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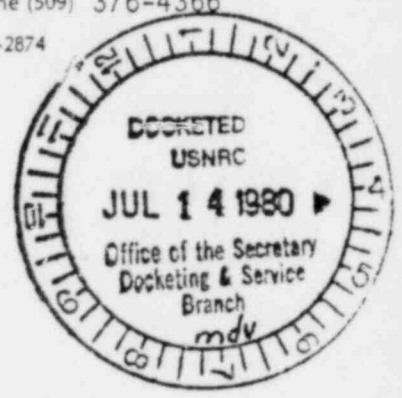

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTN: Docketing and Service Branch

SUBJECT: CERTIFICATION OF DOSIMETRY PROCESSORS

The following comments are presented in response to an advanced notice of rulemaking on the certification of personnel dosimetry processors (Federal Register 45(62), 20493, Friday, March 28, 1980). In addition, responses are given to several questions contained in a letter dated April 28, 1980 to me from Nancy Dennis, Occupational Health Standards Branch, Office of Standards Development, U. S. Nuclear Regulatory Commission. Those questions concern the use of specific technical data in a program certifying dosimetry processors.

I support the concept of certification of dosimetry processors. An activity to indicate competent dosimetry programs is needed. Performance criteria derived from the draft standard of the Health Physics Society Standards Committee/American National Standards Institute will in general provide sufficient guidance for certification. However there are several facets of this standard which restrict its influence on the determination of individual doses. This is important because the degree of uncertainty in the determination of individual doses conditionally indicated by the results of the University of Michigan study is stimulating the development of the certification program.

Use of the proposed testing standard to effect an acceptable confidence in individual dose assignments assumes complete reliance on the personnel dosimeter for the dose determination. While this assumption may be frequently valid, important situations occur when the assumption is incorrect. Moreover, these special situations tend to predominate when individual doses become most important or serious such as accident doses, doses approaching or exceeding regulatory limits and doses which considerably deviate from anticipated trends or expectations. Often dose determinations in these situations are based on a variety of information in addition to the data from the personnel dosimeter. This other information can include field measurements of the radiation environment, dose readings from pencil-type pocket dosimeters and electronic dosemeters, mock-up experiments, presence of biological effects and other data stemming from

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health physics investigations. Situations involving lost dosimeters, contaminated dosimeters, damaged dosimeters and faulty dosimeter readouts place little, if any, reliance on the personnel dosimeter. Certification only relating to the personnel dosimeter will exert a minimum influence on those dose determinations resulting from professional review and knowledge. As indicated, these types of dose determinations can be associated with relatively high doses which very likely may afford the best information on the incidence of biological effects for many epidemiological studies. Therefore the proposed certification program may not assure an acceptable uncertainty in the dose determination for some important situations. I cannot offer an adequate solution under the current plan of a testing standard but requiring complete reliance on a personnel dosimeter would be inappropriate.

Another important factor is the extent to which the results of performance tests will represent actual field conditions. The tolerance limit used to determine satisfactory performance in the proposed revised ANSI/HPSSC standard is based on a bias error and the standard deviation. Concentrating on the technical bases of dosimetry, a bias error in general can be related to the calibration of the dosimeter, and the magnitude of the standard deviation of a group of dosimeters is strongly influenced by the dose delivered to the dosimeters. The lower the dose, the greater the standard deviation because with low doses, one approaches the minimum detection level of the dosimeter and precision becomes poor. The tolerance limit reflects not only uncertainty in the dose determination but also the extent to which the tests represent routine field conditions. Therefore, differences between the testing lab and the field may cause test results not to be representative of the field conditions. A situation will occur where a dosimeter processor may demonstrate a satisfactory uncertainty in dose determination in a test but may experience an unsatisfactory uncertainty in actual field conditions. The converse may also occur because of differences between the field and the lab, not error in the dose determination.

In my opinion two elements of the standard may not adequately represent, in some situations, the routine radiation environment encountered by radiation users. The first concern deals with distribution of doses delivered to test dosimeters, the second deals with the calibration sources. The first concern has not been given much attention but it has important impact on many processors and licensees or radiation users.

The criteria presented in the revised ANSI/HPSSC standard may be insufficient to assure that the uncertainty in the determination of low doses is satisfactory. The dose range from which test irradiation levels are randomly selected is too large. This results in a dose distribution for test irradiations that is different from the dose distributions occurring in the field. The following example illustrates the impact of this difference.

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Consider a set of dosimeters that are usually exposed to 100 mrem or less of photon radiation in actual field use. Also assume that an identical set of dosimeters are tested according to the revised standard which specifies doses randomly chosen from a range of 30 mrem to 10 rem with 1/2 receiving doses less than 500 mrem and 1/2 more than 500 mrem. The tested dosimeters will most likely be irradiated to doses much larger than 100 mrem due to chance from random selection, particularly as 1/2 will receive a dose greater than 500 mrem. As indicated in the preceding paragraph, the standard deviation of the test dosimeters will be smaller than the standard deviation of the dosimeters used in the field. This small deviation aids the dosimeter processor in passing the test. The larger standard deviation experienced in actual use may result in an exceedingly large tolerance value and the processor would not meet the performance criteria. This change in the standard deviation as a function of dose was discussed at the public meeting held by the NRC on May 28 and 29, 1980. More constraint is needed on the random selection of doses than currently proposed. Processors predominantly experiencing low doses should be tested such that 80% of the test dosimeters are exposed to random doses less than 300 mrem. The remaining dosimeters would receive random doses between 300 mrem and 10 rem. This forces the test irradiations to better coincide with the actual field doses. Radiation users who would be subject to the constraints on dose level selection would be those not needing certification in either accident dose test category of the revised standard or those with most routine exposures being less than 300 mrem in a dosimeter exchange period, i.e., 1 month or 1 quarter of a year. Radiation users who experience a wide range of routine or expected exposures or who need certification in either accident test category would receive services from a processor who would be tested as currently suggested in the revised standard. The impetus of this suggestion is to have the distribution of doses of the test irradiations more closely correspond to the distribution of doses that occur in field conditions.

As indicated earlier, the tolerance limit for successful performance is dependent on a bias error. This error is influenced by calibration differences between the testing laboratory and a dosimeter processor. When such differences occur, the bias error may not represent incorrect calibrations or irradiations. In this case, the performance of a processor will not be entirely due to uncertainty in the dose determination. A by-product of performance testing will be a more uniform approach to dosimeter calibrations; however, this by-product should not constrain the selection of calibration sources by dosimeter processors. The implementation of a performance testing standard will influence many processors to calibrate using sources corresponding to those used in the test. A processor using identical sources as the testing laboratory will have an advantage in passing the test because there will be little differences in calibration to influence the bias error. However, the sources used by the testing laboratory will not be adequate for all processors. A dosimeter processor must calibrate using sources that best simulate the radiation environment in which the dosimeter will be exposed. The sources recommended by the testing standard appear suitable for a processor serving radiation users who collectively experience a variety of radiation conditions. Examples would be a large commercial processor or a research

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complex such as a large university or laboratory who perform their own dosimetry. The smaller processor serving a selective group of users experiencing a small variety of radiation conditions can select calibration sources that are specific for the field radiation environment. As an example, a uranium fuel fabrication plant doing in-house processing should preferentially calibrate with a Uranium beta source rather than the Strontium-90/Yttrium-90 beta source used in the testing laboratory. Using the Uranium beta source may jeopardize the plant's success in passing the beta dosimetry certification test.

Dosimeter processors must be allowed to calibrate dosimeters for routine use with sources which best suit the field conditions. The success of a processor in the certification tests should not be jeopardized if the processor used calibration sources which differ from the sources specified in the testing standard.

An often expressed criticism of allowing different calibration sources for routine calibrations is the potential for a processor to develop a parallel set of calibrations. One set would be used for routine personnel dosimetry while the other would be used only for performance testing. In this situation there is no direct means for equating the quality of dosimetry performed in a test with the quality of dosimetry performed routinely in the field. I do not believe this is a problem compared to using inappropriate calibration sources for routine dosimetry. However, caution must be taken to prevent the indiscriminant use of special calibration sources and factors for use only in a testing program. I feel each processor using types of calibration sources that differ from those used in the performance tests must notify the testing laboratory of the differences prior to the first testing period. The testing laboratory would determine if under correct use of the source differences would prohibit the processor from passing the test. If so, the testing laboratory would recommend that a processor develop a special set of calibration data that are applicable for the test sources. The special calibration data would be acceptable for use in the testing program but would not be required for use in the routine dosimetry program.

The involvement of the testing laboratory in recommending the use of special calibration data removes the potential for indiscriminant use of parallel dosimetry systems by processors. The option to use a parallel system would only apply to dosimeter calibrations. A processor would be required to use the same dosimeter handling, readout and reporting systems for the performance tests as for the routine dosimetry program.

The proposed testing standard would benefit with more detailed specifications on source design than currently given. This is most important for neutron and beta sources where the shape and construction of the source can influence the amount and energy of scattered radiation. Without detail specifications on sources, calibration differences between the testing lab and processor can develop even when both are using the same type of source.

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An extremely important element of the HPSSC/ANSI draft standard is a table of factors which relate exposure to the dose equivalents occurring at 0.007 cm and 1 cm depth in tissue. These factors are often called C_X factors and apply only for photon irradiations. A major influence of the draft standard will be the values of the C_X factors used by processors. A large bias error will be introduced when a processor calibrates a dosimeter using values of C_X which differ from those used by the testing laboratory. This bias error could cause a test to be failed. In addition, processors will incorporate these factors into routine dosimeter calibrations because the factors are critical for proper calibrations and their use is an important improvement in personnel dosimetry. As a result, the C_X factors will directly and strongly affect the magnitude and accuracy of doses determined with personnel dosimeters. The values of C_X adopted for the testing program may be the most influential element of a testing standard. It is essential that the values of C_X be based on the best available information. It is also important that the C_X factors incorporated into a testing program be accompanied by a statement discussing the basis for the values selected for use.

Until recently, very little research has been directed to deriving C_X values for health physics purposes. Related factors such as tissue-air ratios and percentage depth doses have been developed for therapeutic radiology activities but these activities are not directly applicable for health physics. The following paragraphs discuss the basis for C_X factors and provide justification for adopting in a performance testing program C_X values developed at the Pacific Northwest Laboratory, PNL. PNL is operated for the U. S. Department of Energy by the Battelle Memorial Institute. I feel qualified to present this information because of my involvement in the development of the PNL data and from related studies conducted over the past year and a half.

The C_X factor relates a measurement of a photon radiation field to a dose equivalent (dose) occurring in a phantom of tissue equivalent material located in the radiation field. Because the dose equivalent in the phantom varies as a function of depth in a phantom, deep and shallow C_X factors are used to determine the dose at 1 cm and 0.007 cm depths in the phantom. The basis for these depths is found in ICRU 25 (1976).

The radiation field measurement can be made either free in-air or in the phantom. The free in-air method is most appropriate for health physics. This is due to the low photon energies often encountered in radiation protection and the depths of doses of interest to health physicists. In ICRU 23 (1973), free in-air measurements are recommended for determining the dose in a phantom from photons with energies less than 150 keV. In addition, in-phantom measurements at the 0.007 cm depth for any photon energy are difficult and require special instruments and methods which are not suitable for routine use. With relationship to the draft HPSSC/ANSI standard, in-phantom measurements would be preferred only for the deep dose from ^{137}Cs or ^{60}Co irradiations. There is sufficient information

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that in-air measurements can be easily used to alternatively determine deep doses from those two radionuclides. Finally, in-air measurements are relatively easy to perform. I recommend that the performance testing standard adopted by the NRC not propose in-phantom calibration measurements nor introduce C_X factors for in-phantom measurements, particularly for low energy photon test categories.

Several variables strongly influence the value of C_X factors. These are:

- effective energy and energy spectrum of the primary radiation beam,
- depth in tissue,
- relative dose contribution from the primary and scattered radiation,
- values of basic dosimetry data such as composition of tissue, photon interaction data, stopping powers of electrons and the average energy to produce an ion pair.

Differences in the variables will cause different C_X values to be derived. As part of justifying the PNL data, comparisons will be made with other sets of data. These comparisons are meant to reflect how the variables listed above can be differently used or emphasized. The comparisons are not meant to discredit any particular research effort.

Two approaches, experimental and calculational, can be used to develop C_X values. In either approach the objective is to combine the variables to create a desired radiation condition in tissue. For health physics, the radiation condition must relate to the actual radiation environments encountered by people. The C_X values must be directly applicable for dose determinations and performance testing. In addition, they must be practical to use to avoid introducing added assumptions and approximations which will increase the uncertainty in dose determinations.

The revised version of the draft testing standard lists at least 12 different radiation beams that can be used for the low energy photon tests. Seven of these are NBS filtered x-ray techniques while the rest are K-fluorescence x-rays. All were selected for use in the tests relative to their being representative of actual field conditions encountered in health physics. The photon energies for which C_X values are presented in both the draft and revised standard do not correspond with the energies of the x-rays to be used in the performance tests. The C_X values presented in the draft standard correspond to monoenergetic photons at arbitrarily selected energies from 15 keV to 3 MeV. Except for one energy, 100 keV, the generic energies do not directly correspond to any of the x-ray energies to be used in a test. The values are more

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suited to theoretical applications rather than an applied application such as a performance test. Processors and the testing laboratory will have to calculate from the C_X values in the standard, an effective C_X for each x-ray technique to be used. These calculations will require interpolations of the standard's C_X data and spectroscopy of x-ray beams so that the C_X values can be properly weighted. This situation presents a great opportunity for error in the spectroscopy and the calculations. Requiring processors to develop effective C_X values will not significantly improve the quality of personnel dosimetry. The testing standard should present C_X values specific for the test categories. This specific information was experimentally measured in the PNL study. Such measurements eliminate the need to calculate an effective C_X value from a generic table of data. In this sense the PNL data appear much more suitable than the data presently contained in the standard. The PNL report presents C_X values for ten of the NBS filtered techniques and for seven K-fluorescence x-ray energies. The K-fluorescence x-rays were developed for health physics purposes (Kathren et al. 1971). The generic C_X values currently proposed in the draft standard should be presented in an Appendix so that C_X values for special radiation beams can be derived and used until a direct measurement can be made.

Three sets of C_X values have been associated with the development of a dosimetry certification program. One set was developed for the first draft of the HPSSC/ANSI standard; one set was adopted in a revised draft of the standard; one set was derived to confirm the data in the initial draft. Comparing the three sets of C_X values and justifying one set for use is difficult because the amount and detail of supporting information is quite varied. Detailed information on the techniques and assumptions used to develop each set of values is essential for hypothesizing reasons for differences. Some of the information in both the initial and revised drafts of the standard are based on data from personal communications (see Appendix C of initial draft, Appendix E of revised draft). This information is usually not subject to review by the scientific community. The importance of the C_X factors is such that only readily available information should be used to select the factors.

At issue are differences between the PNL measured C_X values and the calculated values appearing in the revised draft. These calculated values resulted from work conducted at the Gesellschaft Fur Strahlen (Kramer, 1979). The calculations were made with a new Monte-Carlo computer code. I have received information on these calculated values from several members of the committee authoring the standard. This information consists of excerpts from a GSF report. Details of the computer code are not included so that an evaluation of the code cannot be made. I have been unable to obtain a complete copy of the report. After surmising information from the excerpts and comparing it with information, several puzzling items become apparent.

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1) Differences exist between the GSF calculated C_X values and values calculated by Oak Ridge. The Oak Ridge calculations were also based on a Monte-Carlo code that has been used in several published research works. The Oak Ridge calculations were used for the deep C_X values for energies less than 100 keV and for shallow C_X values for energies less than 40 keV (Appendix C, ANSI N13.11). These differences are most notable for the deep C_X values as indicated below.

Energy (keV)	GSF	Oak Ridge	% Difference
20	.51	.45	13.3
30	1.01	.94	7.4
40	1.32	1.18	11.9

I am uncertain why two calculations using similar computational techniques would be different. The answer might be found from a detailed analysis of the computer codes. Since differences exist between calculations, similar differences between experiment and calculation should not be surprising.

2) The GSF calculations were limited to a shallow depth of 0.2 cm because of the statistical nature of the computer program. This is different than the recommended shallow depth of 0.007 cm. The PNL experiments were able to measure C_X values at the 0.007 cm depth and will likely allow a more suitable determination of the true dose to the skin.

3) An identical C_X value for deep and shallow depths should not occur for high energy photons (greater than 1.0 MeV). Velkley et al. (1975) conducted a study of the buildup region for several high energy photon beams. For ^{60}Co, the dose at the surface of the phantom was 18% of the maximum dose which occurred at a depth of 5 mm. At 2 mm depth, the dose was 90% of the maximum. If the GSF computer code was sufficiently sensitive, a difference between the shallow and deep C_X values should have occurred. The reason for the similarities for high energy photons cannot be adequately developed without an in depth review of the GSF Monte-Carlo code.

The impact of the high energy C_X values will be minimal on the performance testing program because no test is prescribed for the shallow doses. Instead, the high energy C_X values indicate a possible deficiency in the calculations. Comparing the deep C_X value calculated by GSF for 1.25 MeV with similar data for ^{60}Co from the British Journal of Radiology (BJR), Supplement No. 11 (1972) indicates a small 4% difference, 1.05 for the GSF, 1.01 for the BJR data.

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The objective of the preceding paragraphs has been to show that differences exist between the GSF calculated C_X values and other similar calculations, and with experimental measurements not made at PNL. The reasons are unknown but calculations are sometimes difficult to substantiate without experimental measurements. Even with measurements, exact agreement is seldom attained.

Experimental measurements of C_X factors were made at PNL. A detailed report discussing the methods and listing all fundamental data was published in November 1979 (Yoder et al. 1979). This report was widely distributed by the Nuclear Regulatory Commission. I have met several times with representatives of the Department of Energy, National Bureau of Standards and the Nuclear Regulatory Commission to re-examine the measured data and compare it with the GSF calculated C_X values. Only one change resulted from these re-examinations. This change involved only the deep and shallow C_X value for the 100 keV U K-fluorescence x-ray technique. The deep C_X value now recommended is 1.64 rem/R and the shallow is 1.50 rem/R. The change arose from a discrepancy in exposure calibration of the 100 keV x-ray. The incorrect values were 1.74 rem/R and 1.50 rem/R.

The design of the PNL measurement study was influenced by several basic concerns. These are:

- the need to measure C_X values that could be compared to similar published information,
- the need to measure C_X values that corresponded to theoretical C_X values for monoenergetic photons,
- the need for a versatile measurement instrument that could be used to measure C_X values for unique photon beams,
- the need for a tissue equivalent plastic that could be cast into large blocks or thin sheets,
- the desire to well document all underlying assumptions, corrections and decisions.

By addressing these concerns during the planning phase of the study, my collegues and I have produced a study that is complete within itself and capable of being reviewed in detail. The C_X values recommended in the revised draft standard have not be presented in the same detail.

The PNL investigators measured C_X values for ten of the NBS filtered x-ray techniques. These techniques produce Bremstrahlung spectra which are very polyenergetic x-ray beams. As a general rule, the less filtration, the more polyenergetic is the x-ray beam. Data for the NBS technique x-rays can be compared to published data for other Bremstrahlung type x-ray beams. The latter data comes from multiplying

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Tissue-Air Ratios (TARs) by an f factor. This product can be considered a C_X value. TARs derived from measurements and calculations for many Bremstrahlung x-ray spectra and depths in tissue are published in Central Axis Depth Dose Data for Use in Radiotherapy, Supplement 11 of the British Journal of Radiology, 1972. The Physics of Radiology lists f factors. The f factor is a basic dosimetry constant and is analagous to the C_X factor. The differences between the two factors will be discussed later. Figures 1 and 2 compare C_X values measured for the NBS techniques with the corresponding data derived from the British Journal of Radiology (BJR), Supplement 11. In these figures x-ray energy is expressed as Half Value Layers (HVL) in aluminum. The differences at the shallow depth result from energy spectra differences between the NBS x-rays and those listed in the BJR. The spectral differences arise from different filtrations and generating voltage potential of the x-ray machine. At greater depths in tissue the spectral differences are reduced and agreement is very good. The maximum percent difference at the shallow depth is 6% and is for a 3 mm HVL x-ray beam. The agreements between the PNL data and data from the BJR substantiate the PNL measurement approach.

The PNL investigators also measured C_X values for seven K-fluorescence x-ray beams. These x-ray beams are nearly monoenergetic; therefore, C_X values for these beams can be compared to the theoretical or generic C_X values developed from calculations. The C_X values listed in the revised form of the draft standard are primarily based on the calculations of the GSF. Only the C_X values for 15 keV photons are not from the GSF. The 15 keV C_X values were calculated at Oak Ridge for the first draft of the standard. Figures 3 and 4 compare the PNL measurements of C_X to the calculated values listed in the revised form of the draft. For the deep C_X values, agreement is very good except at the low energy and high energy points. A tabular comparison of these differences is presented below.

PNL		Calculated		
Energy (keV)	C_X	Energy (keV)	C_X	Percent Difference
16.1	0.38	15	0.15	-60.5
78	1.72	80	1.52	-11.6
100	1.64	100	1.47	-10.4

Specific reasons for the differences are not certainly known; however deductive reasoning may indicate where a problem might exist.

A major part of the low energy C_X value difference is due to the 1 keV energy difference. In this energy region interaction coefficients rapidly change with energy and a 1 keV difference is significant. From interpolation of the calculated C_X values, a 16 keV C_X value would be 0.22 for a percent difference with the PNL value of -41.6. The remaining difference would appear to result from a deficiency in the calculation of scattered radiation in the computation of the C_X value for 15 keV.

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This apparent deficiency will be discussed later.

The reasons for the differences at 78 and 100 keV are less apparent. Without detailed information on the computer codes, only an examination of the PNL data is possible. One examination is to relate the monoenergetic K-fluorescence data to the polyenergetic filtered x-ray data. C_X values for each monoenergetic energy group are multiplied by the relative percent abundance of each energy group in the energy spectra of the filtered x-ray beam. A calculated C_X value for the filtered x-ray beam is thus obtained. This calculated C_X value should agree with the measured C_X value for the filtered x-ray beam. I have made these calculations for the MFC and MFG NBS filtered techniques using spectra measured at the GSF (Seelentag et al. 1979). These spectra were indicated to be representative of the spectra of the NBS filtered techniques. Agreement between the calculated and measured C_X values was within 3% for both x-ray techniques. If the K-fluorescent data was in error, such agreement would not have occurred. I understand that Dr. Philip Plato of the University of Michigan has made similar calculations using the PNL data and found good agreement between the calculated and measured C_X value for several filtered x-ray techniques. These calculations are extremely tedious and we are developing a computer program to make such calculations easier. This exercise demonstrates the relative consistency of the measured C_X values. Consequently, this re-examination of the PNL data does not allude to possible deficiencies in the measurements.

The agreement between the shallow C_X values is worse than the agreement for deep depths. A major reason for the difference is the Oak Ridge and GSF calculations being limited to a minimum depth of 2 mm. The PNL measurements were made at a depth of 0.007 cm as recommended in the draft standard. Several points are worth noting.

1) The difference between the measured and calculated values at 78 and 100 keV are much less than at the 1 cm depth. The 78 keV values differ by about 5% while the 100 keV values differ by only 2%. The increase in these differences must result from a deficiency in either calculating or measuring the buildup of scattered radiation in the phantom. The calculated C_X values do not change between the two depths for both the 80 and 100 keV photons. This indicates no buildup of scattered radiation at increasing depths in tissue. This indication is contrary to vast amounts of published depth dose information (British Journal of Radiology, 1972, Johns and Cunningham, 1974). From data presented in Supplement 11 of the British Journal of Radiology, an x-ray beam with a half value layer of 1.0 mm Cu has an effective energy of 82 keV. For this x-ray beam, the TAR at 1 cm is 7% higher than the TAR at the surface (Table 3.43 in the BJR report). The increase represents a buildup of scattered radiation. The percent amount of the buildup accounts for some of the percent difference between the calculated and measured

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deep C_x values for the 80 keV x-ray energy region. The inability of the calculations to identify a buildup of scattered radiation as a function of depth above 50 keV suggests a need to re-examine the Monte-Carlo computer program.

2) The shallow C_x values calculated for 15 keV and 20 keV photons appear too low. The f factor relates the dose deposited in a small piece of tissue from an exposure of 1 R. The size of the piece of tissue is just large enough to produce electronic equilibrium at a point of interest in the tissue. For low energy photons, electronic equilibrium occurs at the surface of the phantom and would be well established at a depth of 2 mm. Then for low energy x-rays and doses at the surface, the f factor indicates the dose to tissue from the primary radiation beam. The factor does not account for scattered radiation from surrounding regions of the phantom. The f factor is a minimum limit for a C_x value. In fact, the difference between the f factor and the shallow C_x factor for x-rays is the latter factor accounts for the dose deposited by both the primary and scattered radiation beams. For 15 keV and 20 keV photons, the f factors are 0.907 and 0.903 respectively (Johns and Cunningham, 1974). The calculated C_x values presented in the revised draft standard are 0.77 and 0.95 respectively. The 0.77 value for 15 keV is less than the minimum C_x value, again indicating a computational deficiency. The C_x value for 20 keV is 0.95 which is barely above a minimum C_x value that does not include scatter radiation doses. At this energy, scatter adds 20% to 25% of the dose from primary beam radiation (British Journal of Radiology, 1972). Shallow C_x values from 20 keV should be about equal to 0.903 x (1.2 to 1.25) = 1.08 to 1.13. These projected C_x values agree well with the PNL measured C_x values.

3) Questions have been raised concerning the similar C_x values measured by PNL for photon energies between 16 and 34 keV. This can best be explained by examining the f factor. Figure 5 shows the f factor for energies between 10 and 200 keV (Johns and Cunningham, 1974). Note the parabolic shape of the graph for energies between 10 and 40 keV with a minimum at 20 keV. If the buildup of scattered radiation was constant as a function of energy, shallow C_x values would also appear parabolic. However, in this energy region, the amount of scattered radiation slightly increases with energy (British Journal of Radiology, 1972). Consequently, the C_x values for 23 to 34 keV photon energies would change more than the 16 keV photon energy and the parabolic shape of the curve would become more linear. This is what appears in the PNL measurements.

The selection of a cuboidal phantom was made for several reasons. Comparisons with published depth dose information were desired. Most of this published data is presented for a cuboidal phantom. The design of the extrapolation chamber placed constraints on using alternative designs. The dose equivalent index is defined for a sphere. Unfortunately, the index quantities were not developed for applied health physics. The practicality of using the index concept is strongly questioned and is

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a topic of current health physics discussing. In addition, ICRU 23 (1973) prescribes the use of a cuboidal or parallelepiped phantom for in-phantom dosimetry. For these reasons it seemed most appropriate to use a cuboidal phantom. The difference between the cube and spherical phantom should be relatively small and may account for the remaining 2% to 3% difference not already accounted for between the deep C_X values for 80 and 100 keV photons.

In conclusion the PNL data appear for several reasons most appropriate for use in the performance testing program. These reasons are:

- C_X values were specifically measured for the low energy radiation beams recommended for use in the revised standard
- C_X values for Bremstrahlung x-ray beams agreed well with similar published data
- deficiencies exist in calculating the doses from scattered, and in some cases primary, radiation. These deficiencies are most evident by the failure to identify the buildup of dose as a function of depth for low and high energy photons.
- shallow C_X values were measured at the 0.007 cm depth in tissue recommended
- the PNL measurement method can be used to measure C_X values for special radiation beams that may be employed in calibrations and testing.
- the K-fluorescence x-ray data were consistent with the filtered x-ray data.
- the PNL data has been published in a detailed report describing all aspects of the study.

I appreciate the opportunity to comment and will be happy to discuss any further questions that may arise on the subject of performance testing.

Sincerely,

R Craig Yoder

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REFERENCES

British Journal of Radiology. 1972. Central Axis Depth Dose Data for Use in Radiotherapy. Supplement 11, edited by M. Cohen, D. E. A. Jones and D. Greene, British Institute of Radiology, London, England.

American National Standard Institute. 1978. Draft American National Standard Criteria for Testing Personnel Dosimetry Performance. ANSI N13.11.

International Commission on Radiation Units and Measurements (ICRU). 1973. Measurement of Absorbed Dose in a Phantom Irradiated by a Single Beam of X or Gamma Rays. ICRU 23, Washington, D.C..

International Commission on Radiation Units and Measurements (ICRU). 1976. Conceptual Basis for the Determination of Dose Equivalent. ICRU 25, Washington, D.C..

Johns, H. E., and J. R. Cunningham. 1974. The Physics of Radiology. Charles C. Thomas, Inc., Springfield, Illinois.

Kathren, R. L., F. L. Rising and H. V. Larson. 1970. K-Fluorescence X-Rays: A Multi-Use Tool for Health Physics. Permagon Press. Pacific Northwest Laboratory, Richland, WA 99352.

Kramer, R., 1979. Ermittlung Von Konversionsfaktoren Zwischen Körperdosen und Relevanten Strahlungskenngrössen Bei Externer Röntgen and Gamma-Bestrahlung. GSF-bericht-S-556, Gesellschaft für Strahlen- und Umwelt-forschung MBH, Institut für Strahlenschutz, Muchen-Neuherberg, Germany.

Seelentag, W. W., W. Panzer, G. Draxler, L. Platz, and F. Santner. 1979. A Catalogue of Spectra for the Calibration of Dosemeters, Gesellschaft fur Strahlen-und Umweltforschung mbH Munchen.

Velkley, D. E., D. J. Manson, J. A. Purdy, and G. D. Oliver, Jr.. 1975. Build-up Region of Megavoltage Photon Radiation Sources. Medical Physics, Vol. 2, No. 1, Mallinckrodt Institute of Radiology, St. Louis, MO 63110.

Yoder, R. C., W. T. Bartlett, J. W. Courtney, C. D. Hooker, J. P. Holland and B. T. Hogan. 1979. Confirmation of Conversion Factors Relating Exposure and Dose Equivalent Index Presented in ANSI N13.11. NUREG/CR-1057, PNL-3219, Pacific Northwest Laboratory, Richland, WA 99352.

FIGURE 1

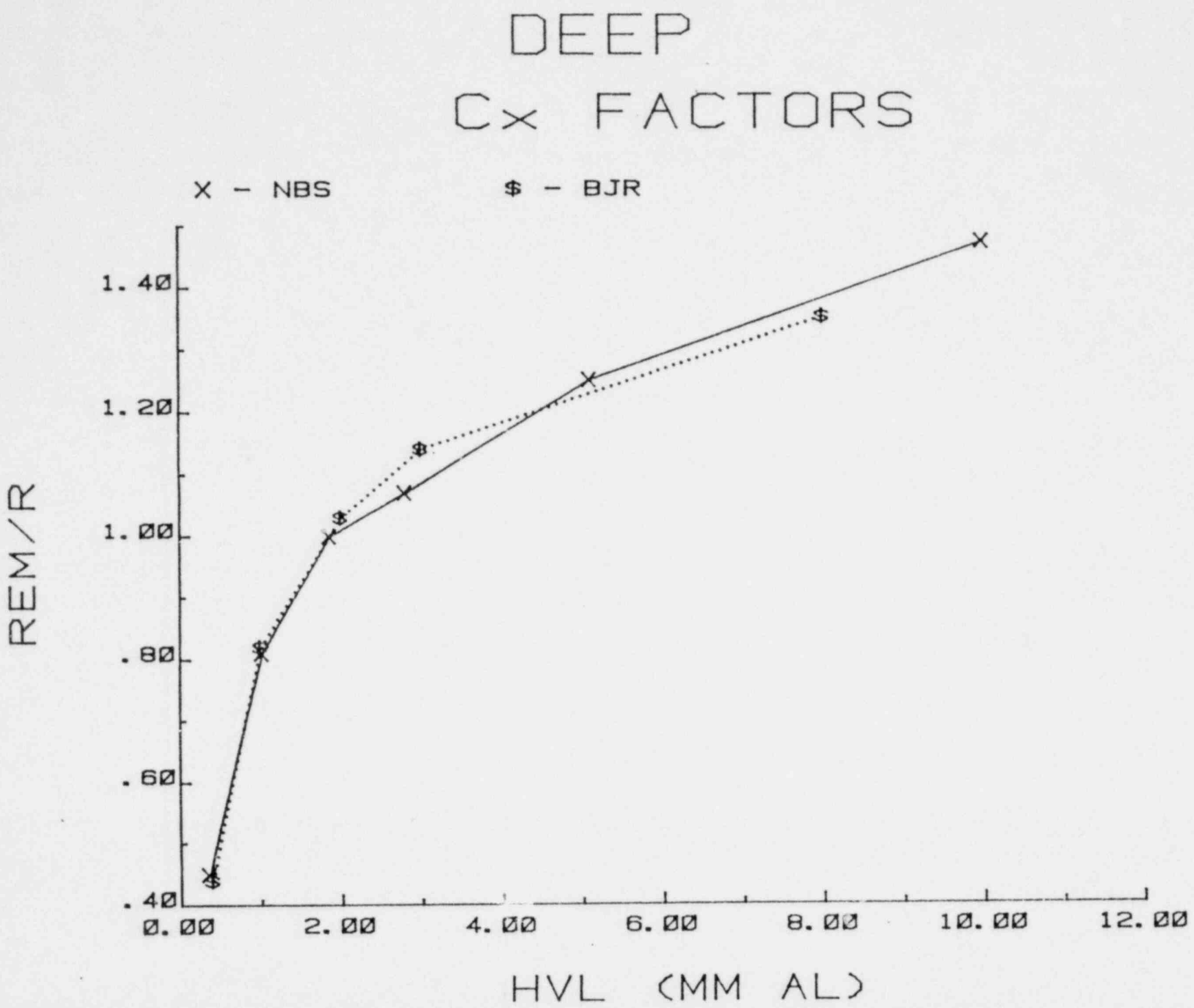

DEEP
Cx FACTORS
X - NBS
$ - BJR
REM/R
1.40
1.20
1.00
.80
.60
.40
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HVL (MM AL)

FIGURE 2

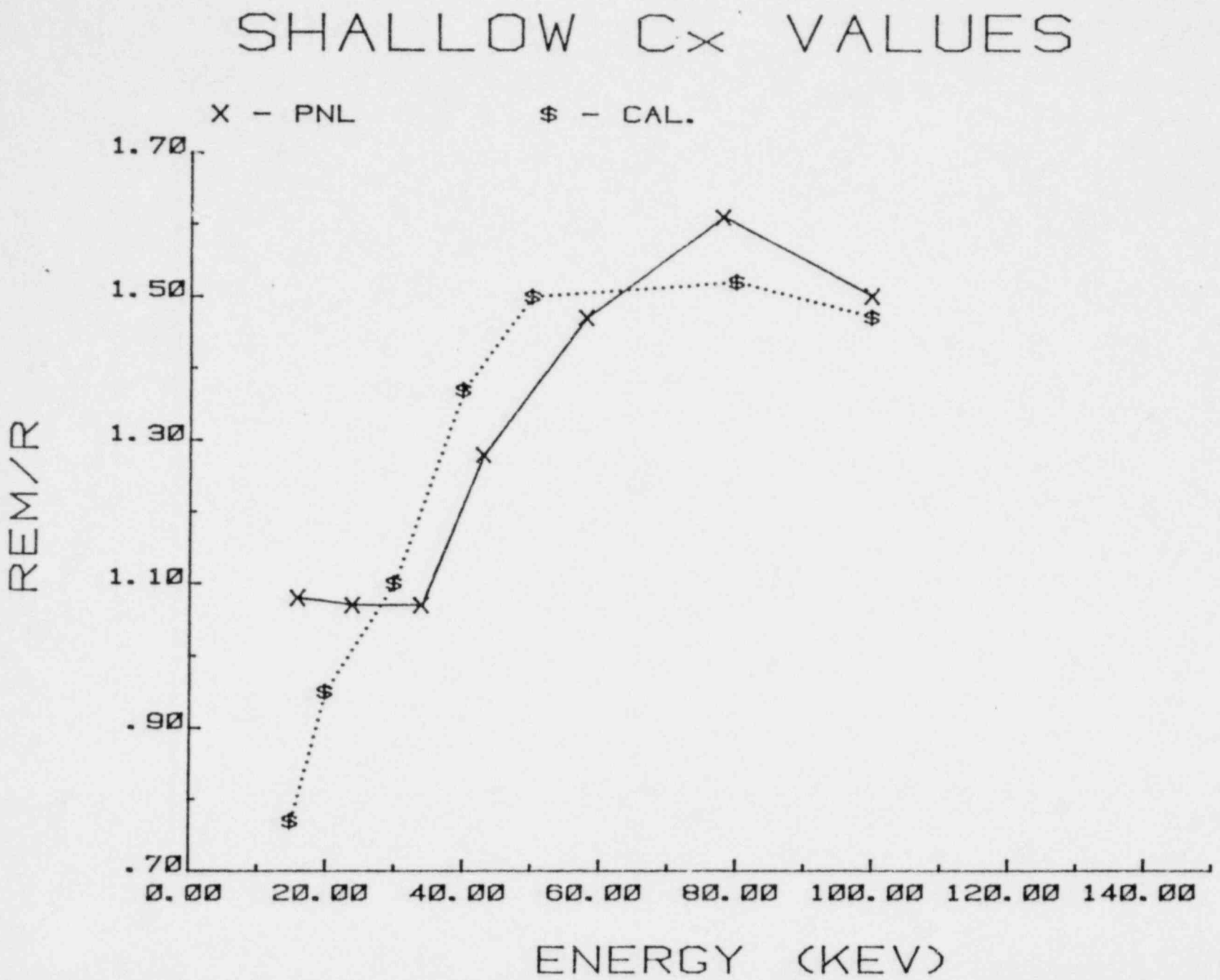

SHALLOW Cx VALUES
X - PNL
$ - CAL.
1.70
1.50
1.30
1.10
.90
.70
REM/R
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
ENERGY (KEV)

FIGURE 3

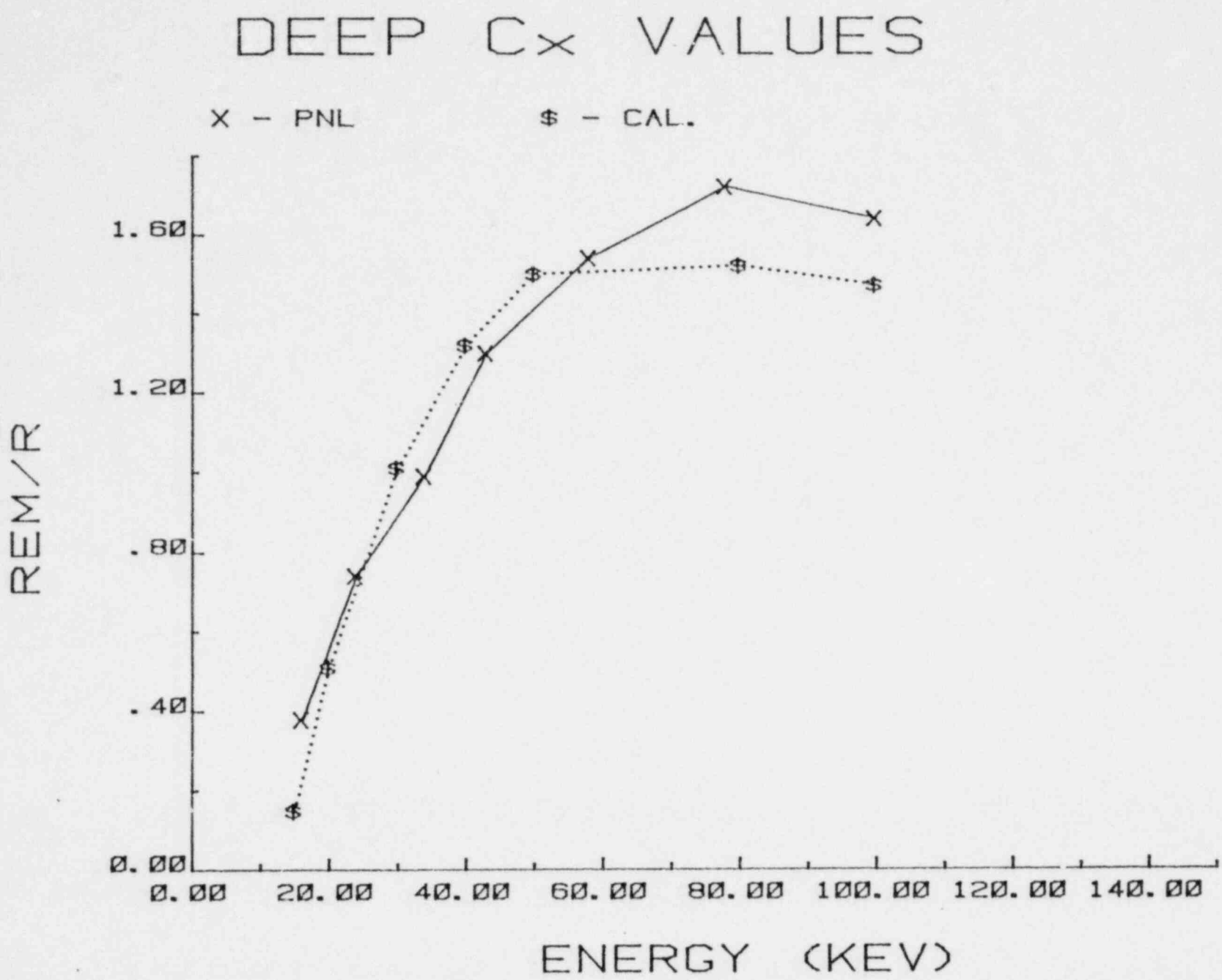

DEEP Cx VALUES
X - PNL
$ - CAL.
REM/R
1.60
1.20
.80
.40
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
ENERGY (KEV)

FIGURE 4

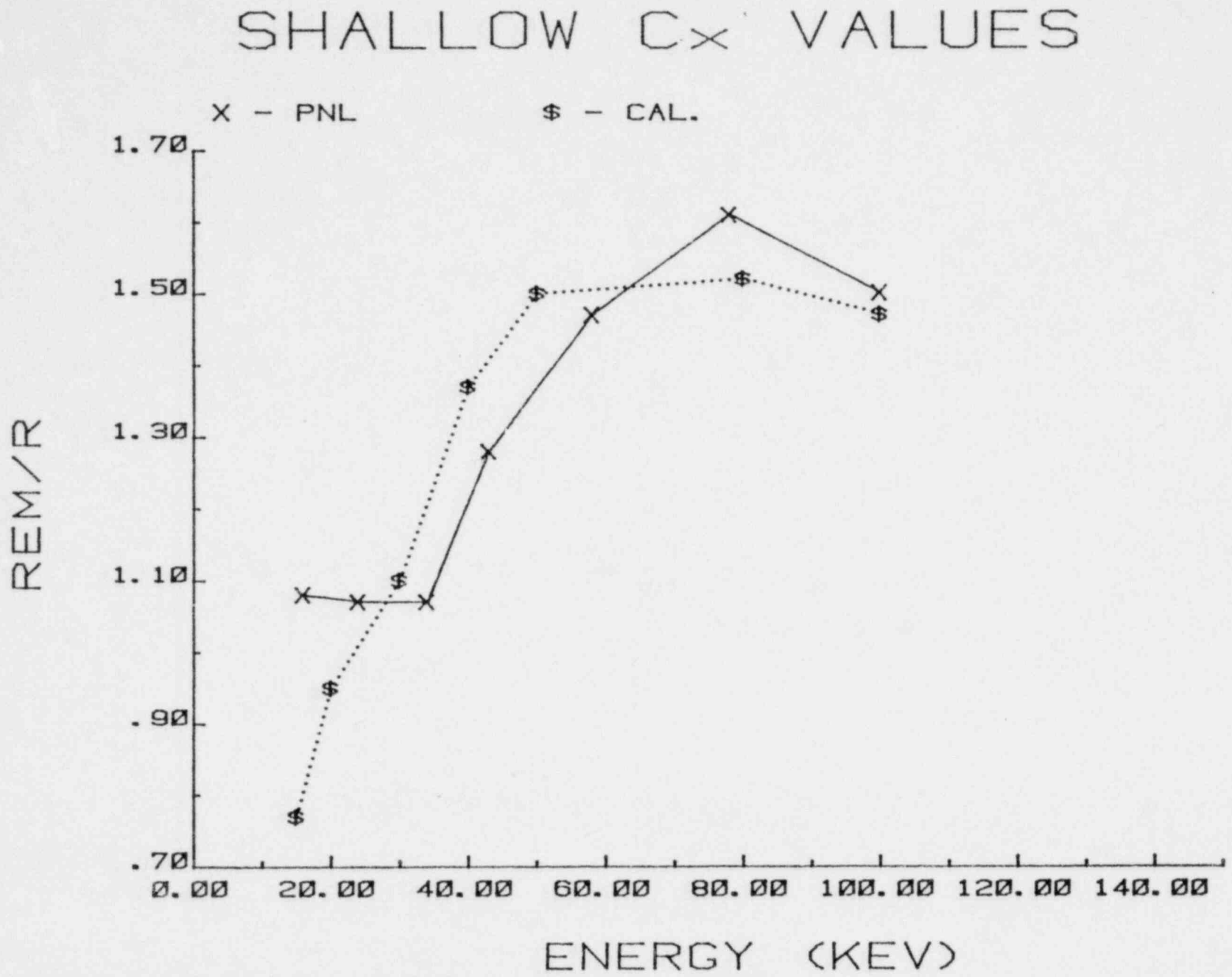
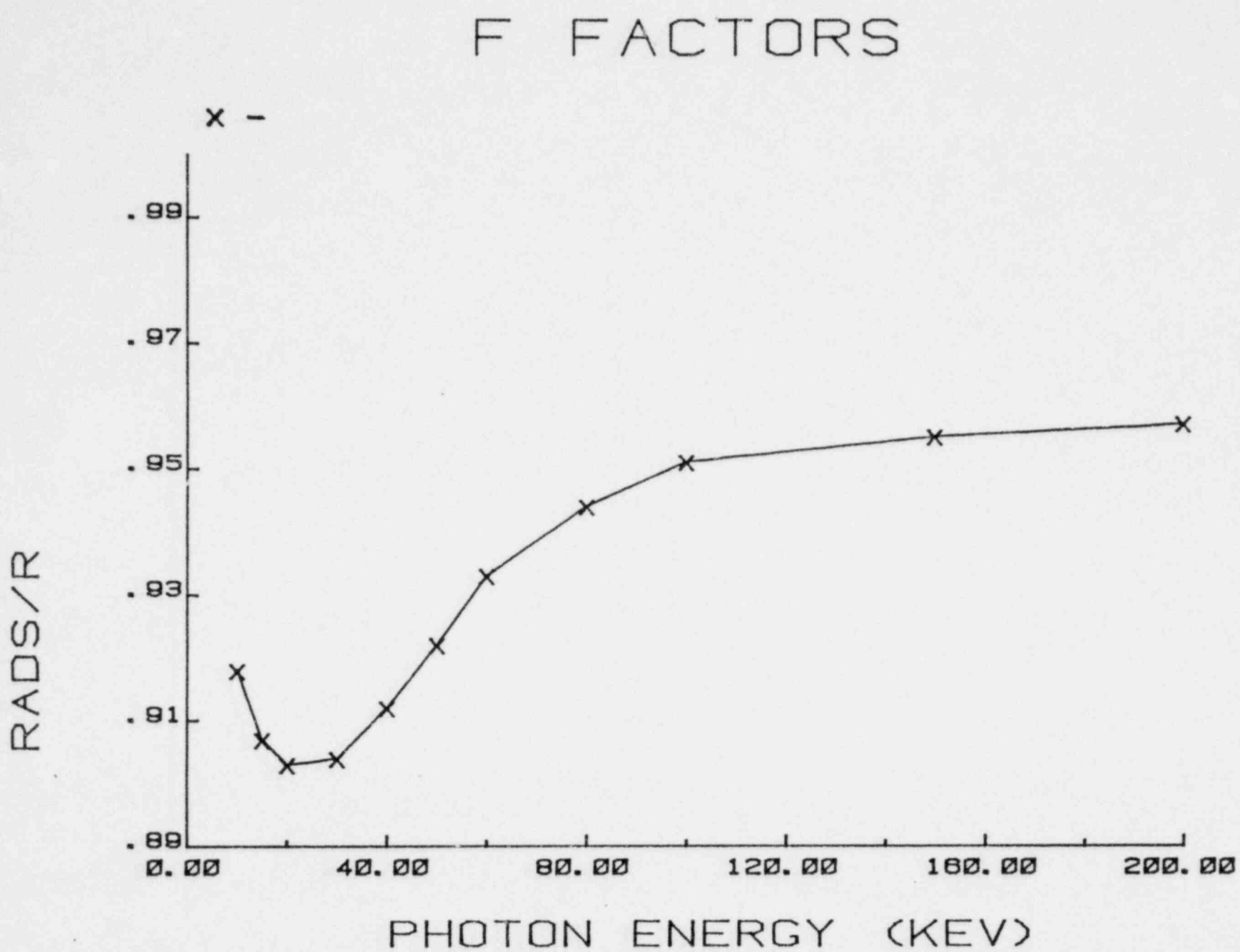

SHALLOW Cx VALUES
X - PNL
$ - CAL.
1.70
1.50
1.30
1.10
.90
.70
REM/R
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
ENERGY (KEV)

FIGURE 5


F FACTORS
X -
.99
.97
.95
.93
.91
.89
RADS/R
0.00
40.00
80.00
120.00
160.00
200.00
PHOTON ENERGY (KEV)