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APPLICABILITY OF GEOMETRICAL PROGRESSION
APPROXIMATION (G-P METHOD) OF GAMMA-RAY
BUILDUP FACTORS

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Applicability of Geometrical Progression Approximation (G-P Method)
of Gamma-Ray Buildup Factors

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The G-P method formula $B_r(X) = 1 + (B-1) \cdot (K^X - 1) / (K-1)$ (X : optical length, B : buildup factor at $X=1$, K : a gamma-ray multiplication factor per one mean free path) gives an accurate representation of the buildup factor for point isotropic sources.

In the present work, a fitting procedure has been developed including a new expression for K -parameter. The method is used for fitting to the buildup factors calculated by the moments method and by the PALLAS code. It improves agreement with the basic buildup factors calculated by the moments method, of air, water, concrete, and iron for the 0.015- to 15 MeV energy range and for the 0.5- to 40-mfp distance range. Furthermore, exposure, absorbed dose, and dose equivalent buildup factor approximated by the G-P fitting parameters are in good agreement with the basic data calculated by the PALLAS code, for water, concrete, iron, and lead. Good agreement is obtained even in the case

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of rapidly increasing buildup factors for low source energies in beryllium and boron and of that in lead, including the effects of bremsstrahlung and fluorescence.

Furthermore, the G-P formula efficacy for use as an analysis and interpolation technique has been confirmed through the various tests for energetic or spatial interpolation.

Keywords: G-P Method Formula, Exposure, Absorbed Dose, Dose-equivalent, Buildup Factor, Parameter Fitting, Air, Water, Concrete, Iron, Lead, Bremsstrahlung, Annihilation, Fluorescence, Interpolation, Extrapolation, Gamma-Ray

ガンマ線再生係数の等比級数法近似
(G-P 法) の適用性

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等比級数法近似 (G-P 法) は、無限媒質中の点等方線源に対するガンマ線再生係数を精度良く近似できる。ガンマ線再生係数に対する近似式とフィッティング方法を改良することにより、モーメント法による透過距離 40 mfpまでの 0.015 ~ 15 MeV の広いエネルギー領域に亘って水、空気、コンクリート、鉄の再生係数を従来の G-P 法近似式より精度良く近似でき、フィッティングパラメータのエネルギー変化がスムーズになった。更に PALLAS コードで計算された水、コンクリート、鉄の照射線量、吸収線量及び線量当量に対する再生係数を精度良く近似できただけでなく、低エネルギーガンマ線に対するベリリウムやホウ素の軽い物質及び制動輻射や特性 X 線を考慮した鉛などの透過距離と共に急速に増加する再生係数に対しても精度良く近似できた。また再生係数データの評価法及び内挿法としての G-P 法の適用性が、透過距離及びエネルギーについての種々のテストによって確かめられた。

本報告書には、モーメント法や PALLAS コードで得られた種々の物質の再生係数に対する G-P 法のパラメータとともに、G-P 法の適用性を確かめる透過距離やエネルギーについての種々のテストの結果が述べられている。

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1. Introduction

This work has been performed as an activity of the Evaluation Sub-Working Group for Simple Calculation Method of RADHEAT Evaluation WG in Nuclear Reactor Code Committee in JAERI.

In the gamma-ray shield design, the point kernel integration method is quite often useful, because the calculation for three dimensional problems is simple and usually gives tolerable accuracy. The key to the reliance on this method is dependent on the accuracy of the gamma ray attenuation coefficient and the buildup factor data for shield materials. Goldstein and Wilkins's data¹ calculated with the moments method have been used as a standard for nearly 30 years. However, they lack low-energy and deep penetration data, and do not include secondary source due to processes such as annihilation, fluorescence, and bremsstrahlung.

The accident at Three Mile Island has served to emphasize the need for a revised standard data set of photon cross sections and the buildup factors. Accordingly, in order to develop the appropriate and comprehensive standard an American Nuclear Society Standards Committee Working Group ANS-6.4.3² started to evaluate buildup factors calculated with the moments method³, in which the contributions of annihilation and fluorescence are considered. Recently, the buildup factors taking into account the contributions of bremsstrahlung⁴ and fluorescence⁵ have been calculated with the PALLAS code.

In many cases, the buildup factors have been represented by parameterized forms, because many analysts prefer a simple calculation of buildup factors at an arbitrary distance or energy. Over the years, Taylor's⁶, Berger's⁷, and the polynomial formula⁸, fitted to the Goldstein and Wilkins's data have been used by shield designers

intimately.

Recently, Jacob et al.⁹ have calculated the buildup factors of air up to 10 mfp by the Monte Carlo method, and have fitted to them by a polynomial form in E^{-1} and μr . However, the value of buildup factor at the energy range between 0.05 and 0.08 MeV could not be calculated by their polynomial form. Moreover, there is no assurance about the validity of using their polynomial form for buildup factors at deep penetration depths above 10 mfp.

Foderaro and Hall¹⁰ pointed out that the large maximum deviations of their fit (these mean the fitting errors) of Taylor form¹⁰ and Chiltons' fit¹¹ of Berger form to the water buildup factors were always associated with data of an order of 10^2 or greater at 40 mfp, and their three exponential form could be fitted to the large buildup factors within 10%.

On the other hand, the fit of the G-P form^{12,13} is more accurate than that of the three exponential form for data increasing rapidly up to 10^4 or greater, though both forms have the five fitting parameters of the same numbers.

Table I and Figure 1 show a comparison between the absolute values of the maximum deviations in the Berger, Taylor, three exponential and G-P forms of the exposure buildup factors in water. The deviations except for the G-P form are taken from Ref. 10.

It was described in Ref. 13 that the success of the G-P fit to buildup factors results from the fact that the G-P parameters were so derived as to fairly well reflect the behaviour of gamma-rays transmitted through the material. That is, the parameter B in the G-P form represents a value of the buildup factor at the penetration depth 1 mfp, where the gamma ray spectrum forms a characteristic shape, being

specific for a given material and source energy. This shape of spectrum shows a slow change with penetration, besides gamma-rays buildup factor smoothly increase with the distance. The parameter K is a photon dose multiplication and its variation as a function of distance represents the change in shape of gamma ray spectrum.

In this paper the G-P method as an analysis and interpolation technique for gamma ray buildup factor for point isotropic sources in infinite homogeneous medium is investigated through the various tests. That is, the validity of using the G-P parameters to interpolate the buildup factor $B_r(E, \mu r)$ is tested in the wide range of μr and E. Furthermore, the extrapolation in μr to the buildup factors is examined for penetration depths above 40 mfp.

In order to use the G-P fitting parameters in the point kernel integration method as library data, the values of the G-P parameters are given in Tables for the buildup factor for air, water, concrete, and iron calculated with the moments method, and for water, concrete, iron, and lead including the bremsstrahlung or fluorescent radiations calculated with the PALLAS code. Also, the values of parameters for the buildup factors are given at low source energies in light media such as beryllium and boron.

The values of buildup factors including fluorescent radiations are not smooth with respect to the energy. For such a case, a treatment of the G-P parameter to interpolate in E is proposed.

2. Parameter Fitting to the G-P Formula

2.1 The G-P formula for point-source buildup factor

The G-P form for buildup factors is represented by

$$\left. \begin{aligned} B_r(E_0, X) &= 1 + (B-1) \frac{K^X - 1}{K-1} & K \neq 1 \\ &= 1 + (B-1)X & K = 1 \end{aligned} \right\} \quad (1)$$

$$K(X) = cX^a + d \cdot \frac{\tanh(X/X_k - 2) - \tanh(-2)}{1 - \tanh(-2)} \quad (2)$$

where X is the source-detector distance in mean-free-path of the medium, B is the value of the buildup factor at 1 mfp, and K represents the photon dose multiplication per mfp penetration. The equation (2) represents the dependence of K on X , where a, c, d , and X_k are the fitting parameters, depending on the source energy.

In Ref. 12, K was expressed by two equations:

$$\left. \begin{aligned} K(X) &= cX^a + d(X-X_k) & X > X_k \\ &= cX^a & X \leq X_k \end{aligned} \right\} \quad (2)'$$

Moreover, these equations, which are replaced by Eq.(2), occasionally gave a minus value for deep penetration. By introducing a hyperbolic tangent function, the parameter fitting to $K(X)$ was improved.

2.2 Procedure of parameter fitting and results

In order to perform a fit of the G-P form to the basic buildup factors, a GPFIT code has been developed.¹⁴

At first, the values of K at different distances are calculated from Eq.(1) by using the value of the buildup factor at 1 mfp as a tentative value of the B parameter. Four parameters in K of Eq.(2) are

determined with the least squares method. The weights are selected to reflect upon a sensitivity of the K parameter at different distances. Next, the above procedure is repeated for the various B values fluctuated within a small range around its original value.

At last, a set of the G-P parameters corresponding to the minimum value among the sums of square deviations of buildup factors was selected as a final set.

The GPFIT code was used to fit the G-P form to exposure and absorbed dose buildup factors for air, water, iron¹¹, and concrete¹⁵, calculated with the moments method. The obtained values of the parameters B, a, c, X_k , and d are listed on the left in Table II. Furthermore, the buildup factors calculated by these parameters are given on the right in Table II. In the previous fit¹², at first the B, a, and c parameters were selected to minimize the deviation from the basic data up to 10 mfp for air and water, and up to 20 mfp for concrete and iron. Next, the X_k and d parameters were determined to minimize the deviation from the basic data up to 40 mfp with fixed parameters B, a, and c. The maximum deviation in the previous fit are attached in the last column in Table II. In almost all source energies, the maximum deviations of the present procedure become smaller than those of the previous, especially for that of 0.1 MeV in water and that of 0.8 MeV in iron. Figure 2 compares the values of the G-P parameters as a function of photon energy between the present and the previous results. It can be distinctly said that the present values of the X_k and d parameters change more smoothly than the previous.

2.3 Applicability of the G-P formula to interpolate buildup factor in μr and in E

The G-P form was able to fit to the buildup factors at all source energies within deviations of 10% from the correct basic data. This fact and the validity of the G-P method¹³ suggest that the fitting technique of the G-P form can be used for the evaluation of the raw data. That is, questionable data due to careless input error or the limit of the approximation, such as singularity of solution near the source in the case of Sn method, are found from large deviations. Furthermore, this technique is able to replace questionable data with estimated values, which are calculated by the G-P parameters fitted to the raw data without questionable data. On the purpose using the G-P parameters to the data verification, it is very important to test how wide the range of distance or energy is reliable for the replacement of questionable data.

The following various tests were performed to obtain the confidence of using the G-P parameters to interpolate the buildup factor in μr and in E.

2.3.1 The applicability of using the G-P parameters to interpolate buildup factor in wide distance range of μr

To reduce the amount of data and to provide an accuracy of interpolation, it is important that an approximated formula is a accurate representation of the buildup factor data as a function of distance.

The G-P formula has reproduced the values of buildup factors calculated by the moments method and the PALLAS codes very well.

The applicability to interpolate buildup factor in μr was confirmed from the following tests. In the first step, the G-P

parameters fitting was performed for the residual data with some omitted data in the total basic data for a specified energy. In the next step, these omitted data are replaced with the values calculated by the above parameters. This test was performed for the exposure water buildup factor data of 0.1 and 1.0 MeV calculated with the moments method¹¹. The number of omitted data was increased from 1 to 5. The replaced results were compared with the basic data in Table III. The results derived from interpolation for a few omitted data were in good agreement with the basic data. Although the deviations from the basic data increased with increasing the number of omitted data. Also, the deviations increased in the cases that the range of a set of omitted data was near the source or near 40 mfp. Especially, they are larger for a set of omitted data, including buildup factor at 40 mfp. (they are listed in the column a of Table V)

The above tests ascertain of the applicability of using the G-P parameters to interpolate the buildup factor in an arbitrary distance μr between basic data. Furthermore, the G-P fitting can be used for the verification as follows. If there are some questionable values in the basic data, the deviations for these become greater than the others in the fitting procedure. For such cases, the values of the parameters are determined for the basic data without the questionable data, and the questionable data can be replaced with the buildup factors interpolated from these parameters.

2.3.2 Extrapolation to buildup factor for deep penetration

above 40 mfp.

The values of the G-P fitting parameters are given for the basic data of 0.5 to 40 mfp. However, it is not clear that these parameters

permit extrapolation to deep penetration above 40 mfp. Some typical buildup factor data up to 100 mfp were calculated with the PALLAS code for water, concrete, iron, and lead, at source energies of 0.1, 0.2, 1.5, and 0.1, respectively. The sample data are those that have maximum value of buildup factors at 40 mfp among all source energies. The results extrapolated by the parameters obtained by the fitting to the basic data up to 40 mfp can hardly reproduce the basic data above 40 mfp. This is because the sensitivity of the K parameter becomes severe as the distance increases.

Here, the authors propose an analytical approximation formula for these sample data,

$$K(X) = 1 + \{K(X_i) - 1\} \exp\left\{\frac{1 - (X/X_i)^{1/n}}{1 - (X_j/X_i)^{1/n}} \ln \frac{K(X_j) - 1}{K(X_i) - 1}\right\}, \quad (3)$$

where, $X_i = 35$ mfp, $X_j = 40$ mfp, and $n = 10$.

The values of buildup factors above 40 mfp can be determined from Eq.(1) using $K(X)$ of Eq.(3) instead of Eq.(2), where values of the parameters of B , $K(35)$ and $K(40)$ are ones fitted to the basic data up to 40 mfp, as shown in Table IV-1.

The results above 40 mfp are the basic data calculated with the PALLAS code in Table IV-2. The results using $K(X)$ of Eq.(3) closely reproduced the basic data within 30%, except 0.1 MeV for lead. These facts are observed in Table IV-2.

Figure 3 shows dependence of $\log K$ on $\log X$ for typical buildup factors, where the values of the K parameters are obtained by fitting to the basic data up to 40 mfp in the range of 0.5 to 40 mfp (solid line), and those above 40 mfp are calculated by Eq. 3 (dot line). It is observed from the figure that the values of K approach to constant.

This fact shows the energy spectrum for deep penetration reaches an equilibrium one.

As seen in Table III, the deviations become larger especially, when a set of omitted data includes the buildup factor at 40 mfp. For such cases, the replacement for omitted data was tried by the extrapolation of the K parameter in Eq. 3. For omission of buildup factors at 35 and 40 mfp the values of K_i and K_j of Eq.(3) were those at 25 and 30, and $n=10$. The results were compared with the basic data as shown in Table V. This test obtained better agreement than the results of omitted tests in the Section 2.3.1.

2.3.3 Interpolation of the G-P parameters in E

When the buildup factor data are applied in the practical problem, the user encounters the problem that the library data are not given at just the required energy but at some discrete energies. In such case it is very convenient, if the requested value of buildup factor is obtained simply using the G-P parameters interpolated in E.

The linear interpolation¹² of each parameter with respect to $\log E$ was revised to parabolic interpolation¹⁴. At first, four energies around E_a of interest were selected in the library, where $E_1 < E_2 < E_a < E_3 < E_4$. The parabolic interpolation was repeated two times, that is, for E_1, E_2, E_3 and E_2, E_3, E_4 . The mean value of the results by two interpolations was adopted as each value of the parameter. The interpolation of the parameters of the G-P form was compared for two methods above mentioned. The values of the G-P parameters at $E_o = 0.05$ MeV for water were estimated by two methods, the one by the linear interpolation of the parameters at $E_o = 0.04$ and 0.06 MeV, and the other by the parabolic interpolation of those at $E_o = 0.03, 0.04, 0.06$ and 0.08 MeV.

The buildup factors at 0.05 MeV were estimated by the interpolated parameters of two methods. The same calculations were repeated for the buildup factors at the source energies of 0.1, 0.5, 1, 5, and 10 MeV. These results are given in Table VI. The buildup factors by the parabolic interpolation could fit the basic data of Ref. 11 with the maximum deviations of 10% or less.

Another comparisons were performed for water buildup factors of 0.66, 1.25, 3.5 and 9 MeV with the results by the Capo form⁸. Both results are in good agreement. The basic data for the G-P form is due to Chilton's et al¹¹., and the basic data for the Capo form due to Goldstein and Wilkins¹. The results are compared in Table VII. Some fairly large deviations at $E_0 = 0.66$ MeV are due to the differences between the basic data, as clearly seen in Table VIII.

In this section, the reliability for the applicability of interpolation or extrapolation of the G-P parameters to a wider range of energy or distance was examined closely and confirmed. As a result, the fitting technique of this method has been developed as the analysis and evaluation technique for the buildup factor data.

3. The G-P Parameter Fitting to Various Buildup Factors

In the preceding section the G-P formula was shown to be a good fitting formula for the buildup factors calculated by the moments method.

In this section, the adequacy of the G-P formula is demonstrated through the application to the buildup factors for water, concrete, and iron, and to some typical examples for very large buildup factors calculated by the PALLAS code:

- (1) buildup factors in beryllium and boron for low energy gamma rays, whose maximum value exceeds the order of 10^6 .
- (2) buildup factors in lead including bremsstrahlung.
- (3) buildup factors in lead including fluorescence whose the maximum value exceeds values on the order of 10^{12} .

3.1 The parameter fitting to buildup factors by the PALLAS code

for water, concrete, and iron

The point source buildup factors by the PALLAS code were calculated for water, concrete, iron, and lead. The values for exposure buildup factors are reported in Ref. 4., and those for absorbed dose and dose-equivalent buildup factors are reported in Ref. 16.

There were differences by almost 30% between results of the moments method and those of the PALLAS, though using the same attenuation coefficients. On the other hand, the G-P form was able to fit both calculated buildup factors to the maximum deviations within 10% at all source energies. The success of the G-P parameter fitting to both basic data suggests the fact that this form is able to fit to any other result. The values of the G-P parameters and the buildup factor data calculated by these parameters are given for water, concrete, and iron

in Appendix A.

3.2 Fitting to buildup Factors of beryllium and boron for low energies

The fractional energy loss per collision decreases with decreasing energy, and the total Compton cross section for the energies of the photon before and after the scattering changes infinitesimally at low energies. Therefore, the density of photons per energy interval continues to increase until the photoelectric absorption effect intervenes. Especially, it is so, for lighter material such as beryllium and boron at the energies of the photon above 20 keV. As a result, scattered photons accumulate rapidly as the energy decreases, and the values of buildup factors become very large. Using the PALLAS code, the buildup factor data for the point isotropic source were calculated in the energy range from 0.03 to 0.3 MeV for beryllium and from 0.03 to 0.5 MeV for boron, up to 40 mfp. The G-P parameters were fitted to these buildup factors using the GPFIT code. The values of the G-P parameters and buildup factor data calculated by these parameters are showed in Appendix A. Values of buildup factors for beryllium and boron calculated with the PALLAS code are given in Appendix B. The values of B and K parameters, for beryllium and boron, are larger than the corresponding values for water, closely reflecting a steep increase of buildup factor with penetration. The maximum deviations were within 6%. The results are in excellent agreement with buildup factors in low atomic number media at low source energies.

3.3 Fitting to buildup factor for lead with bremsstrahlung

K. Takeuchi and S. Tanaka⁴ calculated the buildup factor data for

lead with the PALLAS code modified to take into account the bremsstrahlung radiations. The effect of bremsstrahlung on the buildup factor reaches a maximum at a certain distance, such as 8 mfp for 4 MeV and 20 mfp for 15 MeV. The maximum value of this effect rises with source energy. These behaviours are seen in Table IX. Where the contribution of bremsstrahlung is represented by the ratio of $(B_{\text{brems}})^{-1}$ to $(B_{\text{no brems}})^{-1}$; B_{brems} is buildup factor with bremsstrahlung and $B_{\text{no brems}}$ is buildup factor without. K.V. Subbaiah et al.¹⁷ discussed about similar contributions of bremsstrahlung for gamma rays normally incident on a 10 mfp thick slab. Moreover, A. Natarajan et al.¹⁸ calculated point source buildup factors without bremsstrahlung for lead by the ASFIT. In the absence of bremsstrahlung, both results of the ASFIT and the PALLAS are in good agreement.

The values of G-P fitting parameters were determined by the GPFIT code¹⁴ for these buildup factor data with or without bremsstrahlung. The results are listed in Table X and in Appendix A. In the absence of bremsstrahlung radiations, the values of the parameter B decrease with increasing source energy. This is marked contrast with the case of including bremsstrahlung, where the bremsstrahlung contribution to the parameter B increases considerably with the increasing source energy.

Figure 4 presents the dependence of $\log K$ on $\log X$ for lead exposure buildup factor at the incident energy 10 MeV. In the case of without bremsstrahlung radiations, the value of the parameter K is smaller than that with bremsstrahlung, up to about 15 mfp. With increasing depth beyond 15 mfp, the values of the parameter K attain a flat line regardless of with or without bremsstrahlung contribution. To gauge the relative importance of bremsstrahlung contribution, the deep penetrated spectra are shown in Fig.5: (a) without bremsstrahlung,

(b) with bremsstrahlung, and (c) bremsstrahlung itself. Where the spectrum of (b) is composed of (a) and (c) at the same depth. The addition of annihilation radiation gives rise to a sudden jump in the flux at 0.511 MeV. The annihilation radiation plays a dominant role in the spectrum in the absence of bremsstrahlung radiation, especially near the source. The effect of bremsstrahlung on the spectrum distribution advances the effect of annihilation, especially near the source. The dominant part of spectrum appears at about 1 MeV. With increasing depth, the peak shifts at about 1.5 MeV, because the ratio of scattering cross section to the total attenuation becomes the maximum at about 1.5 MeV. The approach of an asymptotic form is similar for the spectra with and without the bremsstrahlung source. This corresponds to the fact that the values of the K parameters are almost the same for the distance above 15 mfp. In the distance range below 15 mfp, the values of the K parameter including bremsstrahlung contribution is greater than that not including. This phenomenon corresponds to the energy shift of the dominant part, that is, the energy shift with the addition of bremsstrahlung is from 1 to 1.5 MeV, on the other hand, the energy shift for that of no bremsstrahlung is from 0.511 to 1.5 MeV. Moreover, the values of the K parameter are greater than unity independent on the addition of bremsstrahlung. This shows the increase of the dose multiplication.

3.4 Fitting to buildup factor for lead with fluorescence

In the photoelectric effect, a photon disappears and an electron is ejected from an atom. The electron carries away virtually all the photon energy in excess of the electron binding energy E_b as kinetic energy of the photoelectron. As the photon energy decreases, the

photoelectric cross section increases until $E=E_b$, at which the cross section drops discontinuously. In the case of lead, this drop is from 2.45×10^3 b to 5.15×10^2 b where the k shell ($E_b=88$ keV) absorption is 77.8% of the total absorption. As the vacancy left by the photo-electron is filled by an electron from an outer shell, the difference of the binding energy between the initial and the final state is emitted as a photon called a fluorescent radiation. The average energy of fluorescent radiations is 76.539 keV for lead.

The fluorescence contribution to dose buildup is dramatic for source energies close to the K edge of lead.

As the photon energy decreases, a fraction of single back-scattered photons due to Compton scattering increase. According that the energy of this back scattering ($\lambda_0 + 2$) is low energy side or high of the K-edge, the values of buildup factors are influenced greatly, where λ_0 is the wavelength of the source energy.

Tanaka and Takeuchi⁵ have been calculated the buildup factors for lead taking into account the fluorescence contribution with the modified PALLAS, and have indicated that the downward trend for buildup factors with increasing source energy is discontinuous at the source energies of 135 keV.

The energy of back scattering for the incident photon 135 keV is 88.3 keV. This is just high energy side of the K-edge. The comparison of spectra at 1, 10, and 40 mfp are shown in the right of Fig. 6. With deep penetration, the intensity of scattered photons rises suddenly at 88 keV. The spike peak at about 76 keV is the fluorescence contribution. After these photons repeat further scattering, they push up the intensity for the lower energy range.

The comparison of energy spectra are observed for the just K edge

and a little higher incident photons as shown in the left and center of Fig. 6. The difference between energy spectra of 88 and 89 keV are affected on the fact that the photoelectric cross section falls discontinuously at the K-edge.

The results are listed the buildup factor data for the source energies from 0.03 to 0.3 MeV in the Appendix B. Furthermore, the values of parameters fitted to the buildup factors of 32 energies and the buildup factors calculated by these parameters are given in Table XIII. The values of the parameters are discontinuous at the energies region between 88 and 89 keV. The behaviour of each parameter with increasing source energy are drawn in Fig. 7. As shown in figure, the parameter B has a maximum value at about 0.1 MeV, because the energy flux to exposure rate conversion factor has minimum value at about 0.1 MeV.

As observed in the figure, the interpolation of parameter in E should be made within the range of below 0.088, and 0.089 to 0.3 MeV.

As mentioned above, the G-P fitting parameters have reproduced accurately the values of rapidly increasing buildup factors.

4. Conclusion

The G-P formula gives a better fit for the values of buildup factors in the energy region where they are unusually large, or where they behave in a manner not easily or accurately approximated with simple empirical formulas. By various tests performed in the present paper the G-P formula is verified to be used for the interpolation of the buildup factor data in μr and in E. This technique is applicable for use as an analysis or evaluation technique for the buildup factor data. In addition, the formula for extrapolation to data beyond 40 mfp was derived. The authors also demonstrated the treatment of the buildup factor at an energy region close to the K-edge, where fluorescent radiations become the dominant effect.

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TABLE I

Comparison of Maximum Deviations in the Berger, Taylor, Three-Exponential and G-P Fits to the Exposure Buildup Factors in Water

E (MeV)	Absolute Value of MAX DEV(%)			
	Berger*	Taylor*	Three-Exponential*	G-P
0.015	8.1	2.3	1.2	1.7
0.020	10.9	3.9	0.4	2.3
0.030	10.0	3.7	0.5	2.3
0.040	4.6	5.3	0.7	0.9
0.050	16.5	17.2	1.1	1.3
0.060	25.4	27.4	0.9	2.2
0.080	35.5	46.2	4.6	2.9
0.100	40.8	53.2	9.3	3.0
0.150	42.7	46.5	8.7	2.6
0.200	39.3	46.7	5.5	2.5
0.300	38.2	39.9	6.6	2.5
0.400	33.7	36.1	3.7	2.2
0.500	29.9	36.7	2.0	2.5
0.600	26.7	29.3	2.4	2.0
0.800	21.4	22.4	1.0	2.0
1.000	17.0	17.8	2.4	1.6
1.500	10.6	12.3	8.1	1.9
2.000	7.1	7.1	4.6	1.5
3.000	2.5	2.0	1.1	0.7
4.000	0.9	0.4	0.4	0.6
5.000	2.1	1.1	1.1	0.5
6.000	2.0	2.0	1.2	0.9
8.000	3.7	1.8	1.5	0.9
10.000	3.9	1.9	1.7	0.9
15.000	2.9	2.0	1.3	1.0

*The parameters of these formulas were fitted to the values for the thickness 2~40 mfp of the basic data.

TABLE II(1) G-P Parameters and Buildup Factors in Air Medium -

Parameters For Point Source Absorbed Dose Buildup Factors Up To 40 mfp
in Infinite Thick Air And Comparison To Values Calculated
By The Moments Method Code

Absorbed Dose Buildup Factors in Air Medium -

Absorbed Dose Buildup Factors in Infinite Thick Air									
				Energy (MeV)					
R(MFP)	15	10	8	6	5.	4.	3	2	1.5
E (MeV)	B	c	a	X _k	d	max. dev	X _{max}	r _{ms}	max dev
						(mfp)		(mfp)	Ref-12
0.015	1.170	0.459	0.175	13.73	-0.0862	1.4%	0.5	0.51%	0.7%
0.02	1.407	0.512	0.161	14.40	-0.0819	2.1%	0.5	0.83%	1.0%
0.03	2.292	0.693	0.102	13.34	-0.0848	2.5%	0.5	1.24%	2.1%
0.04	3.590	1.052	-0.004	19.76	-0.0068	0.9%	0.5	0.38%	0.9%
0.05	4.322	1.383	-0.071	13.51	-0.0270	1.2%	4	0.78%	2.1%
0.06	4.837	1.653	-0.115	13.66	-0.0511	2.4%	0.5	1.42%	4.9%
0.08	4.929	1.983	-0.159	13.74	-0.0730	2.7%	10	1.91%	4.8%
0.10	4.540	2.146	-0.178	12.83	-0.0759	2.7%	1	1.73%	6.2%
0.15	3.894	2.148	-0.173	14.46	-0.0698	2.5%	35	1.51%	1.7%
0.2	3.345	2.147	-0.176	14.08	-0.0719	2.5%	35	1.54%	3.4%
0.3	2.887	1.990	-0.160	14.13	-0.0633	2.3%	25	1.45%	6.74%
0.4	2.635	1.860	-0.146	14.24	-0.0583	2.2%	35	1.38%	2.7%
0.5	2.596	1.736	-0.130	14.32	-0.0505	2.3%	1	1.28%	2.5%
0.6	2.371	1.656	-0.120	14.27	-0.0472	1.8%	25	1.20%	2.4%
0.8	2.207	1.532	-0.103	14.12	-0.0425	1.9%	0.5	1.13%	2.2%
1	2.102	1.428	-0.086	14.35	-0.0344	1.6%	0.5	0.86%	1.49%
1.5	1.939	1.265	-0.057	14.24	-0.0232	1.2%	0.5	0.61%	2.0%
2	1.835	1.173	-0.039	14.07	-0.0161	1.3%	0.5	0.53%	1.7%
3	1.712	1.051	-0.011	13.67	-0.0024	0.8%	0.5	0.25%	1.0%
4	1.627	0.943	0.006	13.51	-0.0051	0.4%	5	0.26%	0.4%
5	1.558	0.963	0.017	13.82	-0.0117	0.8%	1	0.37%	0.6%
6	1.505	0.915	0.025	16.37	-0.0231	1.0%	1	0.51%	0.7%
8	1.418	0.891	0.032	12.06	-0.0167	1.1%	0.5	0.42%	1.7%
10	1.358	0.875	0.037	16.01	-0.0226	1.2%	0.5	0.55%	1.7%
15	1.267	0.864	0.068	16.55	-0.0344	1.1%	4	0.65%	1.7%
0.5	2.58	2.64	2.51	1.14	1.19	1.12	1.26	1.32	1.35
1.0	4.93	4.84	4.32	1.27	1.36	1.40	1.56	1.63	1.70
2.0	1.19E1	1.07E1	8.70	1.50	1.68	1.72	1.80	1.87	1.94
4.0	2.24E1	1.86E1	1.40E1	2.24E1	2.03E1	1.11E1	1.15E1	1.18E1	1.23E1
5.0	5.64E1	4.10E1	2.74E1	5.64E1	4.10E1	1.44E1	1.44E1	1.44E1	1.44E1
6.0	8.13E1	5.59E1	3.56E1	8.13E1	5.59E1	1.70E1	1.70E1	1.70E1	1.70E1
7.0	1.13E2	7.34E1	4.46E1	1.13E2	7.34E1	2.01E1	2.01E1	2.01E1	2.01E1
8.0	1.50E2	9.37E1	5.47E1	1.50E2	9.37E1	2.35E1	2.35E1	2.35E1	2.35E1
10.0	2.49E2	1.43E2	7.76E1	2.49E2	1.43E2	3.00E1	3.00E1	3.00E1	3.00E1
15.0	6.49E2	3.20E2	1.52E2	6.49E2	3.20E2	4.90E1	4.90E1	4.90E1	4.90E1
20.0	1.33E3	5.89E2	2.54E2	1.33E3	5.89E2	7.13E1	7.13E1	7.13E1	7.13E1
25.0	2.47E3	9.93E2	3.91E2	2.47E3	9.93E2	9.71E1	9.71E1	9.71E1	9.71E1
30.0	4.60E3	1.61E3	5.74E2	4.60E3	1.61E3	1.24E2	1.24E2	1.24E2	1.24E2
35.0	7.33E3	2.46E3	8.04E2	7.33E3	2.46E3	2.51E1	2.51E1	2.51E1	2.51E1
40.0	1.09E4	3.44E3	1.06E3	1.09E4	3.44E3	1.97E2	1.97E2	1.97E2	1.97E2
R(MFP)	0.08	0.06	0.05	0.05	0.05	0.4	0.3	0.2	0.15
						0.4	0.3	0.2	0.15
						0.5	0.4	0.3	0.15
R(MFP)	1	0.8	0.6	0.5	0.5	0.4	0.3	0.2	0.15
						0.5	0.4	0.3	0.15
						0.6	0.5	0.4	0.15
R(MFP)	0.08	0.06	0.05	0.05	0.05	0.06	0.05	0.04	0.015

TABLE II(2) G-P Parameters and Buildup Factors using G-P Method
- Exposure Buildup Factors in Water Medium -

Parameters For Point Source Exposure Buildup Factors Up To 40 mfp
In Infinite Thick Water And Comparison To Values Calculated
By The Moments Method Code

Exposure Buildup Factors in Infinite Thick Water									
Energy (MeV)									
R(MFP)	15	10	8	6	5	4	3	2	1.5
E (MeV)	B	c	a	χ_k	d	max. dev	max. dev	max. dev	max. dev
	(MeV)					(mfp)	(mfp)	(mfp)	(mfp)
0.015	1.182	0.463	0.175	14.23	-0.0908	1.7X 0.5	0.63%	0.8X	Ref.12
0.02	1.427	0.549	0.143	14.86	-0.0707	2.3X 0.5	0.78%	1.0X	
0.03	2.355	0.736	0.087	13.28	-0.0419	2.3X 0.5	1.18%	2.1X	
0.04	3.777	1.117	-0.019	11.67	-0.0026	0.9X 0.5	0.30%	0.6X	
0.05	4.461	1.457	-0.084	13.62	0.0341	1.3X 10	0.85%	1.9X	
0.06	4.983	1.730	-0.126	13.64	0.0561	2.2X 10	1.56%	6.1X	
0.08	5.059	2.059	-0.168	13.67	0.0770	2.9X 35	1.95%	5.6X	
0.1	4.663	2.221	-0.186	13.33	0.0826	3.0X 15	1.93%	6.6X	
0.15	3.897	2.242	-0.185	14.19	0.0777	2.6X 15	1.58%	2.0X	
0.2	3.678	2.154	-0.176	14.50	0.0774	2.5X 0.5	1.49%	2.8X	
0.3	2.920	2.022	-0.164	14.21	0.0655	2.5X 1	1.47%	2.2X	
0.4	2.660	1.882	-0.149	14.24	0.0595	2.2X 35	1.37%	2.8X	
0.5	2.500	1.766	-0.135	14.33	0.0546	2.5X 1	1.38%	3.4X	
0.6	2.377	1.679	-0.124	14.23	0.0503	2.0X 0.5	1.27%	3.2X	
0.8	2.212	1.544	-0.105	14.36	0.0437	2.0X 0.5	1.19%	2.2X	
Energy (MeV)									
R(MFP)	1	0.8	0.6	0.5	0.4	0.3	0.2	0.15	0.1
0.5	1.49	1.53	1.59	1.63	1.68	1.77	1.97	2.12	2.42
1.0	2.10	2.21	2.38	2.50	2.66	2.92	3.48	3.90	4.66
2.0	3.60	3.95	4.91	5.43	6.39	6.70	8.20	9.61	11.86
3.0	5.43	6.18	7.35	8.27	9.56	11.76	14.89E1	23.33E1	
4.0	7.58	8.88	1.10E1	1.26E1	1.51E1	1.90E1	2.67E1	3.28E1	4.03E1
5.0	1.01E1	1.11E1	1.81E1	2.07E1	2.22E1	4.19E1	6.19E1	5.25E1	6.41E1
6.0	1.28E1	1.77E1	2.48E1	3.11E1	4.17E1	6.22E1	7.92E1	9.59E1	
7.0	1.58E1	2.08E1	2.68E1	3.27E1	4.18E1	5.78E1	8.85E1	11.44E2	13.73E2
8.0	1.91E1	2.44E1	3.38E1	4.18E1	5.46E1	7.73E1	11.59E2	15.99E2	
10.0	2.64E1	3.48E1	5.02E1	6.40E1	8.66E1	12.89E1	21.27E2	32.31E2	
15.0	4.81E1	6.72E1	1.05E2	1.42E2	2.04E2	3.15E2	6.11E2	8.55E2	12.59E2
25.0	1.03E2	1.55E2	2.72E2	3.94E2	6.37E2	1.15E3	2.61E3	3.94E3	6.24E4
35.0	1.72E2	2.85E2	5.43E2	8.44E2	1.47E3	3.11E3	8.35E3	1.28E4	1.77E4
40.0	2.12E2	3.52E2	6.90E2	1.10E3	1.98E3	4.30E3	1.32E4	2.00E4	2.08E4
Energy (MeV)									
R(MFP)	0.08	0.06	0.05	0.04	0.03	0.02	0.015		
0.5	2.61	2.68	2.54	2.20	1.73	1.25	1.11		
1.0	5.06	4.78	4.46	3.48	2.34	1.43	1.18		
2.0	1.25E1	1.13E1	9.22	6.21	3.38	1.69	1.28		
3.0	2.39E1	2.00E1	1.52E1	9.15	4.29	1.80	1.34		
4.0	4.02E1	3.14E1	2.23E1	1.23E1	5.13	2.03	1.39		
5.0	6.21E1	4.57E1	3.07E1	1.56E1	5.91	2.16	1.43		
6.0	9.07E1	6.12E1	4.04E1	1.92E1	6.67	2.28	1.46		
7.0	1.27E2	8.40E1	5.13E1	2.29E1	7.40	2.38	1.49		
8.0	1.71E2	1.09E2	6.36E1	8.13	2.48	1.52	1.34		
10.0	2.88E2	1.69E2	9.21E1	3.51E1	9.58	2.66	1.57		
15.0	7.0E2	3.92E2	1.87E2	5.93E1	1.34E1	3.07	1.68		
20.0	1.64E3	7.42E2	3.20E2	8.84E1	1.74E1	3.43	1.76		
25.0	3.11E3	1.28E3	5.05E2	1.23E2	3.74	1.83	1.87		
30.0	5.65E3	2.12E3	7.61E2	1.63E2	5.66E1	3.97	1.87		
35.0	9.57E3	3.31E3	1.09E3	2.08E2	3.03E1	4.16	1.90		
40.0	1.44E4	6.49E3	1.44E3	2.59E2	3.65E1	4.38	1.95		

TABLE II(3) G-P Parameters and Buildup Factors using G-P Method
- Absorbed Dose Buildup Factors in Water Medium -

Parameters For Point Source Absorbed Dose Buildup Factors Up To 40 mfp
In Infinite Thick Water And Comparison To Values Calculated
By The Moments Method Code

E (MeV)	B	c	•	X _k	d	max. dev (mfp)	X _{max} (mfp)	rms (mfp)	max dev Ref 1.12	Absorbed Dose Buildup Factors in Infinite Thick Water									
										R(MFP)	15	10	8	6	5*	4	3	2	1.5
0.015	1.188	0.464	0.172	14.00	-0.0829	1.4x 0.5	0.51x	1.4x	1.12	0.5	1.20	1.23	1.27	1.29	1.32	1.35	1.40	1.44	1.44
0.02	1.149	0.532	0.152	14.61	-0.7664	1.9x 0.5	0.73x	0.8x	1.12	2.0	1.52	1.43	1.52	1.53	1.63	1.72	1.84	1.95	1.95
0.03	2.411	0.741	0.084	14.62	-0.0542	2.3x 0.5	1.06x	1.8x	1.12	3.0	1.74	2.02	2.18	2.45	2.63	2.87	3.23	3.85	3.10
0.04	3.587	1.114	-0.018	12.68	0.0013	0.77x 0.5	0.25x	0.7x	1.12	5.0	2.15	2.59	2.87	3.32	3.64	4.10	4.62	4.61	4.61
0.05	4.554	1.457	-0.084	13.59	0.0341	1.5x 0.5	0.35	0.98x	1.12	6.0	2.34	2.86	3.20	3.74	4.14	4.72	5.63	7.38	9.15
0.06	5.018	1.735	-0.127	13.70	0.0676	2.4x 0.5	1.56x	3.5x	1.12	8.0	2.72	3.13	3.53	4.16	4.63	5.33	6.45	8.67	1.10E1
0.08	5.030	2.054	-0.167	13.84	0.0763	3.0x 0.5	1.98x	4.0x	1.12	10.0	3.09	3.59	3.85	4.57	5.13	5.95	7.29	9.99	1.29E1
0.10	4.627	2.207	-0.184	13.27	0.0799	3.0x 0.5	1.89x	5.4x	1.12	12.0	4.02	4.50	4.49	5.40	6.12	7.18	8.98	1.28E1	1.69E1
0.15	3.888	2.206	-0.180	14.27	0.0338	2.4x 0.5	1.44x	1.7x	1.12	20.0	4.96	6.53	7.63	9.57	1.11E1	1.35E1	2.01E1	2.01E1	2.01E1
0.2	3.462	2.132	-0.173	14.51	0.0750	2.4x 0.5	1.33x	1.7x	1.12	25.0	5.86	7.80	9.10	1.16E1	1.36E1	1.78E1	2.01E1	2.79E1	6.04E1
0.3	2.897	2.008	-0.162	14.18	0.0641	2.4x 0.5	1.33x	1.7x	1.12	30.0	6.66	8.98	1.06E1	1.35E1	1.59E1	1.98E1	2.11E1	4.51E1	6.86E1
0.4	2.646	1.874	-0.162	14.16	0.0591	2.4x 0.5	1.44x	3.5	1.12	35.0	7.39	1.01E1	1.22E1	1.55E1	1.83E1	2.19E1	2.19E1	5.44E1	8.49E1
0.5	2.499	1.769	-0.132	14.16	0.0517	2.0x 0.5	1.44x	3.5	1.12	40.0	8.14	1.13E1	1.41E1	1.80E1	2.08E1	2.61E1	3.64E1	6.34E1	1.01E2
0.6	2.383	1.662	-0.121	14.19	0.0482	2.0x 0.5	1.44x	3.5	1.12	45.0	8.92	1.13E1	1.41E1	1.80E1	2.08E1	2.61E1	3.64E1	6.34E1	1.01E2
0.8	2.223	1.524	-0.101	14.31	0.0403	2.0x 0.5	1.44x	3.5	1.12	50.0	9.68	1.13E1	1.41E1	1.80E1	2.08E1	2.61E1	3.64E1	6.34E1	1.01E2
1	2.106	1.436	-0.088	14.19	0.0367	1.7x 0.5	0.97x	2.0x	1.12	0.5	1.50	1.54	1.59	1.63	1.68	1.76	2.12	2.40	2.40
1.5	1.948	1.265	-0.057	14.98	0.0445	1.5x 0.5	0.62x	0.8x	1.12	2.0	2.11	2.22	2.38	2.50	2.65	2.90	3.46	3.89	4.63
2	1.643	1.169	-0.030	14.22	0.0557	1.6x 0.5	0.55x	1.7x	1.12	3.0	3.60	3.76	4.50	4.89	5.43	6.30	8.12	9.51	1.17E1
3	1.716	1.050	-0.011	13.63	0.0027	1.0x 0.5	0.31x	1.2x	1.12	4.0	5.43	6.17	7.33	8.00	9.45	1.15E1	1.55E1	1.86E1	2.30E1
4	1.633	0.979	0.007	14.23	-0.0080	0.6x 0.5	0.25x	1.4x	1.12	5.0	1.09E1	1.25E1	1.49E1	1.78E1	2.18E1	2.43E1	3.11E1	5.11E1	6.29E1
5	1.571	0.922	0.022	13.20	-0.0057	0.6x 0.5	0.34x	0.6x	1.12	6.0	1.20E1	1.53E1	1.79E1	2.18E1	2.48E1	2.83E1	4.10E1	6.07E1	9.40E1
6	*1.521	0.893	0.033	11.92	-0.0008	1.9x 0.5	1.64x	2.5x	0.9	7.0	1.28E1	1.56E1	1.86E1	2.18E1	2.48E1	2.83E1	4.11E2	6.62E1	1.34E2
8	1.432	0.873	0.038	11.56	-0.0204	0.6x 0.5	0.36x	2.0x	1.0	10.0	2.63E1	3.3E1	4.94E1	6.28E1	8.48E1	1.25E2	2.05E2	2.73E2	3.23E2
10	1.378	0.849	0.045	14.34	-0.0280	1.0x 0.5	0.57x	1.2x	1.52	15.0	4.79E1	6.63E1	1.03E2	1.39E2	2.01E2	2.52E2	3.92E2	8.24E2	9.38E2
15	1.280	0.829	0.052	14.85	-0.0367	1.2x 0.5	0.69x	1.5x	1.52	20.0	7.31E1	1.06E2	1.75E2	2.46E2	3.74E2	6.53E2	1.30E3	1.88E3	2.09E3
30.0	1.34E2	1.34E2	1.34E2	1.34E2	1.34E2	1.34E2	1.34E2	1.34E2	1.34E2	35.0	1.34E2	2.13E2	3.89E2	5.81E2	9.73E2	1.93E3	4.63E3	7.05E3	7.83E3
35.0	1.77E2	1.77E2	1.77E2	1.77E2	1.77E2	1.77E2	1.77E2	1.77E2	1.77E2	40.0	1.77E2	2.81E2	5.35E2	8.22E2	1.43E3	3.02E3	8.05E3	1.24E4	1.35E4
40.0	2.14E2	2.14E2	2.14E2	2.14E2	2.14E2	2.14E2	2.14E2	2.14E2	2.14E2	45.0	2.14E2	3.77E2	6.80E2	1.07E3	1.92E3	4.25E3	1.27E4	1.94E4	2.00E4
0.5	0.08	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	1	0.8	0.6	0.5	0.4	0.3	0.2	0.15	0.1	
1	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	2	0.6	0.5	0.5	0.4	0.3	0.2	0.15	0.15	
2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
6	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
7	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	8	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	9	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	11	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	16	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	21	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	26	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	31	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0

* This value of the buildup factor in the moments method was estimated with a revised value estimated by the interpolation technique of the G-P fitting function.

TABLE II(4) G-P Parameters and Buildup Factors in Iron Medium -
- Exposure Buildup Factors in Iron Medium -

Parameters For Point Source Exposure Buildup Factors Up To 40 mfp
In Infinite Thick Iron And Comparison To Values Calculated
By The Moments Method Code

E (MeV)	B	c	a	X _k	d	max. dev.	X _{max} (mfp)	r _{ms} (mfp)	max dev.	R(MFP)
0.015	1.004	1.561	-0.554	5.60	0.3524	0.4%	1	0.13%	1.0%	0.5
0.02	1.012	0.620	11.39	-0.6162	0.4%	2	0.22%	0.7%	1.0%	1.0
0.03	1.028	0.374	0.190	29.34	-0.3170	0.6%	3	0.28%	1.0%	2.0
0.04	1.058	0.336	0.248	11.65	-0.1188	0.5%	7	0.24%	0.5%	3.0
0.05	1.099	0.366	0.232	14.01	-0.1354	0.6%	3	0.34%	0.7%	4.0
0.06	1.148	0.405	0.208	16.17	-0.1142	1.5%	5	0.58%	1.1%	4.0
0.08	1.267	0.470	0.180	16.48	-0.0974	2.3%	5	0.89%	1.9%	10.0
0.1	1.369	0.557	0.164	14.11	-0.0791	2.6%	5	1.04%	2.1%	15.0
0.15	1.660	0.743	0.079	14.12	-0.0476	2.9%	5	1.14%	2.3%	20.0
0.2	1.839	0.911	0.036	13.23	-0.0334	2.6%	5	1.17%	2.3%	25.0
0.3	1.973	1.095	-0.009	11.86	-0.0183	2.3%	5	0.95%	2.0%	35.0
0.4	1.992	1.187	-0.027	10.72	-0.0140	1.8%	5	0.78%	1.6%	40.0
0.5	1.967	1.240	-0.039	8.34	-0.0074	1.7%	5	0.66%	1.5%	40.0
0.6	1.947	1.247	-0.040	8.20	-0.0086	1.1%	5	0.51%	1.8%	40.0
0.8	1.906	1.233	-0.038	7.93	-0.0110	1.1%	2	0.52%	6.2%	40.0

Exposure Buildup Factors in Infinite Thick Iron

Exposure Buildup Factors in Infinite Thick Iron										
Energy (MeV)										
R(MFP)	15	10	8	6	5	4	3	2	1.5	
0.5	1.10	1.15	1.18	1.22	1.24	1.28	1.35	1.36	1.35	1.36
1.0	1.20	1.30	1.35	1.44	1.48	1.55	1.63	1.71	1.75	1.75
2.0	1.40	1.59	1.71	1.88	1.98	2.12	2.29	2.50	2.62	2.62
3.0	1.60	1.89	2.07	2.33	2.48	2.71	2.98	3.35	3.59	3.59
4.0	1.83	2.05	2.45	2.80	3.01	3.32	3.71	4.26	4.65	4.65
5.0	2.05	2.33	2.84	3.28	3.56	3.96	4.47	5.22	5.79	5.79
6.0	2.33	2.88	3.26	3.79	4.13	4.62	5.26	6.24	7.00	7.00
7.0	2.63	3.26	3.71	4.32	4.72	5.31	6.08	7.31	8.29	8.29
8.0	2.95	3.68	4.18	4.88	5.35	6.02	6.93	8.42	9.63	9.63
10.0	3.73	4.61	5.23	6.10	6.69	7.54	8.74	10.0E1	1.25E1	1.25E1
15.0	6.67	7.74	8.54	9.74	10.6E1	1.19E1	1.38E1	1.74E1	2.06E1	2.06E1
20.0	1.19E1	1.30E1	1.43E1	1.53E1	1.68E1	1.95E1	2.46E1	2.97E1	3.25E1	3.25E1
25.0	2.03E1	1.84E1	1.84E1	1.95E1	2.04E1	2.22E1	2.54E1	3.27E1	3.97E1	3.97E1
35.0	5.20E1	2.45E1	2.58E1	2.58E1	2.78E1	3.16E1	4.10E1	5.05E1	6.19E1	6.19E1
40.0	8.36E1	3.48E1	3.17E1	3.12E1	3.18E1	3.39E1	3.82E1	5.00E1	6.19E1	6.19E1
40.0	4.76E1	4.11E1	3.89E1	3.89E1	4.08E1	4.55E1	5.93E1	5.93E1	5.93E1	5.93E1
R(MFP)	1	0.8	0.6	0.5	0.4	0.3	0.2	0.15	0.1	0.1
0.5	1.39	1.43	1.45	1.46	1.47	1.48	1.43	1.36	1.36	1.36
1.0	1.04	1.91	1.95	1.97	1.97	1.97	1.87	1.66	1.66	1.66
2.0	2.06	2.99	3.10	3.14	3.15	3.15	2.62	2.18	2.18	2.18
3.0	4.02	6.24	6.43	6.48	6.48	6.48	5.38	2.63	2.63	2.63
4.0	5.32	5.65	5.94	6.00	5.91	5.91	5.39	4.13	4.13	4.13
5.0	6.75	7.22	7.63	7.71	7.71	7.71	6.70	4.89	4.89	4.89
6.0	8.31	8.96	9.51	9.59	9.27	9.27	8.08	5.64	5.64	5.64
7.0	9.99	1.02E1	1.12E1	1.12E1	9.56	9.56	3.77	2.19	2.19	2.19
10.0	1.18E1	1.29E1	1.38E1	1.38E1	1.33E1	1.33E1	1.11E1	7.18	7.18	7.18
15.0	1.57E1	1.75E1	1.89E1	1.89E1	1.90E1	1.90E1	1.79E1	1.45E1	1.45E1	1.45E1
20.0	2.14E1	2.46E1	2.49E1	2.49E1	2.66E1	2.66E1	2.46E1	2.08	2.08	2.08
25.0	5.70E1	6.83E1	7.87E1	7.96E1	7.25E1	7.25E1	6.99E1	2.25E1	2.25E1	2.25E1
30.0	7.63E1	9.11E1	1.07E2	1.08E2	9.69E1	9.69E1	8.60E1	4.64E1	4.64E1	4.64E1
35.0	9.34E1	1.17E2	1.38E2	1.41E2	1.25E2	1.25E2	9.77E1	3.14E1	3.14E1	3.14E1
40.0	1.14E2	1.64E2	1.73E2	1.77E2	1.58E2	1.58E2	9.81E1	3.68E1	3.68E1	3.68E1

TABLE II(5) G-P Parameters and Buildup Factors using G-P Method
- Absorbed Dose Buildup Factors in Iron Medium -

Parameters For Point Source Absorbed Dose Buildup Factors Up To 40 mfp
In Infinite Thick Iron And Comparison To Values Calculated
By The Moments Method Code

E (MeV)	B	c	a	X _k	d	max. dev (mfp)	X _{max}	rms dev (mfp)	max dev Ref.12	Absorbed Dose Buildup Factors in Infinite Thick Iron										
										R(MFP)	15	10	8	6	5.	4.	3.			
0.015	1.004	1.561	-0.554	5.60	0.35224	0.4%	1	0.13%	1.0%	0.5	1.08	1.12	1.15	1.20	1.24	1.28	1.34	1.40	1.45	
0.02	1.010	0.258	0.319	16.22	-0.2950	0.5%	3	0.25%	0.7%	2.0	1.15	1.24	1.30	1.39	1.47	1.57	1.68	1.83	1.94	
0.03	1.027	0.318	0.252	18.88	-0.1913	0.7%	2	0.29%	1.0%	4.0	1.45	1.70	1.79	1.95	2.13	2.39	2.75	3.03	3.05	
0.04	1.058	0.331	0.248	13.93	-0.1315	0.4%	35	0.25%	0.4%	5.0	1.61	1.95	2.20	2.42	2.71	3.13	3.75	4.24	4.24	
0.05	1.105	0.344	0.243	14.40	-0.1356	1.1%	0.5	0.38%	0.9%	6.0	1.98	2.49	2.86	3.47	3.93	4.69	5.94	6.97	6.97	
0.06	1.167	0.372	0.229	14.70	-0.1365	1.2%	0.5	0.53%	1.1%	8.0	2.19	2.79	3.23	3.94	4.48	5.23	6.38	7.36	7.36	
0.08	1.340	0.442	0.191	15.11	-0.1085	1.7%	0.5	0.69%	1.4%	10.0	2.42	3.11	3.61	4.42	5.05	5.93	7.27	9.65	1.18E1	
0.1	1.600	0.484	0.178	15.00	-0.1050	1.4%	3	0.08%	5.2%	15.0	2.97	3.83	4.45	5.48	6.26	7.39	9.16	1.24E1	1.53E1	
0.15	2.422	0.584	0.151	14.99	-0.1167	5.5%	0.5	2.54%	4.8%	20.0	6.44	6.21	7.09	8.63	9.33	1.16E1	1.45E1	2.00E1	2.54E1	
0.2	2.887	0.788	0.080	13.12	-0.0720	5.5%	0.5	2.31%	4.5%	25.0	1.06E1	1.42E1	1.66E1	1.82E1	1.93E1	1.65E1	2.05E1	2.85E1	3.67E1	
0.3	3.035	1.034	0.010	12.47	-0.0539	2.9%	0.5	1.46%	6.1%	30.0	2.23E1	1.97E1	1.98E1	2.17E1	2.37E1	2.69E1	3.32E1	4.74E1	6.26E1	
0.4	2.823	1.164	-0.020	11.68	-0.0200	1.9%	0.5	0.96%	3.2%	35.0	3.66E1	2.53E1	2.65E1	2.86E1	3.22E1	4.01E1	5.76E1	7.68E1	9.12E1	
0.5	2.626	1.225	-0.034	10.32	-0.0132	1.3%	0.5	0.69%	1.4%	40.0	5.45E1	3.56E1	3.25E1	3.42E1	3.80E1	4.79E1	6.83E1	8.79E1	9.12E1	
0.6	2.486	1.241	-0.038	10.26	-0.0113	1.0%	0.5	0.61%	1.2%	R(MFP)	1	0.8	0.6	0.5	0.4	0.3	0.2	0.15	0.1	
0.8	2.277	1.241	-0.039	8.31	-0.0126	0.6%	1	0.40%	1.6%	R(MFP)	1	0.5	0.4	0.3	0.2	0.15	0.1			
1	2.130	1.256	-0.049	18.40	0.0121	0.7%	4	0.34%	1.8%	0.5	1.53	1.60	1.70	1.77	1.87	2.01	2.01	1.83	1.36	
1.5	1.938	1.193	-0.039	15.35	0.0096	0.6%	1	0.28%	1.4%	1.0	2.13	2.28	2.49	2.63	2.82	3.04	2.89	2.42	1.60	
2	1.827	1.135	-0.026	25.39	0.0074	0.7%	1	0.24%	0.4%	2.0	3.50	3.82	4.28	4.57	5.15	6.46	7.34	5.34	3.93	
3	1.684	1.035	0.002	12.45	-0.0184	0.9%	1	0.59%	1.6%	3.0	5.08	5.60	6.36	7.26	7.38	7.90	8.46	7.16	5.08	
4	1.565	0.996	0.014	13.95	-0.0296	2.0%	0.5	0.98%	1.9%	4.0	6.84	7.62	8.72	9.36	9.87	10.74	12.29	4.71	2.36	
5	1.476	0.969	0.024	14.14	-0.0384	1.7%	4	0.98%	1.7%	6.0	1.09E1	1.24E1	1.43E1	1.53E1	1.59E1	1.49E1	1.00E1	5.82	2.63	
6	1.394	0.977	0.023	14.33	-0.0380	1.8%	1	0.92%	2.0%	7.0	1.35E1	1.51E1	1.76E1	1.93E1	1.77E1	1.44E1	6.33	2.76	2.76	
8	1.299	0.958	0.033	14.00	-0.0446	2.4%	0.5	1.12%	3.4%	10.0	1.80	1.57E1	1.81E1	2.11E1	2.31E1	2.37E1	1.28E1	6.84	2.87	2.87
10	1.235	0.958	0.037	14.27	-0.0483	2.8%	1	1.26%	2.1%	15.0	3.71E1	4.55E1	5.84E1	6.75E1	7.37E1	5.84E1	1.04E1	3.59	2.50	
15	1.148	0.955	0.047	14.63	-0.0535	2.7%	1	1.27%	3.0%	20.0	5.61E1	7.05E1	8.83E1	9.45E1	9.32E1	7.17E1	3.30E1	1.31E1	4.03	
40.0											1.57E1	2.48E1	3.12E1	3.15E1	2.73E1	2.73E1				
											0.5	0.79E2	1.70E2	2.23E2	2.42E2	2.31E2	1.56E2	5.74E1	1.80E1	4.80
											0.5	1.57E2	2.10E2	2.80E2	3.07E2	2.93E2	1.94E2	6.90E1	1.93E1	5.01
R(MFP)	0.08	0.06	0.05	0.05	0.04	0.03	0.03	0.02	0.015	R(MFP)	0.08	0.06	0.05	0.04	0.03	0.02	0.015			

TABLE II(6) G-P Parameters and Buildup Factors using G-P Method
- Exposure Buildup Factors in Concrete Medium -

Parameters For Point Source Exposure Buildup Factors Up To 40 mfp
In Infinite Thick Concrete And Comparison To Values Calculated
By The Moments Method Code

Emissions For Point Source Exposure Buildup Factors Up To 40 mfp
In Infinite Thick Concrete And Comparison To Values Calculated
By The Moments Method Code

E (MeV)	B	c	a	X _k	d	max- dev (mfp)	x _{max} (mfp)	r _{rms} (mfp)	Exposure Buildup Factors in Infinite Thick Concrete									
									R(MFP)	15	10	8	6	5	4	3	2	1.5
0.015	1.029	0.364	0.240	1.612	-0.1704	0.52	25	0.24%	0.7%	1.14	1.17	1.20	1.24	1.27	1.30	1.33	1.37	1.40
0.02	1.067	0.389	0.214	12.68	-0.1126	0.7%	0.5	0.36%	0.5%	1.26	1.33	1.40	1.46	1.53	1.60	1.67	1.78	1.85
0.03	1.212	0.421	0.201	14.12	-0.1079	1.6%	0.5	0.61%	4.0%	1.48	1.64	1.77	1.93	2.04	2.19	2.37	2.65	2.86
0.04	1.455	0.493	0.171	14.53	-0.0925	2.0%	0.5	0.83%	1.7%	1.69	2.12	2.23	2.38	2.54	2.79	3.10	3.60	3.99
0.05	1.737	0.628	0.115	15.82	-0.0600	1.0%	2	0.50%	1.1%	5.0	2.09	2.52	2.82	3.26	3.54	3.99	4.61	5.23
0.06	2.125	0.664	0.118	11.90	-0.0615	2.9%	0.5	1.39%	2.9%	6.0	2.29	2.81	3.17	3.70	4.05	4.60	5.40	6.58
0.08	2.557	0.895	0.042	14.37	-0.0413	1.9%	0.5	0.96%	1.9%	7.0	1.12	1.42	1.72	2.02	2.38	2.85	3.54	4.61
0.1	2.766	1.069	0.001	12.64	-0.0251	1.1%	35	0.62%	2.3%	20.0	5.62	8.32	11.32	14.06	16.61	18.61	21.60	26.01
0.15	2.812	1.319	-0.050	8.75	-0.0040	0.4%	5	0.27%	1.1%	25.0	7.00	8.71	10.36	12.77	14.46	17.75	22.55	32.96
0.2	2.116	1.430	-0.070	18.52	0.0108	0.5%	0.5	0.16%	0.7%	30.0	8.28	1.06	1.22	1.52	1.72	2.10	2.74	4.23
0.3	2.522	1.492	-0.082	16.59	-0.0161	0.5%	40	0.25%	0.5%	35.0	9.50	1.24	1.41	1.61	1.77	2.06	2.46	5.09
0.4	2.372	1.494	-0.085	15.96	0.0194	0.4%	25	0.19%	0.5%	40.0	1.10	1.46	1.63	1.86	2.07	2.47	2.85	5.94
0.5	2.271	1.466	-0.082	16.25	0.0195	0.3%	15	0.16%	0.5%	40.0	1.10	1.46	1.63	1.86	2.07	2.47	2.85	5.94
0.6	2.192	1.434	-0.078	17.02	0.0199	0.3%	1	0.24%	0.9%	40.0	1.10	1.46	1.63	1.86	2.07	2.47	2.85	5.94
0.8	2.066	1.386	-0.073	15.07	0.0202	0.7%	35	0.30%	0.8%	40.0	1.10	1.46	1.63	1.86	2.07	2.47	2.85	5.94
R(MFP)	1	0.8	0.6	0.5	0.4	0.3	0.2	0.1	Energy (MeV)									
									R(MFP)	1	0.8	0.6	0.5	0.4	0.3	0.2	0.15	0.1
1	1.982	1.332	-0.065	15.38	0.0193	0.5%	35	0.19%	0.7%	1.0	1.98	2.07	2.19	2.37	2.52	2.72	2.84	2.77
1.5	1.848	1.227	-0.047	16.41	0.0160	0.6%	0.5	0.32%	0.6%	2.0	3.23	3.47	3.81	4.03	4.31	4.67	5.05	5.12
2	1.775	1.154	-0.033	14.35	0.0100	0.6%	40	0.19%	0.4%	3.0	4.71	5.18	5.83	6.26	6.78	7.43	8.00	6.68
3	1.671	1.054	-0.010	10.47	-0.0008	0.3%	3	0.15%	0.3%	4.0	6.41	7.17	8.24	9.86	9.83	1.09	1.16	1.12
4	1.597	0.988	0.008	12.53	-0.0115	0.8%	1	0.43%	1.0%	5.0	8.31	9.46	1.11	1.22	1.35	1.50	1.59	1.49
5	1.531	0.945	0.022	10.26	-0.0199	0.6%	40	0.33%	2.1%	6.0	1.04	1.20	1.43	1.59	1.78	1.99	2.09	2.36
6	1.478	0.940	0.021	13.11	-0.0163	1.3%	40	0.56%	1.2%	7.0	1.26	1.49	1.80	2.02	2.26	2.56	2.67	2.42
8	1.395	0.917	0.028	13.45	-0.0213	1.4%	0.5	0.60%	1.2%	10.0	2.07	2.52	3.18	3.65	4.22	4.82	5.96	6.26
10	1.334	0.901	0.035	12.56	-0.0267	1.5%	0.5	0.62%	1.8%	15.0	3.37	4.75	7.36	9.01	10.91	12.76	14.77	18.84
15	1.260	0.823	0.065	14.28	-0.0581	2.0%	3	1.15%	1.8%	20.0	5.72	7.57	11.07	13.16	16.62	19.88	21.01	21.53
25.0	8.00E1	1.10E2	1.61E2	2.03E2	2.58E2	3.22E2	3.82E2	4.42E2	5.02E2	6.16E2	7.00E2	7.82E2	8.64E2	9.46E2	10.28E2	11.08E2	11.88E2	12.68E2
30.0	1.00E2	1.49E2	2.26E2	2.92E2	3.62E2	4.32E2	5.02E2	5.72E2	6.42E2	7.12E2	7.82E2	8.52E2	9.22E2	9.92E2	10.62E2	11.32E2	12.02E2	12.72E2
35.0	1.35E2	1.94E2	3.03E2	4.03E2	5.03E2	6.03E2	7.03E2	8.03E2	9.03E2	10.03E2	11.03E2	12.03E2	13.03E2	14.03E2	15.03E2	16.03E2	17.03E2	18.03E2
40.0	1.66E2	2.41E2	3.89E2	5.29E2	7.17E2	9.80E2	11.47E2	13.16E2	14.85E2	16.54E2	18.23E2	20.02E2	21.81E2	23.60E2	25.39E2	27.18E2	28.97E2	30.76E2
R(MFP)	0.08	0.06	0.05	0.04	0.03	0.02	0.015	0.01	Energy (MeV)									
									R(MFP)	0.08	0.06	0.05	0.04	0.03	0.02	0.015		
0.5	1.81	1.63	1.42	1.24	1.04	0.86	0.66	0.46	1.0	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.05
1.0	2.16	2.13	1.74	1.46	1.23	1.04	0.84	0.64	2.0	2.19	2.17	2.15	2.13	2.12	2.11	2.10	2.09	2.08
2.0	3.99	2.94	2.24	1.71	1.28	1.05	0.81	0.61	3.0	3.27	3.22	3.17	3.12	3.08	3.04	3.01	2.98	2.95
3.0	5.38	5.62	2.64	2.18	1.38	1.07	0.80	0.60	4.0	4.05	4.00	3.95	3.88	3.81	3.75	3.68	3.61	3.54
4.0	6.76	7.43	2.97	2.43	1.53	1.22	0.93	0.73	5.0	5.54	5.34	5.16	4.97	4.78	4.57	4.36	4.15	4.06
5.0	8.14	8.79	3.27	2.72	1.71	1.39	1.09	0.89	6.0	6.26	6.06	5.87	5.68	5.48	5.28	5.08	4.88	4.68
6.0	9.54	5.86	3.79	3.25	2.23	1.89	1.58	1.38	7.0	7.43	7.12	6.83	6.54	6.25	5.96	5.67	5.38	5.09
7.0	1.10E1	5.86	3.79	3.25	2.23	1.89	1.58	1.38	8.0	8.79	8.58	8.28	7.98	7.68	7.38	7.08	6.78	6.48
8.0	1.24E1	6.38	4.03	2.43	1.89	1.58	1.38	1.18	9.0	9.54	9.24	8.94	8.64	8.34	8.04	7.74	7.44	7.14
10.0	1.55E1	7.43	4.48	2.60	1.89	1.58	1.38	1.18	10.0	10.54	10.24	9.94	9.64	9.34	9.04	8.74	8.44	8.14
15.0	2.11E1	1.01E1	5.53	2.96	1.73	1.53	1.33	1.13	15.0	11.71	11.41	11.11	10.81	10.51	10.21	9.91	9.61	9.31
20.0	3.40E1	1.29E1	6.52	3.29	1.93	1.73	1.53	1.33	20.0	17.51	17.21	16.91	16.61	16.31	16.01	15.71	15.41	15.11
25.0	4.48E1	1.54E1	7.43	4.48	2.60	2.39	2.19	1.99	25.0	22.51	22.21	21.91	21.61	21.31	21.01	20.71	20.41	20.11
30.0	5.54E1	1.80E1	8.20	5.37	3.22	2.92	2.72	2.52	30.0	27.51	27.21	26.91	26.61	26.31	26.01	25.71	25.41	25.11
35.0	6.62E1	2.15E1	8.84	5.87	3.72	3.42	3.22	3.02	35.0	34.51	34.21	33.91	33.61	33.31	33.01	32.71	32.41	32.11
40.0	7.86E1	2.68E1	9.48	6.05	4.05	3.85	3.65	3.45	40.0	39.51	39.21	38.91	38.61	38.31	38.01	37.71	37.41	37.11

TABLE II(7) G-P Parameters and Buildup Factors using G-P Method
— Absorbed Dose Buildup Factors in Concrete Medium —

Parameters For Point Source Absorbed Dose Buildup Factor's Up To 40 mfp
In Infinite Thick Concrete And Comparison To Values Calculated
By The Moments Method Code

R(MFP)	Absorbed Dose Buildup Factors in Infinite Thick Concrete									
	ENERGY (MeV)			ENERGY (MeV)						
	15	10	8	6	5	4	3	2	1.5	
0.5	1.12	1.17	1.20	1.24	1.28	1.31	1.35	1.40	1.44	
1.0	1.23	1.32	1.38	1.48	1.55	1.61	1.70	1.82	1.93	
2.0	1.43	1.62	1.76	1.93	2.07	2.22	2.43	2.78	3.06	
3.0	1.63	1.90	2.08	2.36	2.57	2.82	3.19	3.81	4.33	
4.0	1.82	2.18	2.42	2.79	3.07	3.43	3.97	4.91	5.74	
5.0	2.01	2.45	2.75	3.22	3.56	4.05	4.77	6.07	7.26	
6.0	2.19	2.72	3.08	3.65	4.06	4.66	5.58	7.29	8.90	
7.0	2.38	3.00	3.41	4.08	4.56	5.29	6.42	8.56	1.0E1	
8.0	2.57	3.27	3.75	4.51	5.07	5.92	7.27	9.87	1.25E1	
10.0	2.96	3.83	4.42	5.38	6.10	7.22	9.01	1.22E1	1.64E1	
15.0	4.03	5.29	6.19	7.65	8.04	1.06E1	1.36E1	2.00E1	2.72E1	
20.0	5.24	6.86	8.03	1.00E1	1.17E1	1.41E1	1.86E1	2.81E1	3.92E1	
25.0	6.51	8.49	9.87	1.24E1	1.45E1	1.77E1	2.33E1	3.66E1	5.24E1	
30.0	7.93	1.01E1	1.17E1	1.47E1	1.72E1	2.12E1	2.84E1	4.58E1	6.69E1	
35.0	8.93	1.17E1	1.37E1	1.67E1	2.02E1	2.48E1	3.15E1	5.53E1	8.25E1	
40.0	1.02E1	1.35E1	1.61E1	1.86E1	2.39E1	2.86E1	3.87E1	6.44E1	9.76E1	
R(MFP)	1	0.8	0.6	0.5	0.4	0.3	0.2	0.15	0.1	
	ENERGY (MeV)									
0.5	1.51	1.56	1.63	1.69	1.77	1.90	2.17	2.59	2.60	
1.0	2.12	2.24	2.43	2.57	2.77	3.09	3.48	4.07	5.87	
2.0	3.58	3.92	4.46	5.05	5.40	6.23	7.58	8.19	7.00	
3.0	5.31	5.99	7.04	7.81	8.08	1.04E1	1.27E1	1.33E1	1.04E1	
4.0	7.32	8.43	1.02E1	1.15E1	1.33E1	1.58E1	1.79E1	1.94E1	1.41E1	
5.0	9.58	1.13E1	1.39E1	1.59E1	1.86E1	2.24E1	2.68E1	2.66E1	1.80E1	
6.0	1.21E1	1.45E1	1.70E1	1.93E1	2.03E1	2.51E1	3.19E1	3.61E1	2.22E1	
7.0	2.32E1	2.52E1	2.80E1	3.02E1	3.24E1	3.74E1	4.43E1	4.69E1	2.67E1	
10.0	4.10E1	5.39E1	6.10E1	6.96E1	7.87E1	9.17E1	10.47E1	11.85E1	8.15E1	
15.0	6.42E1	8.48E1	1.04E1	1.25E1	1.45E1	1.75E1	2.00E1	2.45E1	6.21E1	
20.0	6.77E1	9.39E1	1.14E2	1.35E2	1.56E2	1.82E2	2.14E2	2.44E2	7.45E1	
25.0	9.47E1	1.14E2	1.36E2	1.58E2	1.83E2	2.13E2	2.44E2	2.74E2	6.66E2	
30.0	1.26E2	1.86E2	2.05E2	2.30E2	2.53E2	2.86E2	3.16E2	3.46E2	8.86E2	
35.0	1.61E2	2.44E2	4.13E2	5.73E2	8.27E2	1.22E3	1.41E3	1.70E3	2.86E2	
40.0	1.96E2	3.03E2	5.27E2	7.45E2	1.09E3	1.66E3	1.93E3	2.29E3	3.59E2	
R(MFP)	0.08	0.06	0.05	0.04	0.03	0.02	0.015			
	ENERGY (MeV)									
0.5	2.18	1.69	1.48	1.29	1.14	1.04	1.02			
1.0	3.26	2.25	1.83	1.47	1.22	1.07	1.03			
2.0	5.33	3.21	2.37	1.73	1.32	1.10	1.04			
3.0	7.32	4.03	2.79	1.92	1.39	1.12	1.05			
4.0	9.29	4.77	3.15	2.06	1.44	1.13	1.06			
5.0	1.13E1	5.46	3.46	2.18	1.48	1.14	1.06			
6.0	1.33E1	6.11	3.74	2.28	1.51	1.15	1.07			
7.0	1.53E1	6.74	4.01	2.38	1.54	1.16	1.07			
8.0	1.73E1	7.35	4.26	2.47	1.57	1.17	1.07			
10.0	2.17E1	8.54	4.73	2.63	1.62	1.18	1.08			
15.0	3.38E1	1.15E1	5.84	3.01	1.74	1.21	1.09			
20.0	4.79E1	1.45E1	6.90	3.33	1.83	1.23	1.10			
25.0	6.31E1	1.75E1	7.86	3.60	2.18	1.44	1.24			
30.0	7.83E1	2.01E1	8.64	3.78	2.18	1.55	1.31			
35.0	9.44E1	2.22E1	9.28	3.93	1.98	1.26	1.11			
40.0	1.14E2	2.40E1	9.95	4.09	2.03	1.28	1.11			

* This value of the buildup factor in the moments method was questionable. The authors replaced it with a revised value estimated by the interpolation technique of the G-P fitting function.

TABLE III

The Percent Deviations of the Values Interpolated by the G-P Formula from Exposure Buildup Factor Data of Water at the Source Energy 0.1 MeV Calculated by the Moment method

R ($m^2 p$)	Buildup Factor	The number of a set of data omitted from the basic buildup factor data				
		0	1	2	3	4
0.5	2.37	1.9(1)	2.9	5.6	10.3	13.9
1	4.55	2.5	2.8	6.4	11.3	15.3
2	11.8	0.1	-0.1	-0.4	6.6	9.6
3	23.8	-2.0	-2.6	-2.5	-3.5	-3.4
4	41.3	-2.4	-2.9	-3.3	-3.4	-3.7
5	65.2	-1.7	-2.1	-2.7	-2.5	-3.1
6	96.7	-0.8	-1.0	-1.1	-1.6	-0.8
7	137	0.1	0.1	-0.1	0.4	0.2
8	187	1.2	1.4	2.3	1.5	1.3
10	321	3.0	3.8	4.3	5.1	5.3
15	938	2.2	3.7	3.0	4.9	6.0
20	2170	-1.9	-3.1	-1.2	-6.6	1.7
25	4360	-2.7	-3.9	-5.0	-6.9	12.7
30	7970	0.6	1.3	-2.1	8.5	23.6
35	13500	2.7	4.6	9.5	18.8	-5.5
40	21100	-1.5	-12.7			

The values of percent deviations show the relative errors of the results calculated by the G-P parameters, which are determined from the basic data excluded the buildup factors in a bracket, to the basic data.

TABLE III (continued)

The Percent Deviations of the Values Interpolated by the G-P Formula from Exposure Buildup Factor Data of Water at the Source Energy 1 MeV Calculated by the Moment Method

The values of percent deviations show the relative errors of the results calculated by the G-P parameters, which are determined from the basic data excluded the buildup factors in a bracket, to the basic data.

TABLE IV-1

Parameters for Point Source Exposure Buildup Factors Up to 40 mfp
in Infinitely Thick Materials and Comparison to Values Calculated
by the PALLAS Code

Material	E (MeV)	B	C	a	X _k (mfp)	d	Max. Dev. (%)	Xmax (mfp)	rms Dev. (%)
Water	0.1	4.897	2.279	-0.193	13.82	0.0882	4.0	10	2.6
Concrete	0.2	2.779	1.535	-0.090	13.87	0.0241	2.4	0.5	1.3
Iron	0.5	1.887	1.328	-0.060	13.03	0.0136	2.7	0.5	1.4
Lead	0.1	1.949	1.471	0.069	12.40	-0.1136	8.0	0.5	3.8

TABLE IV-2

Material	E ₀ (MeV)	Thickness (mfp)		
		60	80	100
Water	0.1	a	9.29 + 4*	2.68 + 5
		b	8.89 + 4	2.28 + 5
		c	-4.3	-15
Concrete	0.2	a	3.77 + 3	7.77 + 3
		b	4.17 + 3	9.23 + 3
		c	+11	+19
Iron	0.5	a	3.94 + 2	6.72 + 2
		b	4.32 + 2	7.27 + 2
		c	+10	+8.1
Lead	0.1	a	5.09 + 15	3.36 + 21
		b	4.37 + 15	1.52 + 21
		c	-14	f0.45**
				f0.24

* Buildup factor calculated by the PALLAS code.

** Buildup factor calculated by the G-P form.

** Percentage deviation "b" from "a".

$$* \quad 9.29 + 4 = 9.29 \times 10^4$$

$$** f 0.45 = \text{factor of } 0.45$$

TABLE V

Percent Deviations of values of buildup factors extrapolated by Eqs. (1) and (3) from the basic data

1) Exposure buildup factors of 0.1 MeV for water

R (mfp)	Buildup factor	Buildup factors omitted from the basic data			
		no	40 mfp	35, 40 mfp	30 - 40 mfp
		a*	b**	a	b
10	3.21E2	3.0	2.7	1.8	0.8
15	9.38E2	2.2	0.9	-0.7	-1.2
20	2.17E3	-1.9	-2.3	-1.6	0.9
25	4.30E3	-2.7	-0.9	1.7	0.1
30	7.97E3	0.6	2.4	-0.5	(-14.4)
35	1.35E4	2.7	-0.8	(-14.3)	-2.5
40	2.11E4	-1.5	(-12.7)	-2.0	(-33.8)
Max. Dev. (%)	X_M (mfp)	3.0	2.7	1.8	-2.4
		10	10	10	(-57.7)
				15	-2.2
					(-76.8)
					-3.0
					(-83.1)
					-3.6
					(-49.8)
					-2.6
					(-69.9)
					-4.2
					(-10.9)
					-3.0
					(-11.9)
					1.0
					0.5
					0.5

2) Exposure buildup factors of 1 MeV for water

R (mfp)	Buildup factor	Buildup factors omitted from the basic data			
		no	40 mfp	35, 40 mfp	30 - 40 mfp
		a	b	a	b
10	2.61E1	1.3	1.0	0.7	0.1
15	4.77E1	0.8	0.0	-0.4	-0.9
20	7.40E1	-0.7	-1.1	-0.6	0.5
25	1.04E2	-0.8	0.1	1.1	-0.2
30	1.39E2	-0.2	0.9	-0.4	(-8.8)
35	1.77E2	1.0	-0.6	(-6.7)	-1.1
40	2.18E2	-0.6	(-6.8)	-1.9	(-17.4)
Max. Dev. (%)	X_M (mfp)	1.6	1.4	1.3	0.9
		0.5	0.5	15	0.5
					6
					0.5
					5
					0.4
					3

* a : due to extrapolation by Eq. (1), ** b : due to extrapolation by Eq. (3)

TABLE V (Continued)

R (mfp)	Buildup Factor	Buildup factors of 0.1 MeV for lead				Buildup factors omitted from the basic data						
		no		40 mfp		35, 40 mfp		30 - 40 mfp		25 - 40 mfp		
		a	b	a	b	a	b	a	b	a	b	
10	3.08E2	-4.6	-4.8	-3.6		-1.2		2.1		-0.5		
15	5.99E3	-2.8	-1.0	2.1		3.8		-0.5		0.0		
20	1.14E5	2.9	3.8	2.7		-2.2		0.0		97.3	-19.6	
25	2.16E6	2.8	0.2	-3.6		0.9		(61.7)	6.0	(F7.0)	61.5	
30	4.12E7	-1.8	-4.0	1.4		(40.3)	7.2	(F4.0)	18.8	(F34.8)	(F2.4)	
35	8.03E8	-3.2	1.6	(29.5)	7.4	(E2.50) **	14.9	(F12.6)	34.4	(F214)	(F3.7)	
40	1.63E10	2.0	(20.7)*	6.1	(90.9)	12.0	(F5.12)	21.4	(F46.2)	51.0	(F1530)	(F6.1)
Max. Dev. (%)		8.0	6.5	5.2		3.8		2.1		0.9		
X_N (mfp)		0.5	0.5	0.5		15		10		5		

*) due to extrapolation by Eq.(2)

**) Read as factor of 2.50

TABLE VI The comparison of two interpolation methods in the energy for exposure buildup factor in water by the moment method

E= 10 MEV								**E= 0.5 MEV**									
		LINEAR INT.		REVISED PARABOLIC INT.				LINEAR INT.		REVISED PARABOLIC INT.							
X(MFP)	BS	Y1	DY1	Y2	DY2	X(MFP)	BS	Y1	DY1	Y2	DY2	X(MFP)	BS	Y1	DY1	Y2	DY2
0.5	1.20E+0	1.191E+0	-0.7%	1.189E+0	-0.9%	0.5	1.50E+0	1.528E+0	1.8%	1.524E+0	1.5%	1	2.44E+0	2.504E+0	2.6%	2.495E+0	2.2%
1	1.37E+0	1.367E+0	-0.2%	1.362E+0	-0.6%	1	4.88E+0	4.929E+0	1.0%	4.903E+0	0.5%	2	1.999E+0	1.983E+0	0.7%	1.983E+0	0.7%
2	1.68E+0	1.694E+0	0.8%	1.684E+0	0.2%	2	8.35E+0	8.305E+0	-0.5%	8.251E+0	-1.2%	3	2.290E+0	2.268E+0	0.8%	2.272E+1	-1.4%
3	1.97E+0	1.999E+0	1.5%	1.983E+0	0.7%	3	1.28E+1	1.272E+1	-0.6%	1.262E+1	-1.4%	4	2.53E+0	2.571E+0	1.6%	2.543E+0	0.5%
4	2.25E+0	2.290E+0	1.8%	2.268E+0	0.8%	4	1.84E+1	1.826E+1	-0.8%	1.810E+1	-1.6%	5	2.80E+0	2.845E+0	1.6%	2.810E+0	0.4%
6	3.07E+0	3.114E+0	1.4%	3.072E+0	0.1%	6	3.27E+1	3.300E+1	0.9%	3.265E+1	-0.2%	7	3.34E+0	3.380E+0	1.2%	3.330E+0	-0.3%
8	3.86E+0	3.906E+0	1.2%	3.839E+0	-0.6%	8	4.15E+1	4.230E+1	1.9%	4.181E+1	0.7%	10	5.14E+0	5.214E+0	1.4%	5.097E+0	-0.8%
15	6.38E+0	6.5215E+0	2.2%	6.341E+0	-0.6%	15	1.39E+2	1.448E+2	4.1%	1.418E+2	2.0%	20	7.59E+0	7.777E+0	2.5%	7.538E+0	-0.7%
25	8.78E+0	8.940E+0	1.8%	8.695E+0	-1.0%	25	4.03E+2	4.105E+2	1.9%	3.965E+2	-1.6%	30	9.96E+0	1.007E+1	1.1%	9.908E+0	-0.5%
35	1.12E+1	1.129E+1	0.8%	1.130E+1	0.9%	35	8.28E+2	8.857E+2	7.1%	8.437E+2	1.9%	40	1.20E+1	1.215E+1	0.8%	1.205E+1	-0.9%
40	1.12E+1	1.129E+1	0.8%	1.130E+1	0.9%	40	1.11E+3	1.161E+3	4.6%	1.096E+3	-1.2%						
E= 5 MEV								**E= 0.1 MEV**									
		LINEAR INT.		REVISED PARABOLIC INT.				LINEAR INT.		REVISED PARABOLIC INT.							
X(MFP)	BS	Y1	DY1	Y2	DY2	X(MFP)	BS	Y1	DY1	Y2	DY2	X(MFP)	BS	Y1	DY1	Y2	DY2
0.5	1.28E+0	1.284E+0	0.3%	1.284E+0	0.3%	0.5	2.37E+0	2.431E+0	2.6%	2.447E+0	3.3%	1	1.56E+0	1.558E+0	-0.1%	1.558E+0	-0.1%
.1	2.08E+0	2.090E+0	0.5%	2.088E+0	0.4%	1	4.55E+0	4.647E+0	2.1%	4.731E+0	4.0%	2	2.08E+0	2.090E+0	0.5%	2.088E+0	0.4%
2	2.08E+0	2.090E+0	0.5%	2.088E+0	0.4%	2	1.18E+1	1.151E+1	-2.4%	1.195E+1	1.3%	3	2.58E+0	2.609E+0	1.1%	2.602E+0	0.9%
3	3.05E+0	3.118E+0	1.2%	3.107E+0	0.9%	3	2.38E+1	2.228E+1	-6.4%	2.348E+1	-1.3%	4	3.05E+0	3.118E+0	1.2%	3.059E+0	0.7%
4	3.05E+0	3.118E+0	1.2%	3.107E+0	0.9%	4	4.13E+1	3.788E+1	-8.3%	4.045E+1	-2.1%	5	3.58E+0	3.622E+0	1.2%	3.605E+0	0.7%
6	4.08E+0	4.122E+0	1.0%	4.099E+0	0.5%	6	5.52E+1	5.933E+1	-9.0%	6.406E+1	-1.8%	7	4.58E+0	4.619E+0	0.9%	4.591E+0	0.2%
7	4.58E+0	4.619E+0	0.9%	4.591E+0	0.2%	7	1.37E+2	1.240E+2	-9.5%	1.364E+2	-0.5%	8	5.07E+0	5.116E+0	0.9%	5.080E+0	0.2%
10	6.05E+0	6.110E+0	1.0%	6.059E+0	0.2%	10	3.21E+2	2.914E+2	-9.2%	3.266E+2	1.8%	15	8.49E+0	8.517E+0	1.5%	8.525E+0	0.4%
15	8.49E+0	8.517E+0	1.5%	8.525E+0	0.4%	15	5.38E+2	8.213E+2	-12.4%	9.378E+2	-0.0%	20	1.05E+1	1.115E+1	2.3%	1.101E+1	1.0%
20	1.05E+1	1.115E+1	2.3%	1.101E+1	1.0%	20	2.17E+3	1.782E+3	-17.8%	2.054E+3	-5.4%	25	1.33E+1	1.362E+1	2.4%	1.344E+1	1.0%
25	1.33E+1	1.362E+1	2.4%	1.344E+1	1.0%	25	4.26E+3	3.455E+3	-20.8%	4.002E+3	-8.2%	30	1.57E+1	1.593E+1	1.5%	1.568E+1	-0.1%
30	1.57E+1	1.593E+1	1.5%	1.568E+1	-0.1%	30	7.97E+3	6.376E+3	-20.0%	7.413E+3	-7.0%	35	1.80E+1	1.809E+1	0.5%	1.774E+1	-1.5%
35	1.80E+1	1.809E+1	0.5%	1.774E+1	-1.5%	35	1.35E+4	1.099E+4	-18.6%	1.277E+4	-5.4%	40	2.04E+1	2.021E+1	-0.9%	1.971E+1	-3.4%
E= 1 MEV								**E= 0.05 MEV**									
X(MFP)	BS	Y1	DY1	Y2	DY2	X(MFP)	BS	Y1	DY1	Y2	DY2	X(MFP)	BS	Y1	DY1	Y2	DY2
0.5	1.47E+0	1.498E+0	1.9%	1.493E+0	1.6%	0.5	2.52E+0	2.476E+0	-1.7%	2.522E+0	0.1%	1	2.08E+0	2.115E+0	1.7%	2.104E+0	1.2%
1	2.08E+0	2.115E+0	1.7%	2.104E+0	1.2%	1	4.42E+0	4.306E+0	-2.6%	4.415E+0	-0.1%	2	3.62E+0	3.632E+0	0.3%	3.599E+0	-0.6%
2	3.62E+0	3.632E+0	0.3%	3.599E+0	-0.6%	2	9.25E+0	8.862E+0	-4.2%	9.116E+0	-1.4%	3	5.50E+0	5.501E+0	0.0%	5.432E+0	-1.2%
3	5.50E+0	5.501E+0	0.0%	5.432E+0	-1.2%	3	1.53E+1	1.462E+1	-4.5%	1.501E+1	-1.9%	4	7.58E+0	7.710E+0	0.4%	7.587E+0	-1.2%
5	1.01E+1	1.025E+1	1.5%	1.005E+1	-0.5%	5	3.10E+1	2.997E+1	-3.3%	3.042E+1	-1.9%	6	1.28E+1	1.311E+1	2.4%	1.282E+1	-0.1%
6	1.28E+1	1.311E+1	2.4%	1.282E+1	0.1%	6	4.05E+1	3.972E+1	-1.9%	4.000E+1	-1.2%	7	1.58E+1	1.628E+1	3.0%	1.586E+1	0.4%
7	1.58E+1	1.628E+1	3.0%	1.586E+1	0.4%	7	5.13E+1	5.097E+1	-0.6%	5.087E+1	-0.8%	8	1.90E+1	1.974E+1	3.9%	1.918E+1	0.9%
10	2.61E+1	2.750E+1	5.4%	2.654E+1	1.7%	10	9.09E+1	9.463E+1	4.1%	9.144E+1	0.6%	15	4.77E+1	5.104E+1	7.0%	4.844E+1	1.6%
20	7.40E+1	7.951E+1	7.4%	7.420E+1	0.3%	20	3.23E+2	3.860E+2	19.5%	3.252E+2	0.7%	25	1.04E+2	1.135E+2	9.2%	1.042E+2	0.1%
25	1.04E+2	1.135E+2	9.2%	1.042E+2	0.1%	25	5.11E+2	6.713E+2	31.4%	5.244E+2	2.6%	30	1.39E+2	1.551E+2	11.6%	1.399E+2	0.6%
30	1.39E+2	1.551E+2	11.6%	1.399E+2	0.6%	30	7.59E+2	1.116E+3	47.0%	8.045E+2	6.0%	35	1.77E+2	2.033E+2	14.9%	1.805E+2	2.0%
35	1.77E+2	2.033E+2	14.9%	1.805E+2	2.0%	35	1.08E+3	1.750E+3	62.0%	1.156E+3	7.0%	40	2.18E+2	2.515E+2	15.4%	2.202E+2	1.0%

BS : The buildup factor by the moment method
 Y1 : " by the linear interpolation
 Y2 : " by the parabolic interpolation
 DY1,DY2 : Maximum deviation

TABLE VII
Comparison of the Values of Exposure Buildup Factors in Water Calculated by the G-P and Capo Fits Parameters.

E (MeV)	0.66			1.25			3.5			9		
	G-P	Capo	Dev(%)									
0.5	1.57	1.56	-0.2	1.46	1.51	3.1	1.33	1.31	-1.3	1.20	1.18	-2.1
1	2.32	2.31	-0.5	2.01	2.07	3.2	1.66	1.63	-2.0	1.39	1.35	-3.0
2	4.31	4.35	1.1	3.30	3.36	2.0	2.33	2.27	-2.8	1.74	1.68	-3.4
3	6.93	7.15	3.2	4.81	4.86	1.0	3.02	2.92	-3.2	2.06	2.00	-3.2
4	10.2	10.7	5.0	6.53	6.55	0.3	3.70	3.58	-3.3	2.37	2.30	-2.9
5	14.2	15.1	6.4	8.44	8.44	0.0	4.39	4.25	-3.4	2.67	2.60	-2.7
6	18.8	20.3	7.5	10.5	10.5	-0.2	5.09	4.92	-3.3	2.97	2.89	-2.6
7	24.2	26.3	8.5	12.8	12.8	-0.1	5.79	5.60	-3.3	3.26	3.17	-2.6
8	30.3	33.1	9.4	15.2	15.2	0.0	6.50	6.29	-3.2	3.54	3.44	-2.8
10	44.4	49.3	11.2	20.4	20.5	0.7	7.96	7.67	-3.7	4.11	3.97	-3.4
15	90.3	106	17.1	35.1	36.3	3.5	11.5	11.2	-3.1	5.52	5.21	-5.5
20	150	186	24.6	51.5	54.9	6.6	15.1	14.6	-3.7	6.93	6.44	-7.1
25	224	293	30.9	69.9	75.6	8.1	18.8	17.8	-5.2	8.30	7.75	-6.5
30	319	428	34.2	91.0	97.3	6.9	22.5	20.8	-7.5	9.60	9.27	-3.5
35	433	594	37.2	114	119	4.6	26.1	23.3	-10.7	10.9	11.1	1.3
40	544	792	45.6	136	141	3.3	29.7	25.3	-14.9	12.5	13.3	6.7

The parameters of the G-P formula were determined for Hilton et al.'s data , while those of the Capo formula for Goldstein and Wilkins .

TABLE VIII

Comparison of the Values of Exposure Buildup Factors in Water Calculated by the Moments Method Code

E (MeV)	0.2	0.255	0.3	0.5			1		
R (mfp)	C ^a	G ^b	Dev(%)	C	G	Dev(%)	C	G	Dev(%)
1	3.42	3.09	2.85	2.44	2.52	3.3	2.08	2.13	2.4
2	8.31	7.14	6.30	4.88	5.14	5.3	3.62	3.71	2.5
4	27.0	23.0	19.3	12.8	14.3	11.7	7.68	7.68	0.0
7	88.5	72.9	57.8	32.7	38.8	18.7	15.8	16.2	2.5
10	208	166	126	62.9	77.6	23.4	26.1	27.1	3.8
15	600	456	327	139	178	28.1	47.7	50.4	5.7
20	1350	982	676	252	334	32.5	74.0	82.2	11.1
E (MeV)	2			3			4		
R (mfp)	C	G	DeV(%)	C	G	DeV(%)	C	G	DeV(%)
1	1.83	1.83	0.0	1.71	1.69	-1.2	1.63	1.58	-3.1
2	2.81	2.77	-1.4	2.46	2.42	-1.6	2.24	2.17	-3.1
4	4.98	4.88	-2.0	4.00	3.91	-2.3	3.46	3.34	-3.5
7	8.65	8.46	-2.2	6.43	6.23	-3.1	5.30	5.13	-3.2
10	12.7	12.4	-2.4	8.97	8.63	-3.8	7.16	6.94	-3.1
15	20.1	19.5	-3.0	13.3	12.8	-3.8	10.3	9.97	-3.2
20	28.0	27.7	-1.1	17.8	17.0	-4.5	13.4	12.9	-3.7
E (MeV)	6			8			10		
R (mfp)	C	G	DeV(%)	C	G	DeV(%)	C	G	DeV(%)
1	1.51	1.46	-3.3	1.43	1.38	-3.5	1.37	1.33	-3.1
2	1.97	1.91	-3.0	1.80	1.74	-3.3	1.68	1.63	-3.0
4	2.84	2.76	-2.8	2.49	2.40	-3.6	2.25	2.19	-2.7
7	4.12	3.99	-3.2	3.48	3.34	-4.0	3.07	2.97	-3.3
10	5.37	5.18	-3.5	4.44	4.25	-4.4	3.86	3.72	-3.6
15	7.41	7.09	-6.0	5.99	5.66	-5.5	5.14	4.90	-4.7
20	9.42	8.85	-6.1	7.49	6.95	-7.2	6.38	5.98	-6.3

a Exposure buildup factors by Chilton et al.(Ref. 11)

b Exposure buildup factors by Goldstein and Wilkins (Ref. 1)

TABLE IX

The Contribution of Bremsstrahlung to the Exposure Buildup Factors
calculated by the PALLAS

Material $\mu r(mfp)$	Water			Iron				
	8	10	15	5	6	8	10	15
0.5	1.08	1.15	1.25	1.19	1.23	1.35	1.45	1.71
1	1.07	1.11	1.19	1.13	1.19	1.32	1.49	1.89
2	1.05	1.08	1.17	1.11	1.16	1.29	1.47	2.02
3	1.05	1.07	1.13	1.10	1.14	1.26	1.47	2.13
4	1.04	1.05	1.12	1.08	1.13	1.24	1.43	2.15
5	1.03	1.05	1.11	1.07	1.11	1.22	1.40	2.14
6	1.03	1.04	1.10	1.07	1.10	1.20	1.37	2.09
7	1.03	1.04	1.09	1.06	1.09	1.19	1.34	2.05
8	1.03	1.04	1.08	1.06	1.08	1.17	1.32	2.02
10	1.02	1.03	1.07	1.05	1.08	1.15	1.29	1.94
15	1.02	1.03	1.06	1.04	1.06	1.12	1.22	1.79
20	1.02	1.03	1.06	1.04	1.06	1.11	1.19	1.67
25	1.02	1.02	1.05	1.03	1.05	1.09	1.16	1.59
30	1.02	1.03	1.05	1.03	1.04	1.08	1.14	1.52
35	1.02	1.02	1.05	1.03	1.04	1.08	1.13	1.46
40	1.02	1.03	1.05	1.03	1.04	1.09	1.12	1.41

Material $\mu r(mfp)$	Concrete		Lead					
	10	15	4	5	6	8	10	15
0.1	1.20	1.38	1.25	1.39	1.53	1.80	2.23	2.91
1	1.21	1.38	1.24	1.38	1.62	2.09	2.83	3.88
2	1.15	1.36	1.17	1.34	1.54	2.16	3.23	5.48
3	1.11	1.30	1.16	1.29	1.51	2.17	3.35	6.55
4	1.09	1.25	1.13	1.26	1.47	2.17	3.37	7.30
5	1.08	1.24	1.12	1.24	1.43	2.12	3.45	7.89
6	1.08	1.21	1.11	1.21	1.40	2.11	3.76	8.36
7	1.07	1.19	1.09	1.19	1.38	2.08	3.48	8.81
8	1.06	1.19	1.09	1.18	1.35	2.05	3.47	9.14
10	1.06	1.16	1.08	1.16	1.32	2.01	3.50	9.64
15	1.05	1.13	1.06	1.13	1.26	1.89	3.40	10.0
20	1.05	1.11	1.05	1.10	1.21	1.81	3.29	9.82
25	1.04	1.10	1.05	1.09	1.18	1.74	3.17	9.52
30	1.04	1.09	1.04	1.07	1.16	1.69	3.04	9.15
35	1.04	1.09	1.04	1.07	1.14	1.64	2.96	8.89
40	1.04	1.09	1.04	1.06	1.13	1.60	2.87	8.62

TABLE X

Parameters for Point Source Exposure Buildup Factors Including
the Effect of Bremsstrahlung Up to 40 mfp in Infinitely Thick Lead
and Comparison to Values Calculated by the PALLAS Code

E (MeV)	B	C	a	Xk (mfp)	d	Max. Dev. (%)	Xmax (mfp)	rms Dev. (%)
With Bremsstrahlung								
4	1.378	0.954	0.042	14.04	-0.0603	4.6	0.5	1.7
5	1.361	0.956	0.051	13.95	-0.0709	5.3	0.5	2.1
6	1.377	0.941	0.062	14.14	-0.0795	5.3	0.5	2.2
8	1.424	0.968	0.068	13.98	-0.0874	4.2	0.5	2.4
10	1.448	1.121	0.036	13.98	-0.0599	5.5	0.5	2.2
15	1.548	1.287	0.024	13.50	-0.0571	4.7	0.5	2.2
Without Bremsstrahlung								
4	1.311	1.028	0.020	13.88	-0.0439	3.8	0.5	1.4
5	1.253	1.081	0.015	13.74	-0.0442	4.7	0.5	1.7
6	1.225	1.072	0.025	13.90	-0.0531	5.0	0.5	1.8
8	1.174	1.086	0.034	14.46	-0.0572	5.6	0.5	2.1
10	1.134	1.092	0.045	14.63	-0.0670	5.7	0.5	2.0
15	1.092	1.044	0.085	14.94	-0.1088	5.9	1	2.6

TABLE XI Parameters for Point Source Exposure Buildup Factors Including the Effect
Fluorescence up to 40 mfp in infinite Thick Lead and Comparison to Values
Calculated by the PALLAS Code and Buildup Factors using G-P Method

PARAMETERS FOR POINT SOURCE EXPOSURE BUILDUP FACTORS UP TO 40 MFP
IN INFINITE THICK LEAD AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

Exposure Buildup Factors in Infinite Thick Lead									
E (MeV)	B	C	A	XK	D	MAX. DEV(X) (MFP)	XMAX (MFP)	RMS DEV(X)	ENERGY (MEV)
						0.4	0.3	0.2	0.16
0.4	1.247	0.396	0.234	13.64	-0.1340	1.8	0.5	0.85	0.5
0.3	1.175	0.323	0.286	12.94	-0.1708	1.3	0.5	1.21	1.24
0.2	1.206	0.130	0.484	13.26	-0.2274	0.9	3	0.71	1.47
0.16	1.359	0.290	0.054	13.57	0.0930	0.4	5	0.44	1.29
0.15	1.453	0.350	0.137	6.80	-0.1374	1.6	2	0.22	1.30
0.145	1.468	0.357	0.265	7.44	-0.2954	3.8	40	1.71	1.67
0.142	1.525	0.271	0.446	8.19	-0.5458	7.0	35	3.70	1.24
0.14	1.452	0.769	-0.034	26.71	1.1263	6.7	15	1.91	1.54
0.135	1.563	0.721	0.291	6.21	-0.1944	4.2	15	3.73	2.05
0.135	1.584	0.489	0.241	9.92	-0.1303	3.6	35	1.70	2.16
0.134	1.576	0.539	0.221	10.38	-0.1198	3.1	35	1.37	2.23
0.132	1.551	0.694	0.151	9.22	0.0863	2.8	0.5	1.43	3.68
0.13	1.659	0.658	0.195	28.08	-0.1400	2.6	15	1.23	3.50
0.125	1.626	0.849	0.142	19.60	-0.0589	4.0	0.5	1.90	3.50
0.12	1.669	0.969	0.120	11.01	-0.0573	4.7	0.5	2.53	3.50
0.117	1.687	1.055	0.109	10.97	-0.0721	5.4	0.5	2.70	3.50
0.115	1.733	1.124	0.101	11.38	-0.0935	5.4	0.5	2.81	3.50
0.112	1.752	1.178	0.096	11.45	-0.0979	6.0	0.5	2.99	3.0
0.111	1.767	1.204	0.093	11.61	-0.1007	6.2	0.5	3.10	4.0
0.11	1.790	1.259	0.086	12.22	-0.1106	6.3	1	3.32	5.0
0.109	1.789	1.247	0.090	11.89	-0.1094	6.1	0.5	3.23	6.0
0.105	1.849	1.350	0.080	12.35	-0.1150	6.4	0.5	3.24	7.0
0.1	1.949	1.471	0.069	12.40	-0.1136	8.0	0.5	3.62	10.0
0.095	1.864	1.592	0.063	12.70	-0.1185	7.0	0.5	3.76	10.0
0.09	2.121	1.681	0.062	12.71	-0.1298	7.8	0.5	3.59	15.0
0.089	1.702	1.720	0.057	12.80	-0.1154	6.5	1	3.35	25.0
0.088	1.047	0.419	0.223	13.22	-0.1471	0.8	0.5	0.37	30.0
0.08	1.033	0.523	0.153	13.30	-0.0777	0.4	0.5	0.17	35.0
0.06	1.017	0.487	0.180	13.37	-0.1037	0.3	0.5	0.11	40.0
0.05	1.012	0.405	0.244	14.18	-0.1624	0.1	0.5	0.07	4.00E-05
0.04	1.007	0.438	0.206	14.26	-0.1093	0.1	3	0.05	0.5
0.03	1.003	0.396	0.248	14.56	-0.1696	0.1	5	0.02	0.00
						0.5	1.37	1.38	1.40
						1.0	1.77	1.79	1.79
						2.0	2.75	2.85	3.06
						3.0	4.15	4.39	4.37
						4.0	6.22	6.74	6.69
						5.0	9.33	1.04E1	1.03E1
						6.0	1.41E1	1.61E1	1.61E1
						7.0	2.16E1	2.53E1	2.50E1
						8.0	3.32E1	4.00E1	3.96E1
						10.0	8.14E1	1.03E2	1.02E2
						15.0	0.37E2	0.77E2	0.76E2
						20.0	9.47E3	1.73E5	1.62E3
						25.0	1.02E5	1.76E5	1.62E5
						30.0	1.12E6	2.02E6	1.93E6
						40.0	1.37E7	2.52E7	2.35E7

TABLE XI (Continued)

Exposure Buildup Factors in Infinite Thick Lead

R (MFP)	ENERGY (MEV)			
	0.08	0.06	0.05	0.04
0.5	1.02	1.01	1.01	1.01
1.0	1.03	1.02	1.01	1.01
2.0	1.05	1.03	1.02	1.01
3.0	1.07	1.03	1.02	1.01
4.0	1.08	1.04	1.03	1.02
5.0	1.09	1.04	1.03	1.02
6.0	1.10	1.05	1.03	1.02
7.0	1.10	1.05	1.03	1.02
8.0	1.11	1.05	1.04	1.02
10.0	1.12	1.06	1.04	1.02
15.0	1.15	1.08	1.05	1.03
20.0	1.17	1.09	1.06	1.03
25.0	1.19	1.10	1.07	1.04
30.0	1.20	1.10	1.08	1.04
35.0	1.21	1.11	1.08	1.04
40.0	1.22	1.12	1.09	1.04

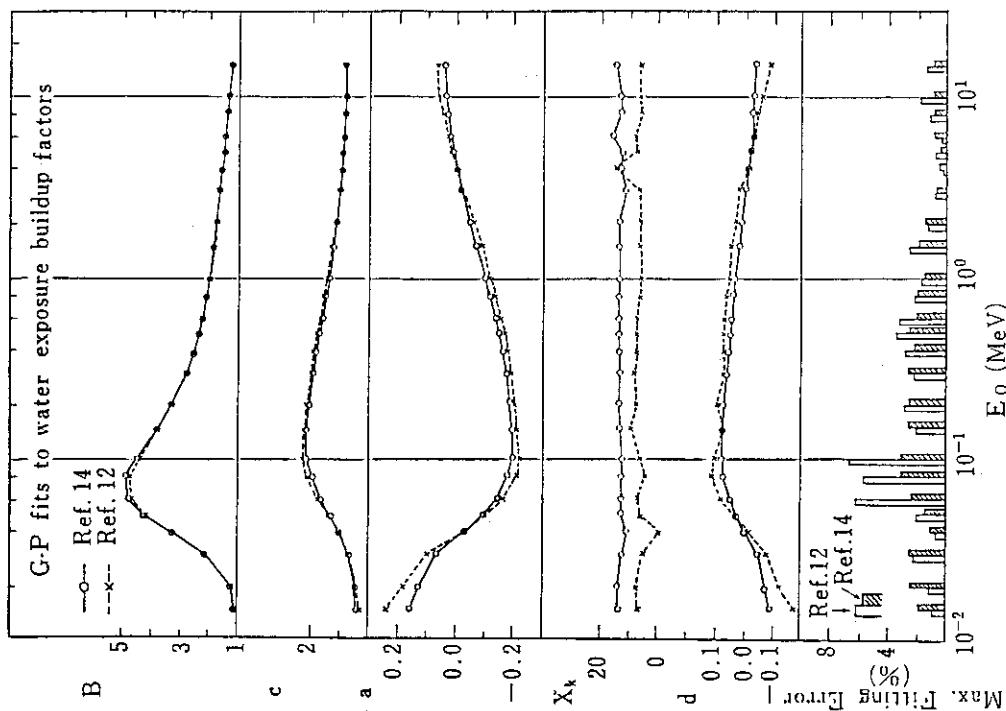


Fig. 1

Comparisons of maximum deviations in the Berger, Taylor, Three-Exponential and G-P fits to the exposure buildup factor in water by the moments method

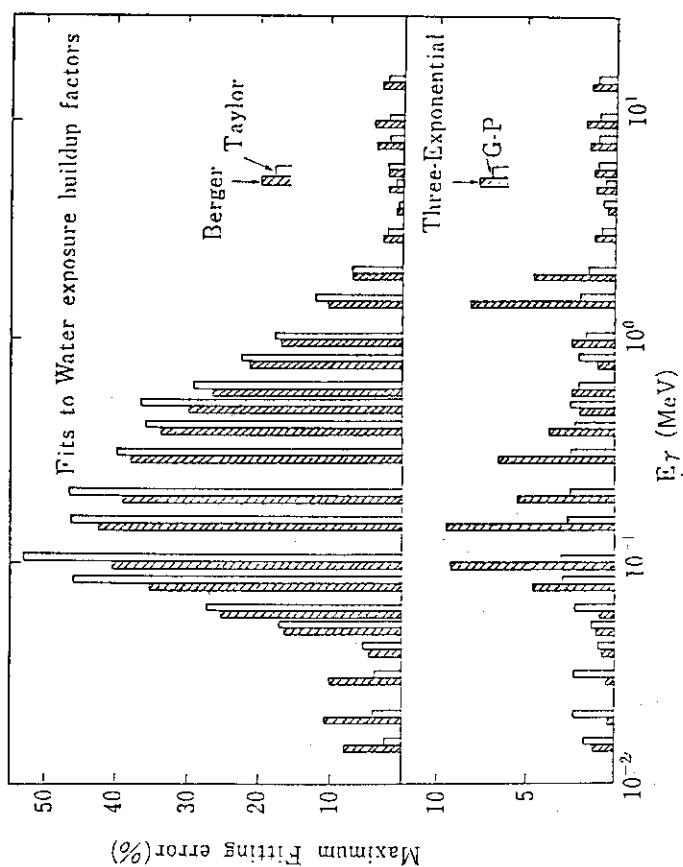


Fig. 2

Comparison of the values of the present G-P fitting parameters with those of the previous for water exposure buildup factors by the moments method

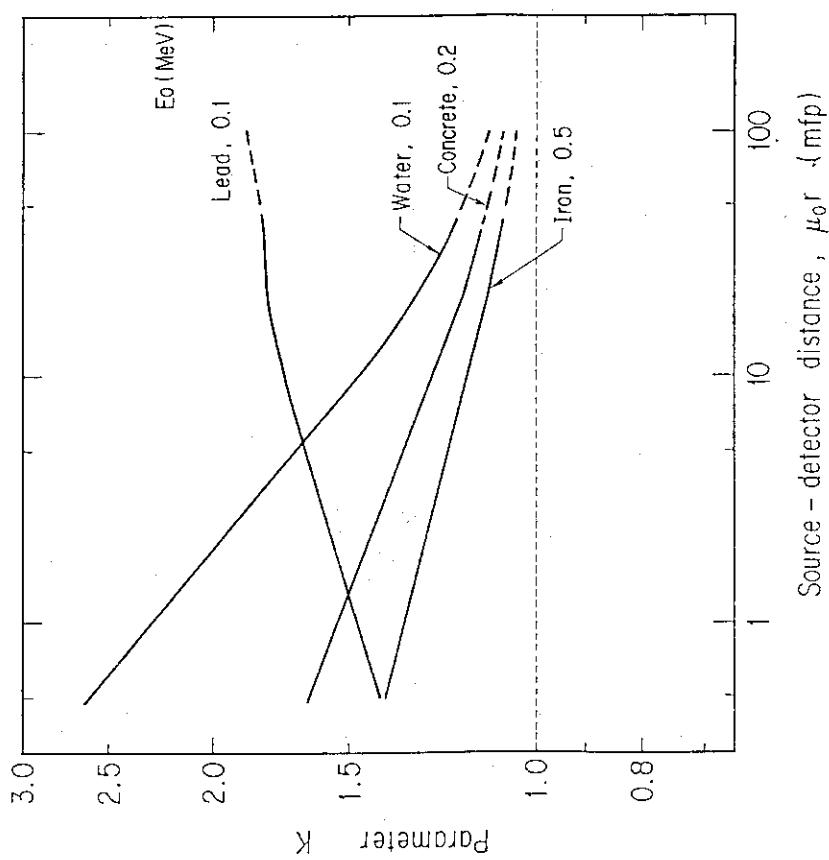


Fig. 3

Dependence of $\log K$ on $\log X$ for the exposure buildup factor, point isotropic source in water, concrete, iron and lead

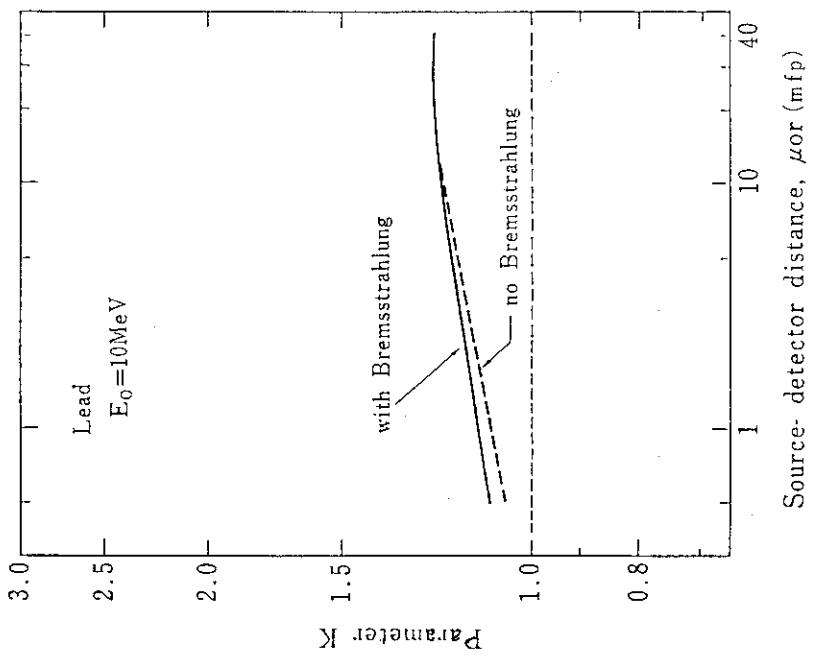


Fig. 4

Dependence of $\log K$ on $\log X$ for the exposure buildup factor in lead with or without bremsstrahlung

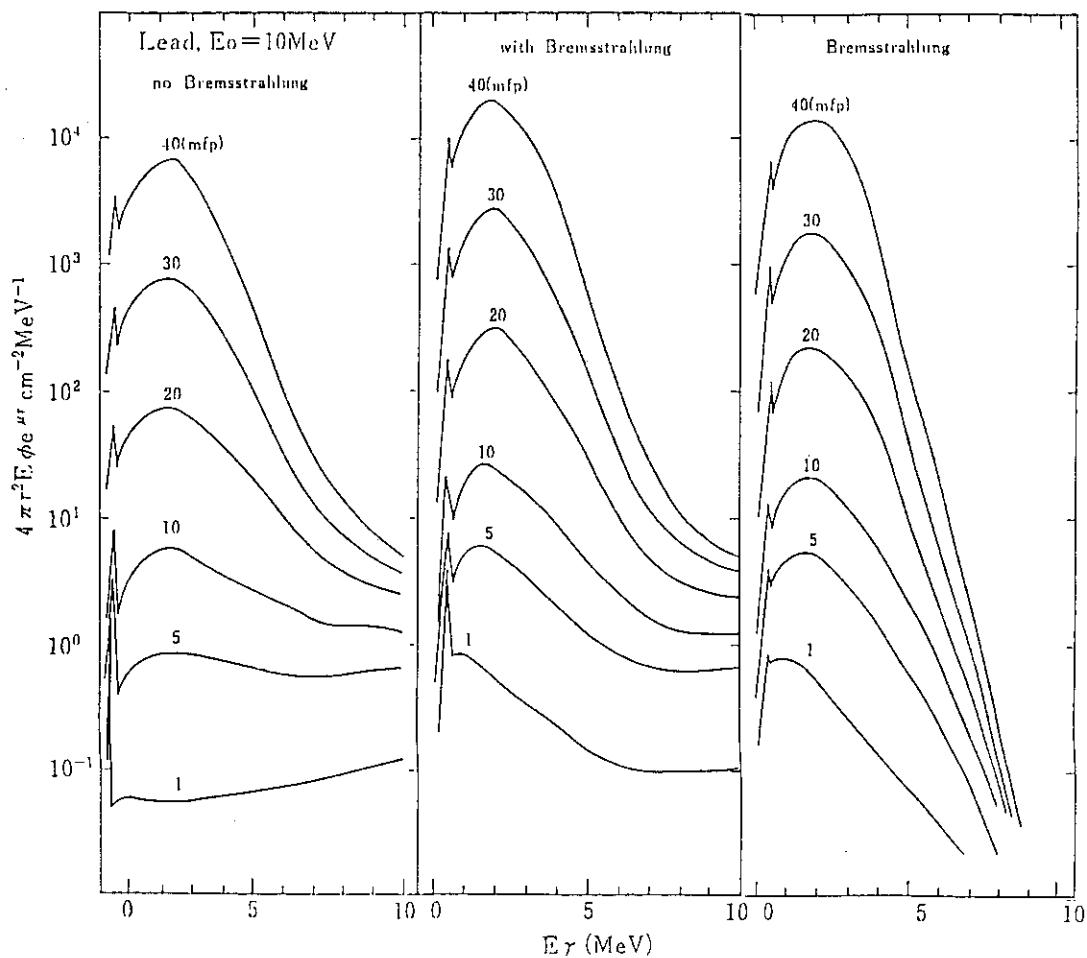


Fig. 5 Energy spectra of without Bremsstrahlung, Bremsstrahlung only, with Bremsstrahlung in lead

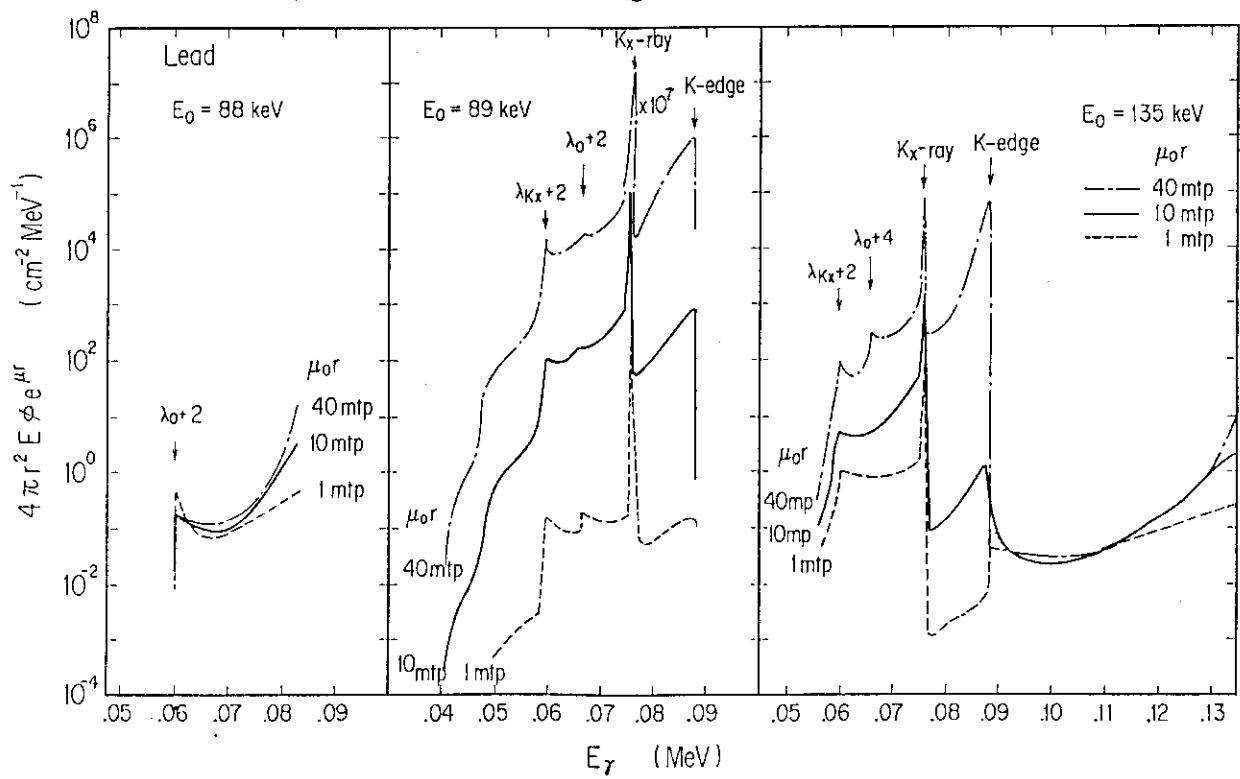


Fig. 6 Comparison of energy spectra for the source energies of 88, 89 and 135 keV in lead

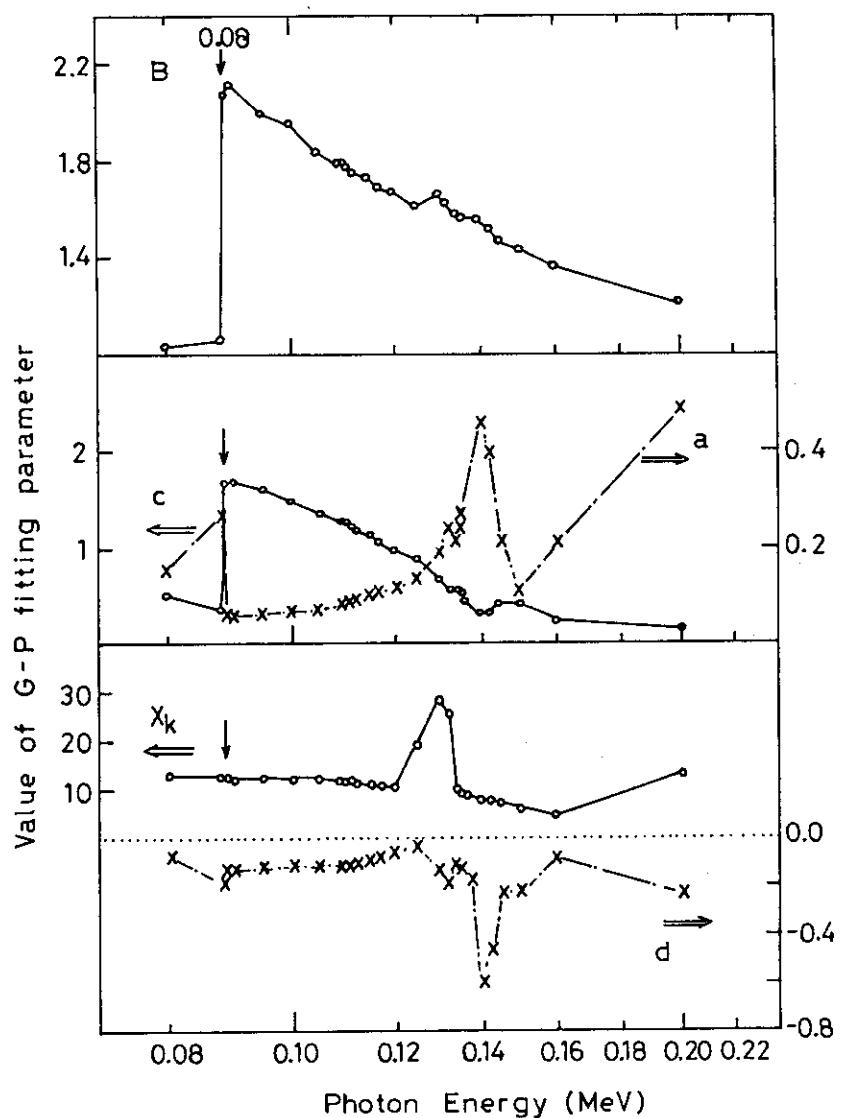


Fig. 7 The G-P fitting parameters in the energy range of 0.08 to 0.22 MeV for lead exposure buildup factors with fluorescence

Appendix A

G-P Parameters fitted to Buildup Factors calculated
by the PALLAS Code and Buildup Factors using G-P Method

TABLE A.1 G-P Parameters and Buildup Factors up to 40 MFP
- Exposure Buildup Factors in Water Medium -

PARAMETERS FOR POINT SOURCE EXPOSURE BUILDUP FACTORS UP TO 40 MFP
IN INFINITE THICK WATER AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

Exposure Buildup Factors in Infinite Thick Water

E (MeV)	B	C	A	XX	0	MAX. DEV(X) (MFP)	RMS DEV(X) (MFP)	DEVS(Z)
15	1.311	0.756	0.076	13.81	-0.0454	2.6	0.5	0.88
10	1.301	0.604	0.060	14.29	-0.0369	2.2	0.5	0.84
8	1.441	0.023	0.054	14.62	-0.0338	2.1	0.5	0.88
6	1.504	0.883	0.034	15.34	-0.0200	0.9	0.46	6.0
5	1.554	0.921	0.024	13.45	-0.0184	0.6	0.15	0.28
4	1.627	0.961	0.012	13.45	-0.0094	0.7	0.15	0.38
3	1.704	1.059	-0.014	17.91	0.0042	1.4	3	0.57
2	1.846	1.183	-0.042	15.90	0.0168	3.1	0.5	1.31
1	2.137	1.472	-0.094	13.77	0.0398	5.2	0.5	2.30
0.6	2.243	1.590	-0.112	15.66	0.0472	5.3	0.5	2.49
0.5	2.417	1.776	-0.133	13.71	0.0562	5.0	0.5	2.52
0.4	2.547	1.798	-0.140	13.79	0.0590	4.6	0.5	2.53
0.3	2.717	1.960	-0.159	13.67	0.0695	4.3	1.0	2.54
0.2	3.533	2.271	-0.165	13.83	0.0771	4.1	1.0	2.39
0.1	4.897	2.279	-0.193	13.82	0.0882	4.0	1.0	2.33
NO BREMSSSTRAHLUNG								
15	1.255	0.838	0.046	13.96	-0.0254	2.2	0.5	0.71
10	1.346	0.848	0.044	15.07	-0.0271	1.6	0.5	0.64
8	1.416	0.941	0.048	14.61	-0.0303	1.7	0.5	0.79

Exposure Buildup Factors in Infinite Thick Water (No Brems.)								
R(MFP)	15	10	8	6	5	4	3	2
0.5	1.14	1.18	1.22					
1.0	1.26	1.35	1.42					
2.0	1.40	1.65	1.78					
3.0	1.68	1.93	2.11					
4.0	1.87	2.19	2.43					
5.0	2.05	2.45	2.73					
6.0	2.22	2.69	3.03					
7.0	2.39	2.93	3.52					
8.0	2.56	3.17	3.60					
10.0	2.88	3.63	4.17					
15.0	3.67	4.78	5.60					
20.0	6.44	5.92	7.05					
25.0	5.16	7.03	8.47					
30.0	5.82	8.06	9.79					
35.0	6.45	9.02	1.11E1					
40.0	7.13	9.99	1.24E1					

TABLE A.2 G-P Parameters and Buildup Factors using G-P Method
- Absorbed Dose Buildup Factors in Water Medium -PARAMETERS FOR POINT SOURCE ABSORBED DOSE BUILDUP FACTORS UP TO 40 MeV
IN INFINITE THICK WATER AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

E (MeV)	B	C	A	χ_K	D	MAX. DEV(χ) (MFP) DEVI(X)	Absorbed Dose Buildup Factors in Infinite Thick Water					
							R(MFP)	15	10	8	6	5
15	1.319	0.755	0.076	13.96	-0.0449	2.3	0.5	0.84	1.21	1.24	1.26	1.29
10	1.397	0.803	0.060	15.05	-0.0398	2.3	0.5	0.87	1.40	1.45	1.51	1.57
8	1.453	0.818	0.057	14.05	-0.0390	2.4	0.5	0.96	1.73	1.84	1.94	2.13
6	1.508	0.891	0.031	13.58	-0.0174	0.8	1	0.47	5.0	2.19	2.03	2.24
5	1.567	0.916	0.026	13.36	-0.0206	0.5	20	0.27	6.0	2.37	2.58	2.81
4	1.631	0.956	0.014	12.57	-0.0116	0.8	0.5	0.38	7.0	2.55	2.83	3.69
3	1.700	1.062	-0.015	13.86	0.0040	1.4	3	0.62	10.0	3.05	3.19	5.62
2	1.843	1.183	-0.062	13.75	0.0168	3.0	0.5	1.32	20.0	2.31	2.52	3.87
1	2.132	1.467	-0.093	13.80	0.0394	5.1	0.5	2.20	25.0	2.37	2.84	5.01
0.8	2.235	1.579	-0.110	13.54	0.0456	5.2	0.5	2.40	30.0	6.14	7.83	11.14
0.6	2.386	1.734	-0.133	13.64	0.0569	4.8	0.5	2.48	35.0	6.79	9.44	14.47
0.5	2.512	1.795	-0.140	13.56	0.0595	4.4	0.5	2.47	40.0	7.54	10.0	15.62
0.4	2.703	1.903	-0.152	14.31	0.0626	4.9	10	2.38	R(MFP)	0.8	0.6	0.5
0.3	2.949	2.077	-0.172	13.87	0.0740	4.0	10	2.34	0.5	0.4	0.3	0.2
0.2	3.486	2.234	-0.187	13.97	0.0808	3.5	10	2.16	0.5	0.4	0.3	0.1
0.1	4.738	2.257	-0.190	13.92	0.0858	3.7	10	2.35	1.0	2.24	2.39	2.44
	NO BREMSSTRAHLUNG											
15	1.261	0.836	0.067	13.21	-0.0259	1.9	0.5	0.66	4.0	9.26	1.14E1	1.20E1
10	1.355	0.856	0.041	15.65	-0.0261	2.0	0.5	0.64	5.0	1.27E1	1.82E1	2.42E1
8	1.425	0.842	0.049	13.67	-0.0340	1.4	25	0.78	6.0	1.67E1	1.87E1	2.19E1
	R(MFP)											
0.5	1.16	1.19				1.63			0.5	1.54	1.58	1.63
1.0	1.26	1.36				1.45			1.0	2.24	2.39	2.44
2.0	1.49	1.67				1.84			2.0	4.04	4.58	5.12
3.0	1.69	1.96				2.03			3.0	6.38	7.58	8.87
4.0	1.89	2.23				2.23			4.0	7.41	8.24	9.67
5.0	2.07	2.50				2.55			5.0	8.47	9.87	11.21
6.0	2.25	2.75				2.83			6.0	9.57	11.07	12.56
7.0	2.42	3.00				3.33			7.0	10.67	12.17	13.65
8.0	2.59	3.24				3.75			8.0	11.76	13.26	14.74
10.0	2.92	3.73				4.24			10.0	13.85	15.35	16.83
15.0	3.73	4.91				5.82			15.0	21.76	24.94	28.12
20.0	4.51	6.09				7.51			20.0	34.65	38.83	43.01
25.0	5.23	7.24				9.51			25.0	47.54	52.72	57.90
30.0	5.80	8.31				11.51			30.0	59.43	64.61	69.79
35.0	6.53	9.28				13.51			35.0	71.32	76.50	81.68
40.0	7.26	1.02E1				15.51			40.0	83.21	88.39	93.57

Absorbed Dose Buildup Factors in Infinite Thick Water (No Brems.)

R(MFP)	15	10	8	Absorbed Dose Buildup Factors in Infinite Thick Water (No Brems.)						1
				ENERGY (MeV)	15	10	8	6	5	
0.5	1.16	1.19		1.22						
1.0	1.26	1.36		1.43						
2.0	1.49	1.67		1.67						
3.0	1.69	1.96		1.86						
4.0	1.89	2.23		2.03						
5.0	2.07	2.50		2.23						
6.0	2.25	2.75		2.44						
7.0	2.42	3.00		2.63						
8.0	2.59	3.24		2.83						
10.0	2.92	3.73		3.12						
15.0	3.73	4.91		4.31						
20.0	4.51	6.09		5.12						
25.0	5.23	7.24		5.82						
30.0	5.80	8.31		6.40						
35.0	6.53	9.28		7.12						
40.0	7.26	1.02E1		7.82						

TABLE A.3 G-P Parameters and Buildup Factors using G-P Method
- Dose Equivalent Buildup Factors in Water Medium -

PARAMETERS FOR POINT SOURCE DOSE EQUIVALENT BUILDUP FACTORS UP TO 40
MFP IN INFINITE THICK WATER AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

E (MeV)	B	C	A	XK	D	MAX. DEV(X)	XMAX (CMFP)	RMS (CMFP)	DEV(X)
15	1.351	0.719	0.091	13.85	-0.0566	3.0	0.5	1.11	0.19
10	1.453	0.754	0.079	14.81	-0.0527	2.7	0.5	1.19	0.16
6	1.521	0.773	0.074	13.80	-0.0507	2.3	0.5	1.17	0.15
6	1.587	0.854	0.064	13.48	-0.0272	1.4	1	0.68	0.14
5	1.659	0.892	0.034	13.40	-0.0263	0.8	0.5	0.43	0.13
4	1.737	0.937	0.020	12.86	-0.0159	1.2	0.5	0.58	0.10
3	1.840	1.045	-0.010	10.26	-0.0001	2.5	0.5	0.95	0.15
2	2.025	1.208	-0.049	13.32	0.0233	4.5	0.5	1.90	0.20
1	2.458	1.554	-0.111	13.38	0.0535	6.9	0.5	3.17	0.25
0.8	2.606	1.689	-0.131	13.29	0.0628	7.0	0.5	3.35	0.30
0.6	2.795	1.830	-0.154	13.39	0.0730	6.5	0.5	3.36	0.35
0.5	2.969	1.925	-0.161	13.46	0.0757	5.8	0.5	3.30	0.34
0.4	3.158	2.066	-0.170	13.45	0.0840	4.8	10	3.26	0.30
0.3	3.466	2.242	-0.195	13.63	0.0918	4.5	10	3.05	0.28
0.2	4.222	2.385	-0.207	13.67	0.0967	4.5	10	2.83	0.23
0.1	5.409	2.286	-0.194	13.03	0.0891	4.2	10	2.59	0.15
	NO BREMSSSTRAHLUNG								
15	1.287	0.791	0.064	13.62	-0.0395	3.1	0.5	1.00	0.02
10	1.399	0.808	0.059	14.16	-0.0370	3.0	0.5	1.03	0.02
8	1.479	0.812	0.059	13.75	-0.0391	2.0	0.5	0.97	0.02

R(CMFP)	15	10	8	ENERGY (MEV)
0.5	1.19	1.25	1.28	1.34
1.0	1.35	1.45	1.52	1.59
2.0	1.62	1.81	1.95	2.10
3.0	2.05	2.13	2.32	2.59
4.0	2.06	2.06	2.26	2.68
5.0	2.07	2.07	2.26	2.70
6.0	2.08	2.08	2.26	2.70
7.0	2.09	2.09	2.27	2.71
8.0	2.10	2.10	2.27	2.72
9.0	2.11	2.11	2.28	2.73
10.0	2.12	2.12	2.29	2.74
15.0	2.18	2.18	2.32	2.80
20.0	2.20	2.20	2.35	2.86
25.0	2.24	2.24	2.40	3.00
30.0	2.28	2.28	2.46	3.17
35.0	2.32	2.32	2.54	3.33
40.0	2.36	2.36	2.66	3.51

R(CMFP)	15	10	8	ENERGY (MEV)
0.5	1.15	1.21	1.26	1.34
1.0	1.29	1.40	1.48	1.56
2.0	1.53	1.74	1.89	1.96
3.0	1.74	2.04	2.25	2.35
4.0	1.94	2.32	2.60	2.73
5.0	2.12	2.60	2.93	3.07
6.0	2.20	2.86	3.25	3.44
7.0	2.24	3.11	3.57	3.74
8.0	2.25	3.17	3.68	3.86
10.0	2.28	3.28	3.86	4.05
15.0	2.32	3.32	4.07	4.27
20.0	2.36	3.38	4.38	4.58
25.0	2.40	3.59	4.61	4.81
30.0	2.46	3.69	4.76	4.96
35.0	2.51	3.74	4.82	5.02
40.0	2.56	3.81	4.91	5.11

TABLE A.4 G-P Parameters and Buildup Factors using G-P Method
- Exposure Buildup Factors in Concrete Medium -

PARAMETERS FOR POINT SOURCE EXPOSURE BUILDUP FACTORS UP TO 40 MF_P
IN INFINITE THICK CONCRETE AND COMPARISON TO VALUES CALCULATED
BY THE IALIAS CODE

Exposure Buildup Factors in Infinite Thick Concrete

R(MFP)	Exposure Buildup Factors in Infinite Thick Concrete									
	15	10	8	6	5	4	3	2	1	
0.5	1.18	1.21	1.24	1.26	1.29	1.34	1.37	1.45		
1.0	1.34	1.38	1.40	1.47	1.51	1.58	1.66	1.78	1.98	
2.0	1.61	1.71	1.75	1.91	2.01	2.15	2.37	2.66	3.24	
3.0	1.75	2.01	2.09	2.33	2.49	2.73	3.08	3.58	4.75	
4.0	2.07	2.29	2.42	2.75	2.97	3.30	3.80	4.58	6.50	
6.0	2.49	2.75	2.97	3.30	3.75	4.22	4.75	5.64	8.46	
8.0	2.69	3.05	3.23	3.64	4.04	4.46	5.29	6.75	1.07E1	
10	2.87	3.10	3.37	3.97	4.39	5.05	6.05	7.90	1.35E1	
15	3.16	3.56	3.97	4.38	4.87	5.64	6.83	7.10	1.57E1	
20	3.46	3.92	4.46	5.05	5.64	6.42	7.42	8.42	2.15E1	
30	4.05	4.64	5.29	6.05	6.83	7.83	8.83	9.83	1.15E1	
40	4.58	5.19	5.83	6.54	7.31	8.22	9.22	10.22	1.26E1	
60	5.31	5.92	6.77	7.56	8.37	9.07E1	1.07E1	1.26E1	2.90E1	
80	5.36	5.95	6.77	7.56	8.37	9.07E1	1.07E1	1.26E1	2.90E1	
100	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
150	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
200	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
300	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
400	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
600	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
800	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1500	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
2000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
3000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
4000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
6000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
8000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
10000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
15000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
20000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
30000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
40000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
60000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
80000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
100000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
150000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
200000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
300000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
400000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
600000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
800000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1500000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
2000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
3000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
4000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
6000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
8000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
10000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
15000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
20000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
30000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
40000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
60000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
80000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
100000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
150000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
200000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
300000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
400000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
600000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
800000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1500000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
2000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
3000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
4000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
6000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
8000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
10000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
15000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
20000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
30000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
40000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
60000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
80000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
100000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
150000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
200000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
300000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
400000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
600000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
800000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
1500000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
2000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
3000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
4000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
6000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
8000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
10000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
15000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
20000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
30000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
40000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
60000000000000	5.30	5.90	6.72	7.52	8.32E1	9.02E1	1.02E1	1.22E1	2.80E1	
80000000000000	5.30	5.90	6.72	7.52	8.32E1					

TABLE A.5 G-P Parameters and Buildup Factors using G-P Method - Absorbed Dose Buildup Factors in Concrete Medium -

BY THE PALLAS CODE									
	B	C	A	XK	D	MAX. DEV(χ)	XMAX (NFP)	RMS DEV(χ)	ENERGY (MEV)
E (MEV)									
15.	1.318	0.746	0.087	13.84	-0.0614	3.1	0.5	1.21	1.25
10.	1.390	0.791	0.071	13.32	-0.0541	2.5	1.32	1.39	1.40
8.	1.401	0.858	0.047	13.22	-0.0391	2.4	0.5	1.71	1.76
6.	1.482	0.900	0.033	13.04	-0.0300	1.7	0.5	2.00	2.00
5.	1.549	0.915	0.029	12.96	-0.0286	0.9	2.5	2.39	2.39
4.	1.610	0.966	0.014	12.88	-0.0201	0.6	0.5	2.01	2.09
3.	1.713	1.026	0.002	12.51	-0.0108	1.9	2	2.29	2.35
2.	1.849	1.151	-0.032	16.32	-0.0069	3.5	0.5	2.20	2.55
1.	2.122	1.397	-0.079	14.11	-0.0288	5.4	0.5	2.73	2.81
0.8	2.207	1.494	-0.095	13.78	-0.0363	5.0	0.5	3.04	3.04
0.6	2.461	1.551	-0.102	13.88	-0.0372	5.0	0.5	3.58	3.58
0.5	2.546	1.616	-0.111	13.67	-0.0416	5.4	0.5	4.01	4.01
0.4	2.806	1.661	-0.117	13.50	-0.0454	5.4	0.5	4.49	4.49
0.3	3.106	1.719	-0.124	13.31	-0.0488	5.5	0.5	4.97	4.97
0.2	3.741	1.654	-0.113	13.24	-0.0433	5.0	0.5	5.35	5.35
0.1	4.068	1.206	-0.037	7.09	0.0087	2.2	3	1.02	1.02
NO BREMSSSTRAHLUNG									
15.	1.226	0.858	0.048	13.17	-0.0379	2.8	0.5	1.06	1.18E1
10.	1.323	0.872	0.042	13.28	-0.0341	2.6	0.5	1.11	1.16E1
R(NFP)	0.5	1.17	1.21	1.21	1.21	1.25	1.28	1.31	1.36
	1.0	1.32	1.39	1.40	1.40	1.48	1.55	1.61	1.61
	2.0	1.57	1.71	1.76	1.76	1.93	2.06	2.21	2.24
	4.0	2.00	2.29	2.41	2.41	2.75	2.96	2.80	2.97
	5.0	2.20	2.55	2.73	2.73	3.04	3.39	3.59	3.54
	6.0	2.39	2.81	3.04	3.04	3.38	3.73	3.95	3.95
	7.0	2.58	3.07	3.34	3.34	3.73	4.12	4.49	4.49
	8.0	2.76	3.33	3.65	3.65	4.09	4.57	4.94	4.94
	10.0	3.00	3.66	4.05	4.05	4.57	5.12	5.62	5.62
	15.0	3.58	4.01	4.49	4.49	5.17	5.73	6.33	6.33
	20.0	4.06	4.57	5.17	5.17	5.97	6.62	7.34	7.34
	25.0	4.50	5.06	5.73	5.73	6.52	7.31	8.12	8.12
	30.0	4.92	5.52	6.32	6.32	7.12	7.97	8.87	8.87
	35.0	5.35	6.02	6.92	6.92	7.73	8.62	9.52	9.52
	40.0	5.78	6.42	7.32	7.32	8.12	8.97	9.87	9.87
	45.0	6.21	6.86	7.76	7.76	8.57	9.47	10.37	10.37
	50.0	6.64	7.32	8.22	8.22	9.02	9.92	10.82	10.82
	60.0	7.35	8.06	8.96	8.96	9.76	10.66	11.56	11.56
	70.0	8.03	8.76	9.66	9.66	10.46	11.36	12.26	12.26
	80.0	8.66	9.39	10.29	10.29	11.16	12.06	12.96	12.96
	90.0	9.29	10.02	10.92	10.92	11.83	12.73	13.63	13.63
	100.0	9.82	10.55	11.45	11.45	12.35	13.25	14.15	14.15
	120.0	10.35	11.08	11.98	11.98	12.88	13.78	14.68	14.68
	150.0	11.02	11.75	12.65	12.65	13.55	14.45	15.35	15.35
	180.0	11.64	12.37	13.27	13.27	14.17	15.07	15.97	15.97
	200.0	12.16	12.89	13.79	13.79	14.69	15.59	16.49	16.49
	250.0	13.02	13.75	14.65	14.65	15.55	16.45	17.35	17.35
	300.0	13.84	14.57	15.47	15.47	16.37	17.27	18.17	18.17
	350.0	14.64	15.37	16.27	16.27	17.17	18.07	18.97	18.97
	400.0	15.42	16.12	17.02	17.02	17.92	18.82	19.72	19.72
	450.0	16.18	16.92	17.82	17.82	18.72	19.62	20.52	20.52
	500.0	16.92	17.66	18.56	18.56	19.46	20.36	21.26	21.26
	600.0	17.66	18.39	19.29	19.29	20.19	21.09	21.99	21.99
	700.0	18.39	19.12	20.02	20.02	20.92	21.82	22.72	22.72
	800.0	19.12	19.85	20.75	20.75	21.65	22.55	23.45	23.45
	900.0	19.85	20.58	21.48	21.48	22.38	23.28	24.18	24.18
	1000.0	20.58	21.31	22.21	22.21	23.11	24.01	24.91	24.91
	1200.0	21.31	22.04	22.94	22.94	23.84	24.74	25.64	25.64
	1500.0	22.04	22.77	23.67	23.67	24.57	25.47	26.37	26.37
	1800.0	22.77	23.50	24.40	24.40	25.30	26.20	27.10	27.10
	2000.0	23.50	24.23	25.13	25.13	26.03	26.93	27.83	27.83
	2500.0	24.23	25.00	25.90	25.90	26.80	27.70	28.60	28.60
	3000.0	25.00	25.77	26.67	26.67	27.57	28.47	29.37	29.37
	3500.0	25.77	26.54	27.44	27.44	28.34	29.24	30.14	30.14
	4000.0	26.54	27.31	28.21	28.21	29.11	30.01	30.91	30.91
	4500.0	27.31	28.08	28.98	28.98	29.88	30.78	31.68	31.68
	5000.0	28.08	28.85	29.75	29.75	30.65	31.55	32.45	32.45
	6000.0	28.85	29.62	30.52	30.52	31.42	32.32	33.22	33.22
	7000.0	29.62	30.39	31.29	31.29	32.19	33.09	33.99	33.99
	8000.0	30.39	31.16	32.06	32.06	32.96	33.86	34.76	34.76
	9000.0	31.16	31.93	32.83	32.83	33.73	34.63	35.53	35.53
	10000.0	31.93	32.70	33.60	33.60	34.50	35.40	36.30	36.30
	12000.0	32.70	33.47	34.37	34.37	35.27	36.17	37.07	37.07
	15000.0	33.47	34.24	35.14	35.14	36.04	36.94	37.84	37.84
	20000.0	34.24	35.01	35.91	35.91	36.81	37.71	38.61	38.61
	25000.0	35.01	35.78	36.68	36.68	37.58	38.48	39.38	39.38
	30000.0	35.78	36.55	37.45	37.45	38.35	39.25	40.15	40.15
	35000.0	36.55	37.32	38.22	38.22	39.12	40.02	40.92	40.92
	40000.0	37.32	38.09	38.99	38.99	39.89	40.79	41.69	41.69
	45000.0	38.09	38.86	39.76	39.76	40.66	41.56	42.46	42.46
	50000.0	38.86	39.63	40.53	40.53	41.43	42.33	43.23	43.23
	60000.0	39.63	40.40	41.30	41.30	42.20	43.10	44.00	44.00
	70000.0	40.40	41.17	42.07	42.07	42.97	43.87	44.77	44.77
	80000.0	41.17	41.94	42.84	42.84	43.74	44.64	45.54	45.54
	90000.0	41.94	42.71	43.61	43.61	44.51	45.41	46.31	46.31
	100000.0	42.71	43.48	44.38	44.38	45.28	46.18	47.08	47.08
	120000.0	43.48	44.25	45.15	45.15	46.05	46.95	47.85	47.85
	150000.0	44.25	45.02	45.92	45.92	46.82	47.72	48.62	48.62
	200000.0	45.02	45.79	46.69	46.69	47.59	48.49	49.39	49.39
	250000.0	45.79	46.56	47.46	47.46	48.36	49.26	50.16	50.16
	300000.0	46.56	47.33	48.23	48.23	49.13	50.03	50.93	50.93
	350000.0	47.33	48.10	49.00	49.00	49.90	50.80	51.70	51.70
	400000.0	48.10	48.87	49.77	49.77	50.67	51.57	52.47	52.47
	450000.0	48.87	49.64	50.54	50.54	51.44	52.34	53.24	53.24
	500000.0	49.64	50.41	51.31	51.31	52.21	53.11	54.01	54.01
	600000.0	50.41	51.18	52.08	52.08	52.98	53.88	54.78	54.78
	700000.0	51.18	51.95	52.85	52.85	53.75	54.65	55.55	55.55
	800000.0	51.95	52.72	53.62	53.62	54.52	55.42	56.32	56.32
	900000.0	52.72	53.49	54.39	54.39	55.29	56.19	57.09	57.09
	1000000.0	53.49	54.26	55.16	55.16	56.06	56.96	57.86	57.86
	1200000.0	54.26	55.03	55.93	55.93	56.83	57.73	58.63	58.63
	1500000.0	55.03	55.80	56.70	56.70	57.60	58.50	59.40	59.40
	2000000.0	55.80	56.57	57.47	57.47	58.37	59.27	60.17	60.17
	2500000.0	56.57	57.34	58.24	58.24	59.14	60.04	60.94	60.94
	3000000.0	57.34	58.11	59.01	59.01	59.91	60.81	61.71	61.71
	3500000.0	58.11	58.88	59.78	59.78	60.68	61.58	62.48	62.48
	4000000.0	58.88	59.65	60.55	60.55	61.45	62.35	63.25	63.25
	4500000.0	59.65	60.42	61.32	61.32	62.22	63.12	64.02	64.02
	5000000.0	60.42	61.19	62.09	62.09	62.99	63.89	64.79	64.79
	6000000.0	61.19	61.96	62.86	62.86	63.76	64.66	65.56	65.56
	7000000.0	61.96	62.73	63.63	63.63	64.53	65.43	66.33	66.33
	8000000.0	62.73	63.50	64.40	64.40	65.30	66.20	67.10	67.10
	9000000.0	63.50	64.27	65.17	65.17	66.07	66.97	67.87	67.87
	10000000.0	64.27	65.04	65.94	65.94	66.84	67.74	68.64	68.64
	12000000.0	65.04	65.81	66.71	66.71	67.61	68.51	69.41	69.41
	15000000.0	65.81	66.58	67.48	67.48	68.38	69.28	70.18	70.18
	20000000.0	66.58	67.35	68.25	68.25	69.15	70.05	70.95	70.95
	25000000.0	67.35	68.12	69.02	69.02	69.92	70.82	71.72	71.72
	30000000.0	68.12	68.89	69.79	69.79	70.69	71.59	72.49	72.49
	35000000.0	68.89	69.66	70.56	70.56	71.46	72.36	73.26	73.26
	40000000.0	69.66	70.43	71.33	71.33	72.23	73.13	74.03	74.03
	45000000.0	70.43	71.20	72.10	72.10	73.00	73.		

Absorbed Dose Reduction Factors in Infinite Thick Concrete (No. Bem.-1)

R(MFP)	ENERGY (MEV)	
	15	10
0.5	1.12	1.17
1.0	1.23	1.32
2.0	1.43	1.61
3.0	1.62	1.89
4.0	1.80	2.15
5.0	1.98	2.41
6.0	2.15	2.67
7.0	2.33	2.92
8.0	2.50	3.18
10.0	2.06	3.69
15.0	3.10	5.02
20.0	4.78	6.37
25.0	5.75	7.66
30.0	6.59	8.83
35.0	7.48	9.98
40.0	8.57	1.13E1

TABLE A.6 G-P Parameters and Buildup Factors using G-P Method
- Dose Equivalent Buildup Factors in Concrete Medium -

PARAMETERS FOR POINT SOURCE DOSE EQUIVALENT BUILDUP FACTORS UP TO 40
MFP IN INFINITE THICK CONCRETE AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

E (MeV)	B	C	A	XK	D	MAX. DEV.(%)	XMAX (MFP)	RMS (MFP)	DEV.(%)
15	1.399	0.692	0.110	13.84	-0.0795	3.1	0.5	1.44	4.0
10	1.446	0.775	0.077	13.39	-0.0591	3.9	1.63	2.19	5.0
8	1.458	0.831	0.057	13.21	-0.0473	3.0	0.5	1.25	5.0
6	1.539	0.873	0.043	13.00	-0.0393	1.5	0.5	0.81	6.0
5	1.598	0.912	0.030	13.02	-0.0295	1.4	1	0.60	7.0
4	1.650	0.968	0.013	13.07	-0.0186	0.6	1	0.33	8.0
3	1.769	1.010	0.003	12.38	-0.0148	1.7	0.5	0.72	10.0
2	1.895	1.144	-0.030	23.48	0.0098	2.9	0.5	1.10	20.0
1	2.187	1.380	-0.075	14.57	0.0257	4.6	0.5	1.76	25.0
0.8	2.265	1.475	-0.091	13.97	0.0334	4.8	0.5	1.91	30.0
0.6	2.460	1.525	-0.097	13.90	0.0332	4.5	0.5	1.93	35.0
0.5	2.525	1.574	-0.103	13.86	0.0353	4.6	0.5	2.02	40.0
0.4	2.676	1.606	-0.107	13.49	0.0376	4.5	0.5	1.99	
0.3	2.835	1.632	-0.108	13.66	0.0358	4.5	0.5	1.86	
0.2	3.156	1.569	-0.097	13.22	0.0303	3.1	0.5	1.62	
0.1	3.116	1.177	-0.027	14.38	-0.0071	1.5	0.5	0.73	
	NO BREMSSSTRAHLUNG								
15	1.270	0.823	0.061	13.46	-0.0489	3.9	0.5	1.42	
10	1.367	0.857	0.047	13.27	-0.0371	3.9	0.5	1.49	

Dose Equivalent Buildup Factors in Infinite Thick Concrete									
R(MFP)	15	10	8	6	5	4	3	2	1
0.5	1.22	1.24	1.28	1.31	1.33	1.38	1.43	1.54	
1.0	1.40	1.45	1.46	1.54	1.65	1.77	1.90	2.19	
2.0	1.70	1.81	1.85	2.02	2.16	2.29	2.55	2.90	3.74
3.0	1.95	2.14	2.22	2.48	2.69	2.92	3.34	3.98	5.61
4.0	2.19	2.45	2.57	2.93	3.22	3.56	4.14	5.14	7.79
5.0	2.41	2.74	2.91	3.37	3.74	4.17	4.96	6.36	1.03E1
6.0	2.62	3.03	3.25	3.80	4.26	4.81	5.79	7.64	1.30E1
7.0	2.83	3.32	3.58	4.23	4.78	5.45	6.64	8.97	1.60E1
8.0	3.04	3.60	3.92	4.67	5.30	6.09	7.50	1.04E1	1.93E1
10.0	3.47	4.18	4.59	5.55	6.36	7.39	9.27	1.33E1	2.66E1
15.0	4.61	5.70	6.36	7.83	9.09	10.86	1.39E1	2.11E1	4.87E1
20.0	5.86	7.28	8.18	10.26	11.9E1	1.47E1	1.67E1	2.95E1	7.52E1
25.0	7.05	8.75	9.85	12.3E1	1.45E1	1.79E1	2.34E1	3.82E1	1.06E2
30.0	8.06	1.00E1	1.13E1	1.41E1	1.68E1	2.05E1	2.78E1	4.70E1	1.42E2
35.0	9.07	1.13E1	1.27E1	1.60E1	1.91E1	2.34E1	3.22E1	5.59E1	1.83E2
40.0	1.07E1	1.29E1	1.45E1	1.71E1	2.17E1	2.65E1	3.68E1	6.48E1	2.22E2

Dose Equivalent Buildup Factors in Infinite Thick Concrete (No Brems.)

Dose Equivalent Buildup Factors in Infinite Thick Concrete (No Brems.)									
R(MFP)	15	10	8	6	5	4	3	2	1
0.5	1.14	1.19							
1.0	1.27	1.37							
2.0	1.50	1.69							
3.0	1.72	2.00							
4.0	1.92	2.29							
5.0	2.12	2.58							
6.0	2.32	2.86							
7.0	2.52	3.14							
8.0	2.71	3.42							
10.0	3.12	3.98							
15.0	4.18	5.66							
20.0	5.32	6.94							
25.0	6.42	8.35							
30.0	7.40	9.63							
35.0	8.39	1.09E1							
40.0	9.62	1.24E1							

TABLE A.7 G-P Parameters and Buildup Factors up to 40 MFP
— Exposure Buildup Factors in Iron Medium —

PARAMETERS FOR POINT SOURCE EXPOSURE BUILDUP FACTORS UP TO 40 MFP
IN INFINITE THICK IRON AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

Fineure Buildup Factors in Infinite Thick Iron

E (MeV)	B	C	A	XK	D	MAX. DEV(%)	XMAX (MFP)	RMS DEV(%)	Exposure Buildup Factors in Infinite Thick Iron					
									15	10	8	6	5	4
15	1.504	0.811	0.096	14.21	-0.0984	3.3	35	2.09	1.27	1.25	1.28	1.29	1.32	1.36
10	1.469	0.814	0.088	14.07	-0.0898	3.4	1.94	1.94	1.50	1.47	1.50	1.54	1.57	1.64
8	1.500	0.812	0.088	13.82	-0.0905	3.3	0.5	1.91	1.94	1.94	2.02	2.07	2.14	2.30
6	1.535	0.859	0.066	13.42	-0.0749	3.0	0.5	1.69	7.0	2.37	2.65	2.75	2.79	3.39
5	1.554	0.910	0.044	13.31	-0.0558	2.6	0.5	1.44	7.0	3.26	3.05	3.17	3.43	4.30
4	1.573	0.967	0.024	12.98	-0.0386	1.3	5	0.90	8.0	4.27	3.74	3.60	3.92	4.43
3	1.642	1.025	0.005	12.70	-0.0239	2.0	0.5	0.94	15.0	6.19	5.43	4.38	4.53	5.36
2	1.733	1.107	-0.018	12.30	-0.0095	2.0	0.5	0.94	20.0	1.11E1	1.11E1	1.11E1	1.11E1	1.11E1
1	1.849	1.264	-0.052	14.06	-0.0136	3.4	0.5	1.53	25.0	3.21E1	2.04E1	2.04E1	2.04E1	2.04E1
0.8	1.840	1.330	-0.066	13.88	0.0197	3.4	0.5	1.54	30.0	4.09E1	2.75E1	2.75E1	2.75E1	2.75E1
0.6	1.886	1.341	-0.063	13.92	0.0143	3.4	0.5	1.50	35.0	7.21E1	3.58E1	3.58E1	3.58E1	3.58E1
0.5	1.887	1.328	-0.060	13.03	0.0126	2.7	0.5	1.37	40.0	1.12E2	4.82E1	3.84E1	3.49E1	3.61E1
0.4	1.949	1.255	-0.045	13.24	0.0051	2.1	3	1.08	R(MFP)	0.8	0.6	0.5	0.4	0.3
0.3	1.947	1.171	-0.029	16.50	-0.0019	1.6	3	0.82	R(MFP)	15	10	8	6	5
0.2	1.785	0.971	0.015	13.65	-0.0219	0.9	1	0.42	0.5	1.39	1.41	1.41	1.45	1.45
0.1	1.303	0.642	0.110	13.64	-0.0596	1.6	0.5	0.64	1.0	1.06	1.06	1.06	1.06	1.17
	NO BRENSSTRAHLUNG													
15	1.217	0.881	0.077	14.23	-0.0916	4.9	1	2.47	3.0	4.17	4.38	4.36	4.44	4.44
10	1.295	0.919	0.053	13.82	-0.0713	4.1	1	2.05	4.0	5.62	5.96	5.92	5.94	5.94
6	1.363	0.913	0.050	13.68	-0.0674	3.5	0.5	1.83	6.0	9.06	9.76	9.65	9.48	9.53
5	1.446	0.928	0.041	13.26	-0.0574	2.5	0.5	1.52	7.0	1.10E1	1.20E1	1.19E1	1.19E1	1.19E1
	0.960													
15	1.217	0.881	0.077	14.23	-0.0916	4.9	1	2.47	8.0	1.32E1	1.44E1	1.42E1	1.37E1	1.37E1
10	1.295	0.919	0.053	13.82	-0.0713	4.1	1	2.05	10.0	1.80E1	2.00E1	1.97E1	1.86E1	1.86E1
6	1.363	0.913	0.050	13.68	-0.0674	3.5	0.5	1.83	15.0	3.25E1	3.75E1	3.71E1	3.41E1	3.41E1
5	1.446	0.928	0.041	13.26	-0.0574	2.5	0.5	1.52	20.0	5.05E1	6.03E1	6.01E1	5.42E1	5.42E1
	0.960													
15	1.217	0.881	0.077	14.23	-0.0916	4.9	1	2.47	25.0	7.23E1	8.87E1	8.74E1	7.90E1	7.57E1
10	1.295	0.919	0.053	13.82	-0.0713	4.1	1	2.05	30.0	9.81E1	1.24E2	1.09E2	7.62E1	7.27E1
6	1.363	0.913	0.050	13.68	-0.0674	3.5	0.5	1.83	35.0	1.27E2	1.62E2	1.43E2	9.64E1	8.24E1
5	1.446	0.928	0.041	13.26	-0.0574	2.5	0.5	1.52	40.0	1.57E2	2.03E2	2.11E2	1.79E2	1.42E1

R(NFP)	Exposure Buildup Factors in Infinite Thick Iron (No Broms.)					
	15	10	8	6	5	4
0.5	1.11	1.15	1.19	1.23	1.25	1.25
1.0	1.22	1.30	1.36	1.45	1.49	1.49
2.0	1.42	1.58	1.71	1.87	1.97	1.97
3.0	1.62	1.86	2.05	2.30	2.45	2.45
4.0	1.84	2.16	2.40	2.74	2.95	2.95
5.0	2.08	2.47	2.77	3.19	3.46	3.46
6.0	2.33	2.81	3.16	3.66	3.99	3.99
7.0	2.62	3.17	3.57	4.15	4.55	4.55
8.0	2.93	3.56	4.01	4.67	5.13	5.13
10.0	3.69	4.45	4.99	5.81	6.38	6.38
15.0	6.65	7.47	8.11	9.55	1.01E1	1.01E1
20.0	1.20E1	1.19E1	1.23E1	1.35E1	1.45E1	1.45E1
25.0	2.06E1	1.76E1	1.72E1	1.82E1	1.92E1	1.92E1
30.0	3.27E1	2.41E1	2.35E1	2.26E1	2.38E1	2.38E1
35.0	5.00E1	3.10E1	2.74E1	2.74E1	2.86E1	2.86E1
40.0	7.95E1	4.29E1	3.54E1	3.58E1	3.60E1	3.60E1

TABLE A-8 G-P Parameters and Buildup Factors using G-P Method
- Absorbed Dose Buildup Factors in Iron Medium -

PARAMETERS FOR POINT SOURCE ABSORBED DOSE BUILDUP FACTORS UP TO 40 MFP
IN INFINITE THICK IRON AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

E (MeV)	B	C	A	XK	D	MAX- DEV(X)	RMS (MFP)	RMS DEV(X)
15	1.373	0.819	0.091	14.39	-0.0897	4.0	1	1.93
10	1.380	0.800	0.091	14.05	-0.0932	2.9	0.5	1.88
8	1.480	0.751	0.108	13.93	-0.1111	3.3	1	2.19
6	1.538	0.808	0.082	13.67	-0.0872	3.3	0.5	2.09
5	1.593	0.840	0.069	13.48	-0.0767	2.9	1	1.81
4	1.619	0.910	0.043	13.23	-0.0546	1.7	35	1.13
3	1.739	0.971	0.022	13.02	-0.0370	1.7	2	0.88
2	1.906	1.074	-0.009	13.45	-0.0127	2.4	0.5	1.09
1	2.169	1.263	-0.052	13.30	0.0140	3.7	0.5	1.82
0.8	2.223	1.326	-0.063	13.61	0.0190	4.1	0.5	1.05
0.6	2.411	1.329	-0.060	13.21	0.0119	3.7	0.5	1.69
0.5	2.563	1.287	-0.050	11.39	0.0059	2.8	0.5	1.38
0.4	2.838	1.190	-0.028	13.80	-0.0089	1.8	3	0.81
0.3	3.084	1.085	-0.005	14.09	-0.0215	1.2	3	0.57
0.2	2.800	0.829	0.064	13.66	-0.0611	3.4	0.5	1.27
0.1	1.493	0.508	0.177	13.64	-0.1074	2.6	0.5	1.08
	NO BREMSSTRÄHLUNG							
15	1.175	0.870	0.078	14.41	-0.0880	5.2	1	2.37
10	1.259	0.861	0.073	13.86	-0.0882	2.9	0.5	1.95
8	1.346	0.847	0.073	13.72	-0.0855	3.9	0.5	2.13
6	1.431	0.886	0.055	13.42	-0.085	3.3	1	1.74
5	1.500	0.909	0.045	13.37	-0.0582	2.6	1	1.57

R(MFP)	15	10	8	6	5	4	3	2	1
0.5	1.20	1.26	1.29	1.31	1.32	1.37	1.45	1.55	1.55
1.0	1.37	1.38	1.48	1.54	1.59	1.62	1.74	1.91	2.17
2.0	2.02	2.01	2.07	2.00	2.12	2.20	2.47	2.87	3.57
4.0	2.34	2.32	2.43	2.50	2.62	2.77	3.21	3.89	5.23
6.0	3.04	2.96	3.20	3.24	3.30	3.46	3.96	4.97	7.06
7.0	3.42	3.31	3.68	4.20	4.67	5.18	6.37	8.49	1.36E1
8.0	3.85	3.68	4.08	4.68	5.23	5.83	7.23	7.76	1.61E1
10.0	4.02	4.50	4.97	5.73	6.43	7.23	9.06	1.29E1	2.17E1
15.0	6.35	7.23	7.85	8.96	1.01E1	1.43E1	2.01E1	2.78E1	
20.0	1.42E1	1.12E1	1.18E1	1.31E1	1.46E1	1.62E1	2.03E1	2.86E1	5.72E1
25.0	2.31E1	1.62E1	1.66E1	1.76E1	1.76E1	2.12E1	2.64E1	3.77E1	7.97E1
30.0	3.51E1	2.17E1	2.09E1	2.17E1	2.36E1	2.58E1	3.23E1	4.70E1	1.06E1
35.0	5.17E1	2.80E1	2.56E1	2.61E1	2.81E1	3.07E1	3.84E1	5.47E1	1.33E1
40.0	7.92E1	3.77E1	3.23E1	3.43E1	3.70E1	4.57E1	6.61E1	1.60E1	

Absorbed Dose Buildup Factors in Infinite Thick Iron (No Brems.)

R(MFP)	15	10	8	6	5	4	3	2	1
0.5	1.56	1.65	1.72	1.88	2.02	1.95	1.30		
1.0	2.22	2.41	2.54	2.84	3.08	2.80	1.49		
2.0	3.78	4.21	4.46	4.98	5.34	4.36	1.78		
3.0	5.61	6.35	6.71	7.41	7.76	5.82	1.98		
4.0	7.71	8.83	9.29	1.01E1	1.04E1	7.24	2.15		
5.0	1.01E1	1.17E1	1.22E1	1.31E1	1.41E1	8.64	2.30		
6.0	1.27E1	1.48E1	1.55E1	1.64E1	1.61E1	1.00E1	2.64		
7.0	1.56E1	1.83E1	1.99E1	1.99E1	1.93E1	1.15E1	2.56		
8.0	1.87E1	2.21E1	2.30E1	2.38E1	2.26E1	1.29E1	2.68		
10.0	2.56E1	3.08E1	3.20E1	3.25E1	3.00E1	1.59E1	2.91		
15.0	4.08E1	5.86E1	6.10E1	6.03E1	5.25E1	2.43E1	3.45		
20.0	7.31E1	9.53E1	1.00E2	9.73E1	8.11E1	3.36E1	5.94		
25.0	1.05E2	1.44E2	1.51E2	1.43E2	1.31E2	4.15E2	4.32		
30.0	1.44E2	1.97E2	2.13E2	1.97E2	1.51E2	5.10E1	4.58		
35.0	1.87E2	2.81E2	2.03E2	2.59E2	1.91E2	5.89E1	6.03		
40.0	2.30E2	3.27E2	3.60E2	3.29E2	2.36E2	6.90E1	5.19		

TABLE A.9 G-P Parameters and Buildup Factors using G-P Method
- Dose Equivalent Buildup Factors in Iron Medium -

PARAMETERS FOR POINT SOURCE DOSE EQUIVALENT BUILDUP FACTORS UP TO 40
MFP IN INFINITE THICK IRON AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

Dose Equivalent Buildup Factors in Infinite Thick Iron

R(MFP)	Dose Equivalent Buildup Factors in Iron Medium									
	15	10	8	6	5	4	3	2	1	ENERGY (MeV)
0.5	1.35	1.31	1.32	1.33	1.33	1.36	1.39	1.45	1.45	1.45
1.0	1.63	1.55	1.61	1.64	1.64	1.66	1.72	1.81	1.97	1.97
2.0	2.13	2.05	2.14	2.22	2.22	2.25	2.46	2.69	3.15	3.15
3.0	2.60	2.44	2.50	2.65	2.65	2.78	3.18	3.63	4.52	4.52
4.0	3.07	2.87	2.95	3.15	3.15	3.48	3.94	4.62	6.06	6.06
5.0	3.56	3.29	3.40	3.66	3.66	3.92	4.11	4.72	5.67	7.75
6.0	4.08	3.74	3.86	4.18	4.18	4.77	5.53	6.77	9.60	9.60
7.0	4.64	4.22	4.35	4.73	4.73	5.13	5.45	6.36	7.92	1.16E1
8.0	5.25	4.75	4.86	5.30	5.30	5.77	6.15	7.24	9.11	1.37E1
9.0	5.86	6.00	6.55	7.66	7.66	9.08	1.17E1	1.84E1	1.84E1	1.84E1
10.0	6.68	7.99	9.67	12.15E1	12.15E1	1.47E1	1.47E1	1.47E1	1.47E1	1.47E1
11.0	7.51	9.47	11.33E1	1.53E1	1.53E1	1.72E1	1.72E1	2.04E1	2.66E1	4.82E1
12.0	8.34	10.44	12.77E1	1.77E1	1.77E1	2.05E1	2.05E1	2.66E1	3.50E1	6.63E1
13.0	9.17	11.57	14.25E1	2.25E1	2.25E1	2.67E1	2.67E1	3.25E1	4.76E1	8.11E1
14.0	10.00	12.74	16.63E1	3.00E1	3.00E1	3.63E1	3.63E1	4.30E1	6.76E1	11.11E1
15.0	10.83	13.96	18.96E1	3.26E1	3.26E1	3.91E1	3.91E1	4.62E1	7.07E1	11.35E1
16.0	11.66	15.21	21.22E1	3.50E1	3.50E1	4.20E1	4.20E1	5.00E1	7.50E1	11.88E1
17.0	12.49	16.46	23.53E1	3.75E1	3.75E1	4.42E1	4.42E1	5.25E1	7.75E1	12.33E1
18.0	13.32	17.71	25.84E1	4.00E1	4.00E1	4.77E1	4.77E1	5.62E1	8.12E1	12.88E1
19.0	14.15	18.95	28.15E1	4.25E1	4.25E1	5.03E1	5.03E1	5.88E1	8.47E1	13.43E1
20.0	14.98	20.19	30.46E1	4.50E1	4.50E1	5.30E1	5.30E1	6.15E1	8.92E1	14.08E1
21.0	15.81	21.43	32.77E1	4.75E1	4.75E1	5.55E1	5.55E1	6.40E1	9.57E1	14.63E1
22.0	16.64	22.67	35.08E1	5.00E1	5.00E1	5.80E1	5.80E1	6.65E1	10.32E1	15.18E1
23.0	17.47	23.91	37.39E1	5.25E1	5.25E1	6.55E1	6.55E1	7.40E1	11.17E1	16.03E1
24.0	18.30	25.15	39.70E1	5.50E1	5.50E1	7.25E1	7.25E1	8.10E1	12.02E1	16.89E1
25.0	19.13	26.39	42.01E1	5.75E1	5.75E1	7.95E1	7.95E1	8.80E1	12.87E1	17.75E1
26.0	19.96	27.63	44.32E1	6.00E1	6.00E1	8.65E1	8.65E1	9.50E1	13.72E1	18.61E1
27.0	20.79	28.87	46.63E1	6.25E1	6.25E1	9.35E1	9.35E1	10.20E1	14.57E1	19.46E1
28.0	21.62	30.10	48.94E1	6.50E1	6.50E1	10.05E1	10.05E1	10.90E1	15.90E1	20.79E1
29.0	22.45	31.34	51.25E1	6.75E1	6.75E1	10.75E1	10.75E1	11.60E1	16.60E1	21.59E1
30.0	23.28	32.57	53.56E1	7.00E1	7.00E1	11.45E1	11.45E1	12.30E1	17.30E1	22.28E1
31.0	24.11	33.81	55.87E1	7.25E1	7.25E1	12.15E1	12.15E1	13.00E1	18.00E1	23.18E1
32.0	24.94	35.04	58.18E1	7.50E1	7.50E1	12.85E1	12.85E1	13.70E1	18.70E1	24.08E1
33.0	25.77	36.27	60.49E1	7.75E1	7.75E1	13.55E1	13.55E1	14.40E1	19.40E1	24.98E1
34.0	26.60	37.51	62.80E1	8.00E1	8.00E1	14.25E1	14.25E1	15.10E1	20.10E1	25.98E1
35.0	27.43	38.74	65.11E1	8.25E1	8.25E1	15.00E1	15.00E1	15.85E1	21.85E1	26.88E1
36.0	28.26	40.00	67.42E1	8.50E1	8.50E1	15.75E1	15.75E1	16.60E1	22.60E1	27.58E1
37.0	29.09	41.23	69.73E1	8.75E1	8.75E1	16.50E1	16.50E1	17.35E1	23.35E1	28.28E1
38.0	30.92	42.47	72.04E1	9.00E1	9.00E1	17.25E1	17.25E1	18.10E1	24.10E1	28.98E1
39.0	31.75	43.70	74.35E1	9.25E1	9.25E1	18.00E1	18.00E1	18.85E1	24.85E1	29.68E1
40.0	32.58	44.94	76.66E1	9.50E1	9.50E1	18.75E1	18.75E1	19.60E1	25.50E1	30.38E1

Dose Equivalent Buildup Factors in Infinite Thick Iron (No. Branches.)

R(MFP)	Dose Equivalent Buildup Factors in Iron Medium									
	15	10	8	6	5	4	3	2	1	ENERGY (MeV)
0.5	1.14	1.18	1.22	1.26	1.29	1.33	1.39	1.45	1.45	1.45
1.0	1.26	1.35	1.42	1.50	1.56	1.62	1.72	1.82	1.97	1.97
2.0	1.49	1.66	1.81	1.96	2.09	2.25	2.42	2.61	2.99	2.99
3.0	1.72	1.97	2.18	2.38	2.55	2.89	3.15	3.70	4.37	4.37
4.0	1.95	2.30	2.56	2.95	3.37	3.89	4.46	5.11	6.84	6.84
5.0	2.20	2.63	3.09	3.67	4.37	5.17	6.11	7.44	9.82	9.82
6.0	2.47	2.99	3.46	4.11	5.01	6.07	7.27	8.74	11.44	11.44
7.0	2.77	3.38	3.80	4.59	5.67	6.87	8.16	9.65	12.44	12.44
8.0	3.10	3.80	4.26	5.11	6.26	7.45	8.74	10.23	13.03	13.03
10.0	3.90	4.75	5.30	6.15	7.35	8.62	9.91	11.66	14.46	14.46
15.0	7.09	8.05	8.67	9.82	10.97	12.12	13.37	15.12	17.87	17.87
20.0	1.30E1	1.33E1	1.36E1	1.44E1	1.51E1	1.58E1	1.65E1	1.72E1	1.78E1	1.78E1
25.0	2.26E1	1.97E1	1.86E1	1.79E1	1.71E1	1.64E1	1.54E1	1.44E1	1.30E1	1.30E1
30.0	3.58E1	2.64E1	2.11E1	1.92E1	1.71E1	1.51E1	1.31E1	1.11E1	9.50E1	9.50E1
35.0	5.45E1	3.46E1	2.90E1	2.37E1	1.99E1	1.62E1	1.28E1	1.02E1	6.40E1	6.40E1
40.0	8.80E1	4.28E1	3.20E2	2.29E2	1.98E2	1.52E2	1.12E2	8.40E1	3.61E1	3.61E1

TABLE A.10 G-P Parameters and Buildup Factors up to 40 MFP
in Infinite Thick Beryllium and Comparison to Values Calculated
- Exposure Buildup Factors in Beryllium Medium -

E (MeV)	B	C	A	XK	D	MAX. (MFP)	XMAX. (MFP)	RMS DEV(X)	Exposure Buildup Factors in Infinite Thick Beryllium					
									R(MFP)	0.3	0.2	0.15	0.1	ENERGY (MeV)
0.3	3.448	3.442	-0.304	14.20	0.1422	4.8	2.83	2.0	1.03E1	1.49E1	1.81E1	2.06E1	2.40E1	3.40E1
0.2	4.396	3.877	-0.323	14.44	0.1425	4.4	2.61	3.0	2.44E1	3.88E1	4.94E1	8.08E1	9.08E1	3.77E1
0.15	4.983	4.136	-0.331	14.43	0.1391	4.3	3.5	6.0	6.90E1	6.55E1	1.14E2	1.21E2	2.35E2	9.31E1
0.1	7.303	4.252	-0.333	14.11	0.1406	4.6	2.60	5.0	9.14E1	1.68E2	2.35E2	2.27E2	2.05E2	6.79E1
0.08	8.582	4.200	-0.328	14.01	0.1598	5.0	3.15	7.0	2.47E2	5.17E2	4.42E2	7.75E2	9.03E2	1.03E2
0.06	9.823	3.916	-0.311	13.93	0.1334	4.9	10	8.0	3.74E2	8.30E2	1.40E3	1.66E3	1.59E3	7.59E2
0.05	9.770	3.613	-0.292	14.02	0.1238	4.5	10	10.0	7.57E2	1.82E3	3.16E3	6.01E3	7.19E3	1.27E3
0.04	8.672	3.150	-0.260	14.20	0.1098	3.6	10	15.0	2.67E3	8.37E3	1.67E4	3.51E4	5.69E4	2.05E3
0.03	6.543	2.464	-0.204	14.71	0.0774	2.5	1.47	20.0	6.17E3	2.35E4	5.61E4	1.26E4	1.77E4	1.27E3
0.02	6.543	2.464	-0.204	14.71	0.0774	2.5	1.47	25.0	1.20E4	5.32E4	1.39E5	3.62E5	4.75E5	3.49E5
0.01	3.57E4	3.52E5	1.21E6	1.21E6	1.21E6	1.21E6	1.21E6	40.0	2.22E4	3.33E5	9.36E5	1.28E6	1.04E6	2.44E5
								35.0	3.82E4	2.13E5	6.82E5	2.17E6	3.09E6	1.42E6
								30.0	3.82E4	2.13E5	6.82E5	2.17E6	3.09E6	1.42E6
								25.0	1.20E4	5.32E4	1.39E5	3.62E5	4.75E5	3.49E5
								20.0	6.17E3	2.35E4	5.61E4	1.26E4	1.77E4	1.27E3
								15.0	2.67E3	8.37E3	1.67E4	3.51E4	5.69E4	2.05E3
								10.0	7.57E2	1.82E3	3.16E3	6.01E3	7.19E3	7.76E2
								8.0	3.74E2	8.30E2	2.35E3	6.01E3	7.19E3	4.92E2
								6.0	2.47E2	5.17E2	4.42E2	7.75E2	9.03E2	1.89E2
								4.0	1.20E2	2.40E2	5.10E3	1.02E4	1.53E4	2.83E2
								2.0	1.03E1	2.06E1	4.13E2	8.26E2	1.23E3	2.46E1
								1.0	5.00E0	1.00E1	2.00E2	4.00E3	6.00E4	1.00E0

TABLE A.11 G-P Parameters and Buildup Factors using G-P Method
- Absorbed Dose Buildup Factors in Beryllium Medium -

PARAMETERS FOR POINT SOURCE ABSORBED DOSE BUILDUP FACTORS UP TO 40 MFP
IN THE INFINITE THICK BERYLLIUM AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

E (MeV)	B	C	A	XK	D	Absorbed Dose Buildup Factors in Infinite Thick Beryllium						
						MAX. DEV(X)	RMS DEV(X)	0.3	0.2	0.15	0.1	0.08
0.5	2.722	2.183	-0.175	15.88	0.0592	1.5	0.81	1.67	1.79	1.81	2.02	2.13
1.0	3.098	2.416	-0.189	17.56	0.0573	1.7	0.5	2.72	3.10	3.21	3.84	4.20
2.0	3.212	2.600	-0.199	19.35	0.0582	1.6	0.5	6.05	7.55	8.22	1.77E1	1.21E1
0.15	3.842	2.783	-0.210	19.63	0.0630	2.6	0.5	3.07E1	4.66E1	5.83E1	1.42E1	1.69E1
0.1	4.196	2.877	-0.217	17.74	0.0576	2.8	0.5	6.0	4.59E1	7.40E1	9.66E1	3.32E1
0.08	4.750	2.950	-0.227	16.03	0.0689	2.0	0.5	10.0	9.17E1	1.65E2	2.70E2	3.09E2
0.06	5.186	2.923	-0.229	15.43	0.0747	2.0	0.5	15.0	1.63E2	4.90E2	8.93E2	1.36E3
0.05	5.706	2.771	-0.222	14.91	0.0771	2.0	1.3	20.0	4.76E2	1.25E3	2.20E3	4.67E3
0.04	5.682	2.348	-0.190	14.96	0.0674	1.8	1.29	25.0	1.12E3	3.43E3	7.29E3	1.69E4
0.03	5.000	9.03E3	4.66E4	1.47E5	5.12E5	8.46E5	9.37E5	40.0	2.74E4	7.96E4	2.53E5	4.05E5
									6.00E3	4.05E5	6.52E5	3.59E5
									9.03E3	4.66E4	2.53E5	1.91E5
											5.56E4	5.76E4

TABLE A.12 G-P Parameters and Buildup Factors using G-P Method
- Dose Equivalent Buildup Factors in Beryllium Medium -

PARAMETERS FOR POINT SOURCE DOSE EQUIVALENT BUILDUP FACTORS UP TO 40
MFP IN INFINITE THICK BERYLLIUM AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

E (MeV)	B	C	A	XK	D	MAX. DEV(X)	RMS DEV(X)
0.3	4.162	3.612	-0.320	13.92	0.1565	6.1	3.56
0.2	5.397	3.961	-0.151	14.18	0.1506	5.0	2.98
0.15	6.006	4.163	-0.333	14.29	0.1433	5.0	2.98
0.15	6.006	4.163	-0.327	14.12	0.1376	4.6	2.92
0.1	7.925	4.153	-0.318	14.10	0.1327	4.6	2.93
0.08	8.676	4.052	-0.318	14.10	0.1327	4.6	2.93
0.06	9.155	3.768	-0.300	14.06	0.1256	4.4	2.85
0.05	9.079	3.488	-0.282	14.15	0.1167	4.1	2.65
0.04	8.250	3.050	-0.251	14.28	0.1007	3.4	2.15
0.03	6.175	2.409	-0.198	14.74	0.0744	2.1	1.34

Dose Equivalent Buildup Factors in Infinite Thick Beryllium

R(MFP)	0.3	0.2	0.15	ENERGY (MeV)	0.1	0.08	0.06	0.05	0.04	0.03
0.5	2.01	2.36	2.53	3.11	3.36	3.59	3.64	3.50	3.24	3.05
1.0	4.16	5.40	6.01	7.93	8.68	9.16	9.08	8.25	6.18	5.01
2.0	1.33E1	1.93E1	2.25E1	3.09E1	3.41E1	3.23E1	2.49E1	1.71E1	1.18E1	1.00E1
3.0	3.27E1	5.09E1	6.18E1	8.63E1	9.35E1	9.12E1	8.27E1	6.57E1	3.57E1	3.57E1
4.0	6.80E1	1.13E2	1.45E2	2.02E2	2.17E2	1.80E2	1.30E2	6.48E1	1.30E2	1.30E2
5.0	1.27E2	2.27E2	2.93E2	4.21E2	4.51E2	4.14E2	3.50E2	2.40E2	1.08E2	1.08E2
6.0	2.17E2	4.07E2	5.51E2	8.61E2	7.71E2	6.33E2	4.11E2	1.49E2	1.49E2	1.49E2
7.0	3.48E2	6.90E2	9.69E2	1.44E3	1.54E3	1.35E3	1.04E3	6.67E2	2.52E2	2.52E2
8.0	5.20E2	1.11E3	1.61E3	2.44E3	2.61E3	2.24E3	1.74E3	1.06E3	3.61E2	3.61E2
10.0	1.07E3	2.49E3	3.69E3	6.11E3	6.56E3	5.44E3	4.06E3	2.74E3	6.80E2	6.80E2
15.0	3.72E3	1.07E4	2.01E4	3.51E4	3.86E4	3.03E4	2.09E4	9.27E3	2.51E3	2.51E3
20.0	8.46E3	3.02E4	6.46E4	1.25E5	1.43E5	1.09E5	7.69E4	3.05E4	5.79E4	5.79E4
25.0	1.64E4	6.81E4	1.64E5	3.57E5	4.23E5	3.17E5	2.37E5	7.75E4	1.20E4	1.20E4
30.0	3.08E4	1.44E5	3.83E5	9.19E5	1.13E6	8.41E5	6.99E5	1.80E5	2.32E4	2.32E4
35.0	5.32E4	2.78E5	8.09E5	2.12E6	2.71E6	2.00E6	1.44E6	2.62E5	4.17E4	4.17E4
40.0	7.66E4	4.48E5	1.43E6	4.05E6	5.37E6	3.98E6	2.21E6	6.77E5	6.73E4	6.73E4

TABLE A.15 G-P Parameters and Buildup Factors up to 40 MFP
in Infinite Thick Boron and Comparison to Values Calculated
by the PALLAS Code

PARAMETERS FOR POINT SOURCE EXPOSURE BUILDUP FACTORS UP TO 40 MFP
IN INFINITE THICK BORON AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

Exposure Buildup Factors in Infinite Thick Boron

Exposure Buildup Factors in Infinite Thick Boron									
R(MFP)									
ENERGY (MeV)									
R(MFP)	0.5	0.4	0.3	0.2	0.15	0.1	0.08	0.06	0.05
0.5	1.65	1.70	1.78	2.02	2.15	2.76	3.09	3.45	3.47
1.0	2.70	2.92	3.21	4.01	4.51	6.42	7.38	8.20	7.97
2.0	6.07	7.06	8.67	1.19E1	1.44E1	2.20E1	2.57E1	2.69E1	2.46E1
3.0	1.15E1	1.41E1	1.82E1	2.77E1	3.53E1	5.53E1	6.32E1	6.44E1	5.55E1
4.0	1.92E1	2.49E1	3.41E1	5.55E1	7.41E1	1.18E2	1.34E2	1.31E2	1.07E2
5.0	2.99E1	4.04E1	5.83E1	1.01E2	1.40E2	2.27E2	2.54E2	2.40E2	1.88E2
6.0	4.36E1	6.13E1	9.30E1	1.69E2	2.46E2	4.04E2	4.47E2	4.08E2	3.07E2
7.0	6.08E1	8.84E1	1.41E2	2.47E2	4.03E2	6.73E2	7.40E2	6.56E2	6.76E2
8.0	8.17E1	1.23E2	2.03E2	4.04E2	6.32E2	1.07E3	1.16E3	1.01E3	7.05E2
10.0	1.35E2	2.13E2	3.81E2	8.20E2	1.18E3	2.39E3	2.56E3	2.11E3	1.40E3
15.0	3.29E2	5.75E2	1.19E3	3.03E3	5.48E3	1.09E4	1.14E4	1.16E4	5.08E3
20.0	6.07E2	1.13E3	2.62E3	7.55E3	1.66E4	3.28E4	3.37E4	3.45E4	1.31E4
25.0	1.01E3	1.98E3	4.99E3	1.59E4	3.80E4	8.21E4	8.38E4	5.91E4	2.91E4
30.0	1.63E3	3.34E3	9.06E3	3.15E4	8.31E4	1.91E5	1.95E5	1.34E5	6.10E4
35.0	2.45E3	5.25E3	1.53E4	5.78E4	1.64E5	4.06E5	4.09E5	2.77E5	1.18E5
40.0	3.20E3	7.13E3	2.23E4	9.06E4	2.74E5	7.19E5	7.42E5	4.82E5	1.97E5

Exposure Buildup Factors in Infinite Thick Boron

Exposure Buildup Factors in Infinite Thick Boron									
R(MFP)									
ENERGY (MeV)									
R(MFP)	0.04	0.03							
0.08	7.575	3.426	0.1283	4.9	10	2.93	1.09E3	1.14E4	5.08E3
0.06	8.199	3.127	-0.2107	13.89	3.08	15.0	3.29E2	3.37E4	1.31E4
0.05	7.960	2.813	-0.2265	13.85	4.7	35	3.01	2.62E3	7.55E3
0.04	6.765	2.355	-0.241	14.03	4.0	10	2.66	1.01E3	1.98E3
0.03	4.720	1.711	-0.126	14.56	0.0529	1.8	10	1.11	9.06E4

TABLE A-14 G-P Parameters and Buildup Factors using G-P Method
- Absorbed Dose Buildup Factors in Boron Medium -

PARAMETERS FOR POINT SOURCE ABSORBED DOSE BUILDUP FACTORS UP TO 40 MFP IN INFINITE THICK BORON AND COMPARISON TO VALUES CALCULATED BY THE PALLAS CODE										Absorbed Dose Buildup Factors in Infinite Thick Boron									
										ENERGY (MEV)									
R(MFP)	0.5	0.4	0.3	0.2	0.15	0.1	0.08	0.06	0.05	R(MFP)	0.5	0.4	0.3	0.2	0.15	0.1	0.08	0.06	0.05
E (MeV)	B	C	A	KK	D	MAX	XMAX	RMS	DEV(X)	R(MFP)	0.5	1.58	1.63	1.68	1.81	2.10	2.24	2.48	2.67
										1.0	2.41	2.57	2.74	3.16	3.32	4.07	4.45	5.11	5.52
										2.0	4.76	5.36	6.08	7.64	8.47	1.12E1	1.26E1	1.46E1	1.55E1
										3.0	8.12	9.53	1.14E1	1.78E1	2.6E1	2.79E1	3.22E1	3.31E1	3.31E1
										4.0	1.26E1	1.53E1	1.93E1	2.73E1	3.31E1	4.75E1	5.40E1	6.17E1	6.17E1
										5.0	1.83E1	2.30E1	3.02E1	4.49E1	5.69E1	8.40E1	9.58E1	1.08E2	1.05E2
										6.0	2.54E1	3.29E1	4.48E1	6.98E1	9.21E1	1.40E2	1.59E2	1.77E2	1.77E2
										7.0	3.40E1	4.50E1	6.37E1	1.04E2	1.42E2	2.21E2	2.52E2	2.76E2	2.53E2
										8.0	4.40E1	5.98E1	8.77E1	1.49E2	2.11E2	3.35E2	3.83E2	4.14E2	3.69E2
										10.0	6.89E1	9.76E1	1.53E2	2.80E2	4.26E2	7.04E2	8.03E2	8.44E2	7.15E2
										15.0	1.60E2	2.46E2	4.16E2	9.50E2	1.67E3	3.44E3	3.39E3	3.39E3	2.57E3
										20.0	2.93E2	4.79E2	9.57E3	2.35E3	6.73E3	9.22E3	1.03E4	9.67E3	6.67E3
										25.0	4.80E2	8.24E2	1.80E3	4.86E3	1.09E4	2.29E4	2.54E4	2.31E4	1.48E4
										30.0	7.48E2	1.34E3	3.13E3	9.19E3	2.23E4	5.11E4	5.63E4	5.07E4	3.04E4
										35.0	1.09E3	2.04E3	5.10E3	1.62E4	4.26E4	1.05E5	1.15E5	1.03E5	5.81E4
										40.0	1.45E3	2.81E3	7.51E3	2.62E4	7.32E4	1.94E5	2.10E5	1.84E5	9.84E4
											R(MFP)	0.04	0.03	ENERGY (MEV)					
											0.5	2.76	2.50						
											1.0	5.56	4.54						
											2.0	1.45E1	1.01E1						
											3.0	2.91E1	1.75E1						
											4.0	5.08E1	2.72E1						
											5.0	8.15E1	3.91E1						
											6.0	1.23E2	5.33E1						
											7.0	1.70E2	7.02E1						
											8.0	2.47E2	8.96E1						
											10.0	4.39E2	1.36E2						
											15.0	1.32E3	3.00E2						
											20.0	2.94E3	5.31E2						
											25.0	5.84E3	0.46E2						
											30.0	1.09E4	1.28E3						
											35.0	1.86E4	1.85E3						
											40.0	2.89E4	2.42E3						

TABLE A-15 G-P Parameters and Buildup Factors up to 40 MeV in Infinite Thick Boron and Comparison to Values Calculated by the PALLAS Code

PARAMETERS FOR POINT SOURCE DOSE EQUIVALENT BUILDUP FACTORS UP TO 40 MeV IN INFINITE THICK BORON AND COMPARISON TO VALUES CALCULATED BY THE PALLAS CODE

Dose Equivalent Buildup Factors in Infinite Thick Boron									
Buildup Factors in Infinite Thick Boron									
R (CMFP)	0.5	0.4	0.3	0.2	0.15	0.1	0.08	0.06	0.05
E (MeV)	B	C	A	KK	D	MAX.	XMAX	RMS	ENERGY (MeV)
				DEV(X)	(CMFP)	DEV(X)			
0.5	3.234	2.489	-0.234	15.37	0.1234	7.3	10	4.34	1.88
0.6	3.471	2.736	-0.255	13.58	0.1311	6.9	10	4.05	3.83
0.7	3.827	3.032	-0.275	13.76	0.1354	5.9	10	3.52	3.47
0.8	4.912	3.301	-0.289	13.97	0.1358	4.9	10	3.15	2.96
0.9	5.434	3.497	-0.296	14.06	0.1318	4.6	10	3.00	2.76E1
1.0	7.065	3.463	-0.289	13.99	0.1288	4.6	10	3.01	2.76E1
1.1	7.551	3.343	-0.280	14.00	0.1236	4.8	10	2.95	2.76E1
1.2	7.764	3.042	-0.257	13.99	0.1146	4.5	10	2.83	2.76E1
1.3	7.536	2.745	-0.254	14.04	0.1054	4.0	10	2.57	2.76E1
1.4	6.520	2.306	-0.194	14.10	0.0831	3.2	10	1.91	2.76E1
1.5	6.535	1.683	-0.121	14.06	0.0697	1.7	1	0.97	2.76E1
1.6	5.00E3	4.00E3	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
1.7	4.00E3	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
1.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
1.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
2.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
3.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
4.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
5.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
6.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
7.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
8.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.7	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.8	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
9.9	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
10.0	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
10.1	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
10.2	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
10.3	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
10.4	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
10.5	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.97	2.76E1
10.6	3.22E5	3.22E5	-0.0697	14.00	0.0697	1.7	1	0.9	

TABLE A.16 G-P Parameters and Buildup Factors using G-P Method
— Exposure Buildup Factors in Lead Medium —

PARAMETERS FOR POINT SOURCE EXPOSURE BUILDUP FACTORS UP TO 40 MFP
IN INFINITE THICK LEAD AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

Exposure Buildup Factors in Infinite Thick Lead						
E (MeV)	B	C	A	XK	D	MAX. DEV(%) (MFP)
15	1.548	1.287	0.024	13.50	-0.0571	4.7
10	1.448	1.121	0.036	13.98	-0.0599	5.5
8	1.424	0.968	0.068	13.98	-0.0874	4.2
6	1.377	0.941	0.062	14.14	-0.0795	5.3
5	1.361	0.956	0.051	13.95	-0.0709	5.3
4	1.378	0.954	0.042	14.04	-0.0603	4.6
3	1.371	0.967	0.028	13.46	-0.0451	3.4
2	1.388	0.939	0.024	13.33	-0.0266	1.0
1	1.318	0.860	0.035	16.49	-0.0154	0.7
0.8	1.283	0.800	0.050	15.20	-0.0191	0.9
0.6	1.228	0.744	0.064	14.47	-0.0184	0.9
0.5	1.179	0.725	0.072	14.89	-0.0244	0.7
0.4	1.155	0.670	0.085	19.56	-0.0325	0.5
NO BREMSSTRAHLUNG						
15	1.092	1.044	0.086	14.94	-0.1088	5.9
10	1.134	1.092	0.045	16.63	-0.0670	5.7
8	1.174	1.086	0.036	14.46	-0.0572	5.6
6	1.225	1.072	0.025	13.90	-0.0531	5.0
5	1.253	1.081	0.015	13.74	-0.0442	4.7
4	1.311	1.028	0.020	13.88	-0.0439	3.8
R(MFP)						
0.5	1.26	1.22	1.22	1.19	1.19	1.20
1.0	1.55	1.45	1.42	1.38	1.38	1.39
2.0	2.27	1.96	1.75	1.74	1.74	1.60
3.0	3.23	2.58	2.33	2.11	2.11	1.86
4.0	4.54	3.33	2.86	2.54	2.54	2.10
5.0	6.32	4.25	3.48	2.94	2.94	2.33
6.0	0.76	5.39	4.20	3.56	3.56	3.21
7.0	1.21E1	6.80	5.05	4.16	4.16	3.58
8.0	1.68E1	8.56	6.06	4.84	4.84	3.97
10.0	3.20E1	8.71	6.49	6.02	6.02	4.72
15.0	1.35E1	8.71	6.49	6.02	6.02	3.36
20.0	4.20E1	7.92	6.28	6.28	6.28	4.29
25.0	7.91E2	5.40E1	5.68E1	5.11E1	5.11E1	5.17
30.0	3.68E3	3.76E2	5.27E2	5.05E1	5.05E1	6.01
35.0	1.61E4	1.03E3	2.79E2	8.85E1	8.85E1	6.79
40.0	6.89E4	2.76E3	5.94E2	1.50E2	1.50E2	7.52
45.0	3.04E5	7.59E3	1.53E3	6.42E2	6.42E2	8.71
R(MFP)						
0.5	1.15	1.12	1.10	1.08	1.08	1.08
1.0	1.28	1.23	1.18	1.14	1.14	1.14
2.0	1.52	1.41	1.32	1.23	1.23	1.23
3.0	1.73	1.56	1.43	1.31	1.31	1.31
4.0	1.91	1.69	1.53	1.37	1.37	1.37
5.0	2.09	1.80	1.62	1.43	1.43	1.43
7.0	2.40	2.01	1.78	1.52	1.52	1.52
10.0	2.55	2.10	1.85	1.56	1.56	1.56
15.0	2.82	2.27	1.98	1.63	1.63	1.63
20.0	3.44	2.65	2.26	1.79	1.79	1.79
25.0	4.50	3.25	2.74	2.04	2.04	2.04
30.0	4.93	3.50	2.94	2.15	2.15	2.15
35.0	5.35	3.74	3.13	2.25	2.25	2.25
40.0	5.75	3.98	3.31	2.33	2.33	2.33

Exposure Buildup Factors in Infinite Thick Lead (No Broms.)

Exposure Buildup Factors in Infinite Thick Lead (No Broms.)						
R(MFP)	15	10	8	6	5	4
0.5	1.05	1.07	1.09	1.11	1.13	1.16
1.0	1.09	1.13	1.17	1.23	1.25	1.31
2.0	1.19	1.29	1.47	1.53	1.53	1.64
3.0	1.32	1.46	1.59	1.75	1.84	1.98
4.0	1.48	1.68	1.85	2.06	2.18	2.35
5.0	1.68	1.95	2.17	2.42	2.57	2.76
6.0	1.95	2.27	2.54	2.83	3.00	3.19
7.0	2.30	2.68	2.98	3.30	3.49	3.67
8.0	2.77	3.19	3.51	3.84	4.04	4.19
10.0	4.29	4.62	4.93	5.20	5.37	5.38
15.0	1.68E1	1.30E1	1.20E1	1.09E1	1.05E1	9.44
20.0	7.79E1	3.97E1	2.22E1	1.93E1	1.54E1	1.54E1
25.0	3.87E2	1.19E2	6.27E1	3.31E1	2.35E1	2.35E1
30.0	1.77E3	3.41E2	1.66E2	7.64E1	5.33E1	3.33E1
35.0	7.73E3	9.41E2	3.66E2	1.32E2	8.22E1	4.54E1
40.0	3.51E4	2.65E3	8.19E2	2.32E2	1.28E2	6.21E1

TABLE A.17 G-P Parameters and Buildup Factors using G-P Method

- Absorbed Dose Buildup Factors in Lead Medium -

PARAMETERS FOR POINT SOURCE ABSORBED DOSE BUILDUP FACTORS UP TO 40 MFP
IN INFINITE THICK LEAD AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

E (MeV)	B	C	A	χK	D	MAX. DEV(X)	X _{MAX} (MFP)	RMS DEV(X)	ENERGY (MeV)					
									15	10	8	6	5	4
15	1.404	1.124	0.065	13.91	-0.0991	9.2	0.5	3.79	2.0	1.22	1.24	1.29	1.34	1.31
10	1.424	0.940	0.090	14.20	-0.1121	10.4	0.5	3.92	2.0	1.41	1.44	1.50	1.53	1.58
8	1.443	0.808	0.123	14.30	-0.1385	10.9	0.5	4.15	2.0	2.48	2.23	2.35	2.53	2.05
6	1.497	0.721	0.139	14.19	-0.1578	11.5	0.5	4.26	4.0	3.26	2.87	2.27	2.50	2.45
5	1.530	0.722	0.139	14.19	-0.1526	12.1	0.5	4.36	6.0	5.0	4.29	2.66	2.75	2.72
4	1.612	0.706	0.137	14.11	-0.1471	11.3	0.5	4.14	10.0	5.0	5.0	3.51	2.96	2.94
3	1.575	0.778	0.096	13.78	-0.1032	8.4	0.5	3.06	15.0	6.0E1	2.03E1	1.17E1	1.64E1	1.12E1
2	1.670	0.785	0.079	13.58	-0.0696	4.2	0.5	1.66	20.0	4.28E2	0.63E1	4.04E1	2.46E1	1.40E1
1	1.589	0.744	0.076	14.76	-0.0406	0.8	10	0.53	30.0	2.00E3	2.53E2	9.51E1	4.59E1	2.72E1
0.8	1.533	0.682	0.094	14.43	-0.0455	0.9	10	0.53	35.0	8.62E3	6.82E2	7.70E1	5.55E1	3.74E1
0.6	1.424	0.621	0.113	13.77	-0.0478	0.7	0.5	0.42	40.0	1.62E5	1.79E3	1.63E4	1.27E2	0.23E1
0.5	1.532	0.590	0.127	14.62	-0.0572	0.9	1	0.52				6.93E1	2.07E1	1.05E1
0.4	1.237	0.552	0.136	15.25	-0.0504	1.0	0.5	0.43				6.96E1	2.33E1	1.16E1
NO BREMSTRAULUNG														
15	1.094	0.857	0.149	15.15	-0.1690	8.1	1	3.53	0.5	1.30	1.24	1.19	1.14	
10	1.152	0.871	0.112	14.84	-0.1269	10.0	0.5	3.57	1.0	1.53	1.42	1.33	1.24	
8	1.200	0.861	0.105	14.49	-0.1231	10.1	0.5	3.73	2.0	1.92	1.71	1.55	1.38	
6	1.276	0.857	0.094	14.15	-0.1150	11.2	0.5	3.84	3.0	2.24	1.93	1.71	1.47	
5	1.343	0.840	0.094	13.96	-0.1155	10.5	0.5	3.79	4.0	2.52	2.12	1.85	1.57	
4	1.482	0.741	0.125	13.87	-0.1433	7.7	0.5	3.78	5.0	2.77	2.28	1.96	1.66	
									6.0	3.00	2.42	2.07	1.70	
									7.0	3.21	2.56	2.16	1.75	
									8.0	3.41	2.68	2.25	1.80	
									10.0	3.80	2.91	2.42	1.89	
									15.0	4.68	3.43	2.80	2.09	
									20.0	5.50	3.88	3.15	2.26	
									25.0	6.22	4.26	3.44	2.41	
									30.0	6.82	4.57	3.69	2.54	
									35.0	7.37	4.87	3.91	2.65	
									40.0	7.98	5.23	4.16	2.76	

R(MFP)	Absorbed Dose Buildup Factors in Infinite Thick Lead (No Brem.)					
	15	10	8	6	5	4
0.5	1.05	1.08	1.11	1.15	1.18	1.27
1.0	1.09	1.15	1.20	1.20	1.34	1.48
2.0	1.18	1.30	1.39	1.53	1.65	1.87
3.0	1.28	1.45	1.58	1.79	1.96	2.24
4.0	1.39	1.62	1.79	2.06	2.28	2.61
5.0	1.53	1.83	2.04	2.37	2.63	2.99
6.0	1.71	2.07	2.32	2.71	3.01	3.59
7.0	1.93	2.36	2.64	3.09	3.44	3.83
8.0	2.22	2.71	3.03	3.52	3.91	4.31
10.0	3.12	3.68	4.04	4.60	5.06	5.41
15.0	1.02E1	9.27	9.12	9.60	9.44	
20.0	4.51E1	2.71E1	1.08E1	1.23E1	1.48E1	
25.0	2.15E2	8.07E1	5.38E1	3.60E1	3.10E1	4.46E1
30.0	9.60E2	2.26E2	1.20E2	6.32E1	4.07E1	3.39E1
35.0	4.10E3	6.08E2	2.57E2	1.07E2	7.36E1	4.48E1
40.0	1.07E4	1.73E3	5.88E2	1.91E2	1.18E2	6.38E1

TABLE A.18 G-P Parameters and Buildup Factors using G-P Method
- Dose Equivalent Buildup Factors in Lead Medium -

PARAMETERS FOR POINT SOURCE DOSE EQUIVALENT BUILDUP FACTORS UP TO 40
MFP IN INFINITE THICK LEAD AND COMPARISON TO VALUES CALCULATED
BY THE PALLAS CODE

Dose Equivalent Buildup Factors in Infinite Thick Lead						
Buildup Factors in Lead Medium						
Dose Equivalent Buildup Factors in Lead Medium						
						Energy (MeV)
R(MFP)	15	10	8	6	5	4
E (MeV)	B	C	A	XK	D	MAX. XMAX DEV(X) (MFP) DEV(Z)
0.5	1.29	1.25	1.23	1.20	1.21	1.21
1.0	1.61	1.51	1.46	1.40	1.30	1.40
2.0	2.41	2.08	1.92	1.85	1.79	1.78
3.0	3.47	2.76	2.43	2.25	2.18	2.16
4.0	4.90	3.57	2.69	2.00	1.61	2.16
5.0	6.85	4.56	3.67	2.69	2.00	2.53
6.0	9.51	5.79	4.44	3.69	3.04	2.95
7.0	1.32E1	7.30	5.35	4.29	3.38	3.27
8.0	1.02E1	9.19	6.43	4.16	4.02	2.62
9.0	3.48E1	4.97	4.80	4.58	4.31	2.84
10.0	1.45E1	10.0	6.43	4.03	3.05	3.05
15.0	1.38E1	9.27	6.64	5.34	4.82	3.46
20.0	1.02E1	2.32E1	2.32E1	1.21E1	1.02E1	4.42
30.0	8.66E2	1.40E2	5.76E1	2.82E1	2.24E1	9.08
40.0	4.04E3	4.11E2	1.36E2	5.40E1	2.54E1	5.33
50.0	3.00E4	1.76E6	1.13E6	1.62E1	1.13E1	6.20
60.0	7.57E4	2.98E2	9.38E1	6.08E1	3.57E1	1.33E1
70.0	3.00E3	6.73E2	1.57E2	2.25E1	2.25E1	7.01
80.0	7.57E1	4.29E1	2.57E1	1.57E1	1.57E1	7.01
90.0	3.15E1	3.15E1	3.15E1	3.15E1	3.15E1	3.15E1
100.0	6.45E2	1.45E2	1.45E2	1.45E2	1.45E2	1.45E2
150.0	1.00E3	6.29E3	1.41E3	2.82E2	1.45E2	1.45E2
200.0	3.35E5	1.77E5	1.77E5	1.77E5	1.77E5	1.77E5
300.0	1.00E6	3.33E6	3.33E6	3.33E6	3.33E6	3.33E6
400.0	3.00E7	1.00E7	1.00E7	1.00E7	1.00E7	1.00E7
Dose Equivalent Buildup Factors in Infinite Thick Lead (No Brems.)						
R(MFP)	15	10	8	6	5	4
0.5	1.06	1.08	1.10	1.12	1.14	1.16
1.0	1.11	1.15	1.19	1.24	1.26	1.33
2.0	1.22	1.32	1.40	1.50	1.58	1.66
3.0	1.36	1.52	1.64	1.79	1.90	2.02
4.0	1.53	1.75	1.91	2.11	2.26	2.40
5.0	1.75	2.04	2.24	2.49	2.67	2.82
6.0	2.03	2.39	2.63	2.92	3.12	3.27
7.0	2.41	2.82	3.09	3.41	3.64	3.75
8.0	2.92	3.36	3.65	3.98	4.21	4.29
10.0	4.53	4.89	5.14	5.39	5.60	5.80
15.0	1.00E1	1.39E1	1.27E1	1.14E1	1.10E1	9.68
20.0	6.72E1	1.30E2	7.79E1	4.47E1	3.51E1	1.59E1
30.0	1.94E3	3.70E2	1.78E2	8.09E1	5.63E1	3.43E1
35.0	6.42E3	1.02E3	3.93E2	1.39E2	8.70E1	4.67E1
40.0	3.87E4	2.89E3	8.87E2	2.43E2	1.37E2	6.39E1

Appendix B

Buildup Factor Data calculated by the PALLAS Code

TABLE B.1 Buildup Factor Data calculated by PALLAS Code
- Beryllium Medium -

Exposure Buildup Factors in Infinite Thick Beryllium										Dose Equivalent Buildup Factors in Infinite Thick Beryllium									
R(MFP)	0.3	0.2	0.15	0.1	0.08	0.06	0.05	0.04	0.03	R(MFP)	0.3	0.2	0.15	0.1	0.08	0.06	0.05	0.04	0.03
9.5	1.79	2.07	2.19	2.83	3.21	3.54	3.05	0.5	1.97	2.33	2.47	3.04	3.28	3.48	3.55	3.44	2.94		
1.0	3.35	6.27	6.84	7.06	8.32	9.53	9.50	0.47	6.41	4.00	5.22	5.81	7.71	8.41	8.05	8.05	6.07		
1.01E1	1.446E1	1.779E1	2.866E1	3.435E1	3.818E1	3.606E1	2.906E1	1.93E1	1.91E1	1.32E1	1.91E1	2.24E1	3.10E1	3.38E1	3.44E1	3.25E1	1.70E1		
2.45E1	3.90E1	5.01E1	3.29E1	9.92E1	1.06E2	9.60E1	7.10E1	3.94E1	3.05E1	5.20E1	6.32E1	8.88E1	9.61E1	9.40E1	8.50E1	3.60E1			
5.12E1	8.79E1	1.17E2	1.28E2	2.36E2	2.45E2	2.13E2	7.10E1	7.08E1	7.17E2	1.17E2	2.10E2	2.26E2	2.12E2	1.86E2	1.34E2	6.76E1			
9.43E1	1.74E2	2.44E2	4.16E2	4.94E2	4.97E2	4.18E2	2.76E2	1.22E2	5.0	1.32E2	2.33E2	3.03E2	4.36E2	4.66E2	4.28E2	3.61E2	2.46E2	1.10E2	
6.0	1.59E2	3.11E2	4.10E2	7.87E2	9.31E2	9.13E2	7.45E2	1.91E2	1.91E2	6.0	2.22E2	4.15E2	5.60E2	6.17E2	6.39E2	4.15E2	1.70E2		
2.50E2	5.23E2	7.86E2	1.40E3	1.65E3	1.59E3	1.42E3	7.59E2	2.46E2	2.46E2	7.0	3.50E2	6.94E2	9.73E2	1.44E3	1.74E3	2.17E2	2.18E2		
3.72E2	8.27E2	1.29E3	2.34E3	2.77E3	2.61E3	2.03E3	1.17E3	4.07E2	8.0	5.21E2	1.09E3	1.59E3	2.40E3	2.56E3	2.20E3	1.72E3	1.02E3	3.59E2	
10.0	7.25E2	1.81E3	3.06E3	5.75E3	6.06E3	6.24E3	6.65E3	2.50E3	7.60E2	10.0	1.01E3	2.38E3	3.72E3	5.84E3	6.27E3	5.21E3	3.90E3	2.17E3	
15.0	2.55E3	6.02E3	1.60E4	3.37E4	4.13E4	4.13E4	3.44E4	1.05E4	1.93E4	15.0	3.55E3	1.05E4	1.93E4	3.37E4	3.72E4	2.92E4	2.02E4	9.71E3	
29.0	6.26E3	2.37E4	5.40E4	1.29E5	1.63E5	1.36E5	8.79E4	3.45E4	6.60E4	20.0	8.69E3	1.40E5	1.76E5	2.72E4	3.09E4	2.17E3	2.26E3	5.75E3	
25.0	1.23E4	3.55E4	1.45E5	3.79E5	5.00E5	4.09E5	2.51E5	9.47E4	1.43E4	25.0	1.74E4	7.17E4	1.73E5	3.73E5	4.43E5	3.31E5	2.05E5	8.00E4	
30.0	2.22E4	7.32E4	3.24E5	9.35E5	1.24E6	1.28E6	6.13E5	2.14E5	2.71E4	30.0	3.07E4	1.44E5	3.84E5	9.17E5	1.13E6	8.38E5	4.98E5	2.32E4	
35.0	3.66E4	2.06E5	6.54E5	2.07E6	2.95E6	2.30E6	1.36E6	4.61E5	4.79E5	35.0	5.06E4	2.66E5	7.74E5	2.05E6	2.60E6	1.92E6	1.10E6	4.09E4	
40.0	5.69E4	3.98E5	1.23E6	4.23E6	6.25E6	5.03E6	2.78E6	7.97E5	40.0	7.87E4	4.59E5	1.46E6	4.12E6	5.48E6	4.04E6	2.25E6	2.25E6	6.79E4	
Absorbed Dose Buildup Factors in Infinite Thick Beryllium																			
R(MFP)	0.3	0.2	0.15	0.1	0.08	0.06	0.05	0.04	0.03	R(MFP)	0.3	0.2	0.15	0.1	0.08	0.06	0.05	0.04	0.03
7.5	1.66	1.82	1.94	2.07	2.19	2.36	2.50	2.69	2.79	7.5	1.02E2								
1.40	2.69	3.10	3.23	3.86	4.19	4.71	5.12	5.61	5.40	1.40	1.54E1								
4.02	6.02	7.43	8.16	1.05E1	1.19E1	1.40E1	1.54E1	1.67E1	1.52E1	4.02	2.50E1	3.29E1	3.63E1	3.83E1	3.18E1	3.18E1	3.18E1	3.18E1	3.18E1
5.0	1.14E1	1.33E1	1.75E1	2.56E1	2.74E1	2.74E1	2.74E1	2.74E1	2.74E1	5.0	6.79E1	7.40E1	7.57E1	7.57E1	7.57E1	7.57E1	7.57E1	7.57E1	
6.0	1.95E1	2.76E1	3.29E1	4.72E1	5.60E1	5.60E1	5.60E1	5.60E1	5.60E1	6.0	3.07E2	5.90E2	6.07E2	5.44E2	5.44E2	5.10E2	5.10E2		
5.0	2.09E1	4.67E1	5.02E1	8.72E1	1.05E2	1.28E2	1.30E2	1.30E2	1.30E2	5.0	2.26E2	2.36E2							
4.0	6.62E4	7.43E1	9.55E1	1.55E2	1.56E2	1.56E2	1.56E2	1.56E2	1.56E2	4.0	1.02E3	3.70E2	3.07E2	3.07E2	3.54E2	2.18E2	2.18E2	1.76E2	
7.0	6.65E4	1.13E2	1.54E2	2.46E2	2.46E2	2.46E2	2.46E2	2.46E2	2.46E2	7.0	1.02E3	7.40E2							
8.0	9.12E1	1.66E2	2.35E2	3.93E2	4.92E2	4.92E2	4.92E2	4.92E2	4.92E2	8.0	1.02E3	7.40E2							
10.0	1.61E2	2.26E2	5.09E2	8.59E2	1.14E3	1.35E3	1.35E3	1.35E3	1.35E3	10.0	1.02E3	7.40E2							
15.0	4.89E2	1.26E3	2.28E3	6.66E3	6.66E3	6.66E3	6.66E3	6.66E3	6.66E3	15.0	1.02E3	7.18E2	6.72E2	6.72E2	6.72E2	6.72E2	6.72E2	6.72E2	
20.0	1.12E3	3.42E3	7.26E3	1.69E4	2.36E4	2.36E4	2.36E4	2.36E4	2.36E4	20.0	1.02E3	7.84E2	6.66E2	2.36E4	1.58E4	4.04E3	4.04E3		
25.0	2.15E3	7.63E3	1.85E4	4.81E4	7.84E4	7.84E4	7.84E4	7.84E4	7.84E4	25.0	1.02E3	8.65E4	6.65E4	4.07E4	1.05E4	1.05E4	1.05E4		
30.0	3.69E3	1.51E4	6.01E4	1.16E5	1.78E5	1.97E5	1.97E5	1.97E5	1.97E5	30.0	1.02E3	9.11E4							
35.0	5.94E3	2.73E4	7.79E4	2.54E5	6.06E5	6.48E5	6.48E5	6.48E5	6.48E5	35.0	1.02E3								
40.0	7.06E3	4.65E4	1.67E5	5.13E5	8.67E5	9.40E5	9.40E5	9.40E5	9.40E5	40.0	1.02E3								

TABLE B.2 Buildup Factor Data calculated by PALLAS Code
- Boron Medium -

Exposure Buildup Factors in Infinite Thick Boron

Absorbed Dose Buildup Factors in Infinite Thick Boron

R(MFP)	Exposure (MeV)					Absorbed Dose (MeV)				
	0.5	0.4	0.3	0.2	0.1	0.5	0.4	0.3	0.2	0.1
0.5	1.58	1.65	1.74	2.00	2.12	3.00	3.34	3.37	3.34	3.37
1.0	2.59	2.01	3.11	3.90	4.38	6.21	7.15	7.96	7.77	7.77
2.0	6.06	7.01	8.39	1.18E1	1.43E1	2.20E1	2.55E1	2.73E1	2.48E1	2.48E1
3.0	1.11E1	1.44E1	1.85E1	2.81E1	3.59E1	5.70E1	6.54E1	6.66E1	5.73E1	5.73E1
4.0	2.01E1	2.59E1	3.52E1	5.71E1	7.63E1	1.23E2	1.39E2	1.56E2	1.11E2	1.11E2
5.0	3.10E1	4.18E1	6.03E1	1.04E2	1.45E2	2.35E2	2.63E2	2.84E2	1.94E2	1.94E2
6.0	4.45E1	6.25E1	9.44E1	1.72E2	2.49E2	4.09E2	4.53E2	4.12E2	3.10E2	3.10E2
7.0	6.10E1	8.49E1	1.41E2	2.69E2	4.05E2	6.73E2	7.38E2	6.35E2	4.74E2	4.74E2
8.0	8.01E1	1.21E2	2.01E2	4.00E2	6.25E2	1.05E3	1.14E3	9.06E2	6.92E2	6.92E2
9.0	1.22E2	2.02E2	3.64E2	7.87E2	1.32E3	2.28E3	2.44E3	2.02E3	1.34E3	1.34E3
10.0	2.19E2	3.19E2	5.74E2	1.15E3	2.91E3	5.64E3	1.05E4	1.10E4	8.78E3	8.78E3
11.0	3.19E2	5.19E2	1.15E3	2.67E3	7.66E3	1.69E4	3.35E4	3.45E4	2.51E4	2.51E4
12.0	6.24E2	1.16E3	2.16E3	4.05E4	1.66E4	4.03E4	8.59E4	8.78E4	6.16E4	6.16E4
13.0	1.04E3	2.07E3	5.21E3	9.05E3	3.17E3	8.34E4	1.94E5	1.33E5	6.10E4	6.10E4
14.0	1.67E3	3.24E3	5.01E3	1.47E4	5.55E4	1.58E5	3.90E5	3.91E5	1.14E5	1.14E5
15.0	2.24E3	5.27E3	7.29E3	2.27E4	9.21E4	2.80E5	7.40E5	7.37E5	4.01E5	4.01E5
R(MFP)	Exposure (MeV)					Absorbed Dose (MeV)				
	0.04	0.03	0.02	0.01	0.005	0.5	0.4	0.3	0.2	0.1
0.5	7.12	2.56				0.5	2.73	2.50		
1.0	6.62	4.64				1.0	5.43	4.48		
2.0	1.37E1	1.05E1				2.0	1.45E1	1.00E1		
3.0	3.91E1	1.67E1				3.0	2.95E1	1.77E1		
4.0	7.01E1	2.95E1				4.0	5.13E1	2.75E1		
5.0	1.14E2	4.27E1				5.0	8.31E1	3.95E1		
6.0	1.72E2	6.73E1				6.0	1.24E2	5.36E1		
7.0	2.43E2	7.52E1				7.0	1.78E2	7.03E1		
8.0	3.44E2	9.56E1				8.0	2.45E2	8.92E1		
9.0	5.04E2	1.44E2				10.0	4.28E2	1.34E2		
10.0	7.14E2	2.19E2				15.0	1.29E3	2.97E2		
11.0	1.03E3	3.56E2				20.0	3.01E3	5.35E2		
12.0	1.43E3	5.78E2				25.0	5.98E3	8.60E2		
13.0	1.92E3	9.29E2				30.0	1.08E4	1.28E3		
14.0	2.46E3	1.29E3				35.0	1.82E4	1.83E3		
15.0	3.06E3	1.98E3				40.0	2.92E4	2.51E3		

TABLE B.2 (Continued)

Dose Equivalent Buildup Factors in Infinite Thick Boron

		ENERGY (MEV)								
R (MFp)	0.5	0.4	0.3	0.2	0.15	0.1	0.08	0.06	0.05	
0.5	1.72	1.79	1.90	2.24	2.37	2.89	3.08	3.23	3.25	
1.0	3.07	3.31	3.68	4.74	5.26	6.85	7.33	7.54	7.55	
2.0	8.04	9.17	1.09E1	1.55E1	1.81E1	2.64E1	2.58E1	2.52E1	2.35E1	
3.0	1.66E1	1.99E1	2.52E1	3.79E1	4.68E1	6.28E1	6.53E1	6.07E1	5.23E1	
4.0	2.92E1	3.68E1	4.91E1	7.81E1	9.07E1	1.35E2	1.38E2	1.23E2	1.01E2	
5.0	4.60E1	6.05E1	8.54E1	1.43E2	1.87E2	2.56E2	2.59E2	2.22E2	1.74E2	
6.0	6.67E1	9.13E1	1.35E2	2.37E2	3.22E2	4.44E2	4.42E2	3.67E2	2.78E2	
7.0	9.21E1	1.32E2	2.03E2	3.21E2	5.23E2	7.27E2	7.17E2	5.79E2	4.22E2	
8.0	1.22E2	1.78E2	2.89E2	5.52E2	8.04E2	1.13E3	1.11E3	8.71E2	6.14E2	
10.0	1.95E2	3.01E2	5.26E2	1.09E3	1.70E3	2.44E3	2.35E3	1.77E3	1.18E3	
15.0	4.93E2	8.32E2	1.67E3	4.02E3	7.26E3	1.11E4	1.05E4	7.29E3	4.31E3	
20.0	9.72E2	1.75E3	3.89E3	1.06E4	2.15E4	3.53E4	3.28E4	2.17E4	1.17E4	
25.0	1.65E3	3.13E3	7.59E3	2.08E4	5.12E4	9.04E4	8.30E4	5.32E4	2.66E4	
30.0	2.54E3	5.03E3	1.32E4	4.32E4	1.06E5	2.01E5	1.83E5	1.14E5	5.30E4	
35.0	3.71E3	7.66E3	2.15E4	7.62E4	2.00E5	4.09E5	3.68E5	2.27E5	9.89E4	
40.0	5.16E3	1.11E4	3.31E4	1.26E5	3.55E5	7.74E5	6.93E5	4.23E5	1.74E5	
		ENERGY (MEV)								
R (MFp)	0.04	0.03								
0.5	3.05	2.49								
1.0	6.38	4.46								
2.0	1.77E1	9.97								
3.0	3.67E1	1.76E1								
4.0	6.53E1	2.73E1								
5.0	1.05E2	3.92E1								
6.0	1.58E2	5.31E1								
7.0	2.28E2	6.96E1								
8.0	3.15E2	8.82E1								
10.0	5.51E2	1.33E2								
15.0	1.67E3	2.93E2								
20.0	3.90E3	5.28E2								
25.0	7.77E3	8.48E2								
30.0	1.40E4	1.26E3								
35.0	2.37E4	1.81E3								
40.0	3.80E4	2.48E3								

TABLE B.3 Exposure Buildup Factor Data calculated by PALLAS code
in Lead Medium with Fluorescence

Exposure Buildup Factors in Infinite Thick Lead

Exposure Buildup Factors in Infinite Thick Lead						
Exposure Buildup Factors in Infinite Thick Lead						
Exposure Buildup Factors in Infinite Thick Lead						
ρ_{MFP}	0.4	0.3	0.2	0.16	0.15	0.145
0.5	1.18	1.13	1.16	1.24	1.27	1.29
1.0	1.25	1.18	1.21	1.36	1.46	1.50
1.5	1.34	1.23	1.24	1.36	1.60	1.67
2.0	1.42	1.27	1.25	1.50	1.70	1.81
2.5	1.48	1.31	1.27	1.52	1.76	1.90
3.0	1.54	1.34	1.28	1.53	1.79	1.98
4.0	1.59	1.37	1.30	1.53	1.81	2.03
5.0	1.64	1.40	1.31	1.53	1.81	2.03
6.0	1.64	1.40	1.40	1.53	1.81	2.03
7.0	1.64	1.42	1.32	1.53	1.81	2.09
8.0	1.68	1.42	1.32	1.53	1.81	2.09
10.0	1.75	1.46	1.34	1.53	1.81	2.12
15.0	1.91	1.54	1.38	1.55	1.79	2.12
20.0	2.03	1.60	1.40	1.57	1.77	2.09
30.0	2.14	1.65	1.42	1.58	1.77	2.07
50.0	2.23	1.69	1.45	1.60	1.78	2.09
75.0	2.31	1.73	1.46	1.62	1.79	2.17
100.0	2.38	1.77	1.48	1.64	1.82	2.45
ρ_{MFP}	0.135	0.134	0.132	0.13	0.125	0.12
Exposure Buildup Factors in Infinite Thick Lead						
ρ_{MFP}	0.111	0.11	0.109	0.105	0.1	0.095
0.5	1.33	1.33	1.35	1.40	1.39	1.41
1.0	1.56	1.56	1.59	1.68	1.69	1.75
2.0	1.90	1.92	1.99	2.15	2.23	2.41
3.0	2.18	2.22	2.35	2.59	2.82	3.18
4.0	2.44	2.53	2.74	3.09	3.55	4.20
5.0	2.71	2.84	3.17	3.67	4.49	5.60
6.0	2.95	3.14	3.62	4.30	5.67	7.49
7.0	3.20	3.46	4.17	5.08	7.26	10.16
8.0	3.46	3.80	4.78	6.02	9.32	13.06
10.0	4.01	4.57	6.38	8.63	1.52E1	2.66E1
15.0	5.64	7.16	1.52E1	2.45E1	6.77E1	1.48E2
20.0	7.08	1.14E1	1.46E1	2.17E1	3.16E1	5.10E1
25.0	1.13E1	1.88E1	2.47E2	4.34E2	2.36E3	6.31E3
30.0	1.74E1	3.41E1	1.45E3	2.65E3	1.78E4	5.07E4
50.0	3.35E1	7.85E1	9.19E3	1.83E4	1.43E5	4.58E5
70.0	9.66E1	2.68E2	5.98E4	1.33E5	1.19E6	4.49E6
ρ_{MFP}	0.095	0.09	0.089	0.088	0.087	0.086

Exposure Buildup Factors in Infinite Thick Lead						
Exposure Buildup Factors in Infinite Thick Lead						
Exposure Buildup Factors in Infinite Thick Lead						
ρ_{MFP}	0.4	0.3	0.2	0.16	0.15	0.142
0.5	1.44	1.47	1.47	1.50	1.56	1.48
1.0	1.33	1.91	1.90	1.96	1.69	1.78
2.0	2.80	2.90	2.87	3.09	3.67	2.41
3.0	4.05	6.29	4.25	4.77	5.67	3.42
4.0	5.00	6.50	6.44	7.96	9.57	5.53
5.0	5.08	1.01E1	9.99	1.24E1	1.66E1	9.79
6.0	1.38E1	1.50E1	1.57E1	2.06E1	2.92E1	1.80E1
7.0	2.15E1	2.51E1	2.50E1	3.66E1	5.21E1	6.18E1
8.0	3.54E1	4.05E1	4.03E1	5.89E1	9.38E1	1.22E2
10.0	8.48E1	1.07E2	1.07E2	1.73E2	3.08E2	4.54E2
15.0	8.79E2	1.26E3	1.26E3	2.62E3	5.92E3	1.19E4
20.0	9.24E3	1.46E4	1.49E4	3.92E4	1.14E5	3.09E5
30.0	1.96E5	1.71E5	1.78E5	5.18E5	1.81E6	5.75E6
50.0	1.14E6	2.06E6	2.23E6	8.05E6	6.12E7	1.98E8
70.0	1.60E7	2.61E7	2.97E7	1.39E8	8.03E8	5.07E9
100.0	1.89E8	3.50E8	4.26E8	2.31E9	1.63E10	1.32E11
ρ_{MFP}	0.095	0.09	0.089	0.088	0.087	0.086