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# A PROPOSED UNIFIED NATIONAL CALIBRATION AND LABORATORY INTERCOMPARISON SYSTEM FOR RADON/RADON DECAY PRODUCT MEASUREMENT INSTRUMENTATION

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## ABSTRACT

Currently, no formal, written, consensus calibration standards exist for radon/radon decay product measurement instrumentation. Furthermore, the majority of radon measurement firms or laboratories depend heavily on the EPA's Radon Measurement Proficiency (RMP) Program for establishing the "accuracy" of their radon measurements. Traceability of radon measurements to National Standard radiation sources and/or instruments, in many cases, exists only through the RMP program. Establishing a de facto National Standard for radon was not the intended purpose of the RMP Program. There are both 1.) no written, consensus, calibration standards for radon/radon decay product instrumentation, and 2.) few radiation standard sources and/or instruments in use by the radon industry. This is an unacceptable situation from a technical and legal point of view.

This paper examines the shortcomings of the current system and outlines a proposed, organized system of instrument calibration standards and laboratory intercomparisons. This proposed system utilizes written, consensus, calibration standards and radiation standard sources and/or instruments traceable to standards maintained by the National Institute of Standards and Technology. Comparisons of this proposed system are made to other national calibration and laboratory intercomparison programs in the field of radiation protection.

## INTRODUCTION

The measurement of $^{222}$Rn or its short-lived decay products[1] has rarely been a priority for mainstream radiation protection or health physics. In fact, radon is more commonly an interference to the measurement of other airborne alpha and beta-emitting radionuclides. It is very common practice to count filters used to monitor airborne alpha emitters once after the sample is collected, and then, if any activity is detected, to allow the filter to decay 24 — 72 hrs. before recounting. This allows the short-lived radon progeny to decay away, leaving only the long-lived radionuclides of interest on the filter. This was not always the case, however. Prior to the Manhattan Project, the only radionuclides readily

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[1] In this paper, the generic term radon will be used to refer to $^{222}$Rn together with its short-lived decay products.

available to medicine and industry were the members of the naturally occurring Uranium or Thorium Series. Since these nuclides constituted a major health risk to workers, etc., counting techniques for qualitatively and quantitatively analyzing these nuclides were well developed.

The widespread use of more readily available and cheaper man-made radionuclides following World War II, along with the previously mentioned health risks associated with radium (not to mention a chronic problem with leaking sources), led to the demise of these naturally occurring radionuclides. Much of the research and development effort for radiation detection instrumentation as well as the accompanying standards (both radioactive standards and written standards) since World War II have been primarily aimed at the detection and measurement of the man-made radionuclides.

The relatively recent concern over indoor radon has led to a reawakening of the need for accurate, low-cost techniques for the measurement of these radionuclides in air. Unfortunately, we now find ourselves in a situation where the technology and standards (in the broad sense, as above) for the detection and measurement of man-made radionuclides has developed to a point well ahead of the techniques used by the fledgling indoor radon industry.

## DISCUSSION

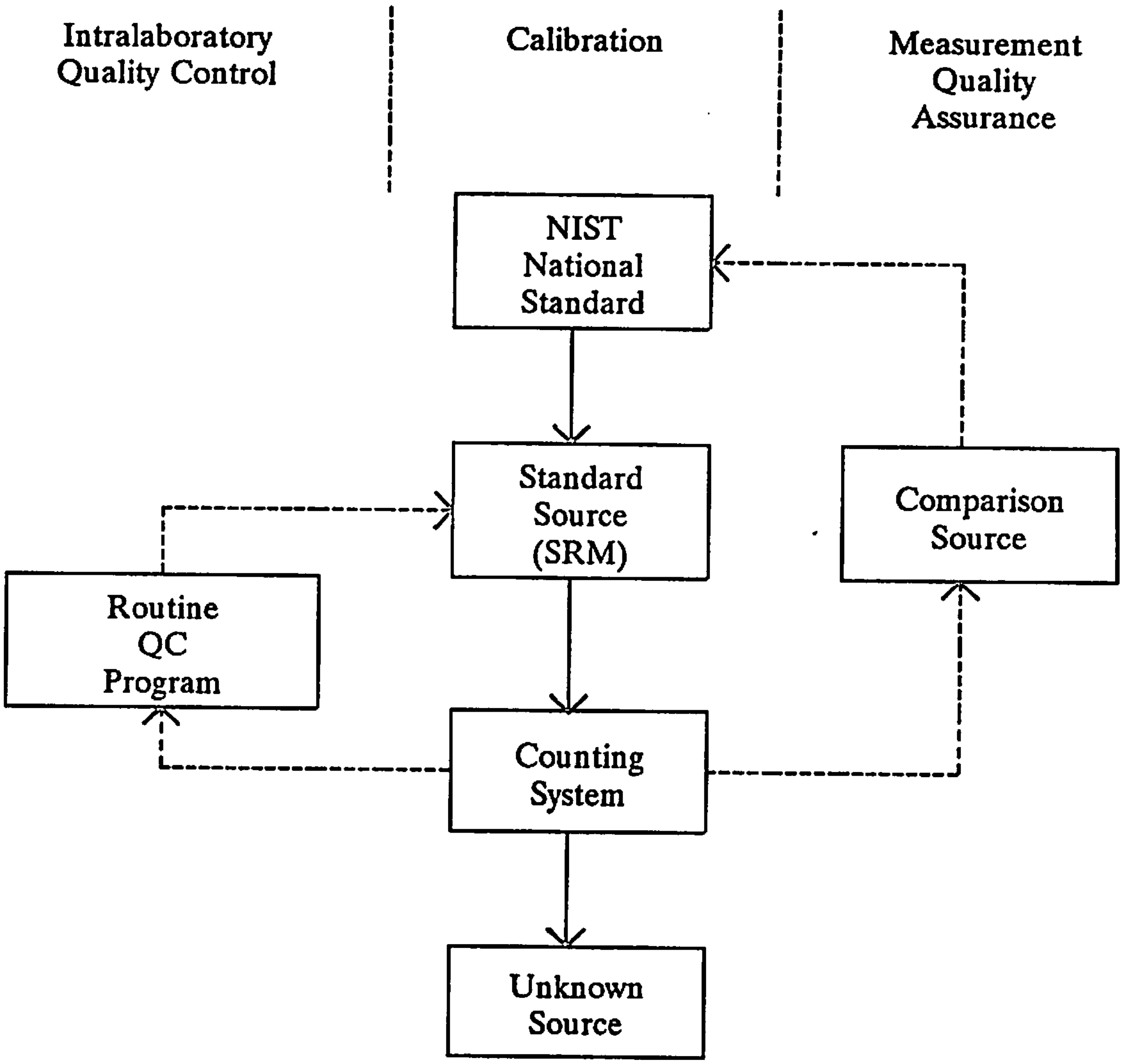
### The Problem

$^{222}$Rn and its short-lived decay products are among the more difficult radionuclides to detect and measure accurately. First, $^{222}$Rn gas is an alpha emitting noble (inert) gas with a relatively short half-life of 3.82 days. Second, the radioactive progeny of $^{222}$Rn are also mainly alpha emitters (although two beta-gamma emitters, $^{214}$Pb and $^{214}$Bi, are present in the chain) and additionally, have extremely short half-lifes (on the order of a fraction of a second to tens of minutes). This means that unique techniques for measurement must be used, and that radon radioactivity standards are difficult to prepare. Historically, the measurement of alpha emitting radionuclides in air, was one of the more difficult challenges to health physicists during the Manhattan Project [Hacker 1987].

An example of this situation is the standard techniques for sampling man-made radionuclides in air. Normally, particulate beta-gamma emitters are sampled by drawing air through a filter paper. The radioactivity on the filter paper can then be measured by a relatively simple Geiger-Müller counting system or gamma counted on one of several types of gamma counters widely used. For noble gases, the situation is somewhat different. In this case a sample is usually collected in a gas-tight container (usually glass) and the gamma radiation is detected and counted through the glass wall of the sampler (luckily, pure beta emitting noble gases are rare).

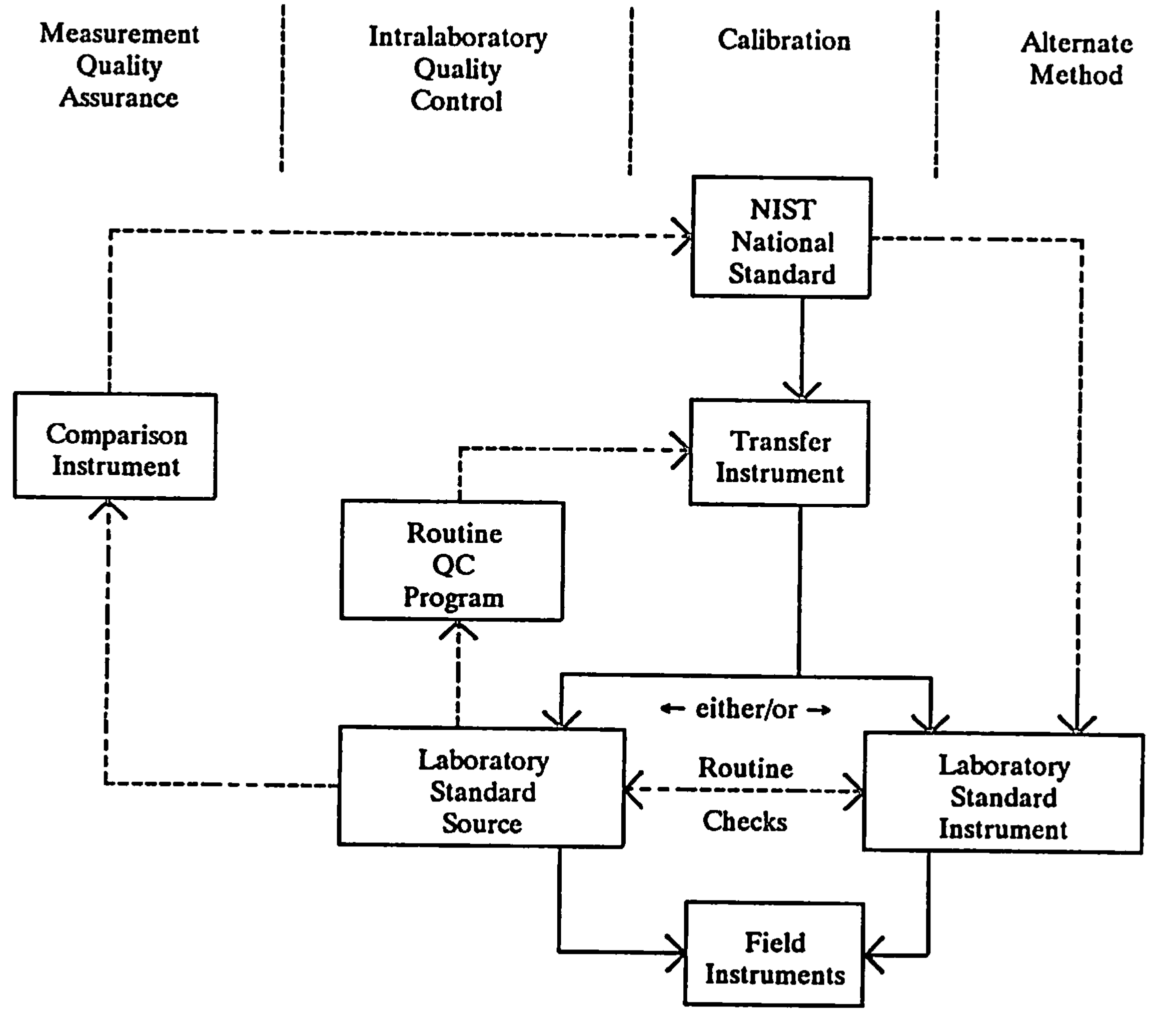
The calibration of such counting systems can best be described by the following example (see Figure 1). If one wished to measure $^{137}$Cs, a particulate radionuclide with a 30 year half-life, the obvious solution is to purchase a source of $^{137}$Cs for which the activity has been accurately determined and certified to be traceable (e.g., relatable) to radioactive sources maintained as National Standards. You would count this known source of $^{137}$Cs on your system and then count the unknown source. The activity of the unknown source would be proportional to that of the standard source.

Figure 1: Laboratory Calibration System Using SRM



A second technique can also be used (see Figure 2). Since this second technique is often used for calibration instruments in terms of dose rates, a different example is used. In this example assume that you were interested in measuring the dose rate from a large $^{137}$Cs source (rather than its activity). Then, you would have an accurate, highly reproducible instrument calibrated to the dose rates from a source of $^{137}$Cs which itself was directly traceable to National Standards, or have the instrument calibrated directly at the National Standards level. Then you would use this instrument (which is now what we call a Transfer Instrument or Transfer Standard) to calibrate your own $^{137}Cs$ source (which would then be a Laboratory Standard). Then field instruments would be calibrated using this Laboratory Standard. This is practical, in part, since the 30 year half life of $^{137}Cs$ makes it a very stable standard.

Figure 2: Laboratory Calibration System Using Transfer Instrument



In general, the uncertainty of the final measurements increase as the number of steps from the National Standard increase. However, by using very accurate and precise instruments as Transfer Standards, this uncertainty can be kept well below the inherent uncertainty of the field instrument under calibration. Again it should be emphasized that this technique is practical for radionuclides such as $^{137}$Cs because their relatively long half-life results in a stable output of radiation.

The above procedures were not developed extemporaneously for the purposes of this discussion, but are well documented techniques which have been incorporated into written standards developed by scientific groups. For example, the groups which prepared the basic standards for radiation protection instrumentation test and calibration [ANSI 1978b, ANSI 1989a, ANSI 1989b, ANSI 1989c] are committees of the American National Standards Institute (ANSI). These committees are composed of members from the ranks of the equipment manufacturers, trade organizations and/or several professional groups similar to AARST, other standards organizations, federal regulatory agencies, end user groups and even interested individuals.

In parallel with this work on written standards, the National Institute for Standards and Technology (NIST) has developed radiation standards (either radioactive sources or Transfer Instruments) for the accurate and highly precise relating of field instrumentation to National Standards maintained by NIST laboratories. In fact, NIST has maintained a National Standard for $^{222}$Rn gas for over 50 years [Colle 1990]. However, the techniques used for maintaining the National Standard were somewhat difficult to implement and transfer to end users. Few laboratories have the equipment or expertise to perform proper intercomparisons with NIST. Due to the recent upsurge in interest in radon, NIST has recently rebuilt the system of pulsed ion chambers maintained as the National Standard, and is developing techniques to allow laboratories to more readily intercompare with the National Standard. As part of this renewed interest, NIST performed an intercomparison between five laboratories in the U.S. who maintain radon chambers for calibration and intercomparison purposes. An unacceptably high systematic measurement discrepancy of over 7% was found. Efforts have been undertaken to reduce these discrepancies. Further laboratory and international intercomparisons were scheduled for 1990, however, results have not yet been published. Another effort undertaken by NIST is to prepare Standard Reference Material (SRM — radioactive sources directly traceable to the National Standard), using newer technologies, which would allow SRM to be utilized by a wider ranges of less sophisticated laboratories. These sources could be used in NaI well counters or liquid scintillation counters without the sophisticated gas handling equipment required for the currently available SRM sources.

One point deserves further discussion. As shown above, even if sound written standards exist together with very accurate radioactive sources or Transfer Instruments, it is possible that an individual laboratory could introduce a bias to their measurements, which defeats this complicated set of standards. Only if the example laboratory and other laboratories performing similar analyses intercompare measurements on a routine basis can this problem be controlled. This Measurement Quality Assurance is an essential part of the overall calibration system. Routine intercomparisons in other areas of radiation measurements are run in conjunction with the U.S. Environmental Protection Agency (EPA) and other organizations, including NIST. As will be pointed out later in this paper, this is how the EPA Radon Measurement Proficiency (RMP) Program came into being.

## Further Confusion

Another unfortunate circumstance concerning radon is that prior to our current concerns, most radon measurements were made for health and safety monitoring in mines, mainly uranium mines. This activity is regulated by a completely separate group of regulatory agencies than those that regulate either the man-made radionuclides or the radon measurement and mitigation industry. In fact, the lead Federal agency for regulating radon in mines in the U.S. Bureau of Mines[2]. Prior to World War II, radium was widely used in industrial and medical applications. Techniques for the measurement of radium and its decay products were well established at the time. However, as stated above, since radium rapidly fell into disfavor following World War II, the technology for the detection and measurement of radium and its progeny (e.g., radon) stagnated for decades. Only the necessity of monitoring radon in mines kept the technology of radon measurement alive until the current time. However, since the primary goal in the mainstream of radiation protection was the detection and measurement of man-made radionuclides, the naturally occurring radionuclides were only considered briefly, if at all, in the development of most of the written standards and radiation standards.

## Current Situation

The current attention being given to indoor radon has created some interesting situations. First, many of the techniques currently used for measuring radon are unique to this field. Second, since many of the older techniques are derived from those used in uranium mining, thus, they have evolved largely along separate paths from mainstream radiation protection. Finally, much of the current radon industry arose ad hoc. Only relatively few members of this industry have close ties to classical radiation protection. Added to this is the fact that the indoor radon industry is relatively young and evolving, and one can see why we find ourselves in the current situation; which is:

> We have many devices and techniques for measuring radon which are unique to the field.
>
> Much of the radon instrumentation manufacturing business was not derived from the mainstream radiation protection instrumentation business but from mining health and safety instrumentation businesses.

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[2] It is often asked why the U.S. Nuclear Regulatory Agency (NRC) does not regulate radium or other naturally occurring radioactive materials. As it happens, this was largely due to the efforts of the American Medical Association. When the Atomic Energy Act was being drafted following World War II, the most common radionuclide in use in medicine was radium. The use of radium was already regulated at the state level. Therefore, the AMA lobbied congress not to double-up on the regulation of radium, and congress complied with the AMA's wishes. Of course now, one cannot find a radium source in any major hospital — they are all using NRC regulated man-made radionuclides!

Much of the radon measurement and mitigation industry was not derived from the classical radiation protection fields but from a variety of backgrounds and technical fields.

There is no Federal regulatory agency regulating the indoor radon industry (the EPA provides guidance). The various states that regulate Naturally Occurring Radioactive Material (NORM) have differing regulations for radium and radon.

Professional organizations, such as AARST, associated with the radon industry are relatively young and immature.

Consensus standards written specifically for the calibration of radon detection and measurement equipment do not exist. Additionally, the traceability of many of the radon measurements performed to National Standards is weak, at best.

## The EPA RMP Program

The RMP program was initially established in 1986 as an intercomparison program for the limited number of laboratories actively engaged in measuring indoor radon at that time. As the commercial sector of the radon industry developed, the RPM Program first attempted to absorb these new firms into the existing small program. This lead to a crisis situation in 1989, when over 1,700 firms enrolled in the RMP Program. It was obvious that the existing program could not handle this volume. At this point, the initial objectives of the RMP Program had become obscured. A major effort was undertaken by the EPA in 1989 - 1990 to reevaluate and redefine the RMP Program with the result which we now see before us.

A major point needs to be made in defense of the EPA. The RMP Program is a proficiency and laboratory intercomparison program. It was not designed or ever intended to be a calibration program. However, many firms intentionally or unintentionally use the RMP Program as a calibration program. Even some suggested changes to the draft AARST Real Estate Guidelines [AARST 1991b], which were not adopted, have alluded to the use of the RMP Program as a substitute for the proper calibration of radon instruments.

Finally, the current EPA RMP Program is a financial hardship to many small radon companies. Although the program has been free up to this time, the EPA has been mandated by congress to recover the expenses of the program. The EPA had proposed a fee schedule for the RMP program which was objected to by the industry. Although the cost recovery is currently on hold, this situation is probably only temporary. Just proposing cost recovery for the RMP Program contributed to a 36% decrease in enrollment and a decrease of 72% in previously listed participants. Of course, it is not only the proposed fees for the RMP Program that has caused this decline. Another factor, aside from the fee recovery proposal, causing a decline in the RMP Program enrollment is the sheer cost of participating from a travel and expenses perspective. A typical small company in New Jersey or Pennsylvania, participating with a "walk-in" technique must take one technician and one or more instruments out of service for several days, pay for travel and expenses to and from Montgomery, AL or Las Vegas, NV, and not know for several weeks if they have passed or failed the round. Assuming that a company offers a full spectrum of testing techniques, this expense amounts to at least $2,000. Add in the proposed fees for three or four different techniques, and this totals 5 or 6 thousand dollars! This would probably exceed the annual profits from radon testing for many of the small companies involved in radon testing.

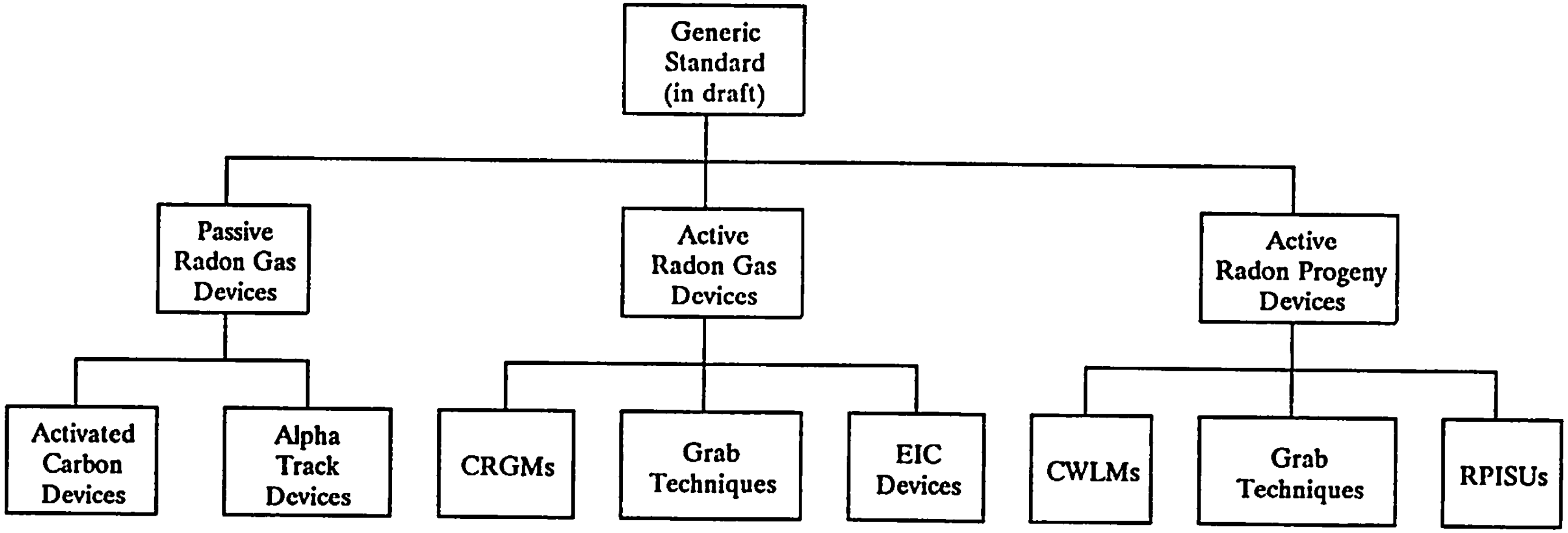
## RECOMMENDATIONS

### 1. Establish Consensus Standards

There is a major need for consensus standards for the calibration and Quality Assurance (QA) requirements for radon measurement systems. Although ANSI standards for calibration and quality assurance of radiation monitoring instruments generally are helpful, more specific standards are needed to take into account the peculiarities of radon and radon decay product active and passive measurement systems. A starting place is the proposed, *AARST Standard: Radon/Radon Decay Product Test and Calibration* [AARST 1991a]. Although very limited in nature, this standard would make a logical starting place for a series of written standards. A suggested framework of standards is enclosed as Figure 3. It should be noted that this structure suggests a multi-tiered approach. For example, the proposed AARST standard would provide basic guidance to all concerned with the design of instruments and their calibration. As such, it is necessarily generic to include all the various types of instruments. Additional future standards would establish more specific requirements for different sub-groups of instruments. For example, the next series of procedures could divide active and passive techniques (which would have somewhat different specific requirements) or radon gas and radon decay products or a combination of both. The most specific level of standards would cover specific groups of radon or radon decay product instruments; such as Continuous Working Level Monitors, Activated Carbon Canisters (gamma analysis), or Alpha-Track Detectors.

Peripheral standards are also required, including: standards for calibration of laboratory counting systems, Measurement and Test Equipment (M&TE), preparation of QA plans, routine QC requirements, record keeping requirements, etc. Standards in several of these areas already exist [ANSI 1978a, ANSI 1980a, ANSI 1980b, ANSI 1986, ANSI 1985, ANSI 1966], but it must be determined if they are directly applicable to radon measurements or require some modifications (e.g., a standard exists for the calibration of M&TE, but it is applicable to Nuclear Power Plants — is it applicable to radon?). Finally, standards would also be needed to establish the laboratory intercomparison program (this could be done along the lines of the National Voluntary Laboratory Accreditation Program for radiation dosimeters).

Figure 3: Consensus Calibration Standards



dosimetry systems. Intercomparisons have been performed on an irregular basis. For example, the Department of Energy's Environmental Measurements Laboratory (EML) conducted an intercomparison of 13 laboratories in 1981 [Fisenne 1983] as well as the NIST sponsored intercomparison of five laboratories circa 1988, previously cited. A routinely scheduled (e.g., annual or biennial) program would ensure that all the secondary laboratories and laboratories performing intercomparison exposures for end users maintain as high a level of quality as possible. This program would most likely be operated by a joint effort of NIST, DOE, EPA and the Bureau of Mines. This oversight group would provide the written standards, perform audits and round robin tests necessary to maintain the quality of the program.

5. **How would this whole system work?**

A radon testing company could decide to either use a vendor to perform routine calibrations of their instrumentation or, with the proper equipment, (Transfer Instruments and SRM or Laboratory Standards), perform the calibrations in-house. Either the company or the vendor would need a radon chamber. However, using Transfer Instruments it would be possible to use natural sources for this. Of course, rigid adherence to procedures, an effective QA program and routine QC procedures are essential for this phase of the program.

All equipment involved in this method, would then be entered into a routine laboratory intercomparison program. This would include field and Transfer Instruments. This program would be conducted annually or by-annually at a regional center. A random selection of each type of instrument would be exposed to known concentrations of radon. The results of the instruments under test and the values measured with "standard" instruments would be compared using valid statistical methods.

NIST would provide the main standards for this program using Transfer Instruments or SRM calibrated against the National Standards. The EPA, DOE and other agencies could assist with or provide the main means of intercomparing the regional facilities, and maintaining overall QA supervision of the entire system.

## CONCLUSION

The current state of the veracity of radon and radon decay product measurements leaves a lot to be desired. The accuracy of radon or radon decay product measurements have yet to be questioned in a court of law. However, when this happens, the weakness of the current system of calibrations and Quality Assurance could intensify to crisis proportions. An excellent model exists in radiation protection technology for the establishment of a well documented calibration and Quality Assurance program based on National Standards and pedigreed traceability to those standards. Rather than try to develop a completely separate program for radon and radon decay product instrument calibration, I advocate developing a model closely based on the existing radiation protection standards, etc. Of course, the existing radiation protection standards can not be used as is, but could be used as a draft for developing radon standards. This comparability would give great import to properly performed radon measurements. The quality of these measurements would then be based on well established standards, with top rate Quality Assurance to assure their veracity, even in a court of law.

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