when the levels were <2.5 mg/cm^2 and higher than the actual levels when the levels were >2.5 mg/cm^2. Eighty-two percent of the validation readings of the 0.6 mg/cm^2 shim on drywall or plaster were <0.6 mg/cm^2

and 52 percent were equal to 0.0 mg/cm^2. At 2.99 mg/cm^2, 44 percent of the readings were <3.0 mg/cm^2 and 45 percent were >3.0 mg/cm^2. The standard deviation of repeated readings was 0.25 mg/cm^2.

For a steel substrate, the readings were higher than the actual levels for all observed levels of lead, and there were substantial differences among the eight instruments. Eighty-eight percent of the validation readings of the 0.6 mg/cm^2 shim on steel were >0.6 mg/cm^2. At 2.99 mg/cm^2, 60 percent of the readings were >3.0 mg/cm^2 although one machine had no readings above 3.0 mg/cm^2. The standard deviation of repeated readings was 0.21 mg/cm^2.

For concrete, brick, and other related substrates, the MAP had difficulty detecting low to moderate levels of lead, and there was much variation both among and within instruments. Ninety-five percent of the validation readings of the 0.6 mg/cm^2 shim were equal to 0.0 mg/cm^2, and only one machine had more than one non-zero reading. At 2.99 mg/cm^2, 95 percent of the readings were <3.0 mg/cm^2 and 11 percent of the readings were equal to 0.0 mg/cm^2. The standard deviation of repeated readings was 0.49 mg/cm^2.

In summary, the MAP readings were found to be systematically different from the amounts of lead in the paint film standards with the direction and magnitude of the differences being related to the substrate material and the lead levels in the paint. The precision of the readings also was found to be dependent upon the substrate. On the basis of this survey, WESTAT concluded that a substrate correction is necessary to accurately determine the presence and amount of lead-based paint on surfaces when using XRFs similar to the Scitec MAP-3 used in the national survey of lead-based paint in housing.

Steve Weitz/HUD - "HUD Needs"

Mr. Weitz briefly presented the needs of the Department of Housing and Urban Development (HUD) with respect to portable XRF technology. The HUD Guidelines are to be revised totally by October 1993. HUD expends considerable funding on testing and is dedicated to producing data of the highest quality. Because lead-in-paint data are the

basis for important decisions, improved instruments are needed to obtain better data. To develop improved instruments, a method for evaluating the current instruments is needed.

Mary McKnight/NIST - "Evaluation of Methods for Field Measurement of Lead in Paint Films"

Dr. McKnight presented a plan for evaluating field methods for measurement of lead in paint. The first step is to characterize the problem by establishing performance criteria, observing field practices and identifying key factors that could affect field results. A limited simulated field study and a limited field study will then be designed. The simulated field study will be carried out in a test chamber using real walls and painted boards that closely represent field samples. The field study will be carried out in actual housing units. If the results of the simulated field study are consistent with the results of the actual field study, an expanded simulated field study will be conducted over a range of field possibilities (lead concentrations, environmental conditions, substrate types, etc.) and a knowledge-based system will be developed for assessment of equipment or field measurement procedures. The data obtained in the simulated field study will be used to develop a standard method or protocol for assessing equipment or other measurement procedures for lead in paint. Other benefits of a study such as this include gaining precision and bias data for the measurements and improved understanding of factors affecting measurement quality.

John Pesce/Star Environmental - "An Examination of Substrate Effect on Portable X-Ray Fluorescence Instrumentation"

Mr. Pesce presented the results of an investigation of substrate effect on portable X-ray fluorescence (XRF) instrumentation. The data presented were derived from both actual field use and round-robin information.

Princeton Gamma-Tech (PGT) XK-3 XRF analyzers were used to test 421 units in an apartment complex for lead in paint. More than 20,000 readings were taken. The testing protocol included measurement of substrate effect levels (SELs) on all surfaces.

The SEL was subtracted from the Apparent Lead Concentration (ALC) to obtain a Corrected Lead Concentration (CLC). Sodium sulfide solution was used for confirmation when the ALCs were 1.2 mg/cm^2, and samples were taken for atomic absorption analysis when CLCs were 0.8 - 1.5 mg/cm^2. The SEL locations also were tested with the Warrington and Scitec XRFs, using a "shoe" or template to fix the orientation of each instrument.

A variety of unpainted substrates was tested, including masonry, cinder block, plaster, brick, sheetrock, concrete, wood and metal. The PGT and Warrington instruments showed significant variability for these building materials. PGT values ranged from 0.0 mg/cm^2 for pressed board to 1.9 mg/cm^2 for a metal window sill. Warrington values ranged from -1.1 mg/cm^2 for a metal window sill and mailbox to 1.7 mg/cm^2 for a plaster column and a concrete column. The Scitec measured 0.0 mg/cm^2 for most substrates. The Scitec response was 0.3 - 0.4 mg/cm^2 for metal, 0.3 mg/cm^2 for a concrete column and oak, and 0.2 mg/cm^2 for sheetrock. It should be noted that the PGT and Warrington instruments can give a negative reading, but the Scitec cannot.

For metals, the PGT and Warrington respond to substrate effects differently, with the elevated (+) readings of the PGT similar in absolute value to the depressed (-) readings of the Warrington. All XRFs appear to work well on less dense materials such as wood.

Substrate effects also were examined as a part of the round-robin study established by a group of private lead inspectors in Massachusetts. Experiments were performed using steel channel, red brick, poplar, belly casing, and sheetrock substrates. The SEL was measured for a piece of each substrate containing no lead paint. The apparent lead concentration (ALC) was measured for the same substrate painted with lead paint. The SEL was subtracted to give a corrected lead concentration (CLC) for each substrate. For steel channel, the CLCs of the PGT and Scitec showed some lead; the CLC of the Warrington showed no lead. For red brick, the CLCs of the PGT and Warrington showed some lead; the Scitec detected no lead on the painted or unpainted brick, indicating that a false negative reading can be observed. All three XRFs identified lead on poplar wood surfaces although the quantitative results were not in good

agreement, ranging from 0.5 mg/cm^2 for the Scitec to 1.2 mg/cm^2 for the PGT. A convex wood molding called belly casing was used to test the effects of an air gap between the XRF probe and the sample. Results were consistent with the results for the poplar wood sample. Sheet rock samples produced consistent results with the three XRFs.

To test for read-through effects, measurements were made on lead flashing under 1-1/2" of wood. The PGT appeared less susceptible to detect this type of lead, giving a reading of 1.7 mg/cm^2. The Warrington and Scitec measured 10.8 and 4.6 mg/cm^2, respectively.

Based upon this study, it was concluded that portable XRFs can be used with a reasonable amount of confidence for a wide variety of substrates, assuming that the operator has the experience to know what the substrate is and to make the appropriate corrections. The operator must know when to doubt the XRF and use secondary and tertiary screening methods. Neither automatic or manual correction can compensate for all possible substrates, and the correction values vary from instrument to instrument from the same manufacturer as well as from different manufacturers. Confirmatory testing should be performed prior to making abatement decisions.

John Zilka/Applied Systems - "XRF Problems and Applications"

Mr. Zilka presented some problems and needs with respect to use of field portable XRFs. Applied Systems uses instruments manufactured by PGT, Scitec and Warrington and has observed variances and reliability problems in the field, particularly with the Scitec. The manufacturers have provided little support in the way of standard operating procedures (SOPs) and validation.

Two major areas of concern that Mr. Zilka would target for study are the reliability of the instrument and the reliability of the inspector. Currently, Applied Systems runs validation checks at the beginning of the day, hourly, and at the end of the day, but detailed validation procedures are needed to determine that the instrument is operating properly. Training field personnel also is a big problem. To do the job correctly, a field tester needs the proper tools including a reliable instrument, site specific standard

operating procedures (SOPs) and a basic knowledge of construction materials. Currently, there are considerable differences in what is required for an inspection and in what is being done to meet these requirements. For example, it is unclear how many inspectors are actually doing substrate corrections.

Finally, there is a need for auditing an inspector's work to give the client some degree of confidence in the results.

Roy Petre/State of Massachusetts Department of Public Health - "General Concerns"

Mr. Petre discussed some policy issues with respect to current standards and future needs. In the past a health-based standard for lead expressed in mass/area was used because children eating paint chips was the focus of concern. Currently, dust is considered to be the major source of exposure. The Childhood Lead Prevention standard of 0.5 percent by weight for paint is high relative to dust. Mr. Petre suggests that the current standards be examined carefully with respect to exposure models, animal studies, and total dust exposure from future disturbances.

Mr. Petre also expressed a need for a cost-effective method for testing on-site. Laboratory testing is expensive and requires considerable delay and detailed chain-of-custody procedures. In some cases, it may be cheaper to replace the architectural elements than to test them. Taking representative field samples for laboratory analysis is also a problem, and scraping creates a potential hazard by putting the lead in its most ingestible form. One on-site method is portable XRF. For a portable XRF to be used with confidence, however, it should have an accuracy and precision of 0.1 to 0.2 mg/cm^2. A "wand" for testing ceilings would be a useful design feature. A self-correction for substrate effects is also a consideration since scraping creates dust. It would be desirable to design a machine that can read by layer to eliminate the read-through effect. For example, an XRF will sometimes detect leaded paint on a plaster surface that has been covered with wood panelling. On the other hand, thin paint films containing 2 to 4 percent lead may be cleared when an XRF is used for testing because of the thin layer

effect. Since the portable XRF reads in concentration units of mass/area, painted surfaces containing high percentages of lead by weight may show lead concentrations below the regulatory limit if the paint is spread thinly enough. Theoretically, a correction can be made for this effect. The State of Massachusetts currently uses sodium sulfide for confirmatory testing, with good results, when concentrations below the abatement threshold are obtained with the portable XRF.

Mr. Petre stressed that operator effect must be addressed. Massachusetts has been training and licensing lead paint inspectors since 1990. An inspector must complete an apprenticeship under a master inspector. In addition, Massachusetts is considering a program to certify individual XRFs.

Chris Papanicolopoulos/Georgia Tech Research Institute - "XRF Instrumentation"

Dr. Papanicolopoulos presented the results of an investigation of portable XRF instruments. From 1987 through 1989, three Princeton Gamma Tech XK-3s were tested, and in 1990 some comparisons of the XK-3s, the Scitec MAP, and the Warrington Microlead instruments were made. Many combinations of sample substrates and paints were analyzed in the field. A goal of the study was to identify problems and to determine whether they are instrument specific or generic.

The Microlead, which has a scintillation counter detector, uses a grease between the scintillation tube and photomultiplier tube that breaks down after repeated use and also in the summer (i.e., at high ambient temperature), causing inconsistent results. Also, a design problem was discovered in the electronics of the Microlead. When it was corrected, measurements were more reliable.

The PGT XK-3's detector is a proportional counter that is temperature sensitive. When the sample substrate is a dense material, backscatter can saturate the counter. Dr. Papanicolopoulos stated that proportional counters have "reached their limit" and cannot be improved.

The Scitec detector is a semiconductor crystal that must be "quiet" to operate properly. The detector can get very hot when subjected to large numbers of X-rays in a

short period of time and should be cooled in some way such as using the Peltier method. Large numbers of X-rays can arise from a large amount of lead present in the sample and/or a very dense substrate causing backscatter of a large percentage of the incident or excitation X-rays.

One of the major problems with the portable XRF is substrate interference. The PGT XK-3 does not adjust the peak height for backscatter. If the backscatter goes up or down, it will be reflected in the measured lead concentration. The Scitec has a proprietary formula for correcting for backscatter, but it is not appropriate for the soil method. A better method for handling the backscatter problem is needed.

Dr. Papanicolopoulos suggested that instruments be certified two times a year with the resulting data forwarded to the EPA. He also suggested that there be an independent quality assurance person to see that the instrument is being used to obtain valid results.

Thomas Spittler/EPA Region I - "Laboratory XRF"

Dr. Spittler presented the results of analysis of paint chips by laboratory XRF. Peeling paint chips are usually multilayered, with the inner layers containing more lead. The outer layers frequently are newer paints containing titanium, zinc, and iron that will absorb lead X-rays from the inner layers. Spectra from a laboratory XRF were presented to demonstrate that significantly different lead concentrations could result when front and back sides of paint chips were measured independently.

Dr. Spittler stated that paint on walls is not a threat to children unless it is peeling or on chewable surfaces. Attempting to remove and analyze paint that is intact could generate another "asbestos situation." However, he is not convinced that portable XRFs will give reliable results. Data from an alternative method using a laboratory XRF were presented. Three standards were prepared using different weight ratios of National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 1579 and somar mix (an inert material) to cover a range of from 2.00 to 9.38 percent lead. An actual paint sample then was ground and blended with somar mix in a dental amalgamator. The standards and samples were analyzed by laboratory XRF with peak

height used for quantitation. A measured value of 23.1 percent lead was obtained compared to the "true" value of 24 percent obtained by a more rigorous XRF method. The somar dilution procedure (three standards and one sample) was performed in approximately five minutes. Dr. Spittler stated that the cost of a good laboratory XRF is ~40,000 (down from ~$100,000) and that it can be operated by a trained high school student.

Dr. Spittler also emphasized that to determine what is poisoning a child, house dust and soil samples should be taken in addition to paint samples that might be posing a threat.

William Gutknecht/RTI - "Portable XRF Manufacturers' Input"

Prior to the workshop, questionnaires were mailed to six manufacturers of portable XRF instruments that were identified by RTI through contacts with a variety of people working on lead studies (see Appendix C). The questionnaire was designed to obtain information on detection limit, sensitivity, accuracy, calibration procedure, operating procedure, analysis time, substrate correction procedures, safety considerations, problems/limitations, and any envisioned improvements. Responses were received from the manufacturers of the Scitec MAP-3, the Spectrace 9000 and the Princeton Gamma Tech XK-3. The responses and other information can be found in Appendix D.

The manufacturers approached the various performance parameters (detection limit, accuracy, precision) in different ways. The PGT XK-3's detection limit of 0.5 mg Pb/cm^2 is taken as the single-reading standard deviation of a series of readings. The Spectrace 9000's detection limit of 0.01 to 0.1 mg Pb/cm^2 (depending upon substrate) for a 200 sec assay is determined as three times the standard deviation of repeated blank analyses. The Scitec manufacturer pointed out that for XRF analysis of lead-based paint, the detection limit is a function of measurement condition, measurement time, confidence level, and source strength. For a 60 sec measurement, K-shell detection limits of 0.10 and 0.43 mg Pb/cm^2 were found for paint on wood and concrete, respectively, based on data from 46 different instruments with 25 repeated measurements each.

Sensitivity is generally defined as the change in response that results from a specified change in concentration. Only the Spectrace manufacturer reported sensitivity in this form as ~50(Pb_L), ~4(Pb_K) cts/sec/mg Pb/cm^2/mCi. Also, only the Spectrace manufacturer reported an accuracy; the Spectrace literature states the accuracy of their instrument to be $\pm$ 0.12 mg Pb for $\leq$ 1 mg Pb/cm^2 on wood using a 60 sec assay. Measurement times for a test are 60 seconds for the Scitec MAP-3 and Spectrace 9000, and 12 seconds for the PGT.

The Scitec and PGT instruments are pre-calibrated by the manufacturer and there are no plans to allow for direct user calibration or recalibration. The PGT XK-3 is calibrated using 10 readings each of the 0 and 1.53 mg/cm^2 HUD standards. The Scitec is calibrated using NIST 2759 standard paint films on different substrates. The Spectrace 9000 is pre-calibrated by the manufacturer using several pure element standards, various substrates, and at least one NIST 2759 reference material. However, the calibration may be modified by user accessible routines via either the keyboard or the RS232 port. The port may be protected to ensure only approved access. Keyboard changes are indicated on the printed (or stored) record and default values can be restored.

The portable XRFs also use different approaches for substrate correction. The PGT XK-3 manufacturer recommends manual substrates correction in accordance with the HUD Guidelines. The Scitec MAP comes with a general or "universal" compensation for K and L shell X-rays that is built into the system's software. Scitec also provides a "dedicated" substrate correction for high density substrates such as steel, brick, concrete and thin metals. If lead is suspected to be present in the substrate, Scitec recommends use of NIST SRMs over the painted surface to characterize the substrate. For the Spectrace 9000, problems with overlapping X-ray peaks or signals are identified and characterized when the instrument is calibrated and correction factors are applied automatically to the spectral data to obtain a substrate corrected readout.

All three manufacturers reported some type of instrument check for satisfactory operation. A calibration check sample is provided with the PGT XK-3. The Scitec MAP system conducts a "self test" during a 15 sec warm-up immediately after the instrument is turned on to determine if all system components are operating within specification.

Scitec software used to download measurement values verifies both measurement integrity and instrument performance and evaluates the calibration check readings. The Spectrace 9000 sounds an alarm if 1) peaks are not in the correct position; 2) the battery is low; 3) there is unusual electronic noise; or 4) there is loss of signal. All alarms are accompanied by a descriptive message on the screen.

Neither PGT nor Scitec released information on planned improvements. Spectrace envisions 1) increasing the detector area; 2) using a battery with a longer life; 3) reducing the size of the probe for easier access to narrow spaces; and 4) more sophisticated substrate corrections.

SECTION 3
GENERAL DISCUSSION

Following the presentations, there was a general discussion of current needs for portable XRF and the spectral and physical problems/limitations that need to be addressed.

Public housing authorities are required, by 1994, to randomly inspect all their housing projects for lead-based paint. There is, therefore, an urgent need for a reliable method for taking representative samples and for producing defensible data with no false negatives. The workshop attendees generally agreed that an on-site, real-time, nondestructive lead measurement method such as the portable XRF is of value for a number of reasons. Use of a reliable portable XRF would result in a considerable savings of time and would not require "touching up" sampling sites after destructive sample collection.

Jim Hayes of the State of N.C. Environmental Health Services is conducting an epidemiological evaluation of lead poisoned children. Two of the goals of the program are to teach parents the reason for concern and to identify potential sources of the contamination. Mr. Hayes pointed out that it is of real value to have an on-site measurement method that can give the parents a lead concentration at the time of the visit without causing damage to painted surfaces. Susan Guyaux of the Maryland Department of the Environment stated that day-care center personnel may react negatively to taking paint scrapings, and that a hazard is actually created by taking samples in this way. She stressed the need for an on-site, non-destructive lead analysis method with appropriate laboratory confirmation. Both the field and laboratory methods need to be the best that they can be.

Dr. William Gutknecht of the Research Triangle Institute stated that portable XRFs "are a reality" and that their sales are increasing. It is anticipated that they will be used more in the future for soil and dust analysis. With this in mind, the workshop attendees turned their attention to answering questions such as:

- How "good" are the portable XRFs that are currently on the market?

- Where and/or under what conditions can portable XRFs be used reliably?
- When is laboratory confirmation necessary?
- What are the problems and limitations of portable XRF technology?
- Is the technology improvable?
- What are the critical parameters needed to evaluate and compare portable XRFs?
- How can these parameters be tested?
- It is sufficient to certify manufacturers or is certification of individual instruments needed?

Several groups represented at the workshop had conducted studies to compare lead measurement results obtained by portable XRF and by atomic absorption spectrometry (AAS). Bill Gutknecht reported that RTI found that the XRF and AA generally agree although occasional significant differences were found. David Cox of David Cox and Associates reported that in a data base of approximately 4000 AAS vs. XRF measurements examined by his company, only 5 to 10 percent were serious outliers and there were ~4 percent false positive results using the portable XRF. The problem is that there is no way to identify the outliers when only one measurement method is used and there is no way to predict when they will occur. John Zilka of Applied Systems emphasized the need for defensible data. From his experience, hourly checks indicate that the portable XRF generally gives consistent readings, and he is usually able to tell if the equipment is not operating properly. However, Chris Papanicolopoulos of Georgia Tech Research Institute cautioned that a portable XRF can be consistently inaccurate.

Based upon their experience and expertise, workshop attendees expressed opinions concerning where and under what conditions portable XRFs could be used. Kevin Ashley of NIOSH stated that the portable XRF is a useful screening tool but that the data obtained are not defensible in court. Merrill Brophy of the Maryland Department of the Environment supported Dr. Ashley's comment and added that "for a vast majority

of housing," portable XRF is a first step. However, more confidence in the XRF data is needed. Bob Clickner of Westat reported that the portable XRF works "fairly well" for measurement of paint on wood and drywall, but generally gives a high reading for paint on steel. Sharon Harper of the Office of Research and Development (ORD) EPA agreed that results were good for paint on wood and drywall. David Cox warned against focusing too much attention on a single XRF measurement. He suggested that a better approach is to take a set of measurements on an aggregate to answer questions such as "Do the doors contain lead?" and he has found that portable XRF technology works well for this.

Much of the discussion centered upon the "gray area" where laboratory confirmation of an XRF measurement is needed. John Scalera of Office of Pollution Prevention and Toxics (OPPT), EPA posed two questions to the group: 1) "Is there a definable concentration limit for XRF at which there is 95 percent confidence in the XRF data?" and 2) "Is the XRF useful at this concentration?" For example, if there is 95 percent confidence in the XRF at 6 or 7 mg/cm^2 and this lead concentration is commonly found, the XRF will be a useful screening tool. Bob Clickner reported that few readings above 6 mg/cm^2 were found in the national Survey of Lead-Based Paint in Housing. If the confirmation limit was set at 6 mg/cm^2 but most levels were <6 mg/cm^2, almost every measurement would require laboratory confirmation. John Zilka, however, stated that he finds levels far in excess of 5 or 6 mg/cm^2, especially in building exteriors.

Another factor to be considered in determining the utility of portable XRFs is the concentration level of lead that is considered dangerous. John Pesce of Star Environmental pointed out that there is a difference in philosophy about how much lead is dangerous and that more data are needed to determine the capabilities of the XRF. John Zilka stated that we need to answer the question "Is there a safe level of lead, and is it tied in with the accuracy, precision, etc. of the XRF?" Chris Papanicolopoulos cautioned that the regulatory levels will probably go lower and lower. Since XRF technology is already struggling, inspectors may be forced to use laboratory analyses for all measurements.

Jim DeVoe of NIST stated that there is a problem with the design of the portable XRF and that more sensitivity is needed. John Pesce reported that he sees differences

in day-to-day field use of the XRF, that the XRF still has trouble with the simplest (non-real-world) samples and that substrate effects should be more closely examined. Jim DeVoe expressed a need for the development and availability of "reference walls" with different substrate layering orders to simulate wall types that are encountered in the field. Chris Papanicolopoulos stated that the instrument should have a feedback mechanism to alert the user to improper operation or an automatic shutoff. Kenn White of T. C. Analytics said that, rather than asking manufacturers their capabilities, users should tell manufacturers their needs and ask if they can be met.

SECTION 4
PERFORMANCE PARAMETERS

4.1 Introduction

After the individual presentations and the general group discussion, the workshop attendees developed a list of performance parameters that could be used to make a direct comparison of portable XRFs. General approaches to the experimental measurement of these parameters were also discussed. However, details of the experiments were not determined and will require consultation with a statistician. The parameters judged to be the most important by a consensus of the workshop participants are discussed in the following sections.

4.2 Manufacturer's Calibration

Proper calibration is essential for obtaining reliable results using any instrumental method for analysis. Most portable XRFs currently on the market are calibrated by the manufacturer and have no provision for user interaction or recalibration. Much of the workshop discussion focused on procedures for checking the manufacturer's calibration. The general agreement among workshop attendees is that calibration checks should be performed at the beginning and end of each testing day and at hourly intervals during use. Suggested standards are the NIST films at 0.0, 1.0 and 3.5 mg Pb/cm^2 on both low and high density materials representing site specific substrates. The periodic calibration checks can be used to evaluate the stability of the calibration and to test for drift. The accuracy of the calibration is tested as described in Section 4.4.

4.3 Precision

One performance parameter that can be experimentally measured is precision, which is generally defined as the scatter of a group of measurements, made under the same specific conditions, about their average value. Precision may be expressed as the standard deviation (σ) or the coefficient of variation ($100\sigma/x$ where x is the average value). Before precision can be used to directly compare portable XRFs, an experiment

must be carefully designed in terms of the number of tests to be performed and the equation used for the calculation of precision. The workshop attendees agreed that a "test" should be performed as described by the manufacturer. For the Scitec, a test is defined as a single 60 second reading. For the PGT XK-3, a test is defined as the average of three cycles collected manually. For the Warrington, a test is defined as the average of three cycles collected automatically. For both the PGT XK-3 and the Warrington, an initial single reading is taken at the beginning of each test but is not used. Test were not defined for other brands of portable XRFs.

It was decided that NIST films at concentrations of 0.0, 1.0, 2.0, and 3.5 mg/cm^2 should be used for the precision tests. Suggested substrates for precision testing are a low density material such as pine or plastic foam, a high density material such as concrete, and a layered substrate containing both high and low density materials such as wood over concrete. The latter has been found to be a major problem for some portable XRFs.

The attendees agreed that the precision tests should be performed both on new (off the shelf) instruments and on instruments that have been used for field measurements for several months. In terms of source depletion, a new instrument would be defined as one whose source is less than 10 percent depleted and an old instrument as one whose source depleted beyond 1-1/2 half lives of the excitation source. In all cases, a "blind" process should be used for selection of instruments to be tested.

4.4 Accuracy

Another performance parameter that can be measured experimentally is the accuracy or bias. Bias (B) is defined as the signed difference between the average (x) of a set of measurements of a reference material and the "true" value (T) of the reference material and is calculated in the units of measurement using the equation

$$B = X - T$$

or as a percentage of the true value using the equation

$$\% B = 100 (X - T)/T$$

Bias can be determined from the precision test data since NIST SRMs will be used. The data will be examined to determine whether the bias is a function of lead concentration.

Of concern is the need to describe clearly the chances of making an improper decision when an X-ray measurement result for lead in paint is compared to a decision level. This involves characterizing the random and systematic error components of the method at or near the decision level. Determination of an acceptable accuracy figure for each instrument will be possible after a definitive field study has been conducted.

4.5 Detection Limit

Because the regulatory limit for lead may be lowered as environmental lead programs continue, it is important to determine the limits of detection and quantitation. Again, this involves characterizing the random and systematic error components at or near the limit of detection. Estimation of each instrument's detection limit over various substrates is expected to be possible using field study data.

4.6 Substrate Effects and Other Interferences

The buildings to be tested under the HUD Guidelines contain a wide variety of building materials that can be painted with lead-based paint. Typical materials that are encountered include wood, plaster, gypsum, concrete, brick, metal, sheetrock, and cinder block, and often these materials are in tandem. Wood over concrete and plaster over metal mesh pose major problems for some portable XRFs. Some instruments will give readings higher than the regulatory limit for certain substrates when no lead is present. Other substrates may yield negative readings that will result in a lead concentration reading that is lower than the true value.

The different manufacturers of portable XRFs treat substrate effects (background) in different ways. To determine whether a portable XRF is suitable for a particular purpose, the effects of various substrates should be evaluated. The workshop attendees

suggested that experiments be performed using NIST films and a variety of substrates that cover a range of densities and thickness. The effects of "read-through" should also be tested by placing an NIST film between two substrates and measuring the apparent lead concentration using the portable XRF.

4.7 Ruggedness

Because of the enormous number of lead measurements to be made and the wide variety of environmental conditions that are likely to be encountered, the portable XRF must be field-rugged. Workshop participants discussed a number of parameters that should be tested to evaluate the ruggedness of portable XRFs.

Experiments should be performed to determine the temperature range over which an XRF operates satisfactorily and to determine the necessary temperature equilibration time. A range of -20 °F to 120 °F was suggested. The International Organization of Legal Metrology (OIML) recommends that the instrument be placed in an environmental chamber and warmed or cooled until it is in thermal equilibrium at the desired temperature. Tests should then be carried out to determine the relative standard deviation of the output signal.

The XRF should also be able to withstand a reasonable mechanical shock to the control box such as a bump against a door facing. A "bump test" was discussed, but the specific procedure is yet to be determined. The OIML describes a mechanical shock test that involves tilting the instrument about one bottom edge to a height of at least 50 mm and allowing it to fall once to the surface.

A third parameter for ruggedness is susceptibility to interference from electromagnetic fields. The OIML recommends exposing the instrument to electromagnetic fields at a field strength of 10 V/m and determining the relative standard deviation of the output signal during this exposure.

4.8 Other Parameters

Other parameters that should be considered in evaluating a portable XRF but are

difficult to measure experimentally are as follows:

- Ease of operation
- Training (level required; usefulness of the manufacturer's manual)
- Cost
- Safety features/radiation leakage/operator exposure
- Physical configuration (handle; shutter; probe size and weight; cord)
- Data retention/storage capabilities
- Manufacturer's support (licensing; availability of a user "hot line;" training)
- Portability/weight of detector/probe assembly

APPENDIX A

Letter of Invitation and Note of Thanks

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

November 24, 1992

Dear :

Numerous programs involving research on the toxicity and bioavailability of lead, the environmental monitoring of lead, and the abatement and clearance of lead in housing are currently active. Examples of past projects include the HUD National Survey, the EPA Three City Study, method evaluation studies sponsored by EPA and abatement programs carried out by Maryland, Massachusetts and many other groups.

Public housing authorities are required, by 1994, to randomly inspect all their housing projects for lead-based paint. Currently, the most common approach to screening housing for the presence of lead in paint is the use of the portable X-ray fluorescence (XRF) detector, which gives rapid results and is non-destructive. Currently, more than six different portable XRF instruments are commercially available. The U. S. Environmental Protection Agency has sponsored studies of the performance of several of these instruments.

The U.S. Environmental Protection Agency is sponsoring a 1-1/2 day workshop limited to Federal and State government personnel and government contractors to review the status of portable XRF technology, to identify problems and limitations that could result in measurement error, and to develop a matrix of performance parameters to generate or verify figures of merit that are comparable across the technology. Parameters to be included in the matrix are detection limits, precision, bias, interferences, productivity, safety, and use or generation of hazardous materials.

As one of the recognized experts in this field, you are invited to attend this workshop, which is scheduled for January 11-12, at the EPA Environmental Research Center in Research Triangle Park, NC. Unfortunately, funds are not available to pay for attendance at the workshop. However, this workshop offers an opportunity to make a contribution to solving what has been called the nation's number one preventable childhood health problem, and it also offers an opportunity to identify future research needs.

If you are able to attend, please inform Dr. Eva Estes at (919) 541-5926 at your earliest convenience. Thank you, and we hope to see you at the portable XRF Workshop.

Sincerely,

Warren Loseke

Warren Loseke

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

January 26, 1993

Dear :

Thank you for attending the Portable XRF Workshop held at the EPA Environmental Research Center on January 11 - 12, 1993 and for presenting the results of your work in this area. As a result of the workshop we have begun to develop a matrix of performance parameters to generate figures of merit that are comparable across the portable XRF technology. Your hands-on experience, knowledge of methodologies, and real-world data were instrumental in its success. We appreciate not only your contributions, but also the preparation and effort required for attending.

In approximately one month you will receive a draft report of the workshop for your comments. We look forward to continuing to work with you on this important issue.

Again, thank you for your contributions and for your interest in lead measurement programs.

Sincerely,

Warren Loseke

Warren Loseke

:acp

APPENDIX B

Questionnaire Sent to XRF Manufacturers

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

December 8, 1992

Dear :

Numerous programs involving research on the toxicity and bioavailability of lead, the environmental monitoring of lead, and the abatement and clearance of lead in housing are currently active. Examples of past projects include the HUD National Survey, the EPA Three City Study, method evaluation studies sponsored by EPA and abatement programs carried out by Maryland, Massachusetts and many other groups.

Public housing authorities are required, by 1994, to randomly inspect all their housing projects for lead-based paint. Currently, the most common approach to screening housing for the presence of lead in paint is the use of the portable X-ray fluorescence (XRF) detector, which gives rapid results and is non-destructive. Currently, more than six different portable XRF instruments are commercially available. The U. S. Environmental Protection Agency has sponsored studies of the performance of several of these instruments.

The U.S. Environmental Protection Agency is sponsoring a 1-1/2 day workshop limited to Federal and State government personnel and government contractors to review the status of portable XRF technology, to identify problems and limitations that could result in measurement error, and to develop a matrix of performance parameters to generate or verify figures of merit that are comparable across the technology. Parameters to be included in the matrix are detection limits, precision, bias, interferences, productivity, safety, and use or generation of hazardous materials.

Such discussions would be of limited productivity without input from the people who actually develop and provide portable XRF spectrometers. As one of the recognized suppliers of these instruments, your input is crucial to the success of this workshop. Consequently, a questionnaire has been enclosed in an attempt not only to address the issues described above but also to provide a means for introduction of additional topics you may wish to see discussed. Your timely response is needed in order to incorporate your input into the workshop agenda. I ask that responses be returned by December 31.

A self-addressed envelope has been included for your convenience. If you have any questions please call Eva Estes at (919) 541-5926. Thank you in advance for your cooperation.

Sincerely,

Warren Loseke

Portable XRF Spectrometer

Name or Model # of spectrometer _____

Please reproduce this form if other models are available.

Applications _____

(Paint, Soil, Dust, etc.)

Detection Limit _____ How is the detection limit determined? _____

_____

_____

_____

Sensitivity _____ How is the sensitivity determined? _____

_____

_____

Accuracy _____ How is the accuracy determined? _____

_____

_____

Briefly describe the calibration procedure _____

_____

_____

_____

Are there any plans to allow for direct user calibration or recalibration? _____

_____

_____

Are you aware of the new NIST paint film SRMs? _____

_____

_____

Have they been of any value to you in calibrating or testing your instruments? _____

_____

_____

_____

Briefly describe the procedure for use of your instrument _____

_____

_____

_____

Approximate analysis time _____

Interferences _____

What substrate correction procedures are used? _____

_____

_____

Are their any new developments or guidelines for using substrate correction procedures? Describe. _____

_____

_____

Are there any built-in instrument checks to test for satisfactory operation? Describe. __

_____

_____

Briefly describe safety procedures/considerations _____

_____

_____

Are there any problems/limitations with the instrument at present? _____

_____

_____

Are improvements to the current instruments envisioned? _____

_____

_____

_____

When might an improved instrument be available? _____

_____

_____

What improvements will be implemented? _____

_____

_____

What do you view as the future needs of the public and/or lead testing organizations regarding portable XRF spectrometers? _____

_____

_____

What topics should be added to the XRF workshop agenda? _____

_____

_____

Please provide any standard operating procedures, instrumentations or other literature you believe would be informative. _____

_____

_____

APPENDIX C

Lists of Attendees and Manufacturers

Portable XRF Workshop Attendees

January 11 - 12, 1993

1. **Mr. Michael E. Beard**
   USEPA/AREAL
   MD-78
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5. **Mr. David Cox**
   David Cox and Associates
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20. **Mr. John Pesce**
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Aliquippa, PA 15001
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FAX: (412) 378-8324

Suppliers of Portable/Transportable XRF Instruments

May 1992

1. MAP
   Scitec Corporation
   2000 Logston Blvd.
   Richland, WA 99352

   TEL (509) 375-5000
   FAX (509) 375-4931

   Larry Lynott

---

2. Spectrace 9000
   Spectrace Instruments
   (Corporate Office)
   345 East Middlefield Road
   Mountain View, CA 94043

   TEL (415) 967-0350
   FAX (415) 967-6316

   Todd Rhea
   (Regional Office)
   2401 Research Blvd.
   Suite 206
   Fort Collins, CO 80526

   TEL (303) 493-2219
   FAX (303) 493-2520

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3. X-MET 880
   Outokumpu Electronicxs
   1900 N.E. Division St., #204
   Bend, OR 97701

   TEL (800) 229-9209
   FAX (503) 385-6750

   Stan Piorek

---

4. PGT XK-3
Princeton Gamma-Tech, Inc.
1200 State Road
Princeton, NJ 08540

TEL (609) 924-7310
FAX (609) 924-1729

---

5. Microlead I
Warrington, Inc.
2113 Wells Branch Parkway
Suite 6700
Austin, TX 78728

TEL (512) 251-7771
FAX (512) 251-7744

Gary Stafford

---

6. Model SEFA-P
HNU Systems, Inc.
160 Charlemont St.
Newton, MA 02161-9987

TEL (617) 964-6690
FAX (617) 965-5812

Robert Petitti

APPENDIX D

Papers/Information Distributed by Speakers and Manufacturers

Data Presented by

Dr. Robert Clickner

On the Performance of the Scitec MAP/XRF in the National Survey of Lead-Based Paint in Housing

by

Robert Clickner and John Rogers

WESTAT

January 11, 1993

This work was sponsored by
Department of Housing and Urban Development
and the Environmental Protection Agency.

National Survey of Lead Paint in Housing

- 381 housing units across the United States
- January to March, 1990

- Scitec MAP-3 spectrum analyzer X-ray fluorescence devices
- Used 8 nominally identical MAPs
- Each MAP delivered from Scitec with
  - Fresh 40 mci Co^{57} radioactive source
  - Calibrated to lead in paint standards of 0.0, 0.22, 1.20, and 2.64 mg/cm^2
  - "Automatic substrate correction" software
- Scitec claim: automatic substrate correction eliminates the need for substrate corrections

- Thousands of 60-second XRF measurements on dozens of different substrates

Validation Measurements in National Survey

- Continual check of MAPs' performance
- Shims (from NIST) with lead paint loadings:

  0.6 ± 0.02 mg/cm^2

  2.99 ± 0.3 mg/cm^2.
- Four substrates:

  Wood, drywall, steel, and concrete
- Daily validation measurements for each MAP/shim/substrate
- Regression analyses on the validation data
  - Estimate the precision and accuracy of the readings
  - Relate readings to
    - Substrate
    - Lead loading level
- Different equation for each machine/substrate
- Equations inverted to calibrate readings for analyses.

Scitec MAP Performance Characteristics

- Readings are systematically different from the amount of lead in the paint.
- The direction and magnitude of the differences are related to
  - Substrate material
  - Lead loading in the paint
- Two nominally identical MAPs may exhibit significantly different performance characteristics
- Precision of the readings depends on the substrate

Therefore, in contrast to the Interim Guidelines and Scitec's claims, substrate correction is in fact a necessary step in the accurate determination of the presence and amount of lead-based paint on surfaces.

- Findings apply only to XRF devices like the Scitec MAP-3s described above and to closely related XRF devices.

Wood

- Readings < actual loadings when loadings < 2.0 mg/cm^2
  Readings > actual loadings when loadings > 2.0 mg/cm^2

- At 0.6 mg/cm^2
  - 88% of the readings were < 0.6 mg/cm^2
  - 52% of the readings were equal to 0.0 mg/cm^2.
  - (MAP never produces a negative reading.)

- At 2.99 mg/cm^2
  - 60% of the readings were > 3.0 mg/cm^2.

- Standard deviation of repeated readings is 0.25 mg/cm^2.

- 7 of the 8 MAPs performed similarly

Drywall or Plaster

- Performance is similar to the performance on wood
- Readings < actual loadings when loadings < 2.5 mg/cm^2
  Readings > actual loadings when loadings > 2.5 mg/cm^2
- At 0.6 mg/cm^2
  - 82% of the readings were < 0.6 mg/cm^2
  - 52% were equal to 0.0 mg/cm^2
- At 2.99 mg/cm^2
  - 44% of the readings < 3.0 mg/cm^2
  - 45% were > 3.0 mg/cm^2.
- Standard deviation of repeated readings is 0.25 mg/cm^2
- 6 of 8 MAPs exhibited similar performance characteristics

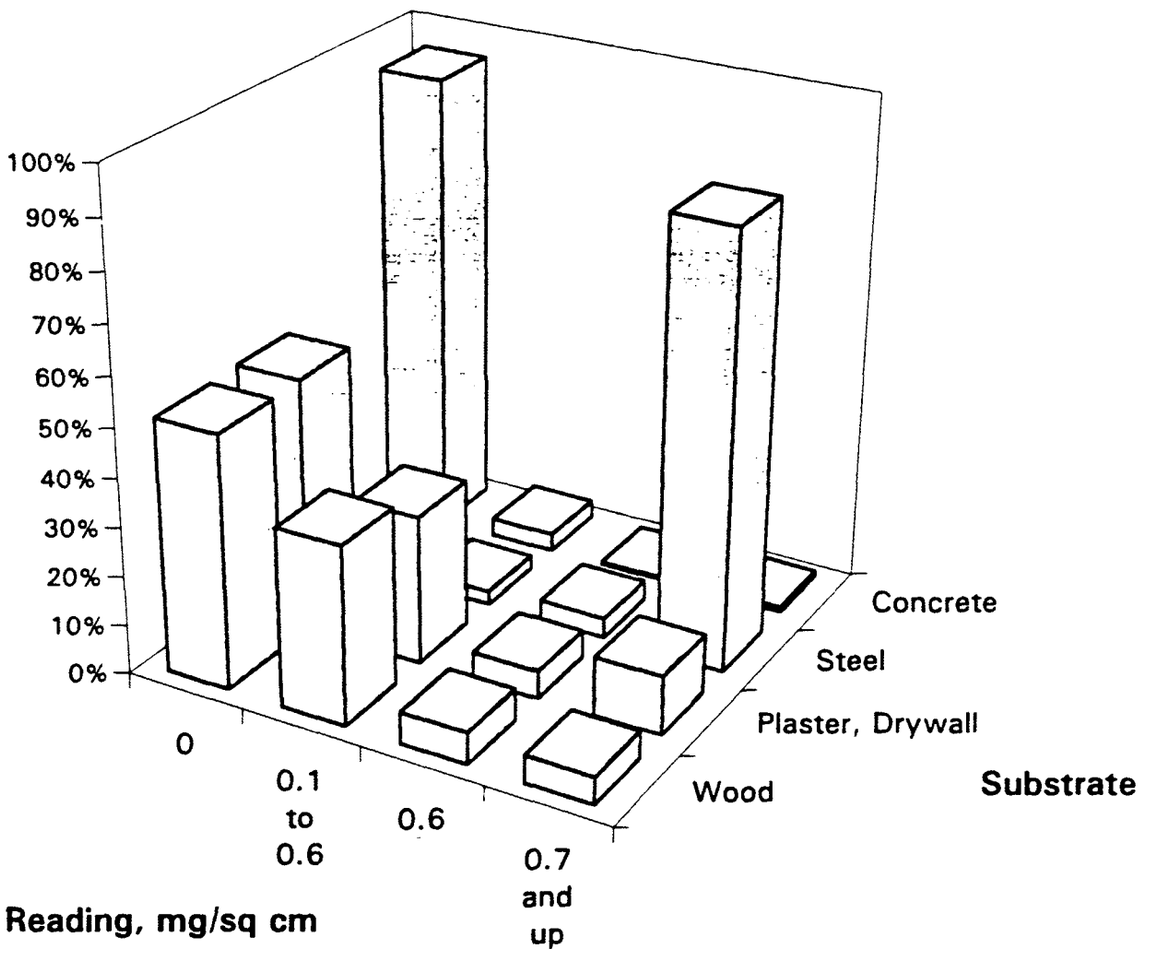
Steel

- Readings > actual loadings, for all observed levels of lead
- At 0.6 mg/cm^2
  - 88% of the readings were > 0.6 mg/cm^2
- At 2.99 mg/cm^2
  - 60% of the readings were > 3.0 mg/cm^2
  - 1 machine had no readings above 3.0 mg/cm^2
- Substantial differences among the 8 machines
- Standard deviation of repeated readings is 0.21 mg/cm^2

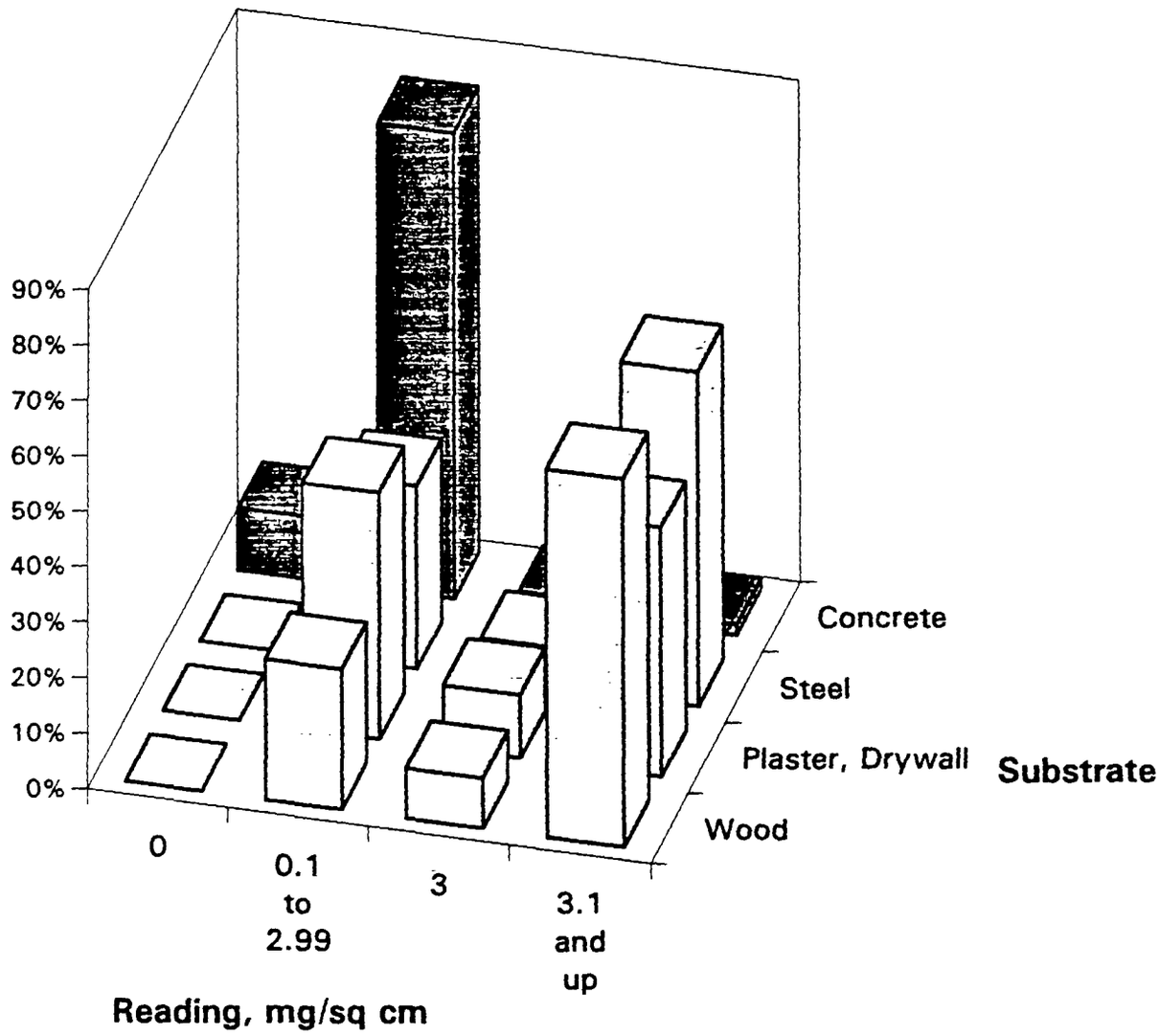
Concrete, brick, and other related substrates

- MAP has difficulty detecting low/moderate levels of lead
- At 0.6 mg/cm^2
  - 95% of the readings were equal to 0.0 mg/cm^2
  - Only 1 machine had more than one non-zero reading
- At 2.99 mg/cm^2
  - 95% of the readings were < 3.0 mg/cm^2
  - 11% of these were equal to 0.0 mg/cm^2
- Standard deviation of repeated readings is 0.49 mg/cm^2
- There is much variation, both among and within machines.

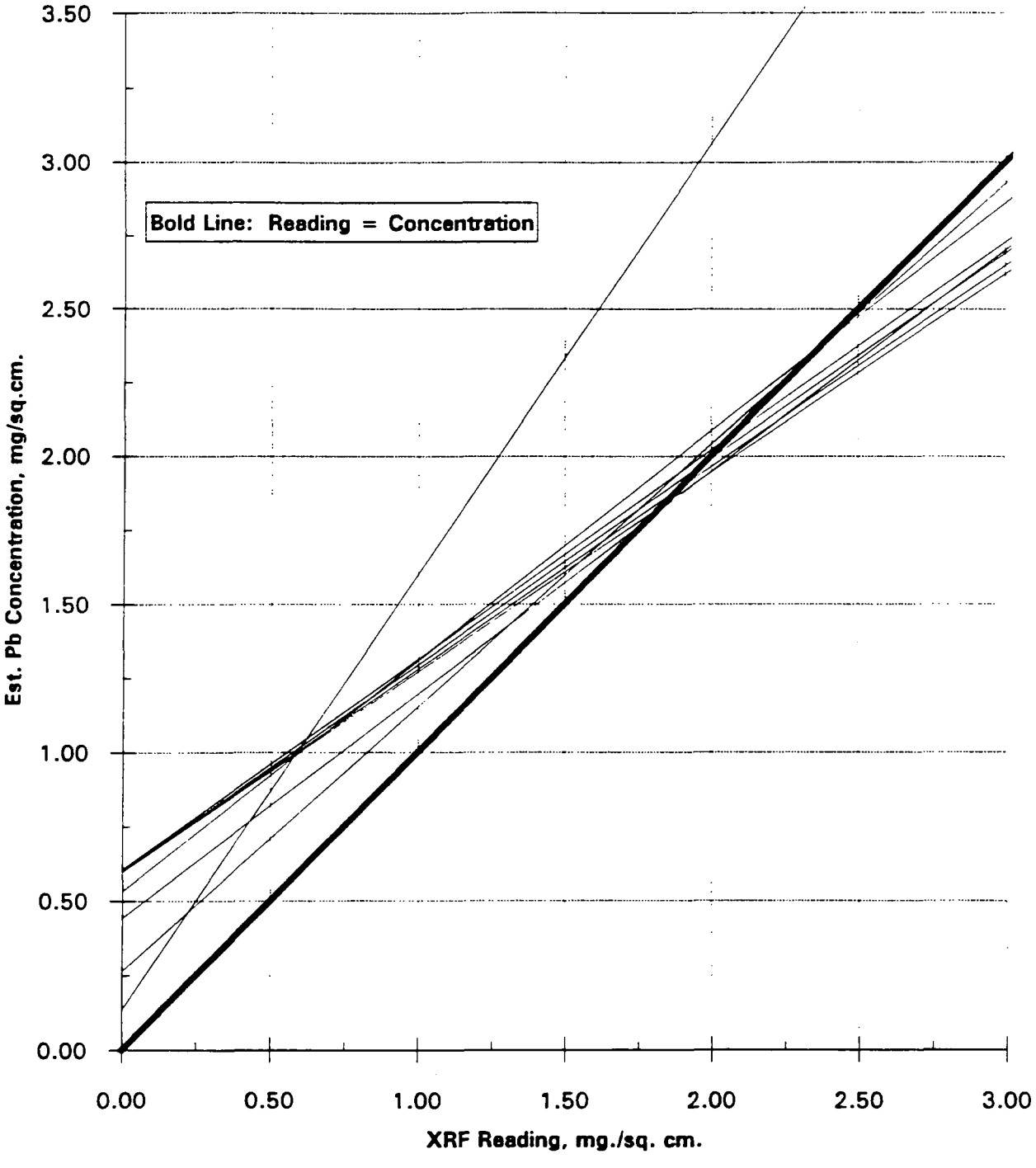
MAP Validation Readings on 0.6 mg/sq cm Shim



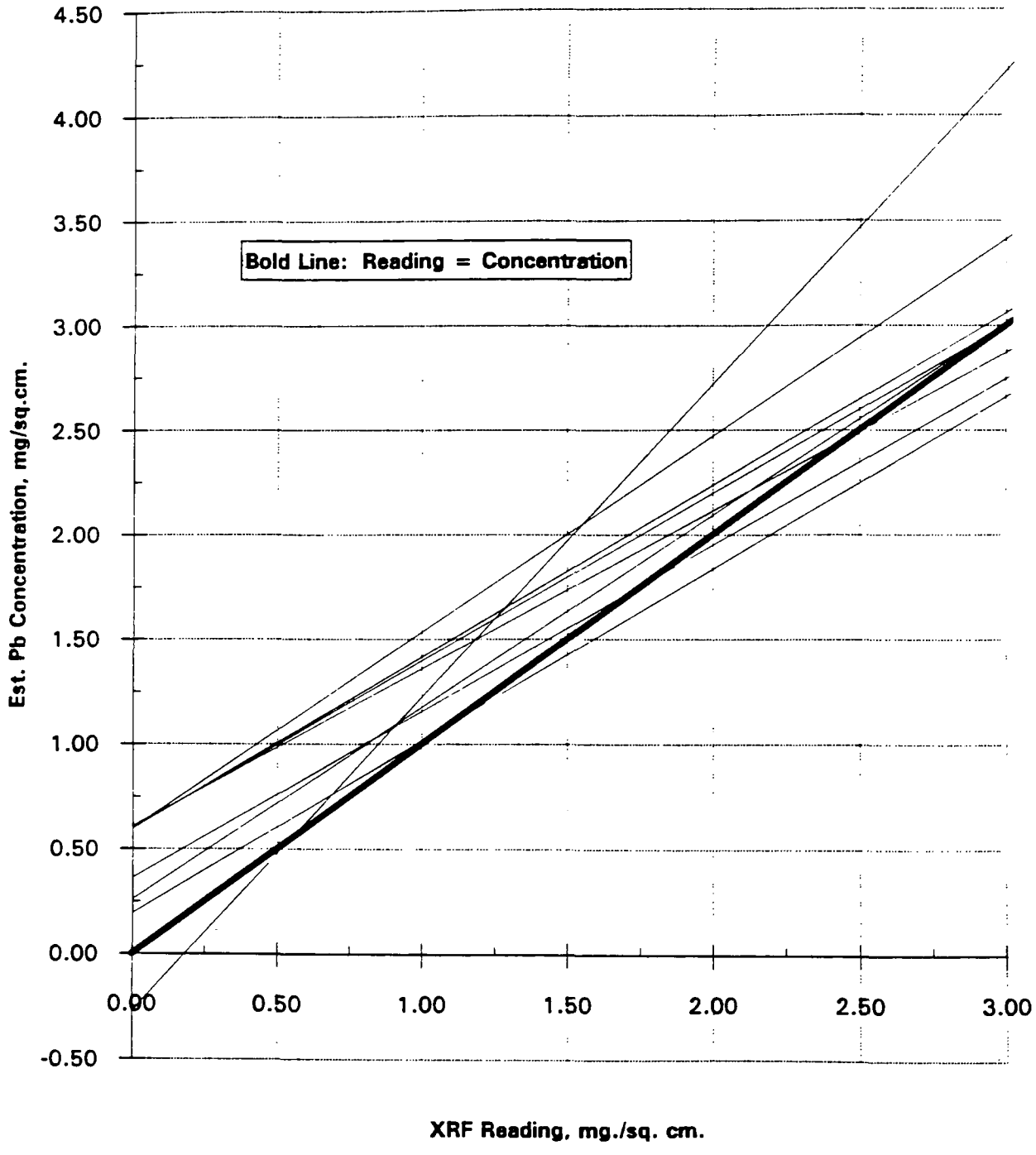
MAP Validation Readings on 2.99 mg/sq cm Shim



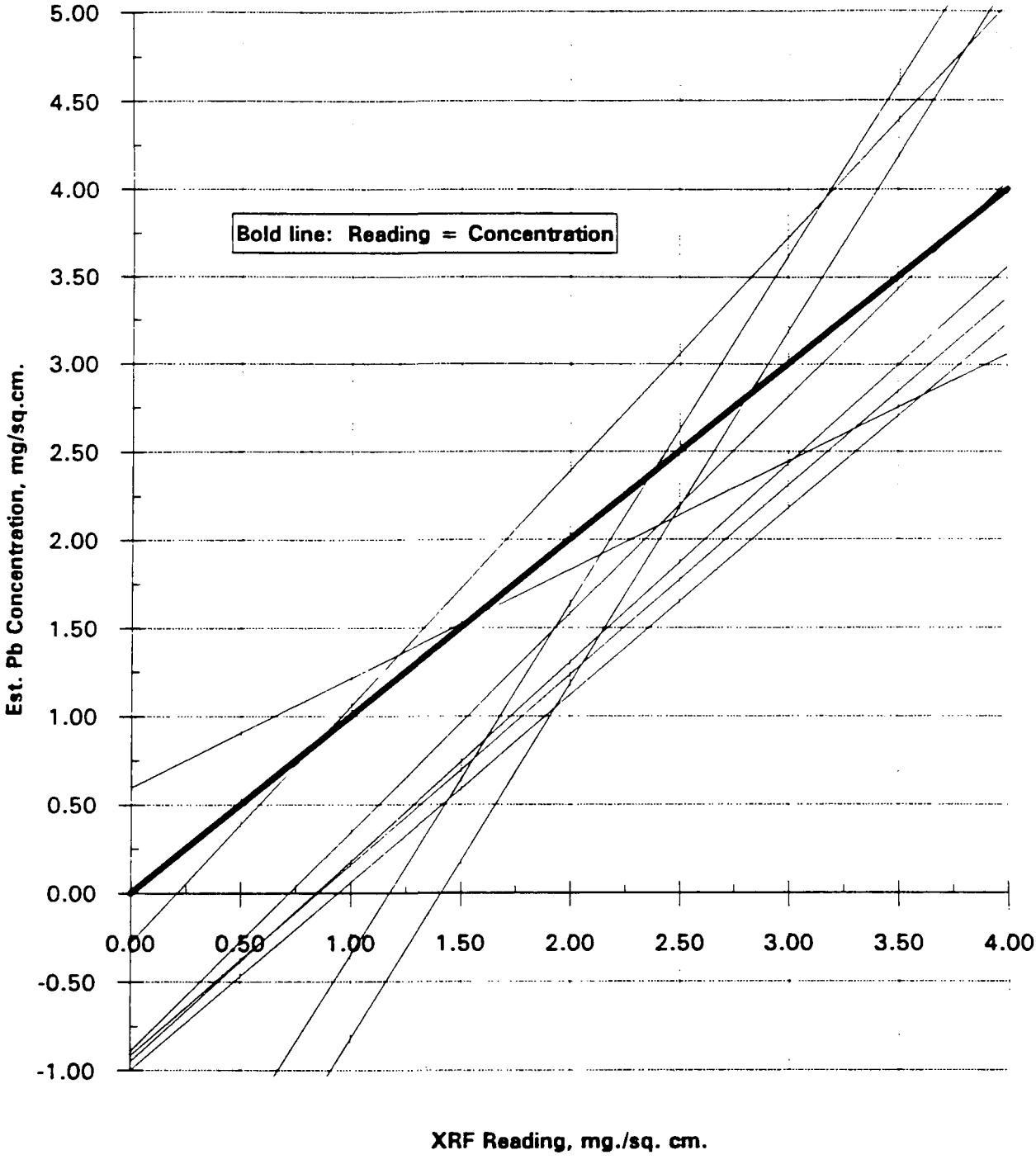
Estimating Lead Concentrations on Wood: Calibration Equations for 8 Spectrum Analyzer XRFs.



Estimating Lead Concentrations on Plaster or Drywall: Calibration Equations for 8 Spectrum Analyzer XRFs.



Estimating Lead Concentrations on Steel: Calibration Equations for 8 Spectrum Analyzer XRFs.



Estimating Lead Concentrations on Concrete: Calibration Equations for 8 Spectrum Analyzer XRFs.

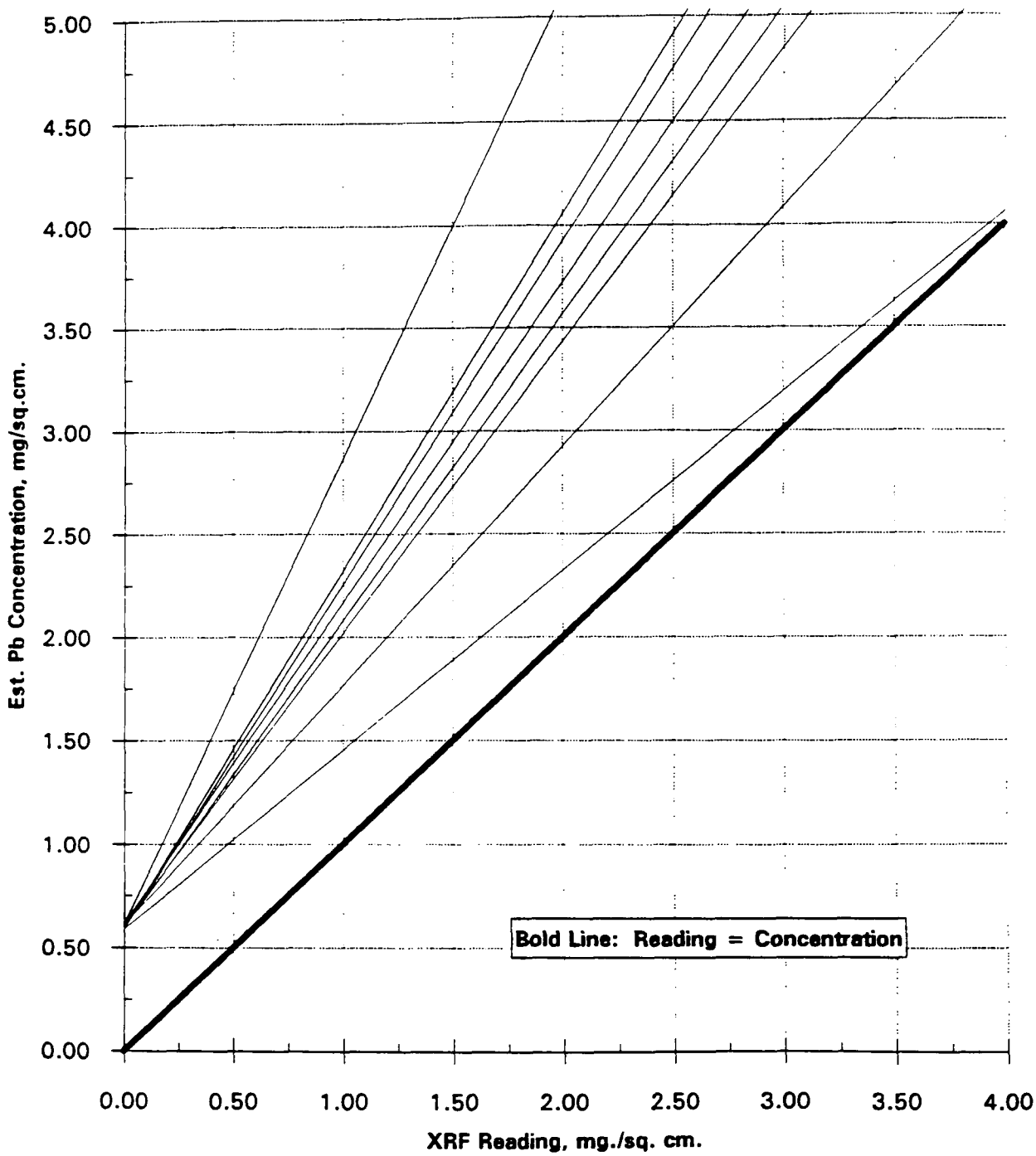
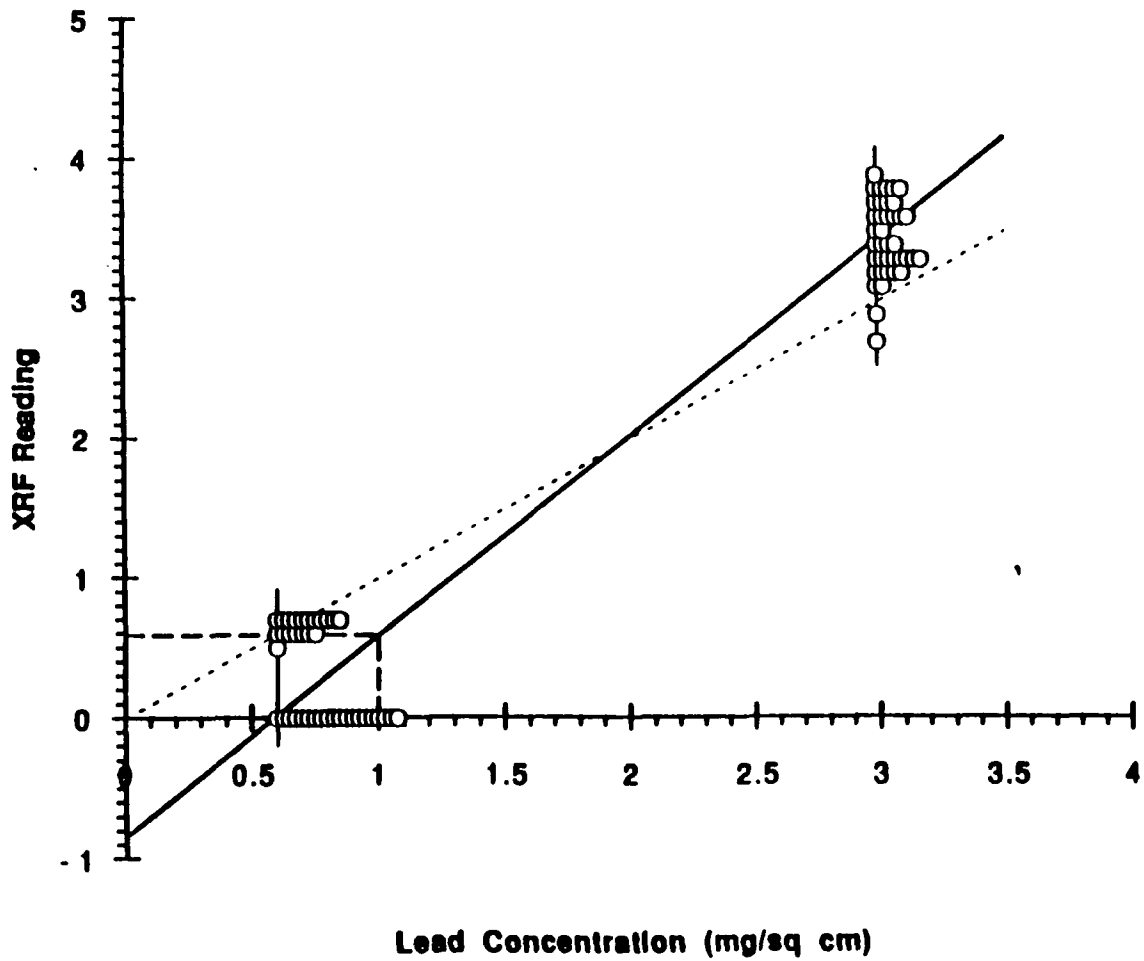
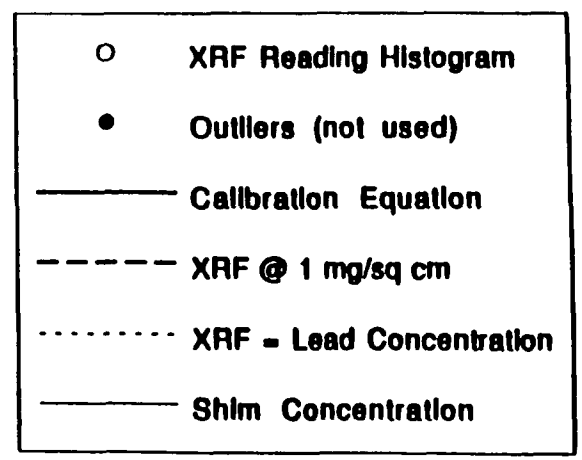


Figure D-18 Validation XRF Readings versus Shim Lead Concentration for XRF Instrument #36 on Wood

Lead concentration (mg/sq cm) = 0.5779 + 0.6977*XRF reading + 0.00069*(Days since 2/2/90)



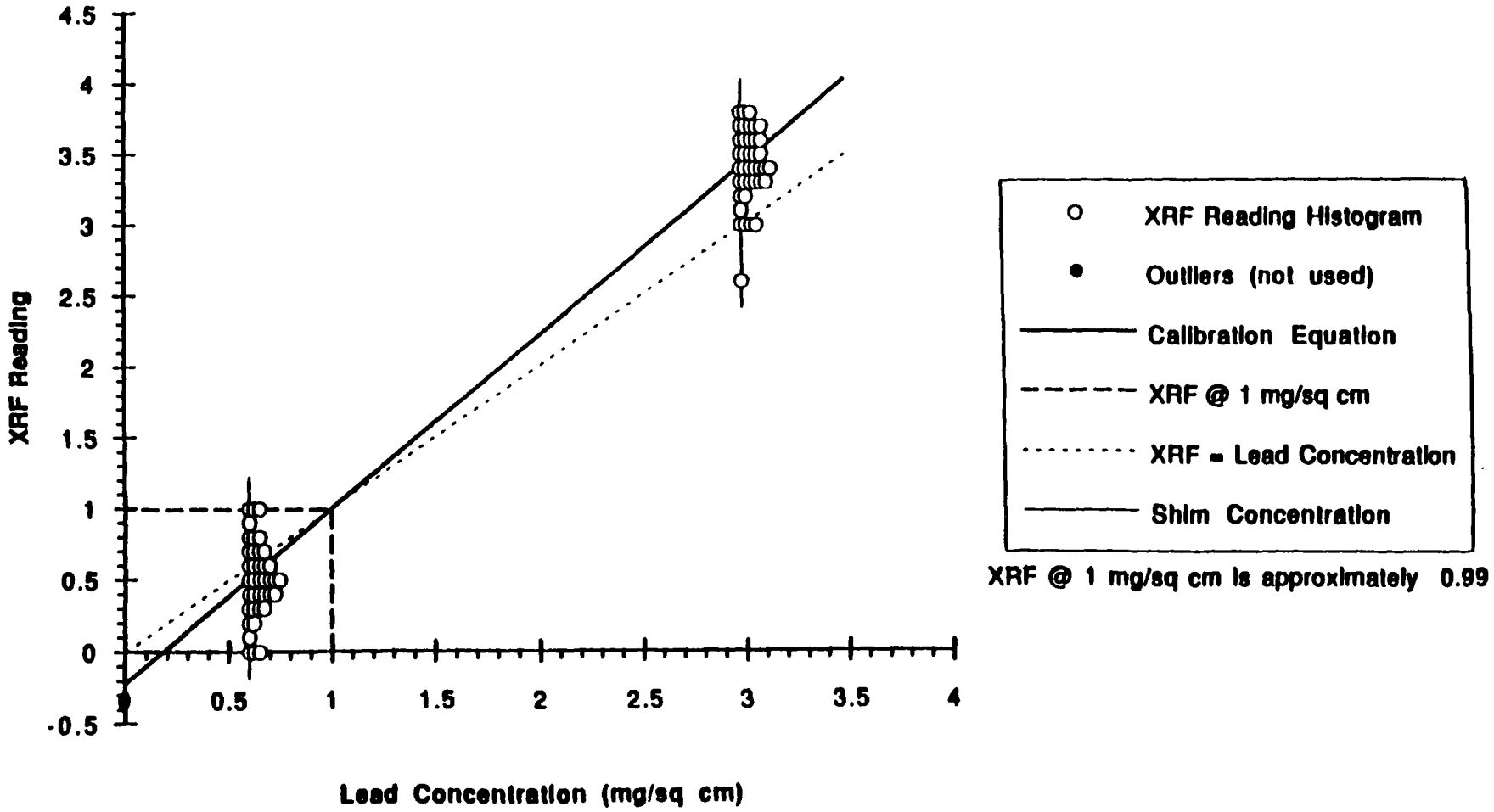


XRF @ 1 mg/sq cm is approximately 0.59

Median used for 0.6 shim

Figure D-34 Validation XRF Readings versus Shim Lead Concentration for XRF Instrument #36 on Drywall

Lead concentration (mg/sq cm) = 0.1694 + 0.8220*XRF reading + 0.00081*(Days since 2/2/90)



XRF @ 1 mg/sq cm is approximately 0.99

Figure D-35 Validation XRF Readings versus Shim Lead Concentration for XRF Instrument #37 on Drywall

Lead concentration (mg/sq cm) = 0.2311 + 0.9186*XRF reading + 0.00091*(Days since 2/2/90)

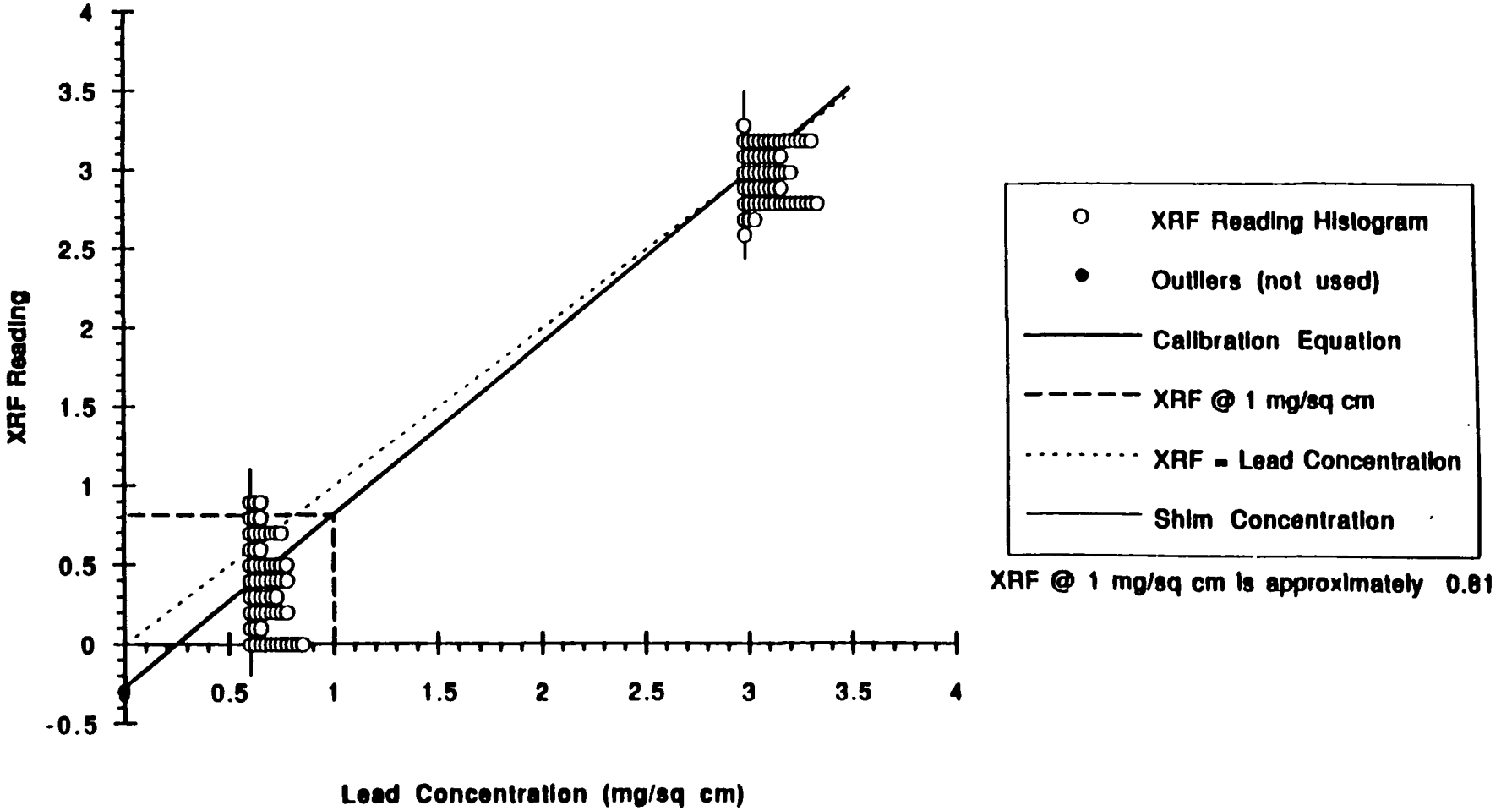
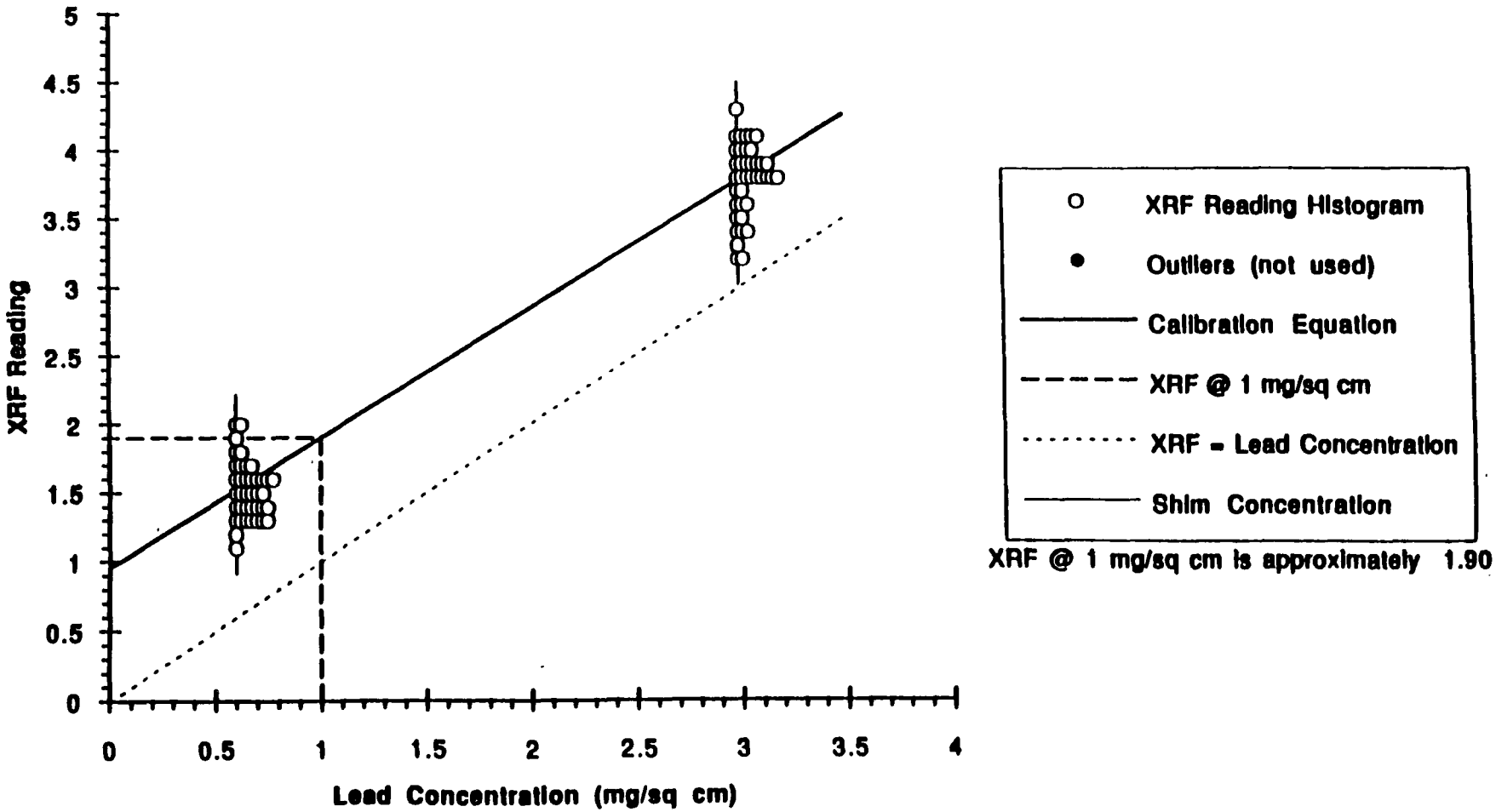


Figure D-10 Validation XRF Readings versus Shim Lead Concentration for XRF Instrument #36 on Steel

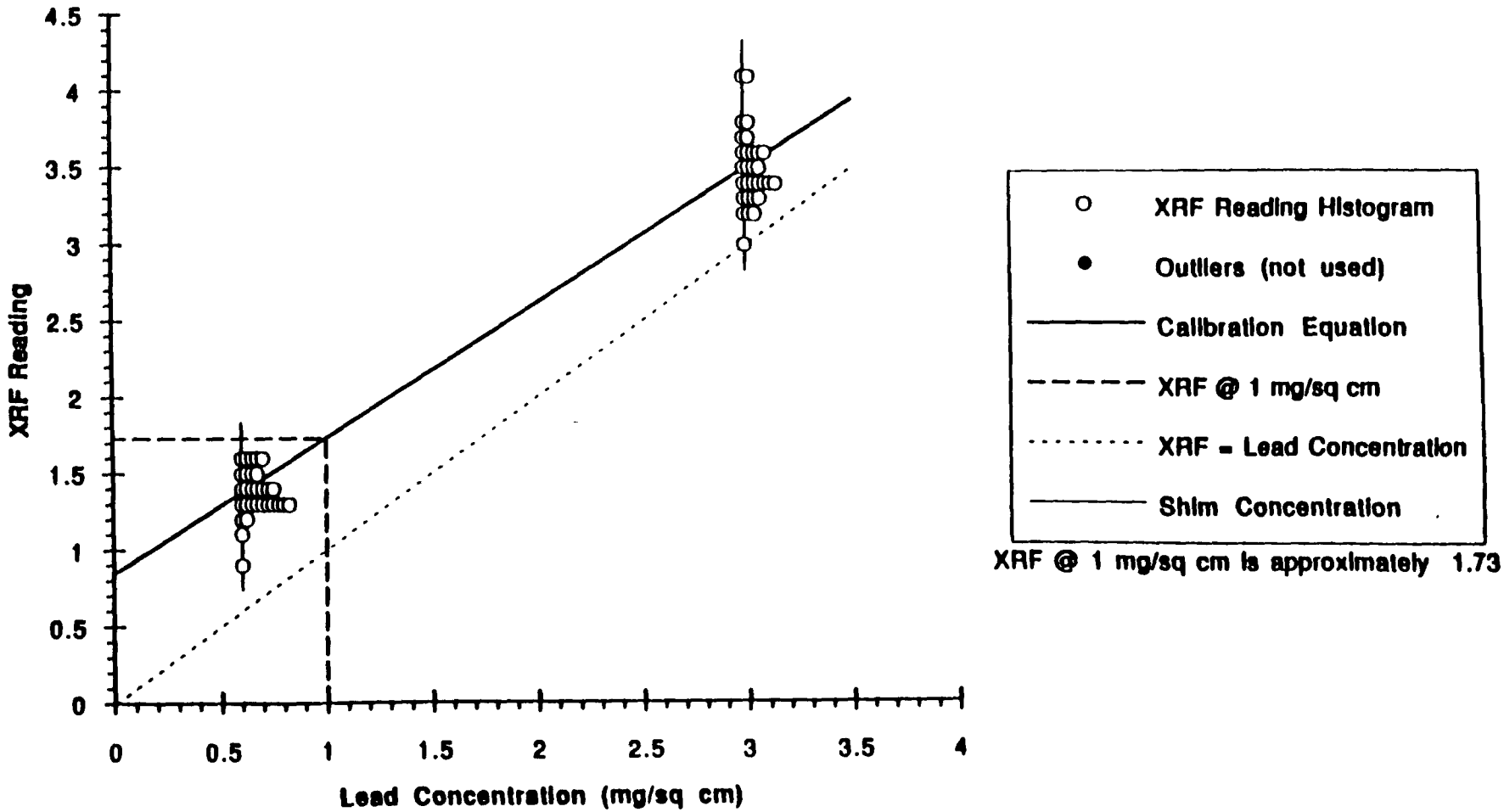
Lead concentration (mg/sq cm) = -1.0285 + 1.0580*XRF reading + 0.00105*(Days since 2/2/90)



XRF @ 1 mg/sq cm is approximately 1.90

Figure D-13 Validation XRF Readings versus Shim Lead Concentration for XRF Instrument #39 on Steel

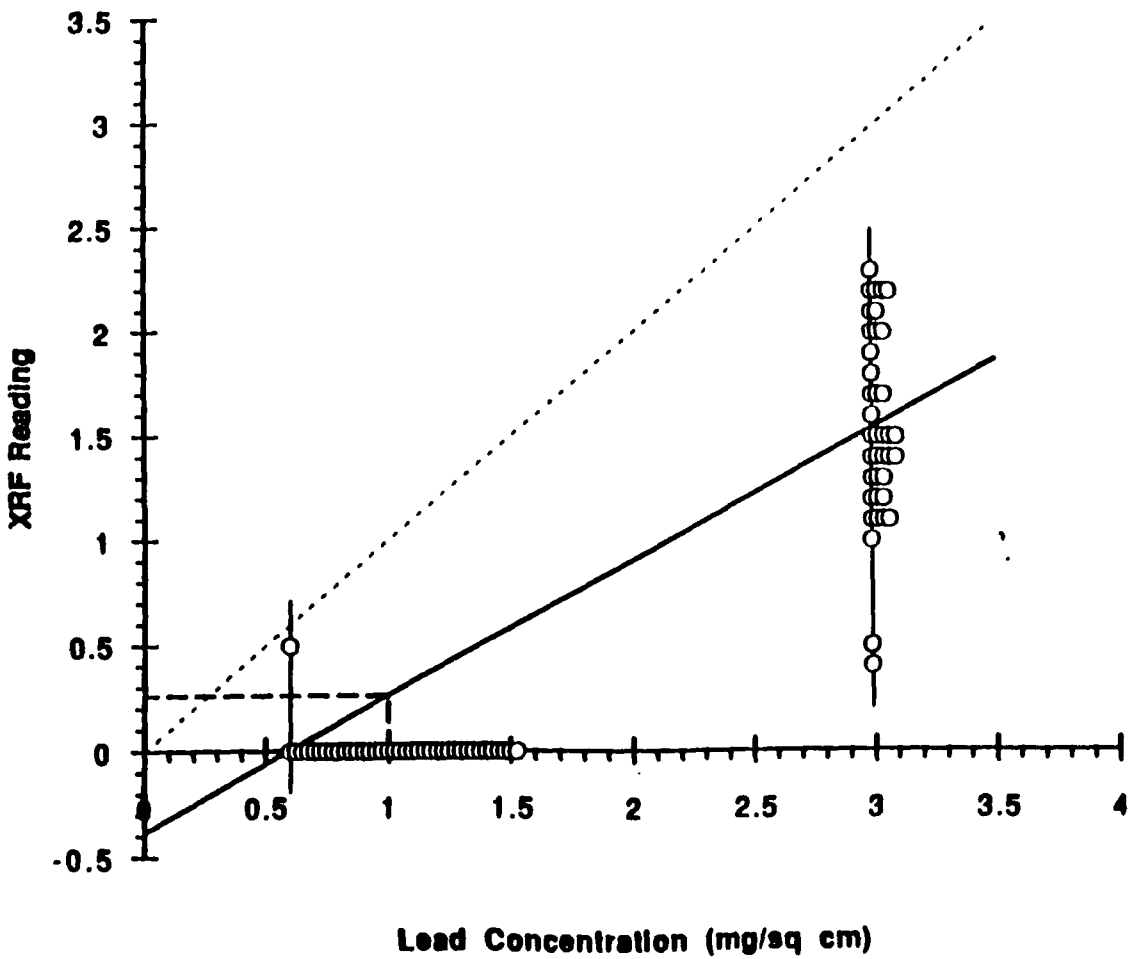
Lead concentration (mg/sq cm) = -0.9832 + 1.1274*XRF reading + 0.00112*(Days since 2/2/90)

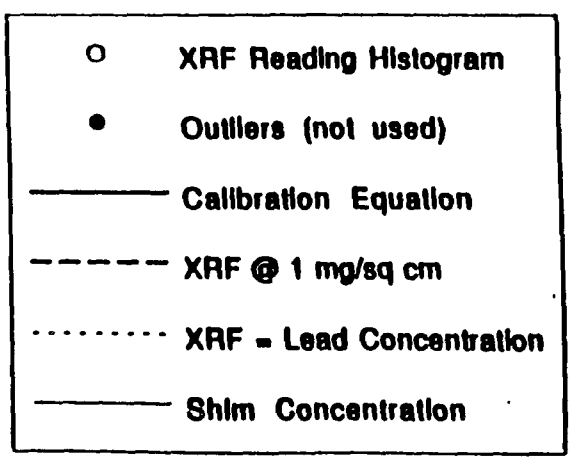


XRF @ 1 mg/sq cm is approximately 1.73

Figure D-26 Validation XRF Readings versus Shim Lead Concentration for XRF Instrument #36 on Concrete

Lead concentration (mg/sq cm) = 0.5692 + 1.5546*XRF reading + 0.00154*(Days since 2/2/90)



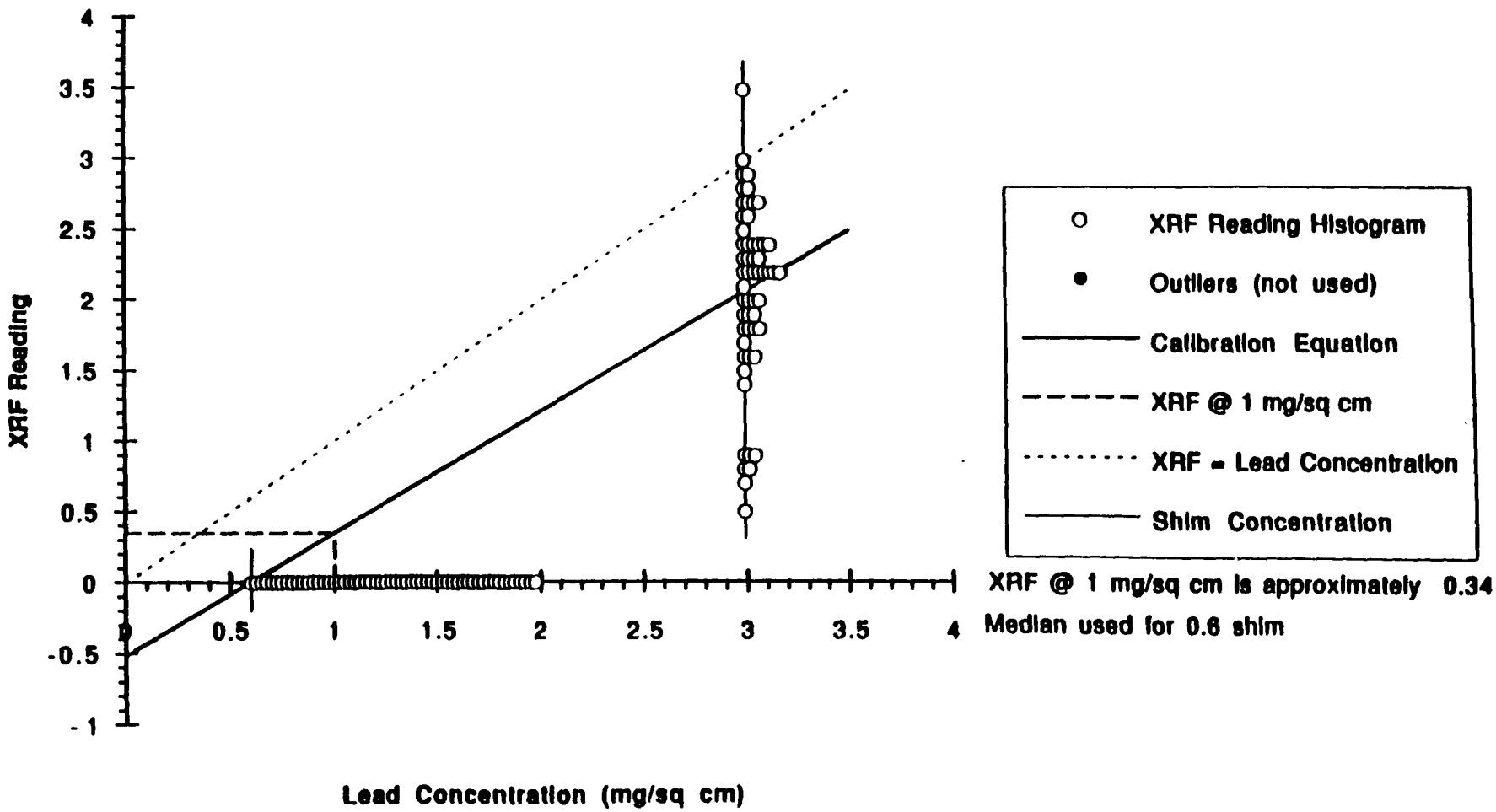


XRF @ 1 mg/sq cm is approximately 0.26

Median used for 0.6 shim

Figure D-28 Validation XRF Readings versus Shim Lead Concentration for XRF Instrument #38 on Concrete

Lead concentration (mg/sq cm) = 0.5753 + 1.1586*XRF reading + 0.00115*(Days since 2/2/90)



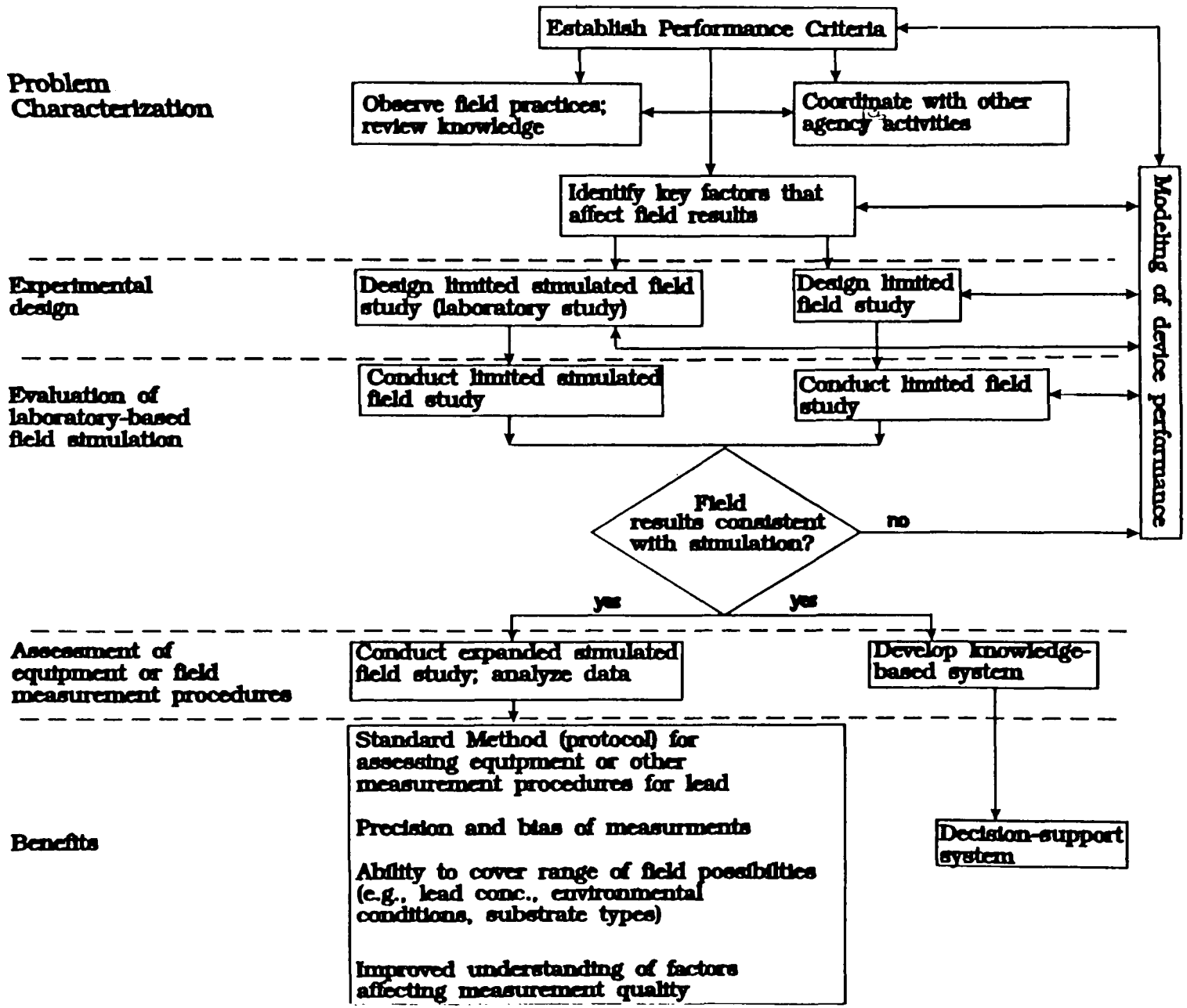
XRF @ 1 mg/sq cm is approximately 0.34

Median used for 0.6 shim

Flow Diagram Presented by

Dr. Mary McKnight

Evaluation of Methods for Field Measurement of Lead in Paint Films



Certification

Data Presented by

Mr. John Pesce

AN EXAMINATION OF SUBSTRATE EFFECT ON PORTABLE X-RAY FLUORESCENCE INSTRUMENTATION

Pesce, J., Star Environmental Services, Inc. P.O. Box 1027, Melrose, MA 02176; Martin, K.P., Massachusetts Institute of Technology, 77 Mass. Ave., Cambridge, MA 02139; Straub, W.E., Straub Industrial Hygiene, 250 Grove St., Melrose, MA 02176; Edwards, R., Massachusetts Institute of Technology, 77 Mass. Ave., Cambridge, MA 02139.

ABSTRACT

Mobile, hand held X-ray fluorescence analyzers (XRF) are used to measure concentrations of lead in paint. The three manufacturers of the instruments treat background readings in different ways. The same surface can give significantly different readings from using different instruments. Some instruments will give readings in excess of legal standards for substrate materials when there is no lead present. Others will give a negative reading for a substrate which will lower the true lead concentration reading. Readings can be corrected by taking readings from bare substrate surfaces, but this is an expensive and time consuming process. Surfaces can also be checked by other confirmatory techniques. This paper examines problems in the use of X-ray analyzers when measuring lead concentrations in painted surfaces. It also demonstrates the need for confirmatory methods.

Test results are presented on the effects of over twenty different substrate materials and conditions. Materials were tested at several lead concentrations. A testing protocol using XRF with confirmatory testing of surfaces using sodium sulfide and atomic absorption spectroscopy is presented with the experience of using it in six buildings containing over four hundred apartment units.

X-ray analyzers alone are not adequate to determine lead concentrations in painted surfaces. Substrate effects and confirmatory testing should be considered. Government regulators should not exclude techniques that are adjunct to the use of the XRF.

INTRODUCTION

The purpose of this presentation is to share our experiences of how various substrates effect the hand held X-ray fluorescent analyzers designed to measure lead in paint. The substrate effect is usually called substrate effect level and sometime referred to as substrate equivalent lead, and abbreviated SEL. Our data is derived from both actual field use and recently developed Round Robin information. The Round Robin encompassed over thirty different instruments that are being used in the fields daily.

The mobile X-ray fluorescent (XRF) analyzers to be discuss are those frequently used for in-situ for lead in paint.

The first to be discussed is that Princeton Gamma Tech, specifically the model XK3. This device uses a cobalt 57 source of approximately 10 millicuries. The instrument counts the X-ray events using a krypton filled proportional tube. Background effects are compensated by monitoring a single lower X-ray frequency, which changes the high voltage in the tube.

The second type is the Warrington Microlead I, Revision 4. The Microlead also uses a cobalt 57 source of approximately 10 millicuries. This instrument uses a high and low band pass screening with a two filter system. The filters are alternated during the reading cycle. The filtered X-rays are then scintillated and counted by a photomultiplier tube. The counts at the high and low frequencies are referenced by computer logic to adjust the voltage of the dynodes in the photomultipier tube.

The third type of XRF to be talked about is the SCITEC Metal Analysis Probe analyzer. This instrument almost always uses a 40 millicurie cobalt 57 source. The detector used is a crystal. The analyzer uses an algorhithem based upon information received from five reference channels at different frequencies. The algorhithem is designed to correct for most substrate effects. Although the SCITEC has the ability to be spectrum read, most of time it is operating in the direct read mode.

FIELD DATA

The broad base of building materials that can be painted with lead based paint, and consequently must be tested, is staggering. Residential wood frame construction poses many wood and plaster items inside, many times these materials are in tandem. Exteriors of these types of buildings also often have various types of coverings over wood, including wood over wood. Larger buildings both residential and commercial generally favor more concrete, brick, and denser plaster. These buildings also have a tendency to contain more metal architectural features and less wood millwork.

FIGURE 1

FIELD TESTING

* 421 units tested in an apartment complex
* All interior and exterior surfaces were tested, resulting in over 20,000 readings
* PGT-XK3, XRF instruments were used
* 32 substrate effect levels (SEL) were measured

A comprehensive lead inspection of 421 units in high-rise apartment building were performed using all PGT's. The inspection was conducted to examine surfaces for lead on 100% of all interior, common and exterior surfaces.

The protocol used for testing included SEL's on all surfaces and confirmatory use of both sodium sulfide solution (6-8%) and atomic absorption. Confirmation techniques were engaged when certain levels were found by XRF. Sodium sulfide solution was used when Apparent Lead Concentrations were 1.2 mg/cm2 and samples, taken for AA analysis when Corrected Lead Concentrations were between 0.8 mg/cm2 to 1.5 mg/cm2. Consequently SEL's had to be take on ceilings, walls, windows, etc. Having this significant amount of data on the SEL's for the building, we took the opportunity to test the SEL locations with the PGT, Warrington and the SCITEC. The following is the data collected:

FIGURE 2

ALL TYPES OF SUBSTRATES

	PGT	WAR	SCI
Masonry			
Cinder Block	1.1	1.2	0.0
Plaster type A	0.6	-0.1	0.0
Plaster column	1.2	1.7	0.0
Red Brick	1.1	1.3	0.0
Cinder Block	1.1	1.2	0.0
Sheet Rock	0.2	-0.3	0.2
Concrete Column	0.9	1.7	0.3
Wood			
Pressed Board	0.0	-0.1	0.0
Hollow Door	0.4	-0.3	0.0
Oak	0.2	-0.2	0.3
Metal			
Window Sill	1.9	-1.1	0.4
Radiator Cover	1.6	-1.0	0.3
Vent Duct	1.1	-0.7	0.3
Mail Box	1.5	-1.1	0.3

Since it is expected that these instruments will be used over a wide variety of materials, we selected representative samples. The tremendous variability of the XRF's SEL on groups within the same type of building materials such as plaster/masonry, cause us to take a more microscopic view of the SEL's within similar building components.

FIGURE 3

MASONRY TYPES OF SUBSTRATE

	PGT	WAR	SCI
Cinder Block	1.1	1.2	0.0
Plaster type A	0.6	-0.1	0.0
Plaster column	1.2	1.7	0.0
Plaster type B	0.6	0.1	0.0
Red Brick	1.1	1.3	0.0
Cinder Block	1.1	1.2	0.0
Sheet Rock	0.2	-0.3	0.2
Concrete Column	0.9	1.7	0.3

Note the variability of the PGT and Warrington with respect to these type of building materials. Also note how the SCITEC almost seems to have a flat response to most of these substrates. It will also be interesting to note that both the PGT and Warrington can give negative readings and the SCITEC cannot. This list demonstrates how important it is to know which type of wall or ceiling that is being tested before any final determination can be stated about its lead content. That is, if the wall is a supporting concrete wall as opposed to a dividing wall, significant differences of substrate effect occur.

FIGURE 4

METAL SUBSTRATES

	PGT	WAR	SCI
Window Sill	1.9	-1.1	0.4
Radiator Cover	1.6	-1.0	0.4
Vent Duct	1.1	-0.7	0.3
Mail Box	1.5	-1.1	0.3

As shown in figure 4, for metals both the PGT and Warrington seem to treat the substrate effects completely opposite. The elevated readings for the PGT are similar in absolute values as the depressed readings of the Warrington. Again the SCITEC seems only modestly influenced by the substrate.

FIGURE 5

WOOD SUBSTRATES

	PGT	WAR	SCI
Pressed Board	0.0	-0.1	0.0
Hollow Door	0.4	-0.3	0.0
Oak	0.2	-0.2	0.3

As shown in figure 5 the XRFs apparently work on less dense materials. The standard deviations reported by the manufactures of .3 mg/cm2 can usually be depended upon for wood type substrates.

ROUND ROBIN INFORMATION

Over the past year, a group of private lead inspectors in Massachusetts have established and participated in a voluntary Round Robin testing procedure for portable X-ray fluorescence instruments. As part of this Round Robin program, substrate effects were examined. A detailed presentation of this Round Robin program will be presented on Wednesday by another author of this paper.

FIGURE 6

STEEL CHANNEL

	PGT(9)	WAR(5)	SCI(1)
ALC	1.8	-0.8	1.2
SEL	0.9	-0.8	0.4
CLC	0.9	0.0	0.8

In this slide the Substrate Effect Level, called the SEL, is a piece of steel channel, with no lead paint. The Apparent Lead Concentration, called the ALC, is the same steel channel with lead paint. To make a substrate effect correction to the steel channel with lead paint, the reading for the steel channel without lead paint is subtracted. This gives a Corrected Lead Concentration called the CLC. All readings are expressed in mg/cm2. For the steel channel samples prepared for the Round Robin the CLC of PGT and SCITEC showed some measure of lead while the Warrington's CLC showed there to be no lead.

FIGURE 7

RED BRICK

	PGT(9)	WAR(5)	SCI(1)
ALC	1.8	1.4	0.0
SEL	1.2	0.3	0.0
CLC	0.6	1.2	0.0

Red bricks were also prepared with and without lead paint on their surfaces. What is shown in figure 7 is obvious that the SCITEC did not pick up any amount of lead. While the zero readings of the SCITEC on substrates is, at first, comforting, it can be seen from this slide that like the Warrington on metals, a false negative reading can result.

FIGURE 8

POPLAR

	PGT(9)	WAR(5)	SCI(1)
ALC	1.2	0.9	0.6
SEL	0.0	-0.1	0.1
CLC	1.2	1.0	0.5

Poplar wood samples prepared for the Round Robin and shown in figure 8 indicates that the XRF's were able to identify leaded surfaces, although quantification are not in good agreement.

FIGURE 9

BELLY CASING

	PGT(9)	WAR(5)	SCI(1)
ALC	1.0	1.2	0.7
SEL	0.0	0.3	0.0
CLC	1.0	0.9	0.7

A decorative wood molding called belly casing was also used during a Round Robin test. This was done to check the effects of an air gap between the XRF probe and the sample. The results shown in figure 9 are consistent with the flat wood sample shown previously. This type of belly casing has a convexed fluted surface that would allow only direct contact with a partial portion of the instrument probe area.

FIGURE 10

SHEET ROCK

	PGT(9)	WAR(5)	SCI(1)
ALC	1.4	0.8	1.2
SEL	0.2	0.1	0.4
CLC	1.2	0.7	0.8

The Round Robin sheetrock samples also produced a consistent result for the three different XRF's.

FIGURE 11

READ-THROUGH EFFECTS
Lead Flashing under 1 1/2" of wood

	PGT(13)	WAR(11)	SCI(1)
ALC	1.7	10.7	4.7
SEL	0.0	-0.1	0.1
CLC	1.7	10.8	4.6

The penetration of the gamma ray and consequently the ability of the K shell X-ray to also penetrate materials, can produce a reading on the XRF's when lead is deep beneath the surface. It is interesting to notice that in figure 11 the PGT is less susceptible to detect this type of lead.

The instruments seem to do well over most of the less dense materials, those which would most likely be found in wood frame houses with less than four families. Higher density materials and metals pose a problem for the XRF's and provide a need to correct for the type of substrate being examined. This would indicate that buildings with construction components of higher density would require a more keen attention to substrate effect on the lead X-ray frequency.

At present most of the level driven lead abatement is based upon XRF reading of around 1.0 mg/cm2. This is well within a range for which substrate effects alone can be contained. It is possible to read above this level and not have any lead present.

In an effort to reduce the error resultant from XRF testing alone, we used secondary and tertiary screening methods. The secondary screening method used was AA. The tertiary screening was done with the use of sodium sulfide solution (6-8%). (The fact that this testing procedure is currently only accepted by the Commonwealth of Massachusetts should not mitigate it usefulness as a confirmatory method.)

CONCLUSIONS

It is our conclusions that for a wide variety of substrates the instruments can be used with a reasonable amount of confidence. This can be aided by using substrate corrections but assumes the operator has the experience to know what the substrate is and how to make appropriate corrections. For example structural concrete walls and those simply that divide rooms can look deceptively similar, yet the XRF can have profoundly different readings. Lead/lead paint behind even one inch thick wood can be mistaken as surface lead. The operator of the XRF must have enough knowledge to know when to doubt the XRF and refer back to secondary and tertiary screening methods.

The XRFs are also not able to compensate for all possible substrates. Substrate correction values can be different from instruments of the same manufacturer as well as differ from those of each manufacturer.

Someone's mistaken perception about the level of lead on a surface could indicate that no lead is present when dangerous levels of lead are present, or could affect the cost of abatement significantly by indicating abatement when none is needed. Although it is possible to use SEL's to correct for these effects to some extent, the degree of correction has limited accuracy. Confirmatory testing should be used on certain substrates when lead levels that could influence the abatement decision are marginal.

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- A

SAMPLE DESCRIPTION	This sample consisted of three layers:

-Top layer> two pieces of unpainted, 3/4" thick, wood.
-Middle layer> lead roofing flashing.
-Bottom layer> 1/4" plywood.
>>>The flashing was the only lead in the sample.

PGT	
ID Code	Reading
watch	2.3
dvblt	2.4
cegbm	1.4
qblam	1.0
mkcfx	1.5
mejsc	1.1
adlwz	1.5
walzj	2.1
qapcu	1.7
pwfal	1.9
bdfhj	1.8
kmprt	1.4
acegi	1.6

Warrington	
ID Code	Reading
tolpk	10.9
lqrom	11.5
azbyc	9.8
notrl	11.3
dfdce	10.5
hcdjr	10.7
npxtc	10.5
andkm	11.6
baino	12.3
dyzag	10.1
fbcps	10.3

SciTec	
ID Code	Reading
lnqbv	4.68

	PGT	Warrington	SciTec
mean	1.7	10.7	4.68
standard deviation	0.42	0.74	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- B

SAMPLE DESCRIPTION	This sample consisted of four layers:

-Top layer> one sheet of heavy paper.
-Second layer> lead paint.
-Third layer> two inch thick concrete (from cinder block).
-Bottom layer> 1/4" plywood.

PGT	
ID Code	Reading
watch	2.6
dvblt	2.2
cegbm	2.3
qblam	1.5
mkcfx	1.3
mejsc	1.5
adlwz	3.0
walzj	2.7
qapcu	2.2
pwfal	2.2
bdfhj	2.8
kmprt	2.0
acegi	1.9

Warrington	
ID Code	Reading
tolpk	1.6
lqrom	1.4
azbyc	1.9
notrl	1.7
dfdce	1.4
hcdjr	2.2
npxtc	1.4
andkm	2.3
baino	1.4
dyzag	2.0
fbcps	1.7

SciTec	
ID Code	Reading
lnqbv	0.13

	PGT	Warrington	SciTec
mean	2.2	1.7	0.13
standard deviation	0.54	0.33	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- C

SAMPLE DESCRIPTION	This sample consisted of two layers:

-Top layer> lead paint.
-Bottom layer> wood door, 1 3/4 " thick.

PGT	
ID Code	Reading
watch	2.3
dvblt	2.6
cegbm	1.4
qblam	1.9
mkcfx	2.1
mejsc	1.6
adlwz	2.3
walzj	2.7
qapcu	2.7
pwfal	2.7
bdfhj	3.1
kmprt	2.0
acegi	2.5

Warrington	
ID Code	Reading
tolpk	1.2
lqrom	1.6
azbyc	0.7
notrl	1.9
dfdce	2.0
hcdjr	2.5
npxtc	1.5
andkm	2.0
baino	1.6
dyzag	1.7
fbcps	1.7

SciTec	
ID Code	Reading
lnqbv	2.13

	PGT	Warrington	SciTec
mean	2.3	1.7	2.13
standard deviation	0.48	0.46	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- D

SAMPLE DESCRIPTION	This sample consisted of two layers:

-Top layer> non-lead paint.
-Bottom layer> wood door, 1 3/4 " thick.

PGT	
ID Code	Reading
watch	0.3
dvblt	0.1
cegbm	-0.3
qblam	0.2
mkcfx	-0.1
mejsc	0.0
adlwz	0.0
walzj	0.2
qapcu	0.3
pwfal	0.0
bdfhj	0.4
kmprt	0.8
acegi	-0.2

Warrington	
ID Code	Reading
tolpk	-0.1
lqrom	-0.2
azbyc	2.2
notrl	0.1
dfdce	-0.4
hcdjr	0.9
npxtc	0.6
andkm	0.4
baino	0.0
dyzag	0.0
fbcps	0.8

SciTec	
ID Code	Reading
lnqbv	0.04

	PGT	Warrington	SciTec
mean	0.1	0.4	0.04
standard deviation	0.29	0.73	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- E

SAMPLE DESCRIPTION	This sample consisted of two layers:

-Top layer> lead paint.
-Bottom layer> wood door, 1 3/4 " thick.

PGT	
ID Code	Reading
watch	1.3
dvblt	1.4
cegbm	0.2
qblam	0.5
mkcfx	0.2
mejsc	0.3
adlwz	0.6
walzj	1.3
qapcu	0.8
pwfal	1.0
bdfhj	1.0
kmprt	0.3
acegi	0.6

Warrington	
ID Code	Reading
tolpk	0.6
lqrom	0.7
azbyc	1.0
notrl	0.9
dfdce	0.6
hcdjr	1.5
npxtc	0.8
andkm	1.0
baino	0.5
dyzag	0.5
fbcps	1.2

SciTec	
ID Code	Reading
lnqbv	0.63

	PGT	Warrington	SciTec
mean	0.7	0.9	0.63
standard deviation	0.43	0.31	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- F

SAMPLE DESCRIPTION	This sample consisted of three layers:

-Top layer> lead paint.
-Middle layer> two layers of cedar shingles.
-Bottom layer> 3/4 " wood.

PGT	
ID Code	Reading
watch	0.6
dvblt	0.9
cegbm	0.4
qblam	0.4
mkcfx	0.6
mejsc	0.5
adlwz	0.6
walzj	0.9
qapcu	0.9
pwfal	0.6
bdfhj	1.2
kmprt	0.4
acegi	0.6

Warrington	
ID Code	Reading
tolpk	1.4
lqrom	1.8
azbyc	1.5
notrl	1.8
dfdce	1.4
hcdjr	1.8
npxtc	1.3
andkm	2.0
baino	1.7
dyzag	1.4
fbcps	1.5

SciTec	
ID Code	Reading
lnqbv	1.102

	PGT	Warrington	SciTec
mean	0.7	1.6	1.10
standard deviation	0.25	0.23	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- G

SAMPLE DESCRIPTION	This sample consisted of three layers:

-Top layer> one sheet of heavy paper.
-Middle layer> non-lead paint primer.
-Bottom layer> metal door jam.

PGT	
ID Code	Reading
watch	0.5
dvblt	0.9
cegbm	0.2
qblam	0.2
mkcfx	0.1
mejsc	0.5
adlwz	1.0
walzj	1.3
qapcu	1.2
pwfal	0.6
bdfhj	1.0
kmprt	0.5
acegi	0.6

Warrington	
ID Code	Reading
tolpk	-0.7
lqrom	-1.1
azbyc	-0.6
notrl	-0.8
dfdce	-1.2
hcdjr	-0.5
npxtc	-1.1
andkm	-1.3
baino	-1.0
dyzag	-0.5
fbcps	-1.3

SciTec	
ID Code	Reading
lnqbv	0.34

	PGT	Warrington	SciTec
mean	0.7	-0.9	0.34
standard deviation	0.38	0.31	----

ROUND ROBIN ----- **ROUND NUMBER ONE**
DATE ---------- **10/03/91 AND 10/04/91**
SAMPLE ID CODE -- H

SAMPLE DESCRIPTION	This sample consists of four layers:

-Top layer> anodized aluminum metal house siding.
-Middle layer> lead paint (painted on bottom layer.
-Bottom layer> 3/4 " wood.

PGT	
ID Code	Reading
watch	1.3
dvblt	1.5
cegbm	1.1
qblam	1.0
mkcfx	0.6
mejsc	0.4
adlwz	1.3
walzj	1.9
qapcu	1.5
pwfal	1.5
bdfhj	1.9
kmprt	1.5
acegi	1.3

Warrington	
ID Code	Reading
tolpk	1.2
lqrom	1.1
azbyc	0.9
notrl	1.5
dfdce	1.0
hcdjr	1.1
npxtc	0.7
andkm	1.4
baino	0.3
dyzag	1.0
fbcps	0.7

SciTec	
ID Code	Reading
lnqbv	1.15

	PGT	Warrington	SciTec
mean	1.3	1.0	1.15
standard deviation	0.42	0.34	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- I

SAMPLE DESCRIPTION	This sample consisted of two layers:

-Top layer> lead paint.
-Bottom layer> 3/8 " sheetrock.

PGT	
ID Code	Reading
watch	1.4
dvblt	2.0
cegbm	1.0
qblam	1.2
mkcfx	1.0
mejsc	0.9
adlwz	1.3
walzj	1.8
qapcu	1.5
pwfal	1.8
bdfhj	1.4
kmprt	1.2
acegi	1.1

Warrington	
ID Code	Reading
tolpk	0.7
lqrom	0.9
azbyc	0.8
notrl	1.5
dfdce	0.8
hcdjr	0.9
npxtc	0.8
andkm	0.9
baino	0.4
dyzag	1.1
fbcps	0.5

SciTec	
ID Code	Reading
lnqbv	1.14

	PGT	Warrington	SciTec
mean	1.3	0.9	1.14
standard deviation	0.36	0.29	----

ROUND ROBIN ----- ROUND NUMBER ONE
DATE ---------- 10/03/91 AND 10/04/91
SAMPLE ID CODE -- J

SAMPLE DESCRIPTION	This sample consists of two layers:

-Top layer> non-lead paint.
-Bottom layer> 3/8 " sheetrock.

PGT	
ID Code	Reading
watch	0.2
dvblt	0.5
cegbm	-0.9
qblam	0.3
mkcfx	0.1
mejsc	0.1
adlwz	0.0
walzj	0.1
qapcu	0.0
pwfal	0.1
bdfhj	0.2
kmprt	-0.1
acegi	0.0

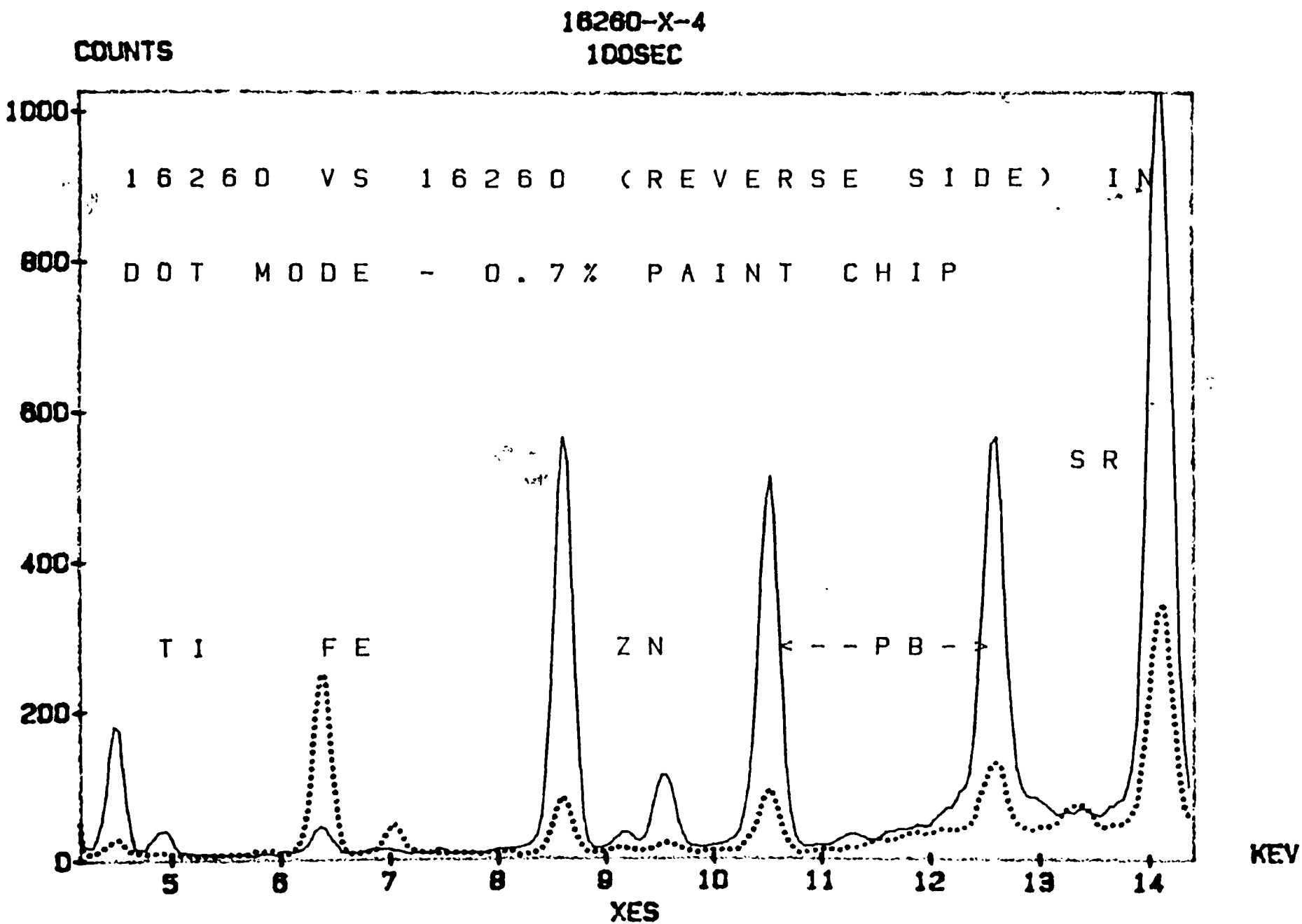
Warrington	
ID Code	Reading
tolpk	-0.1
lqrom	0.0
azbyc	0.0
notrl	0.2
dfdce	-0.2
hcdjr	0.0
npxtc	-0.3
andkm	0.2
baino	-0.4
dyzag	-0.2
fbcps	-0.3

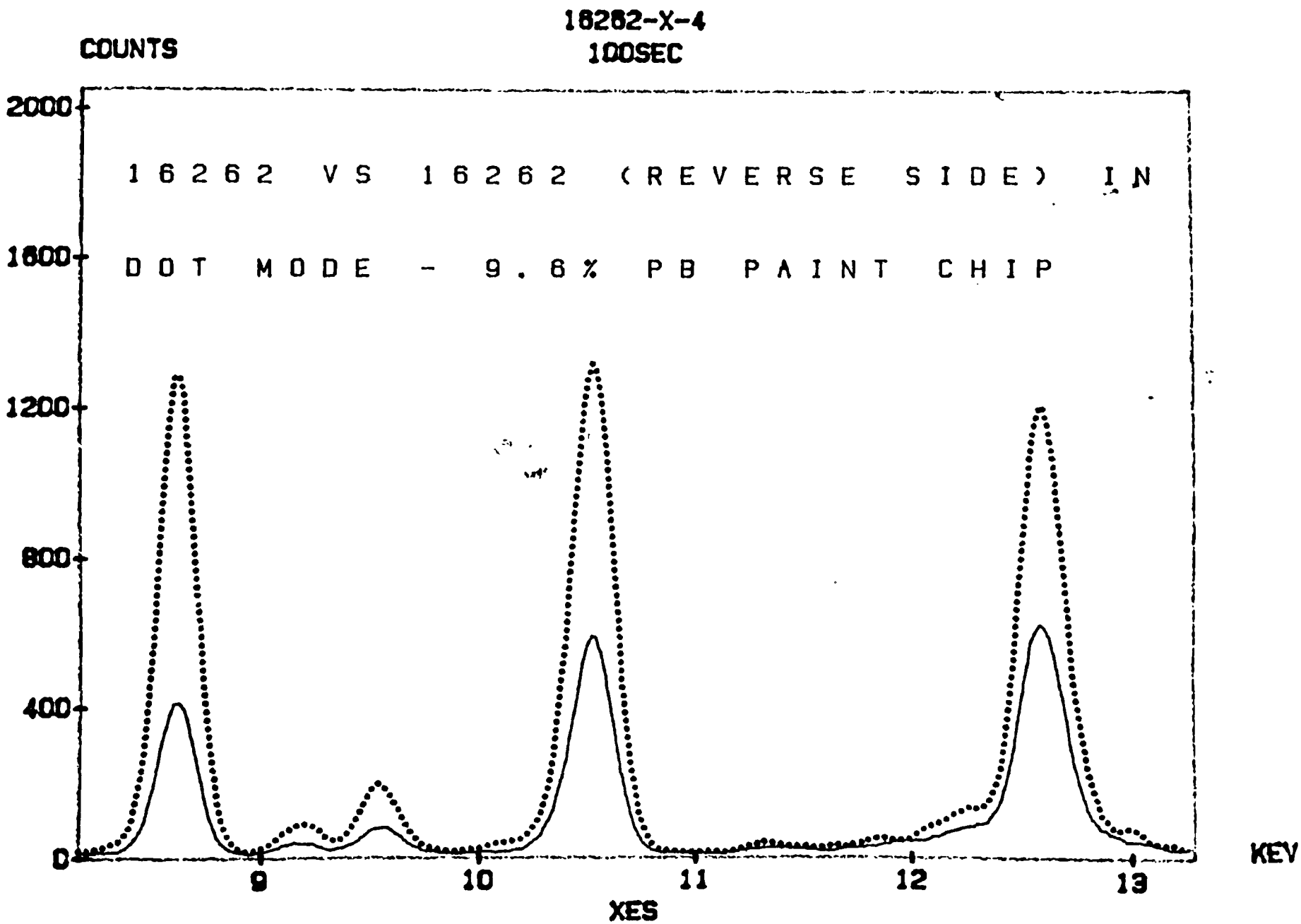
SciTec	
ID Code	Reading
lnqbv	0.12

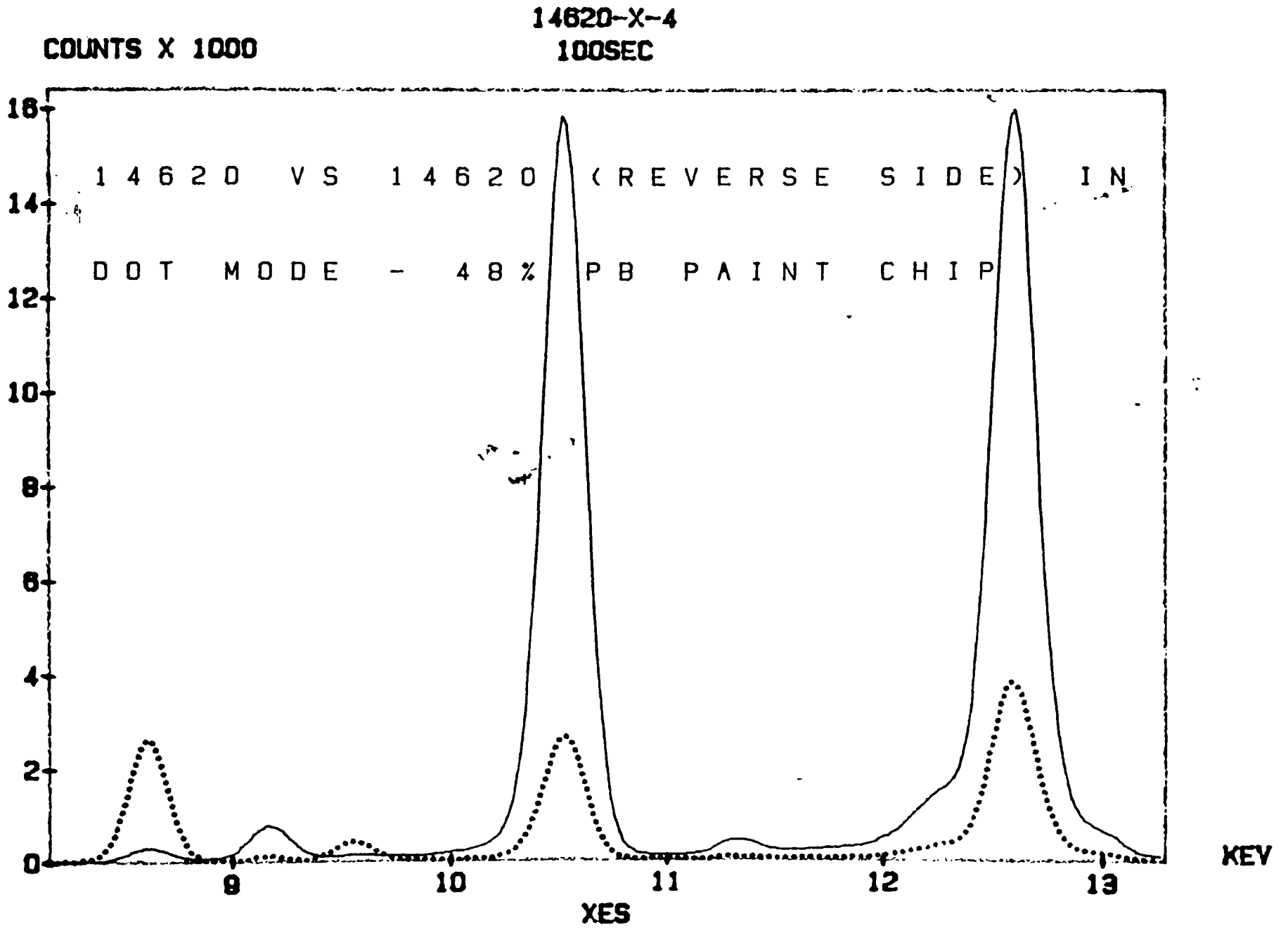
	PGT	Warrington	SciTec
mean	0.1	-0.1	0.12
standard deviation	0.32	0.2	----

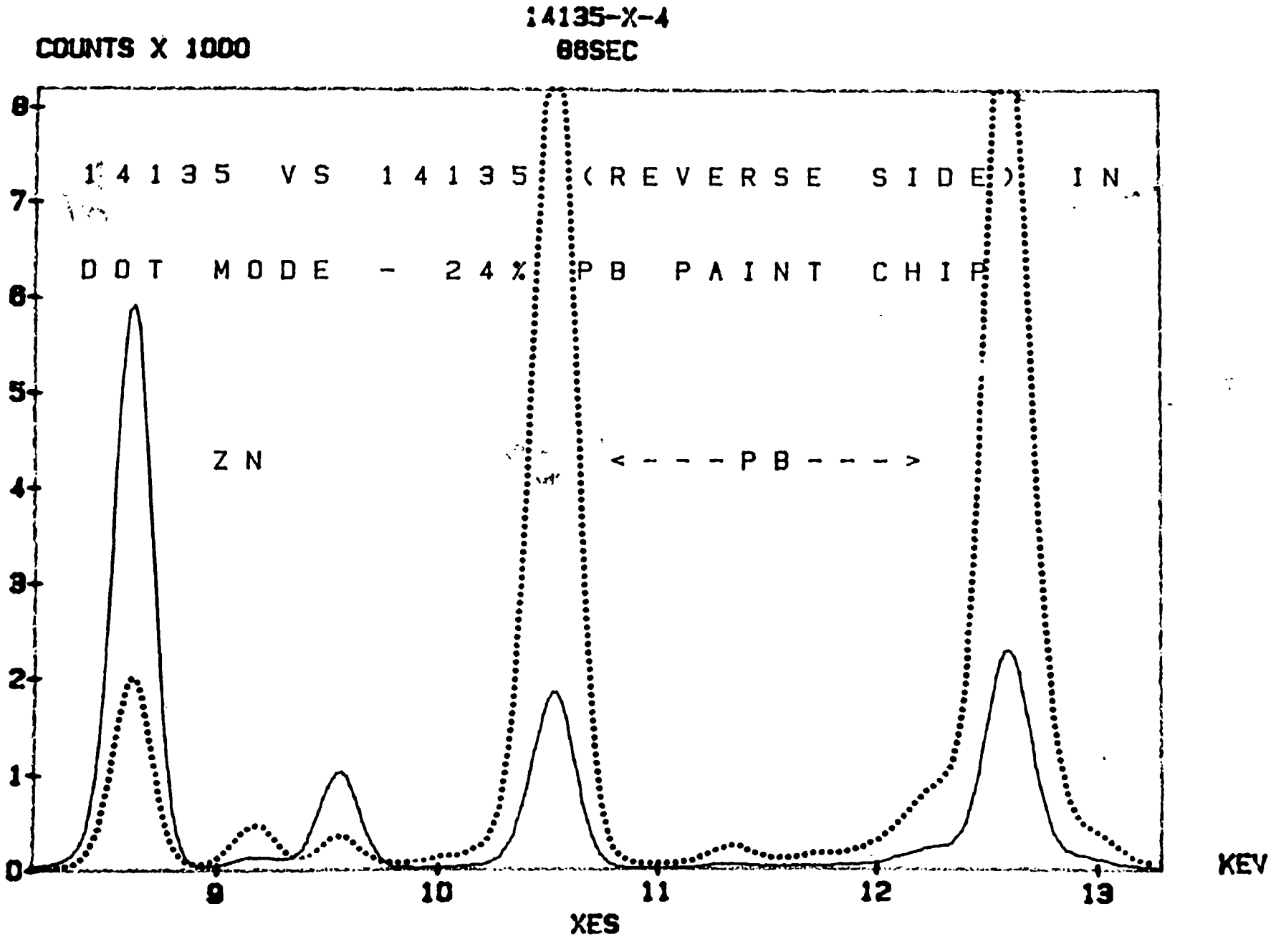
Data Presented by

Dr. Tom Spittler


16260-X-4
100SEC
COUNTS
1000
800
600
400
200
0
16260 VS 16260 (REVERSE SIDE) IN
DOT MODE - 0.7% PAINT CHIP
TI
FE
ZN
<--PB->
SR
5
6
7
8
9
10
11
12
13
14
XES
KEV

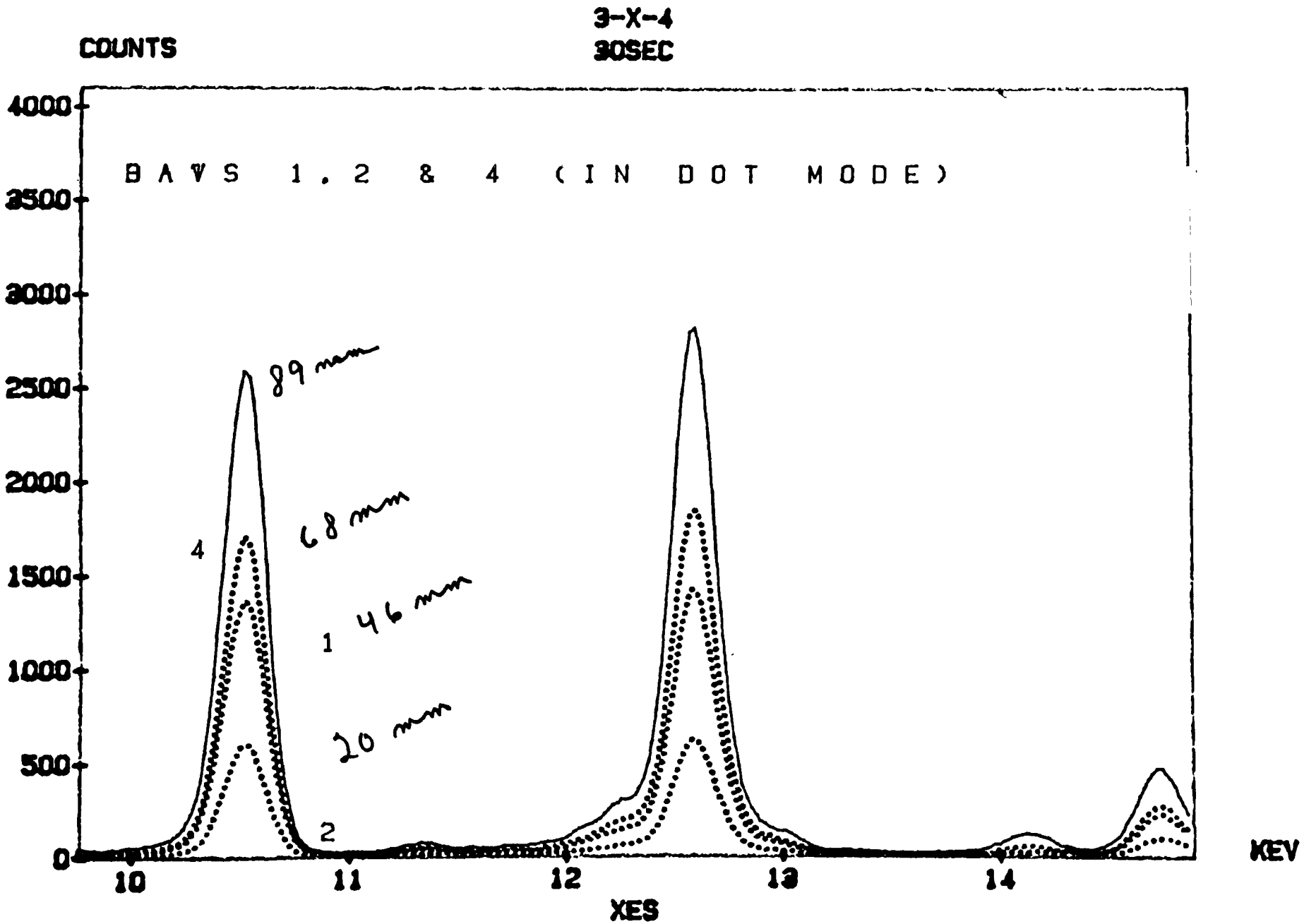

16262-X-4
100SEC
COUNTS
2000
1600
1200
800
400
0
16262 VS 16262 (REVERSE SIDE) IN
DOT MODE - 9.6% PB PAINT CHIP
9
10
11
12
13
XES
KEV

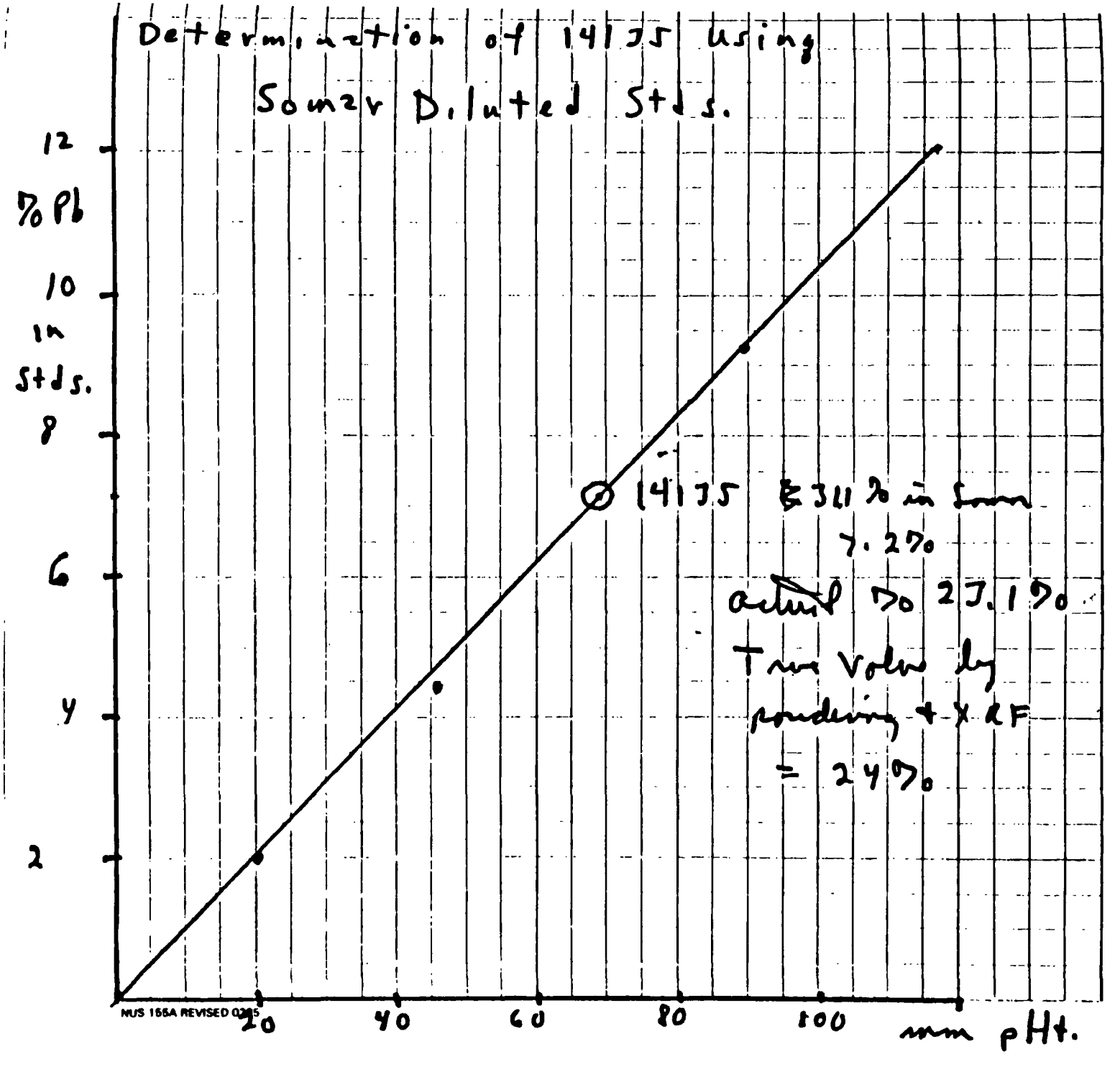

14620-X-4
100SEC
COUNTS X 1000
14620 VS 14620 (REVERSE SIDE) IN
DOT MODE - 48% PB PAINT CHIP
18
14
12
10
8
6
4
2
0
9
10
11
12
13
XES
KEV


14135-X-4
COUNTS X 1000
88SEC
14135 VS 14135 (REVERSE SIDE) IN
DOT MODE - 24% PB PAINT CHIP
ZN
<---PB--->
0
1
2
3
4
5
6
7
8
9
10
11
12
13
XES
KEV

DATA FOR SOMAR DILUTION TEST

SAMP. #	MG 1579	+ SOMAR MIX
1	78	210
2	36	215
3	169	216
	MG 14135	
4	65	209


3-X-4
30SEC
COUNTS
BAVS 1, 2 & 4 (IN DOT MODE)
4000
3500
3000
2500
2000
1500
1000
500
0
89 mm
68 mm
46 mm
20 mm
4
1
2
10
11
12
13
14
KEV
XES


Determination of 1415 using
Somzr Diluted Stds.
12
% Pb
10
in
Stds.
8
6
4
2
1415 Est 11% in Sample
7.2%
actual % 23.1%
True Value by
pouding + XRF
= 24%
20
40
60
80
100
mm pHt.
NUS 155A REVISED 0385

SAMP. #	PEAK H	WT. RATIO	% PB
NBS 1	46 MM	0.371	4.45
NBS 2	20 MM	0.167	2.00
NBS 3	89 MM	0.782	9.38
14153	68 MM	0.311	23.1

Data Presented by

Scitec Corporation

MAP Spectrum Analyzer
SCITEC CORPORATION

April 27, 1993

Warren Loseke
U.S. EPA
Atmospheric Research and Exposure
Assessment Laboratory
Research Triangle Park, NC 27711

Dear Mr. Loseke:

During the 12 years which the MAP technology has been in existence, we've found that the use of X-ray fluorescence for field measurements is often misunderstood, oversimplified, or even disregarded. We appreciate your efforts to bring government and state personnel and their contractors together to accurately identify and resolve the questions, concerns, and confusion which exists.

The purpose of the use of portable XRF is the identification of lead hazards quickly and economically, and in sufficient detail for cost effective abatement strategies to be implemented. Policy makers and government agencies seem to focus their attention on the performance of the XRF instrument as though the device alone is responsible for the valid identification of lead hazards.

However, a majority of the errors that occur in the identification of lead hazards are attributable to the *sampling design* used, the *operator*, the *customer*, and a lack of effective *quality control* practices--***not*** the sampling device. Attention must be given to determining how to control and minimize errors and bias from all sources; sampling designs; operators; instruments; laboratories; record keeping; report generation; and customers.

As the single largest customer for lead paint testing services, the Department of Housing and Urban Development has significant influence over how lead paint testing and reporting is accomplished. However, the objectives, goals, roles, and responsibilities in HUD's LBP testing program are inconsistent and not aligned properly with incentives and control measures. This accounts for most of the errors and data quality problems which result.

041993L.2

2000 Logston Blvd. Telephone: 1-800-4-NO-Lead FAX: 509-375-4931 Richland, WA 99352

The customer should know what to specify in requests for bids and proposals to do testing work, they need to know how to evaluate bids, how to oversee testing, and how to evaluate the test data. Unfortunately most PHA customers today do not have the knowledge or skills to handle these responsibilities. Without fundamental knowledge and skills, they lack the ability to effectively let and administrate contracts. This deficiency is a major reason for the poor quality of test data that is received by HUD.

Few HUD lead paint testing contracts even deal with the issue of "quality," or even specify that the contractor is to provide accurate and verifiable test data! Many PHA's assume they are tasked only with turning in test data to HUD, they have no feeling of obligation to make sure the test data is good. Most PHA's believe they've done their job when they've awarded a contract to the low bidder...as though their only job is to get a test report at a low price.

The sampling design and protocol required by HUD will *not* generate highly accurate data nor result in identification of lead hazards 95% of the time. HUD's Guidelines for testing by XRF require only the minimum level of testing. The apparent objective of the Guidelines is to satisfy HUD's legislative directive to test...not necessarily to locate and determine the presence and extent of lead hazards.

The Guidelines fail to recognize the fact that lead paint is heterogeneous, instead they *assume* that paint is homogeneous and don't even require that such a critical assumption be checked or verified.

A trained inspector will test painted surfaces in a way that will reveal the presence of lead. Current HUD Guidelines reduce inspection requirements to the lowest possible standards and thereby restrict inspectors' ability to utilize their skills and knowledge.

A well trained operator will know how to use the XRF instrument to generate statistically valid data. The instruments are capable of generating valid test data if they are operating properly and used properly. The current HUD testing guidelines don't even require an inspector to *prove* that he/she conducted any testing, let alone prove that testing was accomplished with a properly working instrument!

The current testing protocols underutilize existing XRF technology and worker skills thereby causing total testing costs to be substantially higher than necessary. The full benefits of XRF instruments are ignored and expensive backup laboratory testing required much more frequently than is necessary. Alarmingly, this expensive backup testing is not controlled, checked, monitored, or regulated!

Effective testing protocols would standardize the way dwellings and structures are tested and test data reported so contractors are required to test in a similar manner, check instrument

performance regularly, and report test data in a consistent format. Most importantly, contractors should be required to *prove* that they checked instrument performance, tested surfaces, and followed protocols.

Housing authorities should be made responsible for the quality of test data, released from their obligation to award contracts to the low bidder, and trained in how to write bid specifications and administrate contracts.

Policy makers need to focus their attention on *all* of the issues related to lead paint testing: The objectives of testing need to be clearly stated and protocols developed to meet the objectives. Housing authorities need their role defined, responsibilities identified, and the training to carry them out so they can be held accountable.

Most of all, if HUD wants high quality test data they need to specify and require inspectors to provide and prove the quality of the data, AND, HUD must be willing to pay for it.

In response to your survey we submit the following:

PORTABLE XRF SPECTROMETER

Metals Analysis Probe ("MAP") Model 3B, used with the Ambient Scanner 310B for lead in paint and soil analysis.

MAP 3 - FA2C PS

Detection Limit

Detection limit is defined as the lowest quantity of total lead detectable in optimum conditions with a reasonable measurement time. Detection limits are quantified in terms of Pb K-line X-ray detection.

With XRF used for LBP analysis, the detection limit is a function of:

1. Measurement conditions
2. Measurement time
3. Confidence level desired
4. Source strength.

In LBP analysis the detection limit varies with the density of the substrate, the length of the measurement or number of repeated measurements, and the source strength.

Generally, as measurement conditions worsen (substrate density increases), the detection limit deteriorates, and, as measurement time increases or lengthens, the detection limit improves (gets lower in real terms).

Detection limits for soil vary as a function of measurement time, matrix structure, and the elements contained in the sample.

For lead based paint measurement, the following detection limits are stated in terms of K- and L-line precision levels at 1 standard deviation on various substrates or combinations of building materials.

DETECTION LIMITS - LEAD IN PAINT

The detection limits for lead in paint on low, medium, and high density substrates are stated in terms of precision at 15, 60, and 240 seconds with a 40 mCi Co^{57} radioisotope. Precision is stated as one standard deviation of a series of consecutive measurements.

Substrate (density)	K-Shell Detection Limits in mg/cm² at Preprogrammed Measurement Times		
	15 secs	60 secs	240 secs
Thin wood (low)	0.2	0.1	0.05
Wallboard (medium)	0.3	0.1	0.1
Concrete (high)	0.8	0.4	0.2

The above stated K-shell detection limits were derived from data recently and randomly collected from 46 different instruments with 25 repeated measurements each on plaster wallboard backed with 2x4 (nominal) wood, a hollow core door, and concrete block. The average scatter for stud backed wallboard for all 46 MAP instruments was 0.1938, with one standard deviation of 0.307 mg/cm².

Substrate (density)	L-Shell Detection Limits in mg/cm² at Preprogrammed Measurement Times		
	15 secs	60 secs	240 secs
Thin wood (low)	0.1	0.05	0.025
Wallboard (medium)	0.2	0.1	0.075
Concrete (high)	0.6	0.3	0.15

Q. Are there any plans to allow for direct user calibration or recalibration?

A. Scitec's policy does not allow for premature announcement of new products, features, or services. However, in general, our product strategy has not included user calibration or recalibration features for three important reasons:

1. Accurate field calibration requires highly skilled, trained, and experienced technicians, which are short in supply, difficult to get to do fieldwork, and relatively expensive. This type of person is usually not willing to do paint testing on a regular basis.

2. It is difficult to design parameters that would allow quality control of field calibrations. Allowing user calibration would allow users to set up instruments to produce biased measurements, e.g., "control" data output if desired.

Q. Are you aware of the new NIST paint film SRM's?

A. Yes. Scitec has purchased several sets of these new standards.

Q. Have they been of any value to you in calibration or testing your instruments?

A. No, not yet. Only a small percentage of the XRF instruments in use are calibrated with the new standards. Recalibration requires instrument downtime and expense. It will be some time before all instruments are returned from the field and recalibrated. Many contractors are not willing to purchase the NIST standards at the price NIST is asking nor pay for recalibration of their instruments.

Q. Briefly describe the procedure for use of your instrument.

A.
1. Turn it on
2. Enter current date
3. Enter calibration check ID code
4. Make calibration checks
5. Plot cal check results on graph
6. Verify instrument performance
   If OK,
7. Enter sample reference "ID" number
8. Make a "TEST" type measurement (@ 60 seconds)
9. When apparently homogeneous surfaces show patterns of either no lead or high lead, a shorter "SCREEN" type measurement is sometimes used to reduce labor time.

The results of the measurement(s), the length of the measurement(s), the sample ID number, and the raw spectral data are all stored in the system's on board memory, automatically. The operator cannot select or control which measurements are stored or manipulate the data during transfer to a computer.

Q. Approximate analysis time.

A. User selected. Actual measurement time varies as a function of the source size and the level of precision the operator chooses.

The instrument allows the operator to choose one of three levels of precision, which equate to measurement time, which with a 40 mCi source, are: 15, 60, 240 seconds (adjusted automatically by the instrument for source decay). The actual measurement time is a *combination* of "SCREEN" and "TEST" type readings. Contractors report an average of about 1 minute (includes source decay time) per sample point. This time includes screen and test mode measurements and source decay.

Q. Interferences

A. With K-shell X-rays no known interferences exist. With L-shell X-rays interferences can occur from zinc and copper.

Q. What substrate correction procedures are used?

A. The MAP LBP system comes with a general or "universal" substrate compensation intrinsic in the system's software. Substrate correction is achieved through measurement of the substrate effects during calibration. Proprietary algorithms installed in the instrument during manufacture correct for substrate effects before the measurement result is displayed by the instrument.

Q. Are there any new developments or guidelines for using substrate correction procedures?

A. Substrate characterization using NIST SRM's, dedicated calibrations, longer measurements. We do not recommend using bare substrate measurements unless the operator suspects there is lead in the substrate.

Q. Are there any built-in instrument checks to test for satisfactory operation?

A. Yes. During a 15 second warm up immediately after the instrument is turned on, the system conducts a "self test" to determine if all system components are operating within specification.

After any measurement the operator can view the actual spectrum of energies detected and measured during the analysis. Operators are trained how to evaluate the spectrum to determine if the instrument was functioning properly during the analysis.

Software used to download measurements verifies both measurement integrity and instrument performance. The software analyzes the spectrum to determine measurement validity (total counts, source strength, algorithm calculation, date, etc.). The software also evaluates the calibration check readings, calculates their average and standard

deviation and compares the daily data with the same performance criteria for the instrument when it was manufactured.

Measurements which do not meet valid criteria or which are taken with an instrument out of calibration are not transferred from the console but rather are shown as "invalid."

Q. Briefly describe safety procedures/considerations.

A. 100% positive visual and manual safety shutter with locking ON-OFF key. A "passive-OFF" or dead man OFF feature provides secondary shielding independent of the ON-OFF key. The operator controlled key provides positive off. Since any/all safety ultimately relies on the operator, emphasis is placed on operator training. Operators are required to use dosimetry monitoring and keep observers ten feet from the XRF device when in use.

Q. Are there any problems/limitations with the instrument at present?

A. *Problems*: Policy makers do not allow for proper or optimum use of the instrument.

Limitations:

1. Calibrations are based on the use of "representative" substrate standards which may not always represent every material encountered in the field.

2. Precision of measurements on curved, profiled, or contoured surfaces is variable and unknown.

3. Instrument should not be used in extreme heat (> 110°F).

Related Issues:

Some "influence centers" claim that a "limitation" of the instrument is that negative readings are "truncated to zero." Therefore, results "must be biased high."

This claim is indicative of the lack of understanding of the practical implications of field work, a lack of understanding of XRF technology, and a fundamental understanding of statistics.

First of all, it is impossible to have less than zero mg/cm^2 lead in a paint film, therefore, negative readings are confusing to most inspectors. In order for an XRF operator to fully understand a negative value they must be taught basic statistics. Few field workers have the time, money, or inclination to learn statistics.

When the detection limit of one reading from an instrument is larger than the "target or action level," negative numbers can occur, but are useful or meaningful only if an averaging process is used, that is, if a series of repeated readings are taken on the identical spot and averaged together (typical for direct readers but *not* for the *Spectrum Analyzer*).

However, if the detection limit of one reading is less than the action level, and multiple readings are not used, negative values are meaningless and add confusion to many. Since a negative value is confusing to most people, and the action level is well above the detection limit for the *Spectrum Analyzer*, we do not normally display a negative reading because there is no need to do so.

If the "action level" was at or near zero (0 mg/cm^2), or the precision of a group of measurements at or near zero was being determined, indication of negative results would be useful for the *Spectrum Analyzer*.

It is not a problem for us to display negative readings. We offer our customers the option of having the instrument display negative values.

Q. Are improvements to the current instruments envisioned?

A. Yes. Scitec's policy is to not release new development information prematurely. However, we can indicate that we spend a sizeable portion of our operating budget on research and development, all directed at improving instrument performance and reducing sources of bias--whether instrument or operator generated.

We recently introduced a new data download software program called "AcuTransfer©" which checks and verifies measurement integrity and instrument performance during the data download process.

We also offer "Advanced Report Manager©" (ARM©) software which produces complete HUD type reports and analysis.

These programs provide a complete field testing "system" that includes a number of *quality control* features.

1. Minimization of operator bias or influence. All measurement data are automatically recorded by the instrument. That is, the measurement time/precision, test location, component, paint conditions, substrate, and calibration checks are automatically recorded, analyzed, and reported by the system. The operator cannot bias test data by selecting which measurements to report.

2. Standardized testing and sample numbering protocols allow for fast and easy (accurate) QC oversight during the data transfer and evaluation process.

3. Elimination of field notetaking errors.

4. Elimination of typing, transposing, and analytical errors.

Q. When might an improved instrument be available?

A. We regularly upgrade and enhance our product and software. The version we currently offer is the second model and fifth overall version of the LBP system. All performance related changes are systematically made to older versions during source replacement or service. The current model is adequate for lead based paint testing, but current guidelines do not allow for optimum use of its capabilities.

Q. What do you view as the future needs of the public and/or lead testing organizations regarding portable XRF spectrometers?

A. 1. Training of housing authorities.

2. Clear, concise testing protocols/guidelines with logical objectives.

3. Uniform bidding information.

The major problem contractors have to deal with is the lack of knowledge the PHA has concerning lead testing. Bid requests and requests for proposals are incomplete and poorly written. This does not allow contractors to compete on an equal basis.

Since the Guidelines do not require contractors to provide proof of testing and compliance with protocols, contractors regularly cheat. Housing authorities are not trained or equipped to deal with these problems.

Q. What topics should be added to the workshop agenda?

A. We suggest emphasis be placed on:

1. Ways of eliminating sources of errors and bias from:

   a. Operator influence
   b. Bid requests, contract awards, contract administration
   c. Data handling, recording, reporting.

2. Optimizing the use of XRF for field testing. Current, and even the proposed Guidelines do not allow for or provide incentives for use of the full capabilities of XRF instruments. The Guidelines are written to accommodate the oldest form of technology rather than the most advanced form of technology. Therefore HUD receives poor quality data at very high total costs.

   Attention should be given to:

   a. Limited use of L-Shell XRF Analysis. This type of XRF analysis has been overlooked, or not even allowed. However, we believe there is a potential for the use of L-shell analysis *in conjunction* with K-shell analysis.

      L-line X-rays can be detected only if there is lead on the immediate surface coats of paint (i.e., the top 1 or 2 layers). Because of this many people think that L-shell analysis is not useful since most lead paint is on the bottom, or lowest layers, and therefore only K-line X-rays are useful. However, if lead is on the surface, 1) it is a more immediate potential hazard and 2) it can be measured more accurately.

      In some cases use of an L-shell reading can reduce the need for confirmatory sampling by AA.

      L-shell lead X-ray measurement provides lower detection limits and better precision than K-shell lead X-ray measurement. This is due to the higher yield achievable and the reduced effects from substrate conditions.

We do not propose that L-shell measurement be a substitute for K-shell measurement, but an allowable *alternative* in *some* cases...if there is greater than 1.10 mg/cm² of lead on the surface coat of paint the condition is positive!

In addition, L-shell analysis can be used to help determine whether detected lead is behind an outer substrate (e.g., a pipe, painted wall, flashing, etc.), or in the substrate.

b. Use of short and/or long XRF readings. The current and proposed Guidelines limit the usefulness of XRF by limiting the number of, or length of readings allowed and fixing a single inconclusive range where chip sampling/lab analysis are required. This policy unnecessarily increases the total testing costs incurred by HUD.

With the *Spectrum Analyzer*, a longer, or "CONFIRM" type reading will provide a measurement with twice the precision of the "TEST" measurement which is specified by HUD. Use of a "CONFIRM" type measurement only when the apparent lead concentration is at or near the action level would reduce the amount of lab sampling by 50%.

On the other hand, allowing inspectors to use shorter "SCREEN" type measurements when lead concentrations are at or near zero, or very high (above 1.5 mg/cm²) will reduce field testing costs by 60%.

3. Operator, EPA, HUD Training. The current XRF operator training provided during EPA courses by the universities is not focused on the most important field issues--how to generate statistically valid test results. The training is often provided by scholastic types who have little or no field experience, or by selected contractors whose technical experience is limited, and sometimes biased. Training often includes special interest sub-agendas as the EPA has no policy regarding trainers having conflicts of interest.

We've found that public housing authorities and contract administrators lack a fundamental understanding of XRF, sampling, and/or statistics.

Public housing authorities, for the most part, do not fully understand what it is they are tasked to do, so their requests for proposals and/or requests for bids are poorly worded, structured, and contain inadequate information for contractors to respond to in a meaningful way. Many contractors do not respond to bid invitations simply because of the lack of information.

Most often bids are awarded to the "low bidder," without regard to the technical skills of the bidding firm or the total testing costs. By awarding contracts in this way, public housing authorities and government agencies are providing contractors with the means to rip them off. Many bids allow, even require conflict of interests to take place!

Most contract administrators do not know how to evaluate, inspect or interpret lead testing reports once they get them. Contractors can turn in just about anything, call it a test report, swear to its authenticity (with several disclaimers thrown in throughout the report) and get paid!

Standardized bid requests, evaluation methods and testing contracts are needed. Fundamental training in how to administrate and supervise testing work is needed, and standardized test report and data handling methods will reduce the burden on housing agencies and improve the quality of the test data.

Most of all, testing contractors should provide **proof** that statistically valid random testing was conducted, and conducted with an instrument which was working properly.

4. Laboratory confirmation. HUD's Guidelines require laboratory confirmation of all "inconclusive" and "positive" XRF test results in spite of an absence of any study or data about the accuracy and quality of the chip sampling/lab analysis method of sampling.

   Our informal surveys and evaluation of test data from contractors and labs indicates that the chip sampling/lab analysis method tends to produce results with a low bias, thus providing "false negatives" on inconclusive XRF tests.

   This method is expensive and very time consuming, and does not necessarily provide suitable back-up or "confirmatory" defensible data.

   The main issue here is not the ability of laboratory instruments and technicians to accurately measure lead in paint films (although there is concern about this from one lab to another), but the ability of the contractor to remove a good, *representative* sample.

   We recommend:

   a. A study of the accuracy and cost of the chip sampling/lab analysis method be conducted.

   b. Quality control methods need to be developed for the chip sampling/lab analysis procedure.

   c. Alternative methods of dealing with preliminary "inconclusive" XRF tests be investigated, and/or allowed.

We hope our response is helpful to you and will further your efforts to develop effective evaluations of XRF instruments and guidelines for their use. We urge you to involve instrument manufacturers in all processes; we're a source of expertise and experience! Everyone has their biases, or preferences and prejudices, so you should at least hear and take all input. Scitec is willing to participate openly in any and all discussions. We're looking forward to working with you.

Sincerely,

Larry T. Lynott
President

encl: 14AD

cc: Jim Baugh
Darren Small

Data Presented by

TN Technologies, Inc.

Portable XRF Spectrometer

Name or Model # of spectrometer *Spectrace 9000 (Pb Analyzer)*

Applications *Several applications are provided for; with the primary one being an optimized configuration for the in-situ measurement of Pb in paint film via its "K" and "L" x-ray excitation. This is a mass per unit area analysis which reports the values of both the PbL and PbK results on the same screen. Other unit area analyses provided include an application for dust wipes and filtered (air/water) particulates. An application for the determination of Pb by mass concentration (in ppm. %, or other units) in bulk materials such as soil, dust, water, etc. is also contained. The analyses are not limited to Pb; elements such as Hg, As, and many other metal pollutants can be quantified in the same measurement. This response relates only to the Pb-paint application.*

Detection Limit *For a single 60 sec measurement the approximate MDLs are as follows; ≈ 0.002mgPb/cm^2 for the PbL analysis on any substrate, and in the range 0.04 to 0.12 mgPb/cm^2 for the PbK analysis for substrates ranging from thin wood to thick concrete. It will be ≈ 0.06 on gypsum-over-wood. On thick steel the PbK MDL will be ≈ 0.2mgPb/cm^2.*

How is the detection limit determined? *It is equated to THREE TIMES the standard deviation (3σ) in the results of a measurement (expressed in calibrated concentration units) performed on a blank, or low metal content paint film in contact with a defined substrate. σ-values may be derived from the results of repetitive measurement (negative values can be displayed or printed) or obtained directly from the analysis report. The latter reports the σ-value of each result according to the conditions of the measurement (i.e. time, signal strength, source decay etc) and taking into account the accumulative statistical errors of all aspects of the data processing including the spectrum strip and the substrate correction mathematics.*

Sensitivity *In terms of the net (less substrate) counts/sec/mgPb/cm^2, the sensitivity for PbL analysis is ≈ 300, and that for the PbK is ≈ 5. In units of "per millicurie of exciting source radiation" the respective numbers would be 60 and 5. A Cd-109 source with the emission equivalent of 5mCi x-rays and 1mCi gamma is used in the instrument.*

How is the sensitivity determined? *By measurement on a series of known mgPb paint films and calculation of the initial slope of the source-decay-corrected (SDC) countrate/mgPb response. The NIST 2759 Pb standards present a suitable range. SDC countrate values can be viewed on the instrument screen.*

Accuracy *For a single 60 sec the accuracy of a PbK determination will be* $\approx \pm 0.125 mgPb/cm^2$ *at a loading of* $0.5 mgPb/cm^2$ *and* $\approx \pm 0.16 mgPb/cm^2$ *at a loading of* $1.0 mbPb/cm^2$*. The influence of paint thickness on the PbL measurement makes it difficult to assess the accuracy of that analysis.*

How is the accuracy determined? *From the magnitude of the difference between the x-ray results and the "mass/area" chemical analyses of a representative range of samples on a variety of substrates comprising wood, plaster and concrete. The expected accuracies (listed) are based on the 2-standard deviation criteria and include no allowance for knowledge of the substrate. In reality the accuracy is slightly better on a wood substrate and that can be evaluated on an individual results basis since the statistical uncertainties are always reported with each measurement. For example an accuracy of* $\sim 0.1 mgPb$ *could be expected on wood.*

Briefly describe the calibration procedure. *The primary calibration performed at the factory entails measurement of several pure elements, various bare substrates and at least one NIST 2759 standard reference sample. A secondary calibration using an equivalent of the substrate material and a Pb reference sample can be performed in the field. All calibration constants are retained in a non-volatile on-board memory. They are also importable from a floppy disk.*

Are there any plans to allow for direct user calibration or recalibration? *As indicated there is provision for user recalibration.*

Are you aware of the new NIST paint film SRMs? *Yes.*

Have they been of any value to you in calibrating or testing your instruments? *Yes. They are used in the primary calibration and will be an essential part of the calibration maintenance.*

Briefly describe the procedure for use of your instrument. *Operation is menu driven so all steps are shown on the screen. Measurement can begin ~5min after turn-on. It is push-button initiated and program controlled so that the source shutter will automatically close at the end of a short period of measurement. The probe (of ~4 lbwt) must be held steady but there is no need to maintain any pressure against the surface. The result's display of both PbK and PbL, together with their error level is self-explanatory. A menu choice will automatically store the results, as well as the spectrum if desired. Prior to beginning a series of measurements the operator will perform a check for ~100sec. If an error condition is detected the screen will direct the operator to perform an adjustment. Several automatic checks, such as the spectrum calibration, are also performed during measurement and the operator is alerted to any problem. The need for battery renewal will be indicated with enough warning to protect stored results.*

Approximate analysis time *The time (in real clock seconds) is user selectable from 1 sec up. Recommended time is ~15 secs for an initial check. This should provide for a reliable (95% confidence) x-ray based assessment at the 1mgPb level on all results except for those in an "uncertain" zone of 0.75 to 1.25 mgPb. Results within that zone will require additional time.*

Interferences *The main interference on the analysis is that of the substrate scattered radiation in the spectral window of the Pb x-rays. Other element fluorescent x-rays are excluded by the high resolution of the x-ray detector.*

What substrate correction procedures are used? *The spectrum overlap from the substrate is relatively small, due to the choice of source and good detector resolution. It must still be corrected for however and this is accomplished by a special stripping algorithm that is applied to each spectrum as it is acquired in the measurement. The coefficients of the stripping algorithm are maintainable by the operator using a set of substrate-equivalent standards.*

Are there any new developments or guidelines for using substrate correction procedures? Describe. *None are known at this time however*

there is always room for improvement in this area. The ability to store the entire, high resolution spectrum for further evaluation should prove useful in this direction.

Are there any built-in instrument checks to test for satisfactory operation? Describe. *Yes as described earlier. The spectrum is continuously checked for gain calibration and the operator has a CHECK procedure to conduct periodically. Other continuous checks are made on the signal quality and any malfunction will be indicated on the screen.*

Briefly describe safety procedures/considerations. *The main concern must always be over the chance of accidental exposure to the source. On the 9000 the source gamma ray emission is only 1/35 of that used in other spectrum analyzers and is also of lower gamma ray energy. Adequate shielding is built-in for the source closed position.*

Are there any problems/limitations with the instrument at present? *The probe face may be considered wide (~3") for some situations.*

Are improvements to the current instruments envisioned? *Yes. For example more efficient larger detectors could become available to allow even lower activity source usage or shorter measurement times. A smaller footprint, lighter probe may also be possible in the near future.*

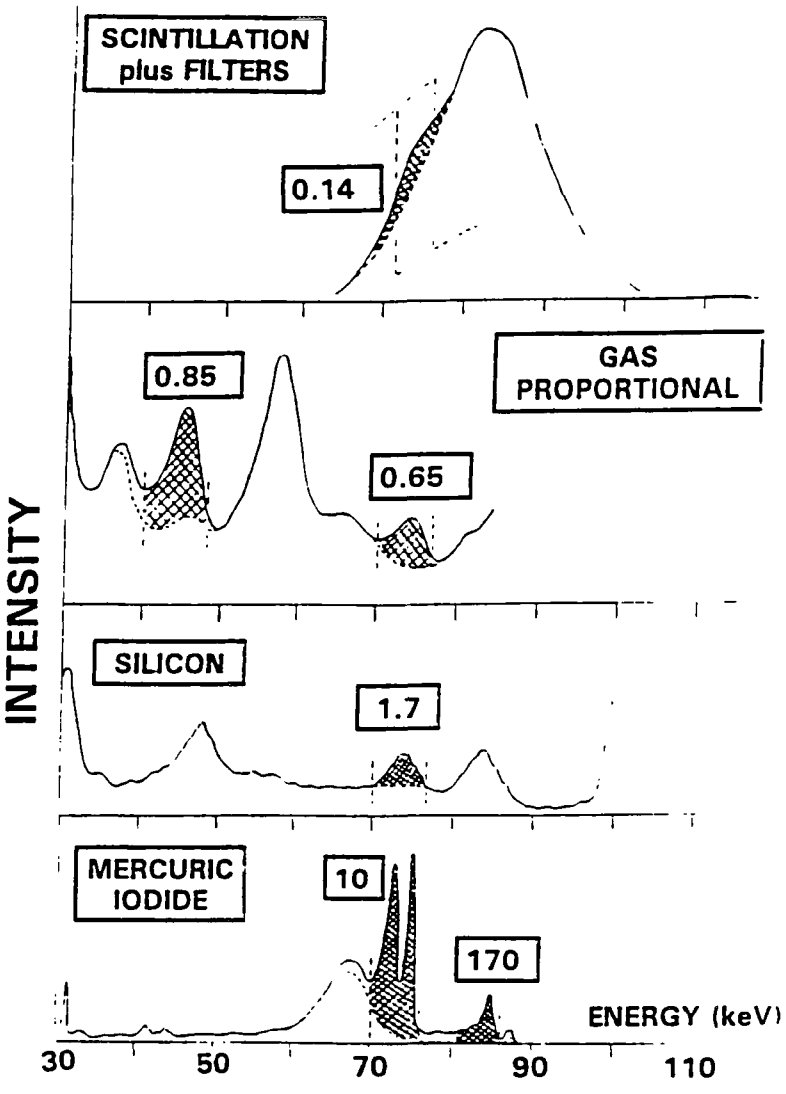
When might an improved instrument be available? *Some improvements could be achieved within a 12 month time frame.*

What improvements will be implemented? *Possibly a lighter, smaller footprint measurement probe*

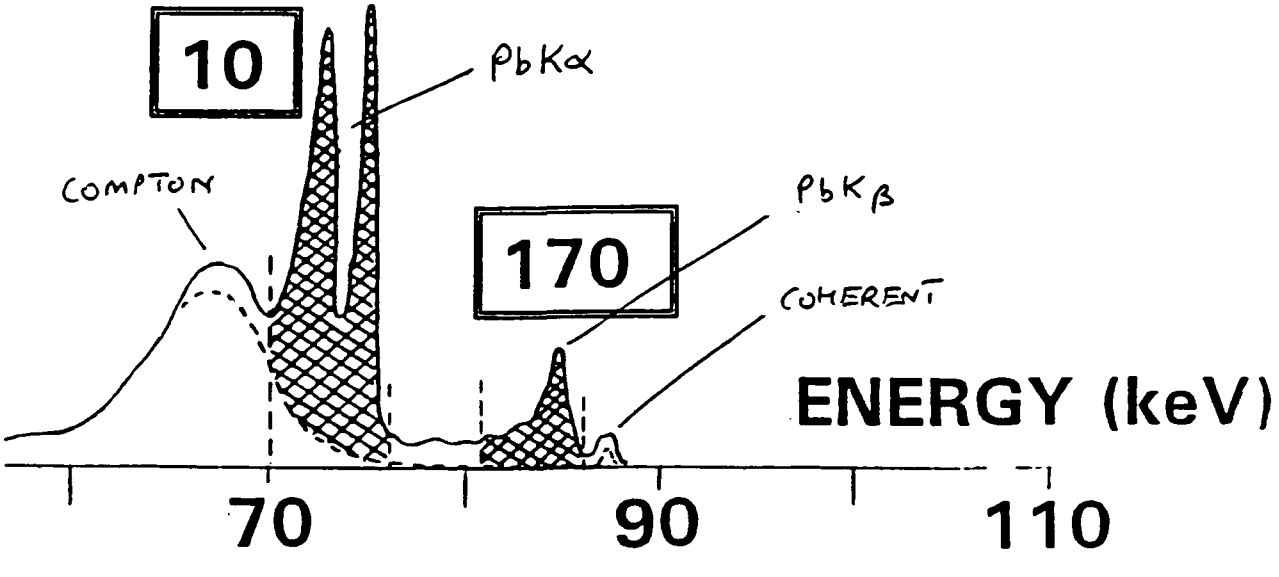
What do you view as the future needs of the public and/or lead testing organizations regarding portable XRF spectrometers? *Better procedures for sampling in regard to XRF instrument verification of the mass/unit analysis and a resolution of the %wt versus mgPb dilemma in the current code.*

What topics should be added to the XRF workshop agenda? *Other analytical techniques. Standardization progress reports of other committees. Opinions on the "%" vs "mg" dilemma.*

Please provide any standard operation procedures, instrumentations or other literature you believe would be informative. *Copies of the standard instrument manual were provided. The attached pictorial comparison of current PbK analysis based instruments shows a wide range of values of the "net signal to background" parameter as a result of the source choice and the system spectral resolution. A high signal to background reduces the effect of the background variation, i.e. the substrate problem, and allows one to expect accuracies that are limited only by the statistical factors imposed by the analysis time.*



Comparison of "NET-to-BACKGROUND" Ratio at 15mgPb/cm^2 on Wood for Various Detectors



Data Presented by

Princeton Gamma-Tech

Portable XRF Spectrometer

Name or Model # of spectrometer PGT Model XK-3

Please reproduce this form if other models are available.

Applications Painted surfaces

(Paint, Soil, Dust, etc.)

Detection Limit 0.5 mg Pb/cm^2 How is the detection limit determined? It is taken as the single-reading standard deviation of a series of readings.

Sensitivity 0.5 mg Pb/cm^2 How is the sensitivity determined? It is taken as the single-reading standard deviation of a series of readings.

Accuracy _____ How is the accuracy determined? Accuracy is determined by comparing instrument readings with U.S. Dept. of HUD lead standards of 0.60, 1.53 and 2.99 mg/cm^2 - traceable to NBS standards. NOTE: Precision can be increased by averaging a number of readings.

Briefly describe the calibration procedure A series of 10 readings are taken on 0 and 1.53 mg/cm^2 HUD standards. Internal adjustments are then made to bring the unit into calibration and the procedure repeated until both readings are within +/- 0.1 mg/cm^2.

Are there any plans to allow for direct user calibration or recalibration? No.

Are you aware of the new NIST paint film SRMs? Yes

Have they been of any value to you in calibrating or testing your instruments?

No. We were lucky enough to have old HUD standards.

Briefly describe the procedure for use of your instrument After checking calibration and stabilization (warmup), the face of the XK-3 is placed against the surface to be tested and the handle pushed in to the stop. The handle is held infirmly until a reading appears on the display, signaled by an audible beep. The reading remains displayed until a new measurement is initiated. We attach an Operator's Manual for your further information.

Approximate analysis time About 12 seconds for a fresh source.

Interferences Only backscattered gamma rays.

What substrate correction procedures are used? Manual substrate corrections are made, in accordance with the recommendations of the HUD guidelines.

Are their any new developments or guidelines for using substrate correction procedures? Describe. No.

Are there any built-in instrument checks to test for satisfactory operation? Describe.

Only the calibration check block provided with the instrument.

Briefly describe safety procedures/considerations The XK-3 is unique. Its radiation source shutter cannot be opened unless the face of the XK-3 is against a solid surface. This prevents anyone from being exposed by the gamma-ray beam, which is possible with other available instruments. Specific safety practices are covered in detail in our User School, attendance at which is strongly recommended for anyone using the instrume

Are there any problems/limitations with the instrument at present?

See cover letter.

Are improvements to the current instruments envisioned?

See cover letter.

When might an improved instrument be available?

See cover letter.

What improvements will be implemented?

See cover letter.

What do you view as the future needs of the public and/or lead testing organizations regarding portable XRF spectrometers?

See cover letter.

What topics should be added to the XRF workshop agenda?

See cover letter.

Please provide any standard operating procedures, instrumentations or other literature you believe would be informative. _____

See attached manual.