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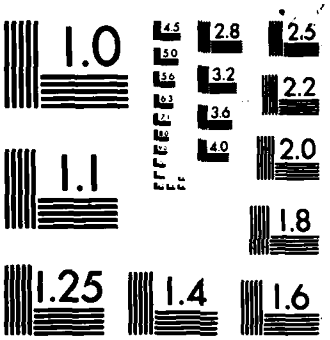

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METHOD FOR CALCULATING THE FRACTIONAL RATE OF RADIOACTIVITY DEPOSITION FOR A RANGE OF YIELDS AND VARIOUS PARTICLE SIZE - ACTIVITY DISTRIBUTIONS

THESIS

AFIT/GNE/PH/84M-5

James H. Gogolin
LCDR USN

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METHOD FOR CALCULATING THE FRACTIONAL RATE OF RADIOACTIVITY DEPOSTION FOR A RANGE OF YIELDS AND VARIOUS PARTICLE SIZE - ACTIVITY DISTRIBUTIONS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

James H. Gogolin, B.S.

LCDR USN

Graduate Nuclear Effects

A1

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James H. Gogolin

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Abstract

A set of empirical equations is produced to calculate the fractional arrival rate of radioactivity on the ground where the radioactivity is the result of a nuclear surface burst. A total of 20 such equations are given for four log-normal particle size distributions and five nuclear yields from 1KT to 15MT. The fractional arrival rate of radioactivity on the ground, g(t), data for the 20 cases were generated by a fast running fallout smearing code. The results were fit with a sixth degree Laurent series for each of five particular yields. For each size distribution the Laurent series coefficients for the five yields were then fit with a polynomial function of yield to enable computation of g(t) data for any arbitrary yield between 1KT and 15MT. Calculation of g(t) data with these empirical equations may be accomplished on a hand held calculator and produce results which are accurate to within at least 4 percent of the fallout smearing computer code data.

I. Purpose

Computer codes modeling physical phenomena may be divided into three categories as depicted in Figure I-1.

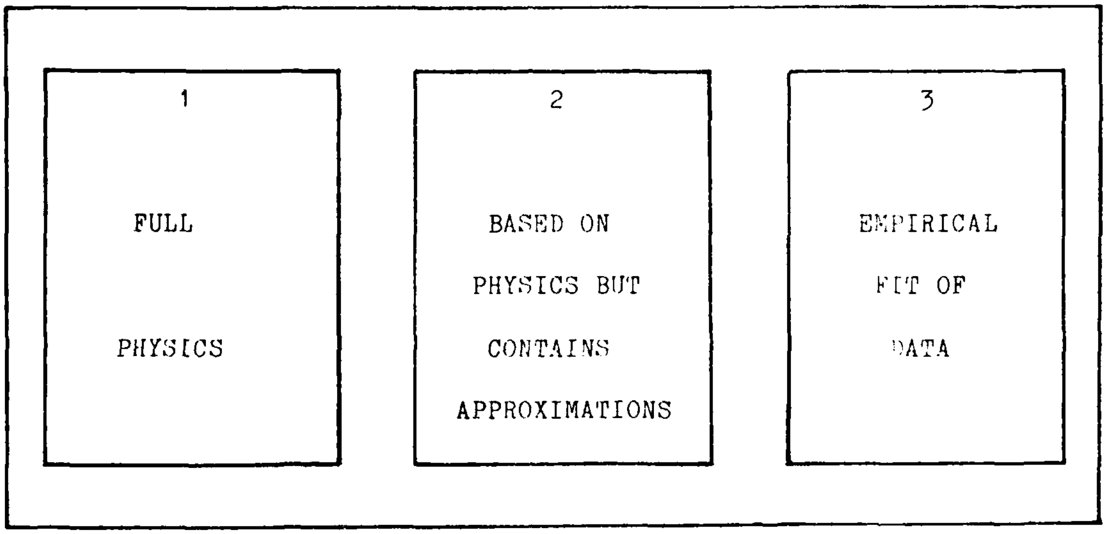

Fig. I-1 Computer Code Models

The first category is the full physics model which contains the most rigorous scientific development, adhering to generally accepted theory in every possible detail. The second category is a model based on physical principles but containing approximations. This type of model is generally less sophisticated than the full physics model and is easier and less costly to run. The third category is the model based on empirical fits of data. An empirical model is very fast running and inexpensive to use.

The purpose of this project is to produce a set of empirical equations to model the fractional rate of arrival of radioactivity on the ground. The model will be limited to fallout from a nuclear burst at the surface of the earth or close enough such that the fireball touches the ground.

II. Background

Since the commencement of peacetime atmospheric testing of nuclear weapons, residual radiation has been recognized as a hazardous nuclear effect. Even before the first detonations which produced significant local fallout, the concept of fallout was known and published (11:15). In the intervening years numerous models have been developed to predict radiation fallout characteristics. The models may be classified as either disk tossers or smear models.

Disk Tossers. The disk tosser fallout prediction model discretizes the nuclear debris cloud into elements (at least one dimension of particle size and one of space (3:205)) and follows the time history of each element. Superposition of all grounded elements yields the fallout footprint. Because of the numerical quadrature of disc tosser codes, computers are required to complete the calculations. The Department of Defense Land Fallout Prediction System (Ref. 5), DELFIC, is a disc tosser code and is generally regarded as the foremost of such codes. It is a full physics model and uses a quadrature of up to 10,000 elements to describe the local fallout pattern (7:27). Such required fine meshes are expensive in computer time and money.

Smearing Codes. Smearing codes do not discretize the stabilized debris cloud into a fine mesh for numerical transport of each element until ground impact, but rather continuously deposit the activity in the stabilized cloud along the ground until all radioactivity of interest is grounded. The process may be compared to smearing a piece of chalk continuously along a chalkboard until the initial piece is entirely depleted. Hence the label of smearing codes. Figure II-1 is an illustration of the smearing process.

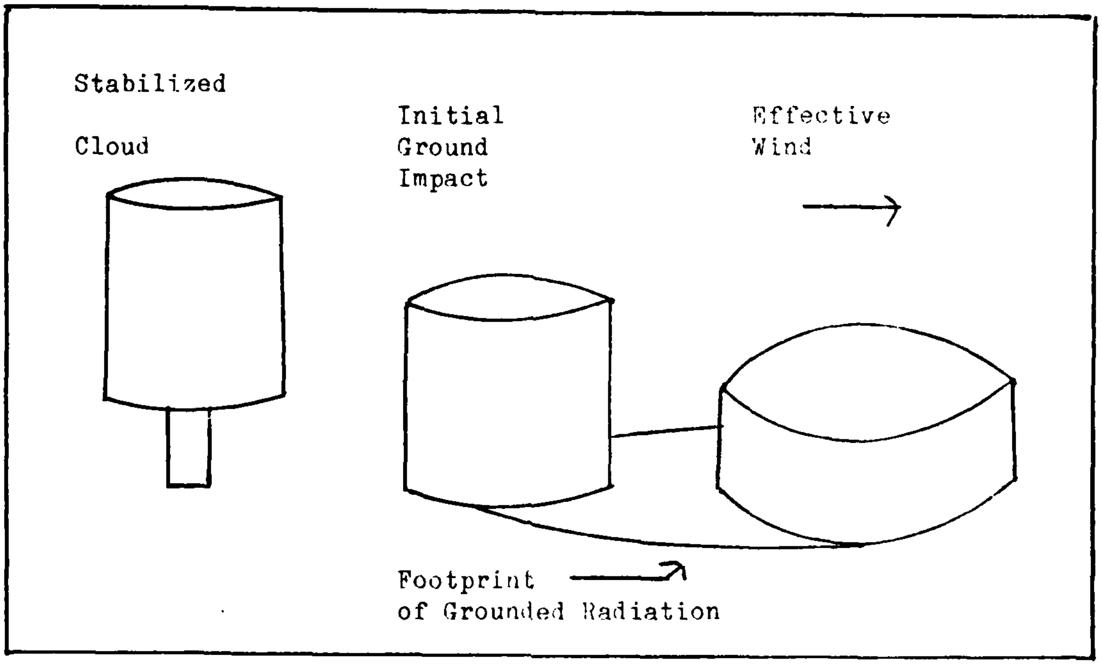

Figure II-1 Smearing a Radioactive Debris Cloud

One of the earliest smearing codes was created by the Weapons Systems Evaluation Group in the Pentagon. The heart of the code, called WSEG-10, lies in a function g(t) (10:208), which is defined in the WSEG-10 report as follows "Specifically, for any radioactive cloud configuration there exists some function of time, g(t), that represents the fraction of total radioactivity that arrives on the ground per unit time." (9:4). The smearing equation using g(t) is

$$A(x,y,t) = A_T(t)\int_0^t f(x,y,t')g(t')dt' \qquad \text{[Ref 3 eqn (2)]} \qquad (1)$$

where A(x,y,t) is the activity footprint on the ground in Curies/m^2

$A_T(t)$ is the total radioactivity in the cloud at time t in Curies

$f(x,y,t')$ is the normalized distribution of activity per area horizontally across the cloud at time t in $1/m^2$

The integral term smears the horizontally distributed activity cloud along the ground at a rate determined by $g(t)$ (3:208).

WSEG-10 has been in use continuously for the last 20 years. Its popularity is due partly to its simplicity and fast computation time (2:III-2). WSEG-10 uses as the $g(t)$ function a simple decreasing exponential which was fit to nuclear test fallout data.

But WSEG-10 has come under strong criticism by Russell (10:209) for its treatment of particle size distribution, fractionation, and $g(t)$; by Polan (8:31) for its [lack of] treatment of particle sizes and settling rates; and by Norment (7:103) for the slope of the particle size - activity distribution. Fractionation is the process whereby part of the radioactivity in the stabilized debris cloud is distributed throughout the volume of fallout particles and the remainder of the radioactivity is distributed on the surface of the particles. Bridgman and Bigelow have published a new fallout prediction smearing model (Ref. 3) which derives the $g(t)$ function from physics and a result is dependent on particle size - activity, particle settling rates and accounts for fractionation (3:20[illegible]).

The Bridgman - Bigelow model is the model used in this project.

III. Method

Theory. If a particle activity-size distribution, $A(r)$, can be determined, the fraction of activity arriving on the ground must be related to $A(r)$ by (3:210)

$$g(t)\ dt = -A(r)\ dr \tag{2}$$

The minus sign indicates particles of decreasing radius are reaching the ground as time increases. Then

$$g(t) = -A(r)\ dr/dt \tag{3}$$

For a particle number-size distribution, $N(r)$, which is taken to be a log-normal distribution, calculation of the activity-size distribution is straight forward. The log-normal distribution is

$$N(r) = N_T/\sqrt{(2\pi)}\beta r\ \exp(-1/2)[(\ln(r)-\alpha_o)/\beta] \tag{4}$$

where α_o is the logarithm of the median particle radius
β is the geometric deviation
N_T is the total number of particles

If all of the activity in the stabilized cloud were distributed in the volume of the fallout particles then the activity-size distribution would be proportional to the third moment of $N(r)$. If all of the activity were distributed only on the surface of the particles then $A(r)$ would be proportional to the second moment of $N(r)$. A property of log-normal distributions is that the nth moment of such a distribution is itself a log-normal distribution with the same geometric deviation, β, and an α defined by the relation (1:12)

$$\alpha_n = \alpha_o + n\beta \tag{5}$$

where α_o is the logarithm of the median particle radius. Since a portion of the radioactivity in the stabilized cloud is volume distributed and the remainder is surface distributed, the activity-size distribution can be expressed as a weighted sum of two log-normal distributions

$$A(r) = FvA_T/[\sqrt{(2\pi)}\beta r] \exp(-1/2)[(\ln(r)-\alpha_3)/\beta]^2$$
$$+ (1-Fv)A_T/[\sqrt{(2\pi)}\beta r] \exp(-1/2)[(\ln(r)-\alpha_2)/\beta]^2 \quad (6)$$

where A_T is the total activity at time t
Fv is the fraction of activity that is volume distributed

Using appropriate fall mechanics for particles descending in atmosphere the time for a particle of radius r to reach the ground from an initial altitude can be determined, and dr/dt can be found.

Model. A fast running computer code based on the smearing model developed by Bridgman and Bigelow (Ref. 3) was used to generate g(t) data for this project. The Bridgman-Bigelow model, hereafter called the AFIT smear model, was chosen because it accounts for fractionation and it contains a g(t) function which was derived from physical principles rather than empirical fits to available test shot data. Further, the g(t) values calculated with this model have been shown to agree well with DELFIC predictions (1:VI-2). Figures III-1 through III-5 illustrate this agreement.

The Bridgman - Bigelow method was recoded by this author and the source program is listed in Appendix A. Inputs to this code are particle size distribution parameters, fractionation ratio and the desired yield. The program will compute g(t) data for fallout to any time after cloud stabilization. For purposes of this project data was limited to local fallout where local fallout is defined as that radioactivity which reaches the ground within 24 hours.

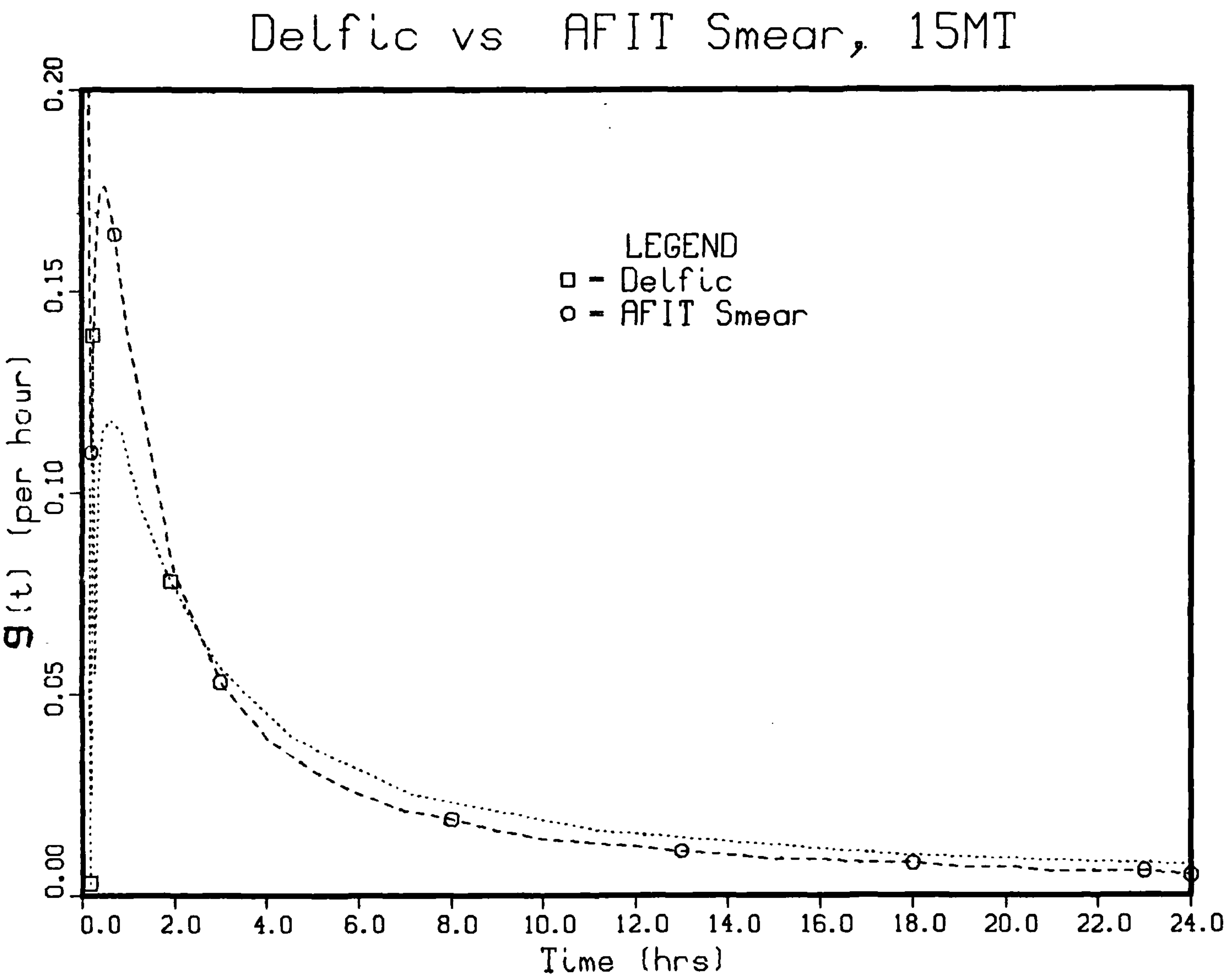

Fig. III-1 Comparison of g(t), 15MT

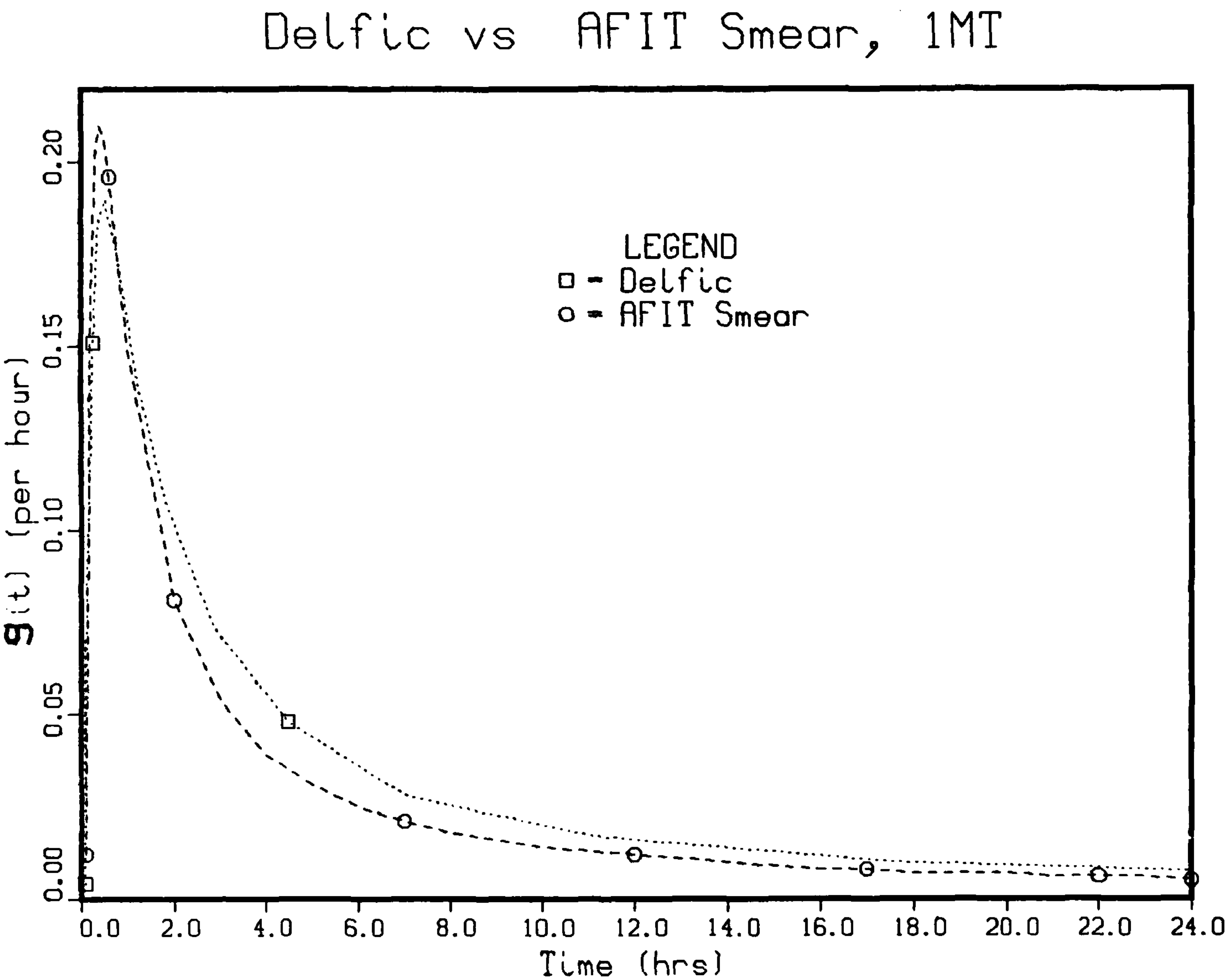

Fig. III-2 Comparison of g(t), 1MT

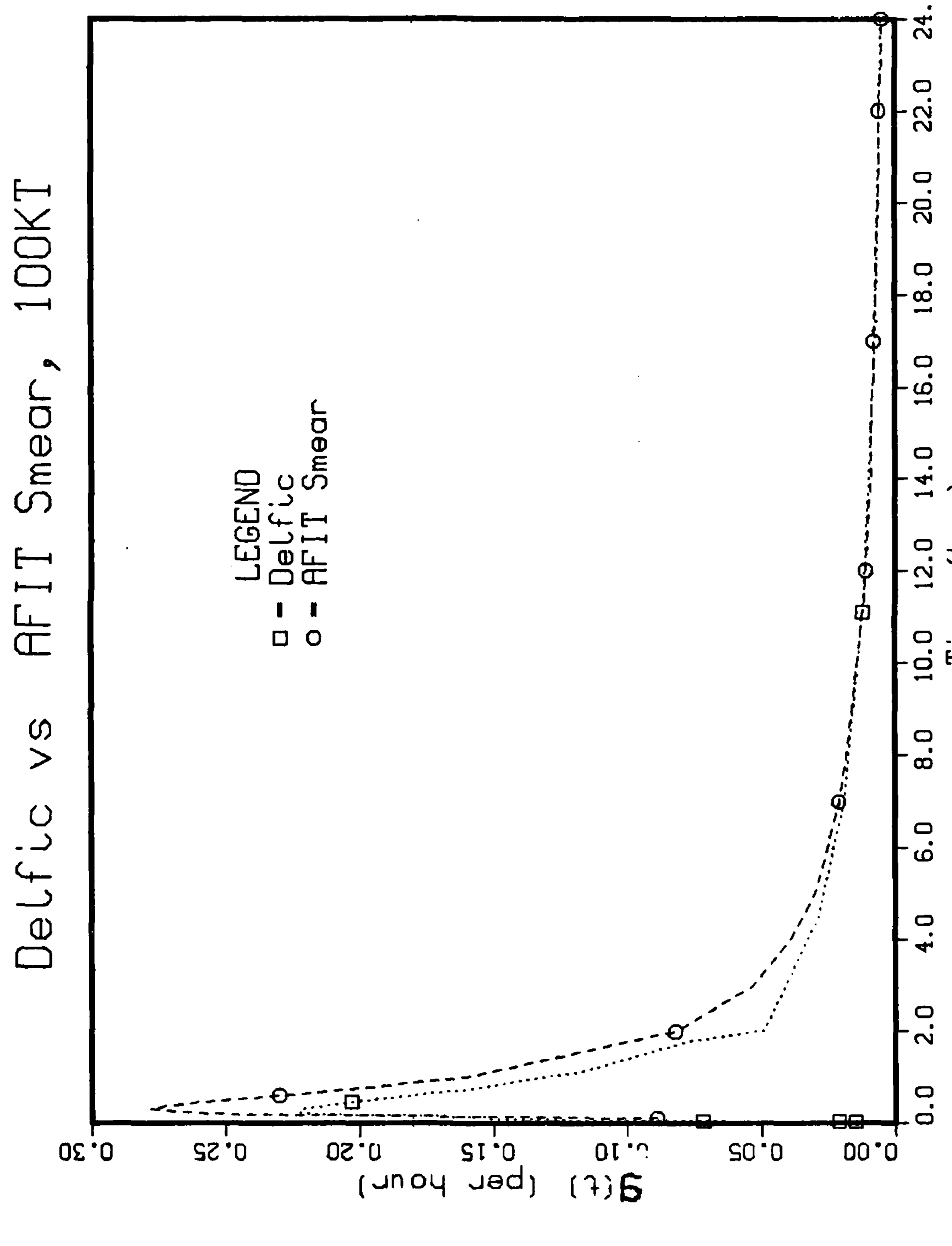

Fig. III-3 Comparison of $g(t)$, 100KT

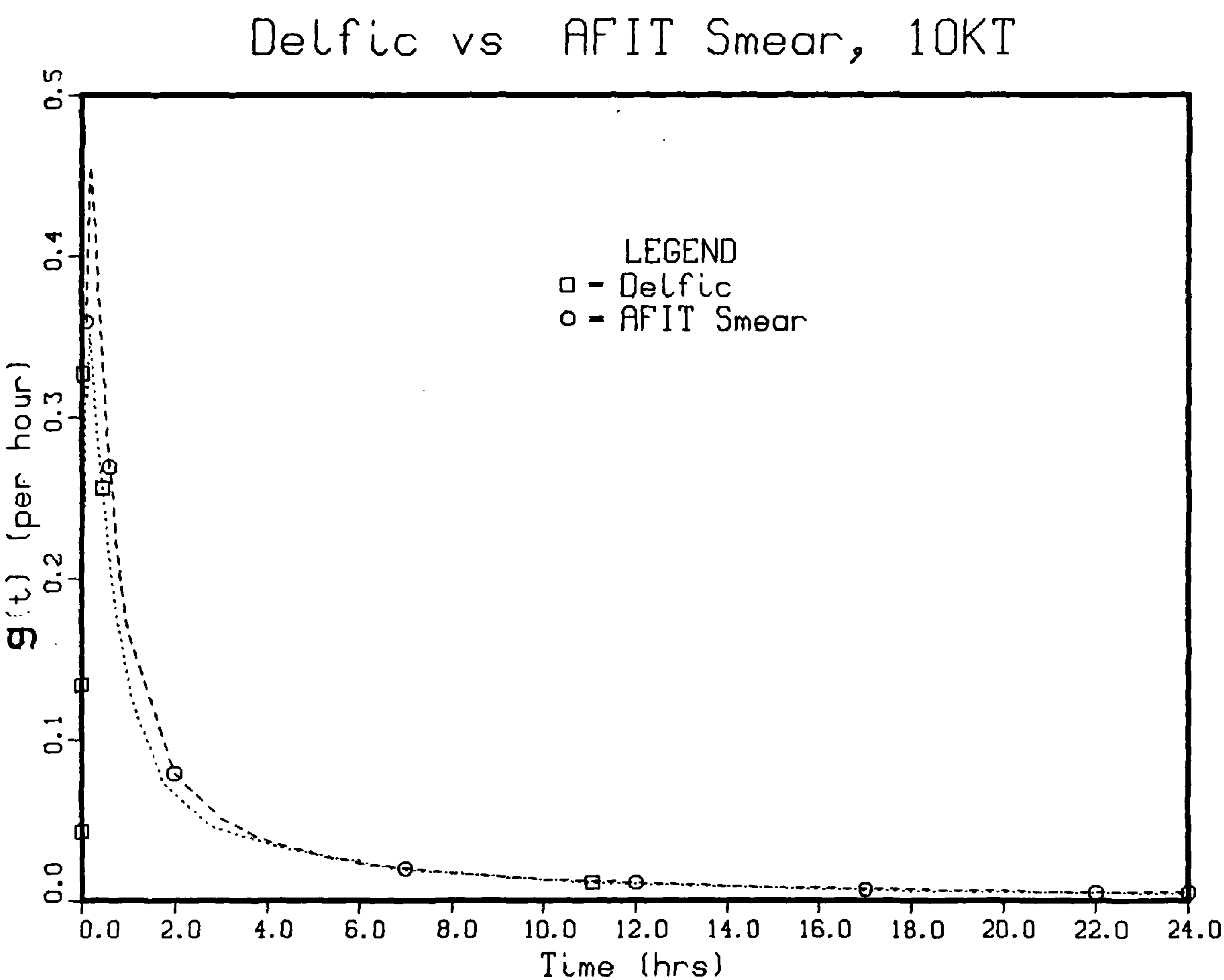

Fig. III-4 Comparison of q(t), 10KT

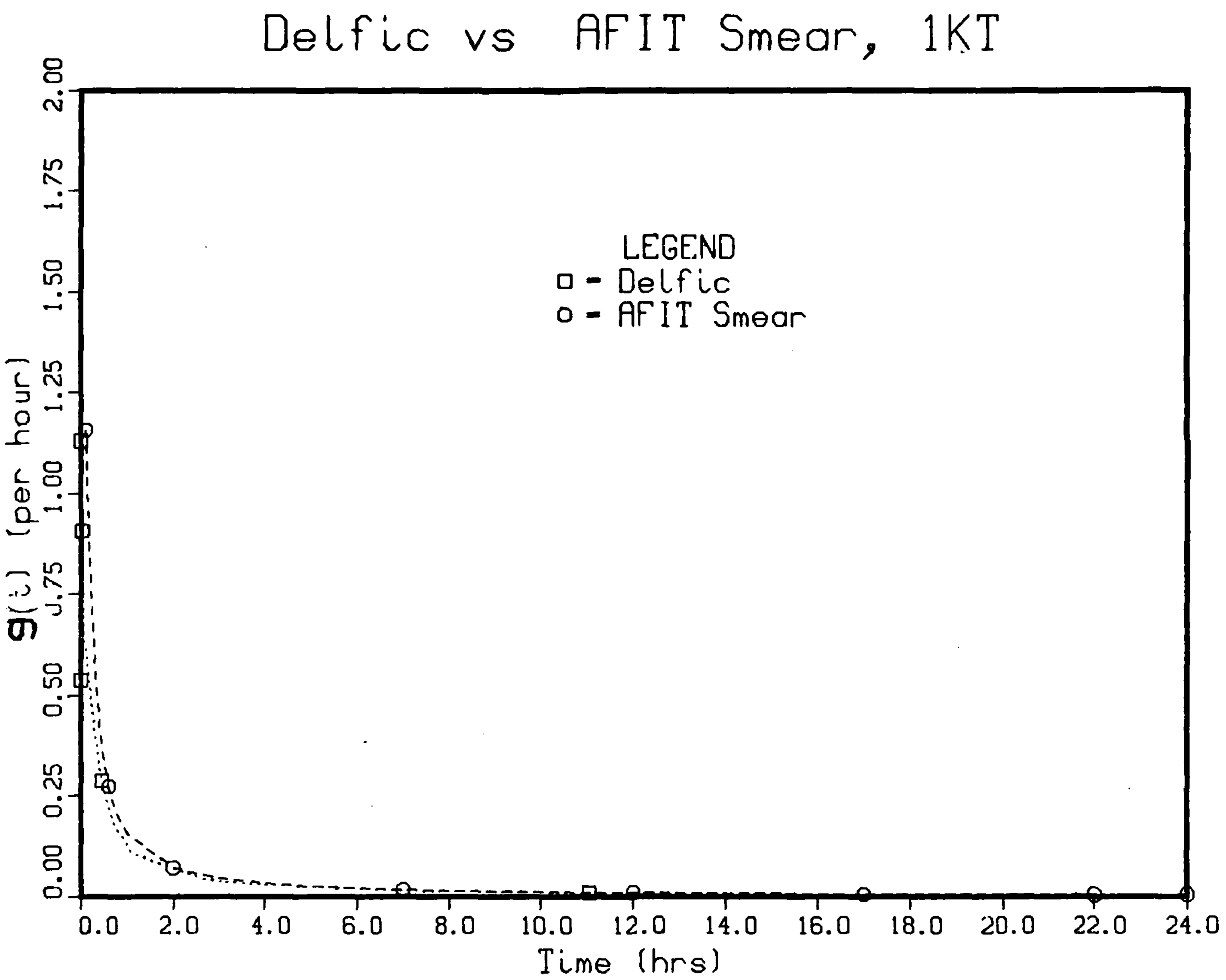

Fig. III-5 Comparison of g(t), 1KT

Procedure. For each particle size distribution listein Table III-1, g(t) data were generated for five different nuclear yields. All of the distributions are log-normal. The five yields chosen were 1 Kiloton (KT), 10KT, 100KT, 1 Megaton (MT) and 15MT. The four smaller yields are standard yields of interest. The 15MT yield was chosen because of the fallout data available from test shot Castle Bravo where the yield was approximately 15MT (4:37). The generated g(t) data were then fit with a Laurent series for each yield

$$g(t) = \sum_{i=1}^{7} C_i \; t^{1-i} \tag{7}$$

where C_i is the coefficient of the ith term
t is the time of activity arrival on the ground

Table III-1
Particle Size Distributions

Distribution Name	Median Radius (μm)	Geometric Deviation	Fractionation Value
DELFIC Default	.204	4.0	.68
High Yield Standard	11.4	2.16	.74
Low Yield Standard	.157	4.0	.66
NRDL-C61	.0424	5.376	.74

Geometric Deviation and Fractionation Value are dimensionless.

The DELFIC default distribution is the particle size distribution used by the DELFIC disc tosser code on the absence of other operator input. The remaining distributions were used by Norment in a DELFIC sensitivity study (6:25). The High Yield Standard distribution was intended to represent the distribution used by WSEG-10. The Low Yield Standard distribution was chosen to represent the particle size-activity data from the Small Boy test shot (2:II-13). The NRDL-C61 distribution was used by the Navy Radiological Defense Laboratory to describe South Pacific Coral. The fractionation values are taken from work by Bigelow (2:IV-3).

Table III-2 is a compilation of the Ci's for the Laurent fit to the AFIT smear code g(t) data generated by using the DELFIC default particle size distribution. A polynomial least squares fit was made of each set of Laurent coefficients, that is, the five C1's, the five C2's, etc. as follows:

$$C_i = \sum_{j=1}^{n} K_j^i \, [\ln(YM)]^{j-1} \qquad (8)$$

where C_i is the Laurent coefficient being fit
K_j is the polynomial coefficient
YM is the nuclear yield in megatons
n is the degree of polynomial required to fit the Laurent coefficient

Table III-3 is a matrix of K_j's for the DELFIC default distribution Laurent coefficients. Appendix B contains tabular listings of the Laurent and polynomial coefficients for all the size distributions analyzed.

The benefit of fitting the Laurent coefficients with a polynomial is that g(t) data can then be calculated for any arbitrary nuclear yield between 1KT and 15MT for any of the four particle size distributions. An illustrative example follows.

Find the fractional activity deposition rate, g(t), at the arrival time of 2 hours given a 50KT yield (.05MT) and using the DELFIC default

Table III-2
Laurent Coefficients for
DELFIC Default Distribution

Yield	C1	C2	C3	C4	C5	C6	C7
15MT	-.00114642	.15162989	.06965252	-.13169294	.06169751	-.01244335	.00092146
1MT	-.00117313	.14934113	.07583249	-.11504912	.04820796	-.00893981	.00062123
100KT	-.00120339	.14426064	.08474593	-.09865934	.03707988	-.00647565	.00043585
10KT	-.00116054	.13743997	.07135541	-.05493684	.01637660	-.00253255	.00016205
1KT	-.00151182	.12220932	.06131543	-.03801546	.01369728	-.00261420	.00019290

particle size distribution. Using equation 3,

$$C1 = K1*[\ln(.05)]^0 + K2*[\ln(.05)]^1 + K3*[\ln(.05)]^2 + K4*[\ln(.05)]^3 + K5[\ln(.05)]^4$$

$$C1 = -.00117313*(-2.996)^0 + .00004020*(-2.996)^1 + .00000601*(-2.996)^2 - .00000427*(-2.996)^3 - .00000077*(-2.996)^4$$

$$C1 = -.00117313 - .00012044 + .00005395 + .00011483 - .00006204$$

$$C1 = -.00118683$$

C2 through C7 are calculated in the same manner. Using equation 2 with the calculated Laurent coefficients

$$g(2\ \text{hr}) = -.00118683/1 + .14255015/2 + .08281579/4 - .08734622/8 + .03127940/16 - .00532854/32 + .00035457/64 \text{ per hour}$$

$$g(2\ \text{hr}) = .0817 \text{ per hour}$$

Table III-3
4th Degree Polynomial Coefficients
for DELFIC Default Distribution

C	K1	K2	K3	K4	K5
1	-.00117313	.00004020	.00000601	-.00000427	-.00000077
2	.14934113	.00198844	-.00017659	-.00006090	-.00001100
3	.07583249	-.00723899	-.00039111	.00062850	.00007084
4	-.11504912	-.00145860	.00122354	-.00079107	-.00011075
5	.04820796	.00259986	-.00044705	.00034778	.00005245
6	-.00893981	-.00071639	.00005011	-.00006898	-.00001043
7	.00062123	.00006028	-.00000092	.00000517	.00000076

IV. Results

Accuracy of Laurent Series Fit. Four particle size distributions were used to generate g(t) data for five different nuclear yields. The g(t) data for each yield in each distribution were fit with a Laurent series. To achieve a fit of good accuracy, g(t) data from .2 hours to 24 hours after cloud stabilization time were used, and coefficients for a sixth degree Laurent series were computed. By ignoring data from times earlier than .2 hours the Laurent series coefficients will produce g(t) data that is within approximately 4 percent of the smearing code g(t) data in most cases. Ignoring the data from times earlier than .2 hours is an insignificant restriction because radioactive fallout is rarely a concern so soon after a nuclear detonation. Other nuclear effects are of greater and overriding concern.

The only exception to the 4% agreement over the range $.2 < t < 24$ hours is the 1KT yield of the High Yield Standard particle size distribution. The High Yield Standard distribution produces a g(t) function characterized by a very sharp peak followed by a slowly dropping plateau. The achieve a Laurent fit with accuracy of order 4 percent it was necessary to fit two different time intervals. The time intervals chosen were from .3 to 2 hours and from 2 to 24 hours. Table IV-1 illustrates the accuracy of the Laurent fit for each of the five yields in each distribution. The g(t) data generated using the Laurent fit are compared to the g(t) data computed with the AFIT smearing model. Tabular lists of the Laurent series coefficients are provided in Appendix B.

Table IV-1
Laurent Fit to Smear g(t) Data

Distribution Name	Yield	Percent Error*
DELFIC Default	15MT	2.62
	1MT	2.65
	100KT	3.02
	10KT	2.07
	1KT	3.14
High Yield Standard		
.3 - 2 Hours	15MT	1.06
	1MT	1.27
	100KT	0.88
	10KT	1.03
	1KT	0.20
2 - 24 Hours	15MT	1.50
	1MT	0.70
	100KT	2.56
	10KT	4.02
	1KT	53.0
Low Yield Standard	15MT	1.05
	1MT	0.83
	100KT	2.67
	10KT	3.60
	1KT	2.28
NRDL-C61	15MT	1.25
	1MT	0.55
	100KT	1.23
	10KT	2.92
	1KT	2.28

* Absolute error is noted. Actual percent error is sometimes positive or negative due to the oscillatory behavior of a high degree Laurent series fit.

Accuracy of Polynomial Fit to Laurent Coefficients. Each set of Laurent series coefficients for the five chosen yields in each particle size distribution was fit with a polynomial series as a function of yield. That is, the set of five C1's, five C2's, etc for each distribution were fit with polynomials. The polynomial fits to the Laurent coefficients provide the capability to generate g(t) data for any nuclear yield between 1KT and 15MT. To achieve an accurate fit coefficients for polynomials to 4th degree were computed. Coefficients for 3rd degree polynomials were computed for all four particle size distributions and coefficients for 2nd degree polynomials were computed for the DELFIC default and NRDL-C61 distributions. In all cases the higher order polynomial yields the most accurate computation of g(t) data, although satisfactory results may be obtained from second order polynomials in some cases. Table IV-2 is a listing of the accuracy of g(t) data calculated with the polynomial fits to the Laurent coefficients as compared to the g(t) data generated by the AFIT smear model. Tabular lists of the polynomial coefficients are provided in Appendix B. Coefficients for 2nd degree polynomials are listed for those distributions where the accuracy of the g(t) data for the 3rd degree polynomial is generally within 5.0 percent of the AFIT smear model data.

In Appendix B Figures B-1 through B-20 graphically compare the g(t) data for each of the five yields for each particle size distribution. Each figure displays the g(t) data as computed by the AFIT smear model, the Laurent fit to the smear model and all applicable polynomial fits to the Laurent coefficients.

Table IV-2
Accuracy of Polynomial Fit g(t) Data

Distribution Name	Yield	% Error 4th Deg. Polynom.	% Error 3rd Deg. Polynom.	% Error 2nd Deg. Polynom.
DELFIC Default	15MT	2.62	2.45	3.49
	1MT	2.64	3.48	4.49
	100KT	3.02	2.82	2.62
	10KT	2.07	1.51	5.00
	1KT	3.09	2.80	3.58
High Yield Standard				
.3 - 2 Hours	15MT	1.13	5.71	N/A
	1MT	1.00	12.13	"
	100KT	0.33	9.35	"
	10KT	0.25	2.97	"
	1KT	0.21	0.73	"
2 - 24 Hours	15MT	1.49	1.67	N/A
	1MT	0.70	1.37	"
	100KT	2.56	1.67	"
	10KT	4.06	6.56	"
	1KT	54.41	49.60	"
Low Yield Standard	15MT	2.57	7.11	N/A
	1MT	0.83	2.14	"
	100KT	2.67	4.81	"
	10KT	3.60	33.21	"
	1KT	3.24	135.7	"
NRDL-C61	15MT	1.24	1.30	2.16
	1MT	0.55	0.94	4.30
	100KT	1.22	1.52	1.21
	10KT	2.87	2.71	5.67
	1KT	2.54	2.32	4.22

V. Conclusions and Recommendations

Conclusions. The fractional rate of radioactivity deposition, g(t), can be calculated using an empirically derived Laurent series equation. A polynomial function of nuclear yield can be used to calculate Laurent coefficients which are in turn used to calculate g(t). Values of g(t) thus calculated will be within 4 percent of values produced by the AFIT smear model. An exception is calculation of low yield g(t) data using the High Yield Standard particle size distribution. Calculation of g(t) data can be made at an accuracy of 4 percent for nuclear yields between 1KT and 15MT. This range is sufficiently broad for accommodation of tactical and strategic applications.

Use of 4th degree polynomials will produce g(t) values which most closely approach the values produced by the AFIT smear model. Use of lower degree polynomials yields percentage errors of less than 5 percent in some cases, as shown in Table IV-2.

No attempt was made to extend the useful range beyond the limits of 1KT or 15MT. In general, attempts to calculate g(t) data for yields outside this range may result in large percentage errors.

Values of g(t) may be obtained with the aid of any hand calculator. Large computer systems like those required for DELFIC or small systems like those required for fast running smearing codes such as the AFIT smear model are not required. The capability to determine fractional fallout rates without computer assistance is advantageous to military field commanders and planners.

Recommendations. Only four particle size distributions were analyzed. These distributions were developed to represent Nevada test site soil and South Pacific coral. Other particle size distributions for soils which are of interest to military commanders and planners should be developed and analyzed.

Bibliography

1. Aitchison, J. and J. A. C. Brown, The Lognorman Distribution. Cambridge: Cambridge University Press, 1957.

2. Bigelow, W. S. Far Field Fallout Prediction Techniques. PhD dissertation. School of Engineering, Air Force Institute of Technology, Wright-Patterson AFB OH, December 1983.

3. Bridgman, C. J. and W. S. Bigelow. "A New Fallout Prediction Model", Health Physics, 43 (2):205-218 (August 1?2).

4. Glasstone, S. and P. J. Dolan. The Effects of Nuclear Weapons (Third Edition). Washington: Government Printing Office, 1977.

5. Norment, H. G. "Department of Defense Land Fallout Prediction System, Vol. I System Description", Report DASA-1800-I, Defense Nuclear Agency, Washington, 1966.

6. Norment, H. G. "Deposition Pattern Sensitivity Analysis of the Defense Land Fallout Interpretive Code (DELFIC)", Report DASA-2328, Defense Nuclear Agency, Washington, 1968.

7. Norment, H. G. "Analysis and Comparison of Fallout Prediction Models", Report DNA-4569F, Atmospheric Science Associates for Defense Nuclear Agency, Washington, 1977.

8. Polan, M. "An Analysis of the Fallout Prediction Models Presented at the USNRDL-DASA Fallout Symposium of September 1962, Vol. I: Analysis, Comparison and Classification of Models", Report USNRDL-TRC-68, U. S. Radiological Defense Laboratory, San Francisco, 1968.

9. Pugh, G. E. and R. J. Galiano. "An Analytical Model of Close-In Deposition of Fallout for Use in Operational Type Studies", WSEG Research Memorandum Report RM-10, Weapon Systems Evaluation Group, The Pentagon, Washington, 1959.

10. Russell, I. J. "A Critique of Land-Surface Fallout Models", Report AFWL-TR-65-76, Air Force Weapons Laboratory, Kirtland AFB NM, 1966.

11. Willis, J. C. "The History of Fallout Prediction", Special Study Report, Air Force Institute of Technology, Wright-Patterson AFB OH, 1979.

Appendix A

This appendix contains the computer listing of the code "PROGRAM g(t)". It was written in BASIC for a Nippon Electric Corporation (NEC) personal computer.

The code was written to generate the AFIT smear g(t) data for this project. Requirements were to provide g(t) data for five specific yields. Using the pancake approximation of the nuclear debris cloud (3:214) would necessitate reading into the code not more than 10 sets of Laurent coefficients. In the interest of flexibility and generality, all the Laurent coefficients were read into the program which are required to enable calculating the g(t) data for any yields up to 15MT.

The following is a glossary of variables used in the code.

Variables

A0 - The log of the mean particle radius

A2 - Log-normal distribution parameter of the second moment of the particle size distribution

A3 - Log-normal distribution parameter of the third moment of the particle size distribution

AR - Activity of particle of radius R

B - Log of the geometric deviation of the particle size distribution

C1 through C7 - Laurent coefficients for R = F(t,Z) for AFIT smear model (3:214)

DR - rate of change of radius of particle reaching the ground in interval dt

FV - Fractionation ratio

GD - Geometric deviation of particle size [illegible]

GT - Fractional arrival rate of activity [illegible], [illegible](t)

HC - Center of stabilized nuclear debris [illegible], [illegible] feet

HM - Center of stabilized nuclear debris [illegible], [illegible]

N$ - Name of particle size [illegible]

PR - Mean particle radius [illegible]

TA - Time of arrival of activity [illegible]

YK - Nuclear yield in kilot[illegible]

YM - Nuclear yield in megat[illegible]

```
10  'PROGRAM g(t)
20  'This program is a smearing fallout prediction code for
30  'the calculation of g(t) data.  The code is based on the
40  'AFIT smearing model.  The program, as written, will
50  'generate g(t) values for five different nuclear yields.
60  'The yields are 1KT, 10KT, 100KT, 1MT, and 15MT.
70  '
80  'The particle size distribution parameters must be input.
90  '
100  INPUT "DISTRIBUTION NAME" ;N$
110  INPUT "MEAN PARTICLE RADIUS, [µm]" ; PR
120  AO = LOG(PR)
130  INPUT "GEOMETRIC DEVIATION, β" ;GD
140  B = LOG(GD)
150  INPUT "FRACTIONATION RATIO " ; FV
160  '
170  PI = 3.14159
180  '
190  DIM C1(85) ,C2(85) ,C3(85) ,C4(85) ,C5(85) ,C6(85) ,C7(85)
200  DATA -.42494E-15, .37874E-12,-.99764E-10, .23375E-07,
          .83123E-06,-.17840E-05, .13110E-04
210  DATA -.13323E-13, .59598E-11,-.78875E-09, .92734E-07,
          .16550E-05,-.17823E-05, .18523E-04
220  DATA -.99099E-13, .29668E-10,-.26305E-08, .20692E-06,
          .24713E-05,-.17806E-05, .22664E-04
230  DATA -.40897E-12, .92185E-10,-.61605E-08, .36479E-06,
          .32801E-05,-.17789E-05, .26144E-04
240  DATA -.12220E-11, .22123E-09,-.11887E-07, .56516E-06,
          .40812E-05,-.17771E-05, .29202E-04
250  DATA -.29772E-11, .45092E-09,-.20291E-07, .80695E-06,
          .48748E-05,-.17754E-05, .31958E-04
260  DATA -.63023E-11, .82136E-09,-.31838E-07, .10892E-05,
          .56610E-05,-.17744E-05, .34484E-04
270  DATA -.12036E-10, .13778E-08,-.46963E-07, .14107E-05,
          .64397E-05,-.17740E-05, .36829E-04
280  DATA -.21240E-10, .21698E-08,-.66068E-07, .17705E-05,
          .72111E-05,-.17732E-05, .39024E-04
290  DATA -.35220E-10, .32509E-08,-.89534E-07, .21673E-05,
          .79750E-05,-.17721E-05, .41093E-04
300  DATA -.55534E-10, .46784E-08,-.11772E-06, .26002E-05,
          .87317E-05,-.17709E-05, .43055E-04
310  DATA -.84005E-10, .65129E-08,-.15098E-06, .30682E-05,
          .94814E-05,-.17695E-05, .44924E-04
320  DATA -.12271E-09, .88171E-08,-.18962E-06, .35702E-05,
          .10224E-04,-.17681E-05, .46711E-04
330  DATA -.17400E-09, .11656E-07,-.23394E-06, .41052E-05,
          .10959E-04,-.17664E-05, .48425E-04
340  DATA -.24045E-09, .15094E-07,-.28419E-06, .46722E-05,
          .11688E-04,-.17647E-05, .50073E-04
350  DATA -.32495E-09, .19202E-07,-.34063E-06, .52701E-05,
          .12409E-04,-.17630E-05, .51662E-04
360  DATA -.43064E-09, .24047E-07,-.40353E-06, .58983E-05,
```

```
          .13123E-04,-.17611E-05, .53196E-04
370  DATA -.56087E-09, .29700E-07,-.47308E-06, .65596E-05,
          .13831E-04,-.17592E-05, .54681E-04
380  DATA -.71923E-09, .36229E-07,-.54947E-06, .72411E-05,
          .14531E-04,-.17572E-05, .56121E-04
390  DATA -.90951E-09, .43702E-07,-.63286E-06, .79537E-05,
          .15225E-04,-.17552E-05, .57518E-04
400  DATA -.11358E-08, .52189E-07,-.72345E-06, .86927E-05,
          .15912E-04,-.17531E-05, .58875E-04
410  DATA -.14023E-08, .61762E-07,-.82138E-06, .94573E-05,
          .16593E-04,-.17510E-05, .60196E-04
420  DATA -.17135E-08, .72488E-07,-.92678E-06, .10247E-04,
          .17266E-04,-.17489E-05, .61483E-04
430  DATA -.20740E-08, .84430E-07,-.10398E-05, .11060E-04,
          .17934E-04,-.17467E-05, .62738E-04
440  DATA -.24884E-08, .97653E-07,-.11604E-05, .11895E-04,
          .18594E-04,-.17444E-05, .63962E-04
450  DATA -.29616E-08, .11222E-06,-.12887E-05, .12753E-04,
          .19248E-04,-.17422E-05, .65158E-04
460  DATA -.34988E-08, .12820E-06,-.14250E-05, .13632E-04,
          .19896E-04,-.17399E-05, .66327E-04
470  DATA -.41051E-08, .14566E-06,-.15691E-05, .14532E-04
          .20537E-04,-.17375E-05, .67470E-04
480  DATA -.47859E-08, .16464E-06,-.17212E-05, .15452E-04,
          .21171E-04,-.17353E-05, .68588E-04
490  DATA -.55464E-08, .18522E-06,-.18814E-05, .16390E-04,
          .21799E-04,-.17331E-05, .69684E-04
500  DATA -.63918E-08, .20744E-06,-.20495E-05, .17347E-04,
          .22420E-04,-.17310E-05, .70757E-04
510  DATA -.73276E-08, .23135E-06,-.22256E-05, .18321E-04,
          .23035E-04,-.17287E-05, .71809E-04
520  DATA -.83591E-08, .25700E-06,-.24098E-05, .19312E-04,
          .23645E-04,-.17264E-05, .72840E-04
530  DATA -.94915E-08, .28444E-06,-.26018E-05, .20318E-04,
          .24248E-04,-.17241E-05, .73852E-04
540  DATA -.10730E-07, .31370E-06,-.28018E-05, .21340E-04,
          .24844E-04,-.17217E-05, .74845E-04
550  DATA -.12080E-07, .34482E-06,-.30096E-05, .22376E-04,
          .25435E-04,-.17192E-05, .75819E-04
560  DATA -.13547E-07, .37786E-06,-.32254E-05, .23426E-04,
          .26020E-04,-.17167E-05, .76777E-04
570  DATA -.15136E-07, .41285E-06,-.34489E-05, .24487E-04,
          .26600E-04,-.17141E-05, .77718E-04
580  DATA -.16852E-07, .44981E-06,-.36801E-05, .25562E-04,
          .27173E-04,-.17115E-05, .78642E-04
590  DATA -.18700E-07, .48876E-06,-.39189E-05, .26643E-04,
          .27741E-04,-.17088E-05, .79551E-04
600  DATA -.20685E-07, .52973E-06,-.41652E-05, .27745E-04,
          .28302E-04,-.17061E-05, .80445E-04
610  DATA -.22812E-07, .57277E-06,-.44190E-05, .28852E-04,
          .28859E-04,-.17034E-05, .81324E-04
620  DATA -.25085E-07, .61788E-06,-.46802E-05, .29970E-04,
```

```
          .29409E-04,-.17006E-05, .82189E-04
630  DATA -.27509E-07, .66508E-06,-.49486E-05, .31096E-04,
          .29955E-04,-.16977E-05, .83040E-04
640  DATA -.30087E-07, .71436E-06,-.52241E-05, .32230E-04,
          .30494E-04,-.16948E-05, .83878E-04
650  DATA -.32824E-07, .76576E-06,-.55066E-05, .33372E-04,
          .31028E-04,-.16918E-05, .84702E-04
660  DATA -.35727E-07, .81932E-06,-.57962E-05, .34522E-04,
          .31556E-04,-.16889E-05, .85514E-04
670  DATA -.38798E-07, .87504E-06,-.60928E-05, .35680E-04,
          .32079E-04,-.16859E-05, .86314E-04
680  DATA -.42040E-07, .93289E-06,-.63960E-05, .36843E-04,
          .32596E-04,-.16829E-05, .87102E-04
690  DATA -.45454E-07, .99285E-06,-.67056E-05, .38012E-04,
          .33108E-04,-.16799E-05, .87878E-04
700  DATA -.49044E-07, .10549E-05,-.70214E-05, .39185E-04,
          .33614E-04,-.16768E-05, .88642E-04
710  DATA -.52814E-07, .11191E-05,-.73434E-05, .40363E-04,
          .34116E-04,-.16736E-05, .89395E-04
720  DATA -.56767E-07, .11855E-05,-.76715E-05, .41544E-04,
          .34613E-04,-.16704E-05, .90137E-04
730  DATA -.60903E-07, .12539E-05,-.80053E-05, .42729E-04,
          .35105E-04,-.16672E-05, .90868E-04
740  DATA -.65224E-07, .13243E-05,-.83446E-05, .43916E-04,
          .35592E-04,-.16639E-05, .91589E-04
750  DATA -.69730E-07, .13968E-05,-.86892E-05, .45105E-04,
          .36074E-04,-.16604E-05, .92301E-04
760  DATA -.74421E-07, .14712E-05,-.90389E-05, .46294E-04,
          .36550E-04,-.16568E-05, .93006E-04
770  DATA -.79296E-07, .15476E-05,-.93934E-05, .47484E-04,
          .37020E-04,-.16530E-05, .93705E-04
780  DATA -.84357E-07, .16258E-05,-.97528E-05, .48674E-04,
          .37483E-04,-.16490E-05, .94397E-04
790  DATA -.89603E-07, .17059E-05,-.10117E-04, .49862E-04,
          .37941E-04,-.16449E-05, .95082E-04
800  DATA -.95031E-07, .17878E-05,-.10485E-04, .51049E-04,
          .38393E-04,-.16406E-05, .95761E-04
810  DATA -.10065E-06, .18715E-05,-.10857E-04, .52234E-04,
          .38840E-04,-.16361E-05, .96434E-04
820  DATA -.10644E-06, .19569E-05,-.11233E-04, .53417E-04,
          .39282E-04,-.16314E-05, .97101E-04
830  DATA -.11242E-06, .20439E-05,-.11612E-04, .54598E-04,
          .39719E-04,-.16266E-05, .97761E-04
840  DATA -.11858E-06, .21326E-05,-.11995E-04, .55774E-04,
          .40152E-04,-.16216E-05, .98416E-04
850  DATA -.12491E-06, .22229E-05,-.12381E-04, .56947E-04,
          .40578E-04,-.16164E-05, .99064E-04
860  DATA -.13144E-06, .23149E-05,-.12771E-04, .58119E-04,
          .41000E-04,-.16110E-05, .99707E-04
870  DATA -.13814E-06, .24084E-05,-.13164E-04, .59286E-04,
          .41418E-04,-.16055E-05, .10034E-03
880  DATA -.14501E-06, .25033E-05,-.13559E-04, .60449E-04,
```

```
          .41832E-04,-.15998E-05, .10097E-03
890  DATA -.15205E-06, .25996E-05,-.13956E-04, .61605E-04,
          .42242E-04,-.15939E-05, .10160E-03
900  DATA -.15926E-06, .26971E-05,-.14356E-04, .62756E-04,
          .42649E-04,-.15879E-05, .10222E-03
910  DATA -.16663E-06, .27961E-05,-.14757E-04, .63902E-04,
          .43052E-04,-.15817E-05, .10283E-03
920  DATA -.17418E-06, .28964E-05,-.15161E-04, .65044E-04,
          .43450E-04,-.15753E-05, .10344E-03
930  DATA -.18189E-06, .29980E-05,-.15567E-04, .66180E-04,
          .43845E-04,-.15688E-05, .10405E-03
940  DATA -.18975E-06, .31006E-05,-.15973E-04, .67309E-04,
          .44237E-04,-.15621E-05, .10464E-03
950  DATA -.19776E-06, .32043E-05,-.16381E-04, .68430E-04,
          .44626E-04,-.15552E-05, .10524E-03
960  DATA -.20593E-06, .33091E-05,-.16790E-04, .69545E-04,
          .45012E-04,-.15482E-05, .10582E-03
970  DATA -.21423E-06, .34147E-05,-.17200E-04, .70652E-04,
          .45396E-04,-.15410E-05, .10640E-03
980  DATA -.22269E-06, .35214E-05,-.17610E-04, .71755E-04,
          .45777E-04,-.15337E-05, .10698E-03
990  DATA -.23128E-06, .36290E-05,-.18021E-04, .72846E-04,
          .46155E-04,-.15261E-05, .10755E-03
1000 DATA -.24001E-06, .37373E-05,-.18432E-04, .73930E-04,
          .46531E-04,-.15184E-05, .10812E-03
1010 DATA -.24886E-06, .38464E-05,-.18843E-04, .75006E-04,
          .46906E-04,-.15106E-05, .10868E-03
1020 DATA -.25783E-06, .39561E-05,-.19254E-04, .76072E-04,
          .47279E-04,-.15027E-05, .10924E-03
1030 DATA -.26692E-06, .40664E-05,-.19663E-04, .77129E-04,
          .47651E-04,-.14946E-05, .10979E-03
1040 DATA -.27611E-06, .41772E-05,-.20072E-04, .78177E-04,
          .48021E-04,-.14863E-05, .11033E-03
1050 FOR I = 1 TO 85
1060 READ C1(I),C2(I),C3(I),C4(I),C5(I),C6(I),C7(I)
1070 NEXT I
1080 YK = 1
1090 YM = YK/1000
1100 IF YM = 10 THEN YM = 15
1110 'COMPUTE FALLOUT TIME OF ARRIVAL,TA
1120 TA = .1  'HOURS
1130 IF TA < .15 THEN GOSUB 1510
1140 'COMPUTE g(ta) [1/Hr]
1150 GT = 0
1160 GOSUB 1270
1170 LPRINT USING "##.####     ";TA,GT
1180 IF TA >= 24 THEN LPRINT CHR$(12)
1190 IF TA>= 24 THEN 1230
1200 IF TA < .1 THEN TA = TA + .01:GOTO 1140
1210 IF TA < 1! THEN TA = TA + .1:GOTO 1140
1220 IF TA < 24 THEN TA = TA + 1!:GOTO 1140
1230 YK = YK * 10
```

```
1240 IF YK > 15000 THEN END ELSE 1090
1250 '
1260 '****************
1270 'SUBROUTINE G(ta)
1280 '****************
1290 '
1300 'COMPUTE HEIGHT OF CLOUD CENTER,HC IN KILOFEET
1310 HC = 44!+6.1*LOG(YM)-.205*(LOG(YM)+2.42)*ABS(LOG(YM)+2.42)
1320 'COMPUTE R IN METERS
1330 HM = HC*1609/5.28 'METERS
1340 N = HM \ 200
1350 RS = C1(N)/TA^5+C2(N)/TA^4+C3(N)/TA^3+C4(N)/TA^2+C5(N)/TA
          +C6(N)+C7(N)/SQR(TA)
1360 RG = C1(N+1)/TA^5+C2(N+1)/TA^4+C3(N+1)/TA^3+C4(N+1)/TA^2
          +C5(N+1)/TA+C6(N+1)+C7(N+1)/SQR(TA)
1370 'INTERPOLATE TO FIND R
1380 R = RG-((N+1)-HM/200)*(RG-RS)
1390 'COMPUTE A(r), AR
1400 RM = R*1E+06
1410 A2 = A0+2*B*B
1420 A3 = A0+3*B*B
1430 AR = (1/(SQR(2*PI)*B*RM))*(FV*EXP(-.5*((LOG(RM)-A3)/B)^2)
          +(1-FV)*EXP(-.5*((LOG(RM)-A2)/B)^2))    '[1/μm]
1440 'COMPUTE dR/dT
1450 DS = -5*C1(N)/TA^6-4*C2(N)/TA^5-3*C3(N)/TA^4-2*C4(N)/TA^3
          -C5(N)/TA^2-.5*C7(N)/TA^1.5
1460 DG = -5*C1(N+1)/TA^6-4*C2(N+1)/TA^5-3*C3(N+1)/TA^4
          - 2*C4(N+1)/TA^3-C5(N+1)/TA^2-.5*C7(N+1)/TA^1.5
1470 DR = DG-((N+1)-HM/200)*(DG-DS)      '[meters/Hr]
1480 DR = DR*1E+06 '[μm/Hr]
1490 GT = AR*ABS(DR) '[1/Hr]
1500 RETURN
1510 '
1520 '***********************
1530 'SUBROUTINE PRINT HEADER
1540 '***********************
1550 '
1560 LPRINT" DATA FOR "; N$;" PARTICLE SIZE DISTRIBUTION"
1570 LPRINT" YIELD =";YM "MT"
1580 LPRINT ""
1590 LPRINT " TIME OF   SMEAR   "
1600 LPRINT " ARRIVAL   G(T)    "
1610 LPRINT ""
1620 RETURN
```

Appendix B

The material in this appendix is organized in four major sections, one for each particle size distribution. Each section contains a table of Laurent coefficients, two or three tables of polynomial coefficients and five figures.

The Laurent coefficients are used in the function

$$g(t) = \sum_{i=1}^{7} C_i \, t^{1-i} \qquad (7)$$

where $g(t)$ is the fractional rate of radioactive fallout deposition per hour
t is the time of arrival in hours

The polynomial coefficients are used in the function

$$C_i = \sum_{j=1}^{n} K_j^i \, [\ln(YM)]^{j-1} \qquad (8)$$

where C_i is the $g(t)$ Laurent coefficient
YM is the nuclear yield in megatons
n is the degree of polynomial

Each figure illustrates the $g(t)$ function as computed by the AFIT smearing model, by using eqn (2) and by using the coefficients for each degree polynomial in eqn (3).

DELFIC Default Distribution

Table B-1
Laurent Coefficients for
DELFIC Default Distribution

Yield	C1	C2	C3	C4	C5	C6	C7
15MT	-.00114642	.15162939	.06965252	-.13169294	.06169751	-.01244335	.00092146
1MT	-.00117313	.14934113	.07583249	-.11504912	.04820796	-.00893981	.00062123
100KT	-.00120339	.14426064	.08474593	-.09865934	.03707988	-.00647565	.00043585
10KT	-.00116054	.13743997	.07135541	-.05493684	.01637660	-.00253255	.00016205
1KT	-.00151182	.12220932	.06131543	-.03801546	.01369728	-.00261420	.00019290

Table B-2
4th Degree Polynomial Coefficients
for DELFIC Default Distribution

C	K1	K2	K3	K4	K5
1	-.00117313	.00004020	.00000601	-.00000427	-.00000077
2	.14934113	.00198844	-.00017659	-.00006090	-.00001100
3	.07583249	-.00723899	-.00039111	.00062850	.00007084
4	-.11504912	-.00145860	.00122354	-.00079107	-.00011075
5	.04820796	.00259986	-.00044705	.00034778	.00005245
6	-.00893981	-.00071639	.00005011	-.00006898	-.00001043
7	.00062123	.00006028	-.00000092	.00000517	.00000076

Table B-3
3rd Degree Polynomial Coefficients
for DELFIC Default Distribution

C	K1	K2	K3	K4
1	-.00120380	-.00001598	.00000807	.00000241
2	.14890350	.00118664	-.00014724	.00003443
3	.07865119	-.00207473	-.00058010	.00001450
4	-.11945574	-.00953216	.00151900	.00016882
5	.05029468	.00642302	-.00058696	-.00010676
6	-.00935487	-.00147684	.00007794	.00002143
7	.00065158	.00011589	-.00000296	-.00000144

Table B-4
2nd Degree Polynomial Coefficients for
DELFIC Default Distribution

C	K1	K2	K3
1	-.00112340	.00000003	-.00000709
2	.15005157	.00141522	-.00036363
3	.07913485	-.00197843	-.00067126
4	-.11382593	-.00841125	.00045792
5	.04673433	.00571415	.00008408
6	-.00864028	-.00133456	-.00005674
7	.00060359	.00010633	.00000609

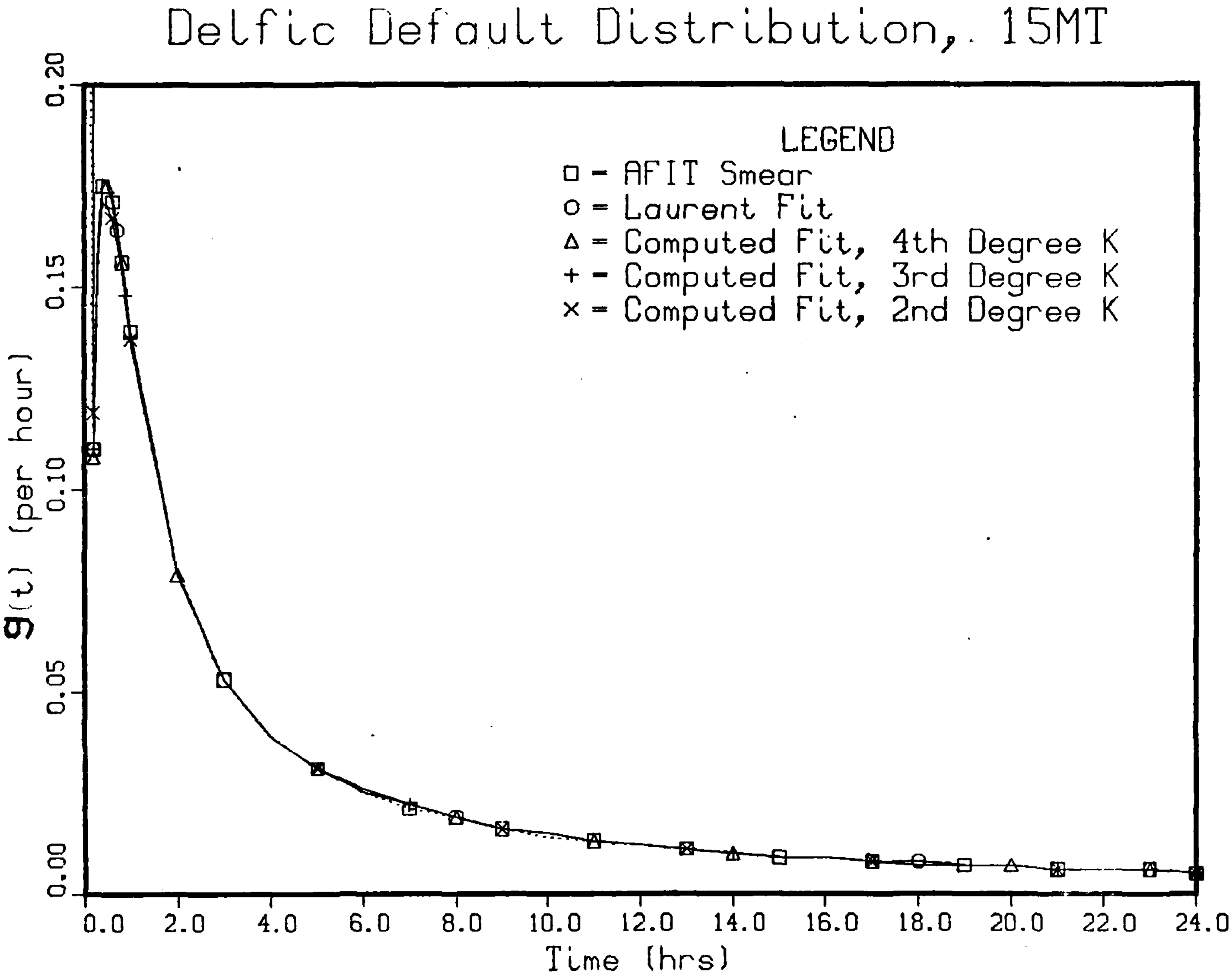

Fig. B-1 DELFIC g(t), 15MT

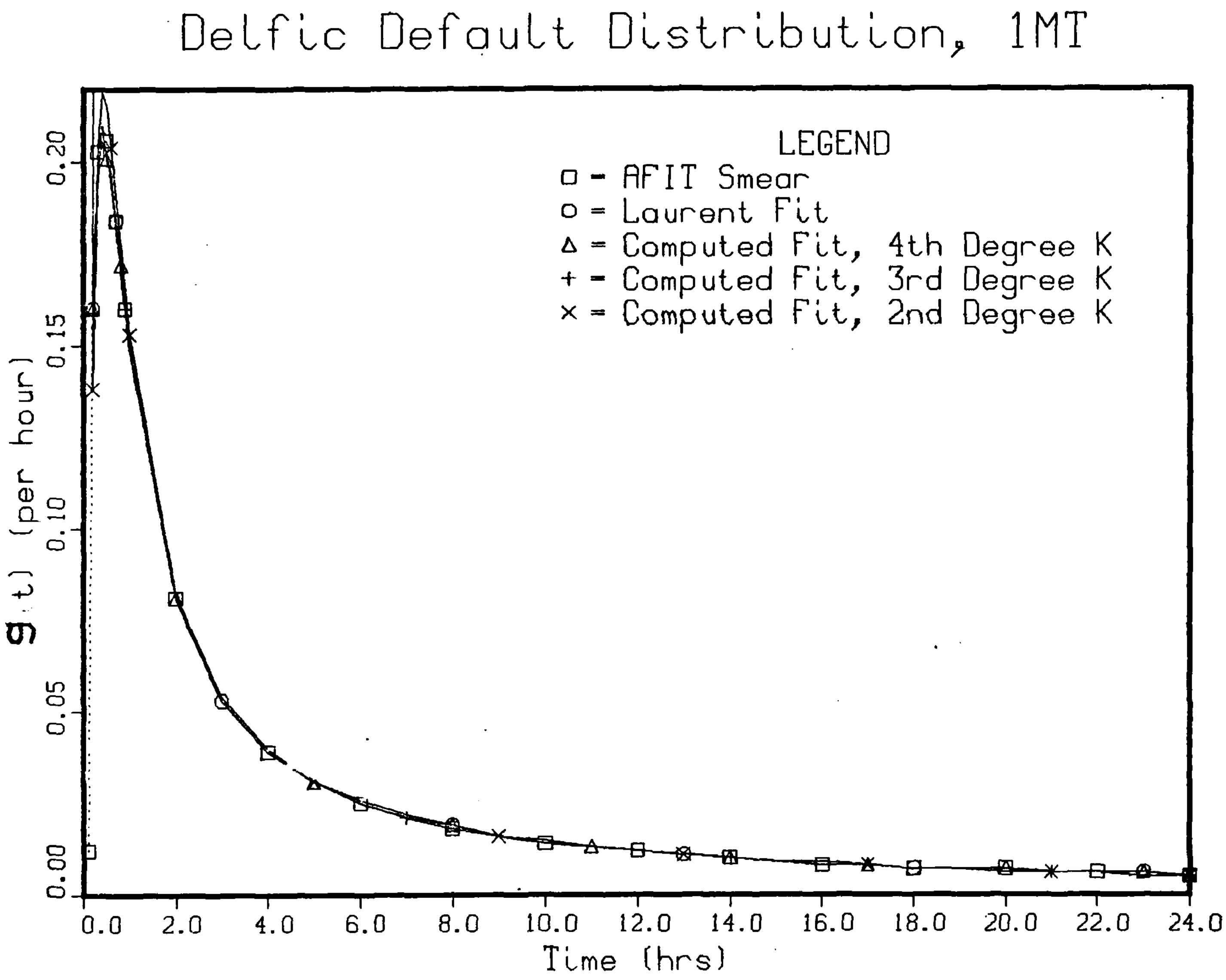

Fig. B-2 DELFIC g(t), 1MT

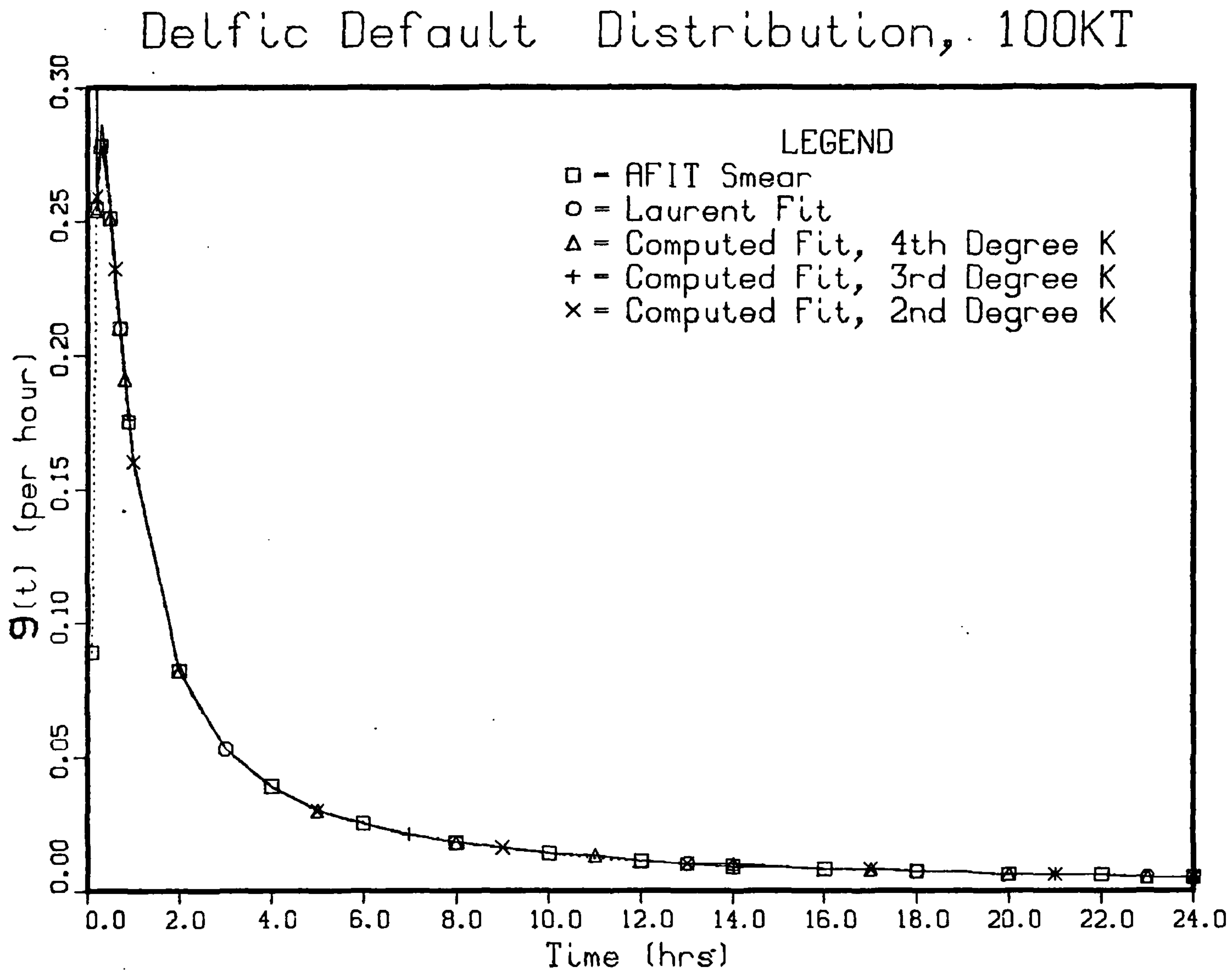

Fig. B-3 DELFIC g(t), 100KT

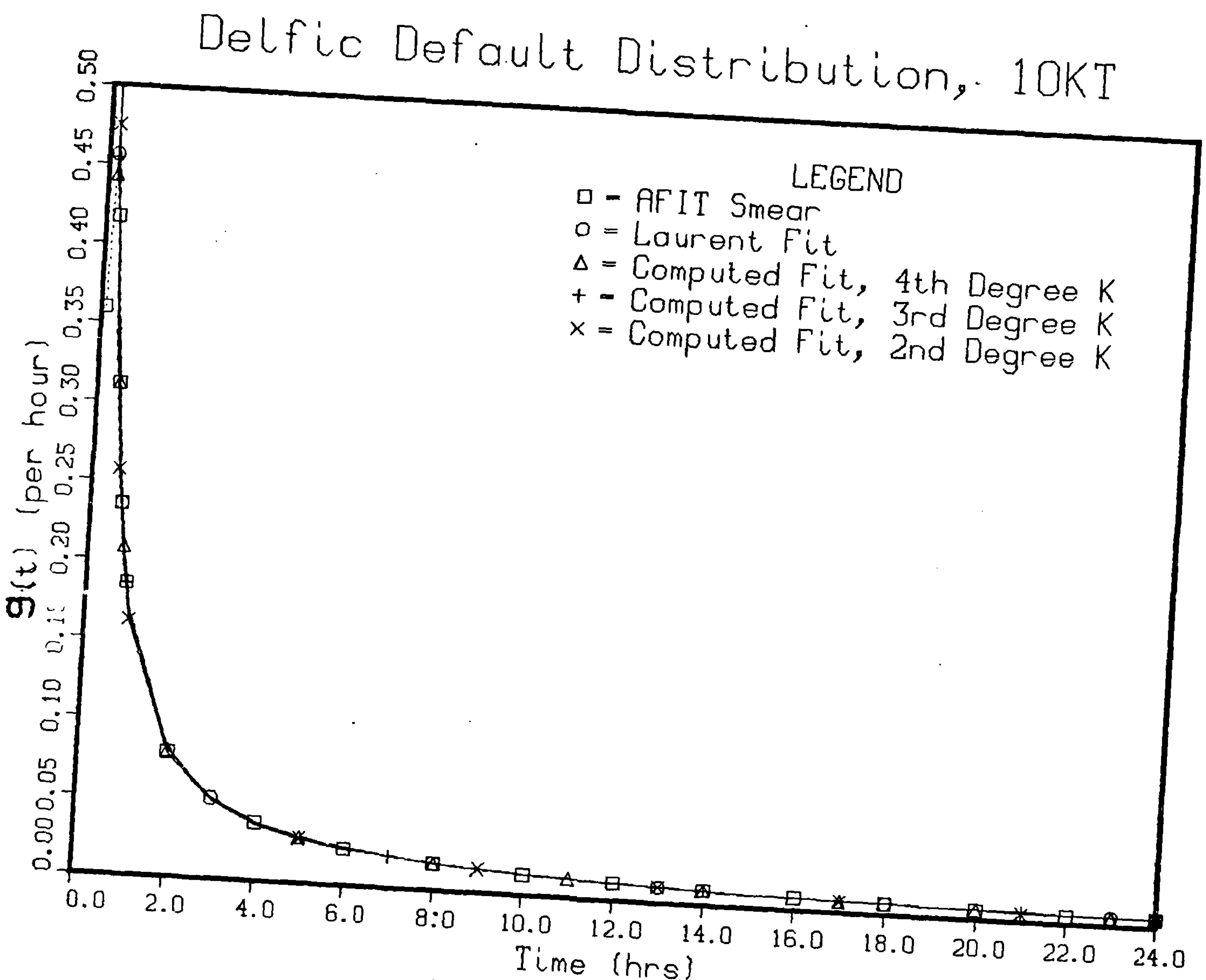

Fig. B-4 DELFIC g(t), 10KT

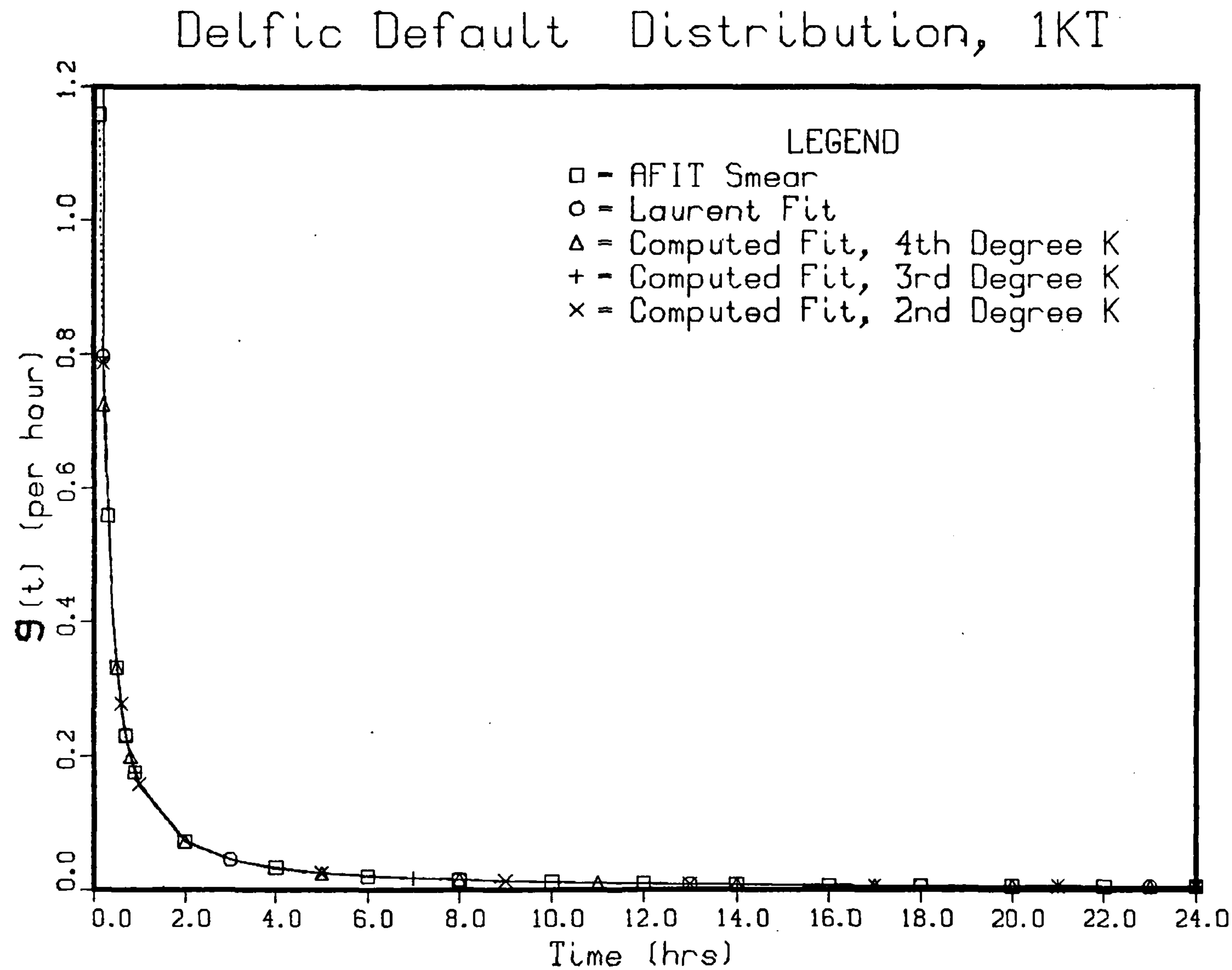

Fig. B-5 DELFIC g(t), 1KT

High Yield Standard Distribution

Table B-5
Laurent Coefficients for
High Yield Standard Distribution

Yield	C1	C2	C3	C4	C5	C6	C7
				0.3 to 2.0 Hours			
15MT	-.02907817	.65180942	.80984224	.38329981	-.06792463	-.00162833	.00125475
1MT	-.10923398	.96961911	-1.14739299	.59529844	-.15557428	.01906435	-.00076094
100KT	-.15947763	1.09411203	-1.13289028	.59736687	-.19419777	.03715178	-.00312257
10KT	-.06601438	.49120393	.02081018	-.18517499	.07541748	-.01173904	.00060497
1KT	-.02020039	.09533188	.45494391	-.32060169	.12274932	-.02671960	.00244661
				2.0 to 24 hours			
15MT	-.00090277	.01652908	4.78615284	-31.62064525	113.63268458	-211.46190038	153.14063111
1MT	.00007495	-.03734010	4.95552861	-30.95189919	109.71700516	-202.98464152	146.47408125
100KT	-.00143434	.04600162	2.22199062	-5.04253058	-3.84290120	32.04467570	-34.55441181
10KT	-.00149050	.05378209	.56330844	7.18365296	-44.13941458	98.05908454	-77.04431322
1KT	-.00069968	.04979740	-.91942214	13.78976931	-58.48358111	111.85884348	-80.02750280

Table B-6
4th Degree Polynomial Coefficients
for High Yield Standard Distribution

C	K1	K2	K3	K4	K5
			0.3 to 2.0 Hours		
1	-.10923398	.04832829	.00580175	-.00349849	-.00044232
2	.96961911	-.19182063	-.03293266	.01656688	.00212254
3	-1.14739299	.23217375	.06139176	-.02705509	-.00379510
4	.59529844	-.16865983	-.04190725	.02003927	.00286529
5	-.15557428	.07829936	.01364492	-.00826275	-.00112233
6	.01906435	-.01988882	-.00220318	.00185087	.00023367
7	-.00076094	.00201641	.00014319	-.00017140	-.00002029
			2.0 to 24 Hours		
1	.00007495	.00067689	-.00013815	-.00007399	-.00000610
2	-.03734010	-.03612199	.00733320	.00397942	.00035108
3	4.95552861	1.09183957	-.17920432	-.07427297	-.00626433
4	-30.95189919	-10.92041164	1.50856293	.73309179	.06103074
5	109.71700516	50.00788799	-6.20018700	-3.51647347	-.30128253
6	-202.98464152	-106.36475841	12.31237105	7.70716109	.67328225
7	146.47408125	83.30016516	-9.23625986	-6.14326213	-.54252517

Table B-7
3rd Degree Polynomial Coefficients
for High Yield Standard Distribution

C	K1	K2	K3	K4
		0.3 to 2.0 Hours		
1	-.12683299	.01608440	.00698177	.00043510
2	1.05407010	-.03709439	-.03859513	-.00182905
3	-1.29839134	-.04447673	.07151624	.00583682
4	.70930171	.04021040	-.04955120	-.00479401
5	-.20022912	-.00351467	.01663904	.00146439
6	.02836140	-.00285529	-.00282655	-.00017430
7	-.00156811	.00053756	.00019731	.00000443
		2.0 to 24 Hours		
1	-.00016787	.00023201	-.00012187	-.00002110
2	-.02337136	-.01052926	.00639659	.00093662
3	4.70628517	.63519007	-.16249248	-.01998038
4	-28.52362613	-6.47146945	1.34574654	.20414209
5	97.72966520	28.04537344	-5.39643250	-.90527624
6	-176.19628656	-57.28467578	10.51620436	1.87186495
7	124.88825047	43.75184798	-7.78892386	-1.44122966

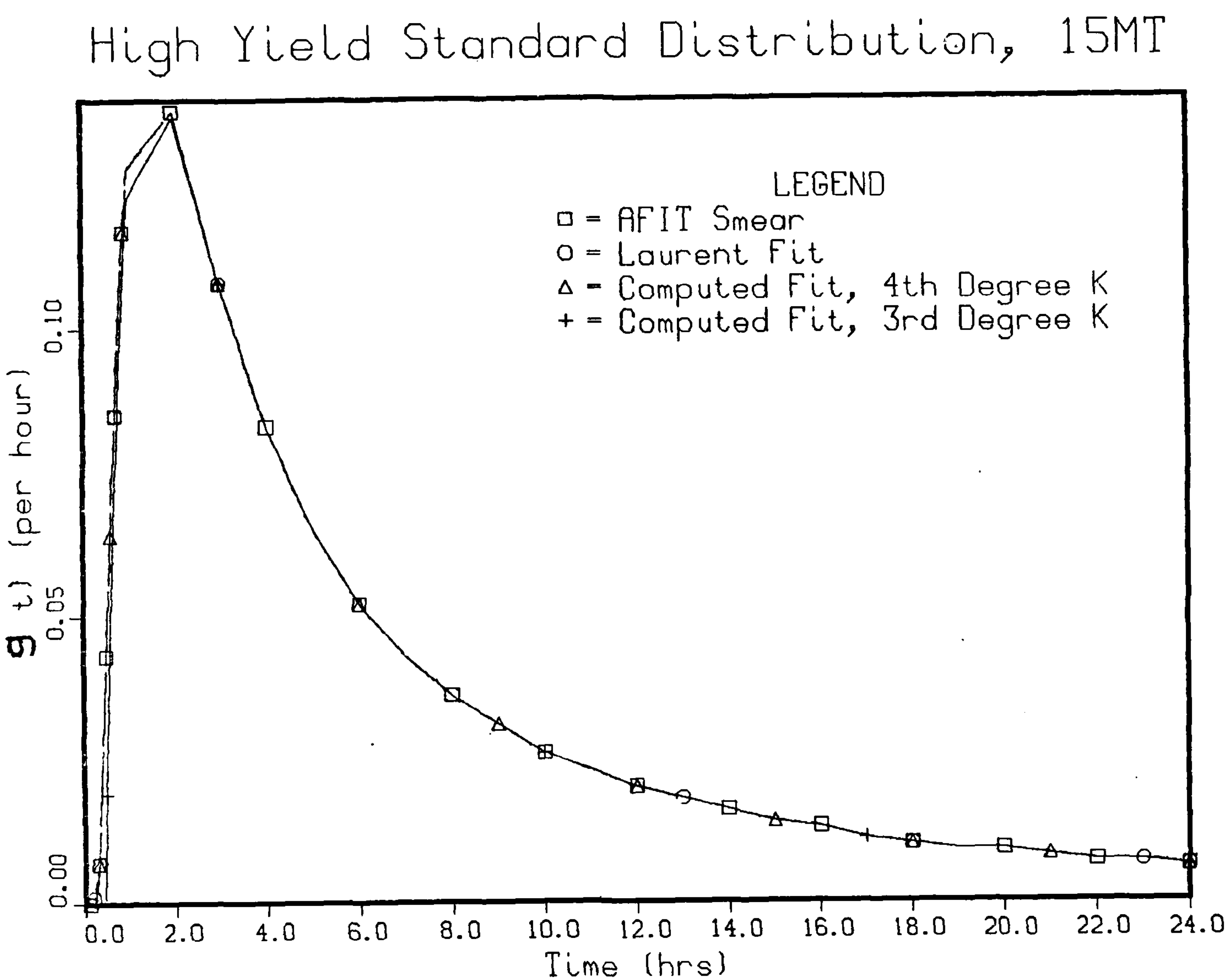

Fig. B-6 High Yield Standard g(t), 15MT

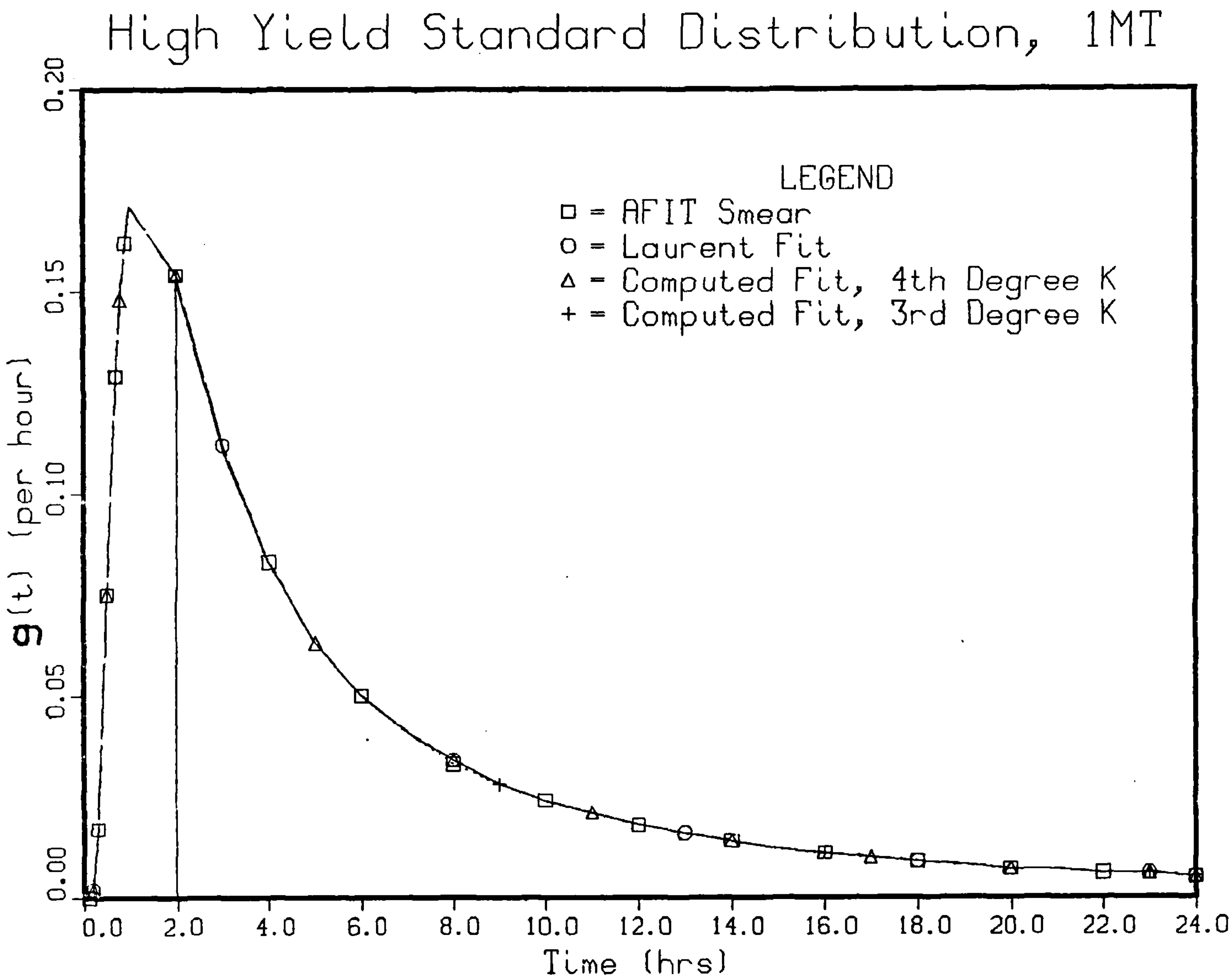

Fig. B-7 High Yield Standard g(t), 1MT

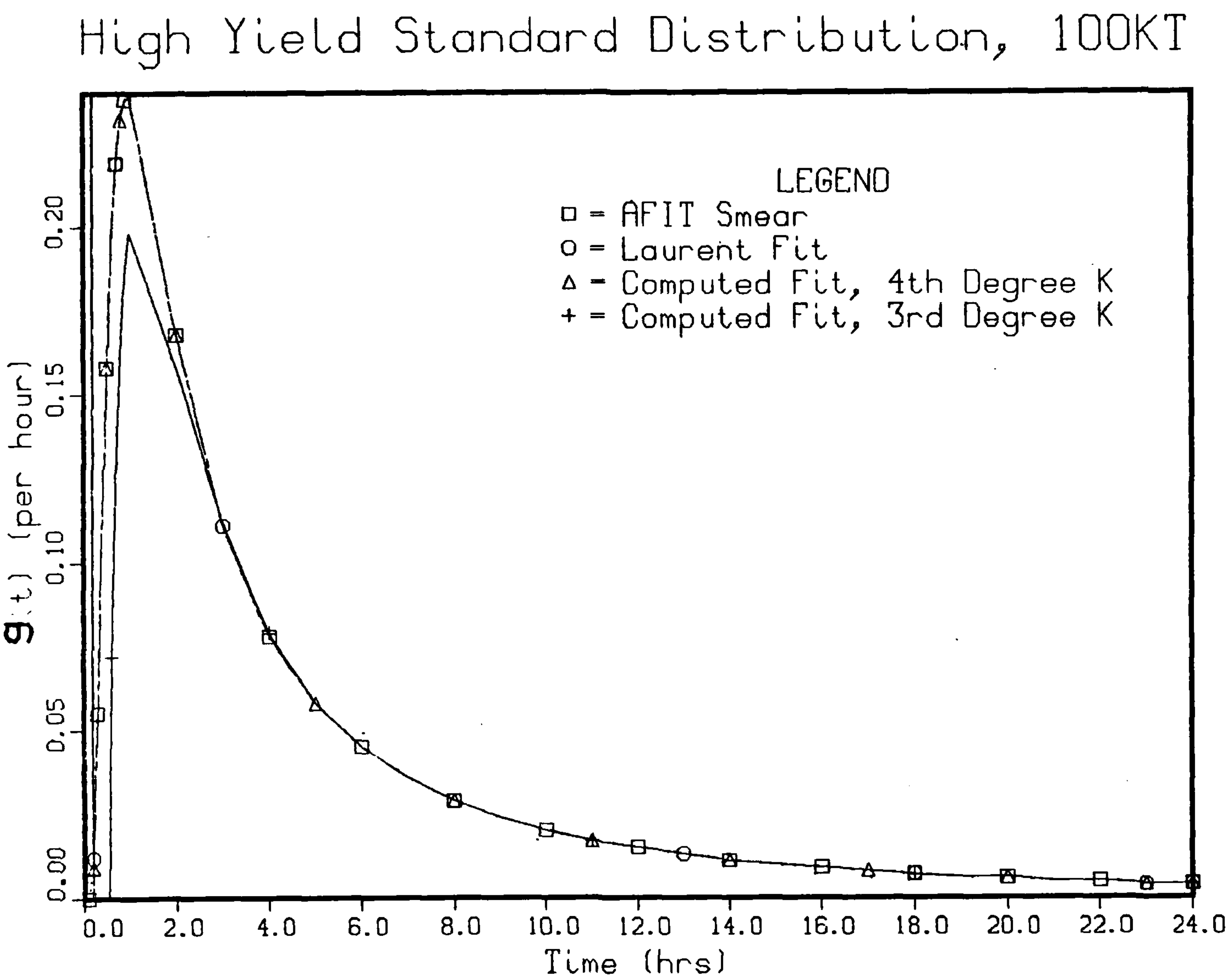

Fig. B-8 High Yield Standard g(t), 100KT

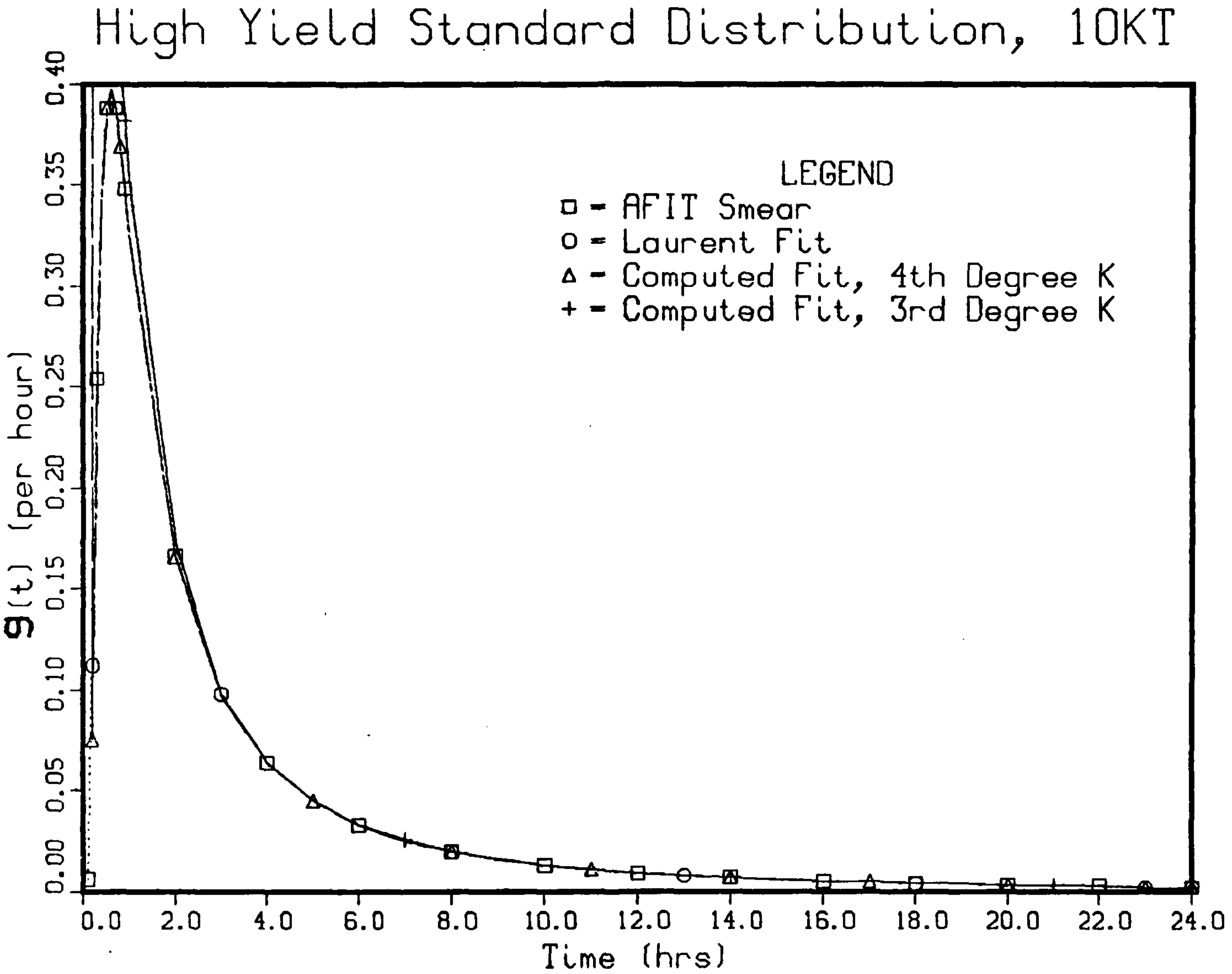

Fig. B-9 High Yield Standard g(t), 10KT

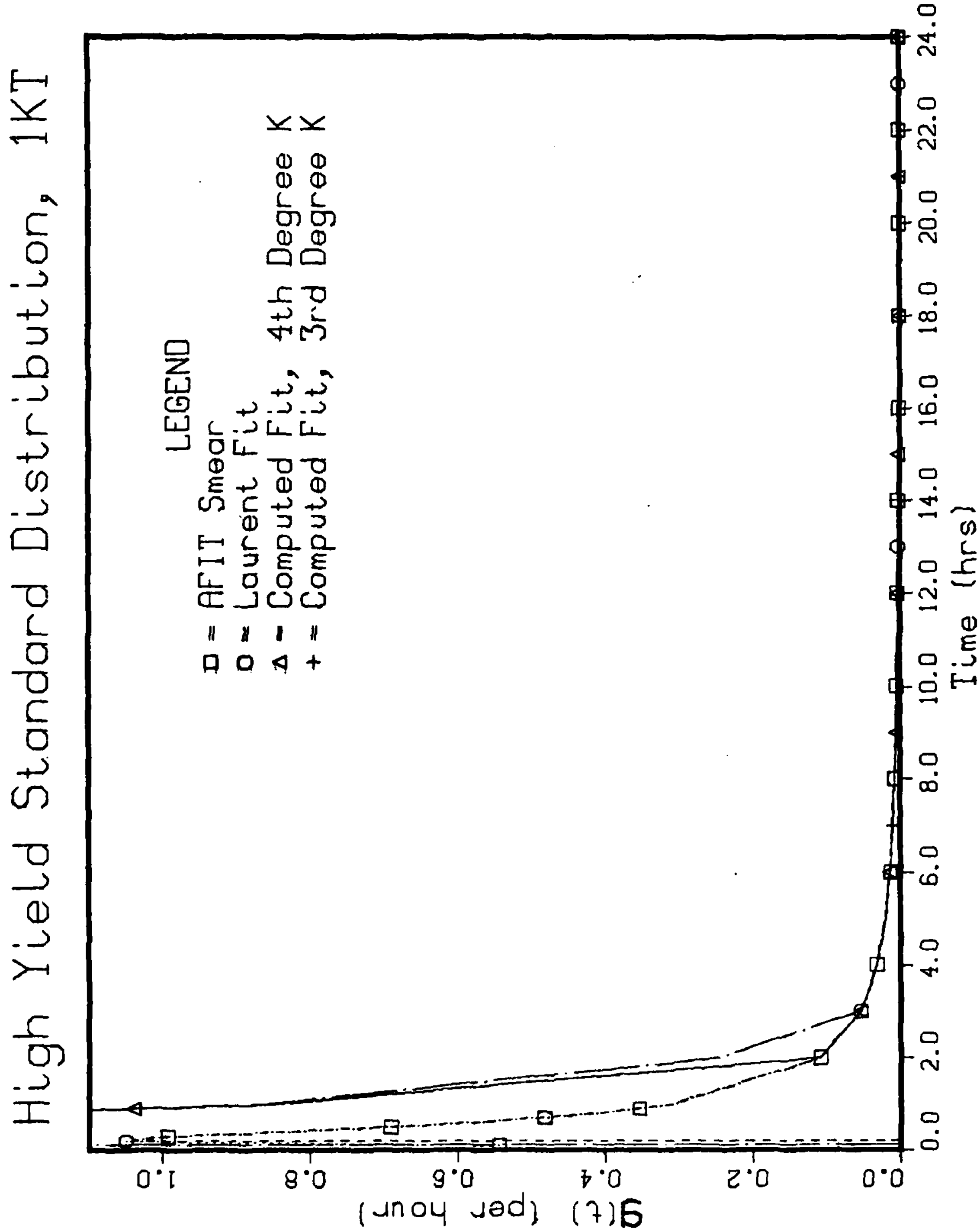

Fig B-10 High Yield Standard g(t), 1KT

Low Yield Standard Distribution

Table B-8
Laurent Coefficients for
Low Yield Standard Distribution

Yield	C1	C2	C3	C4	C5	C6	C7
15MT	-.00065566	.15081322	.00381455	-.07465699	.03976800	-.00838062	.00063263
1MT	-.00060311	.14848257	.02253726	-.07918319	.03794039	-.00756356	.00055149
100KT	-.00046279	.14446009	.03655433	-.06729794	.02688237	-.00472705	.00031476
10KT	-.00114688	.14632132	.02272265	-.02500419	.00570473	-.00050945	.00001194
1KT	-.00133399	.13530795	.03062559	-.02025256	.00666614	-.00119676	.00008501

Table B-9
4th Degree Polynomial Coefficients
for Low Yield Standard Distribution

C	K1	K2	K3	K4	K5
1	-.00060311	-.00020422	-.00002160	.00002478	.00000310
2	.14348257	.00302714	.00016380	-.00025561	-.00003704
3	.02253726	-.01159247	-.00115537	.00077921	.00010540
4	-.07918319	.00264517	.00240210	-.00070063	-.00011786
5	.03794039	.00142584	-.00121715	.00021800	.00004766
6	-.00756356	-.00061801	.00024850	-.00002560	-.00000814
7	.00055149	.00006179	-.00001821	.00000100	.00000051

Table B-10
3rd Degree Polynomial Coefficients
for Low Yield Standard Distribution

C	K1	K2	K3	K4
1	-.00047979	.00002173	-.00002986	-.00000208
2	.14700891	.00032719	.00026261	.00006540
3	.02673082	-.00390927	-.00143655	-.00013427
4	-.08387260	-.00594650	.00271652	.00032086
5	.03983654	.00489984	-.00134429	-.00019504
6	-.00788731	-.00121116	.00027021	.00004392
7	.00057176	.00009892	-.00001956	-.00000341

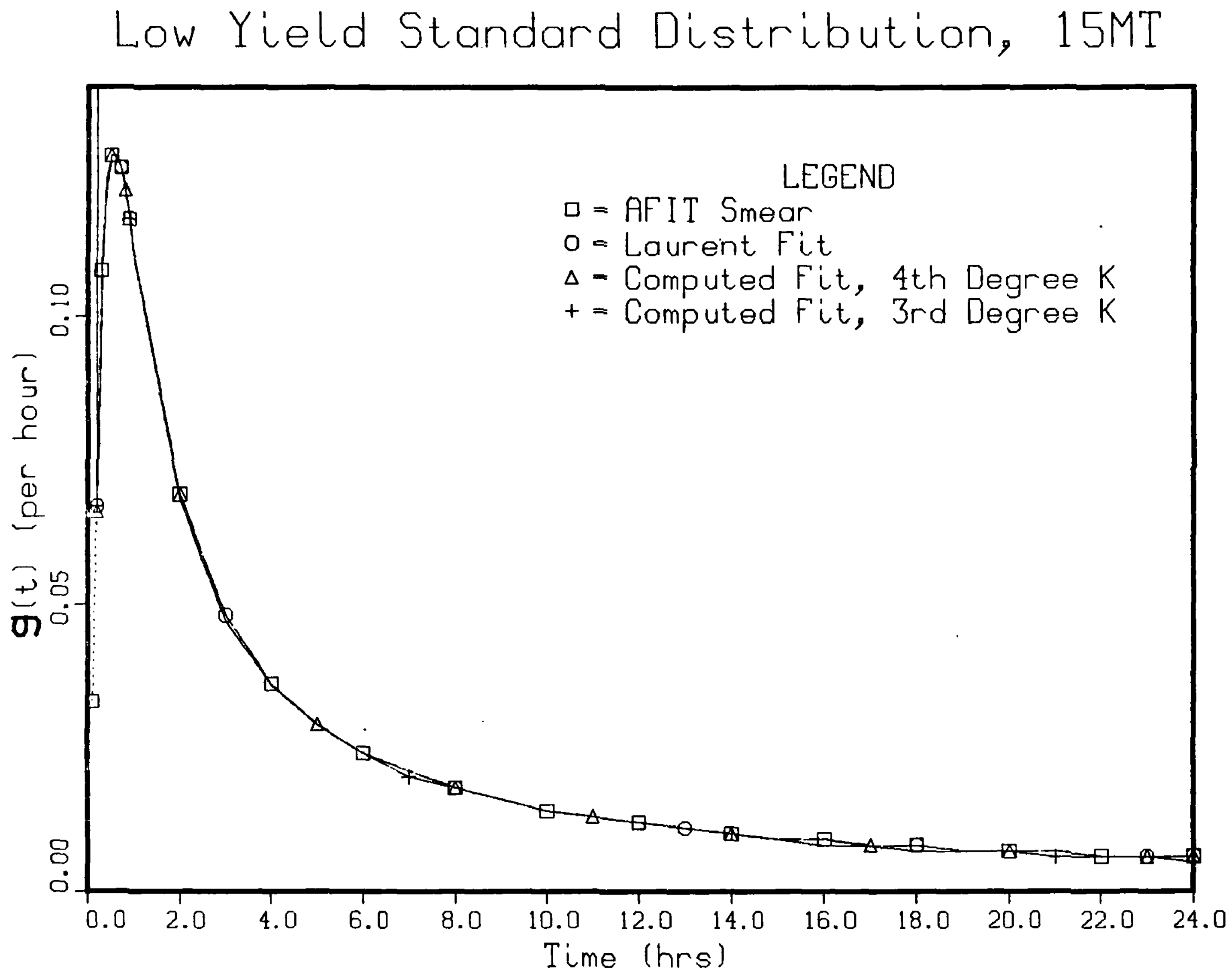

Fig. B-11 Low Yield Standard g(t), 15MT

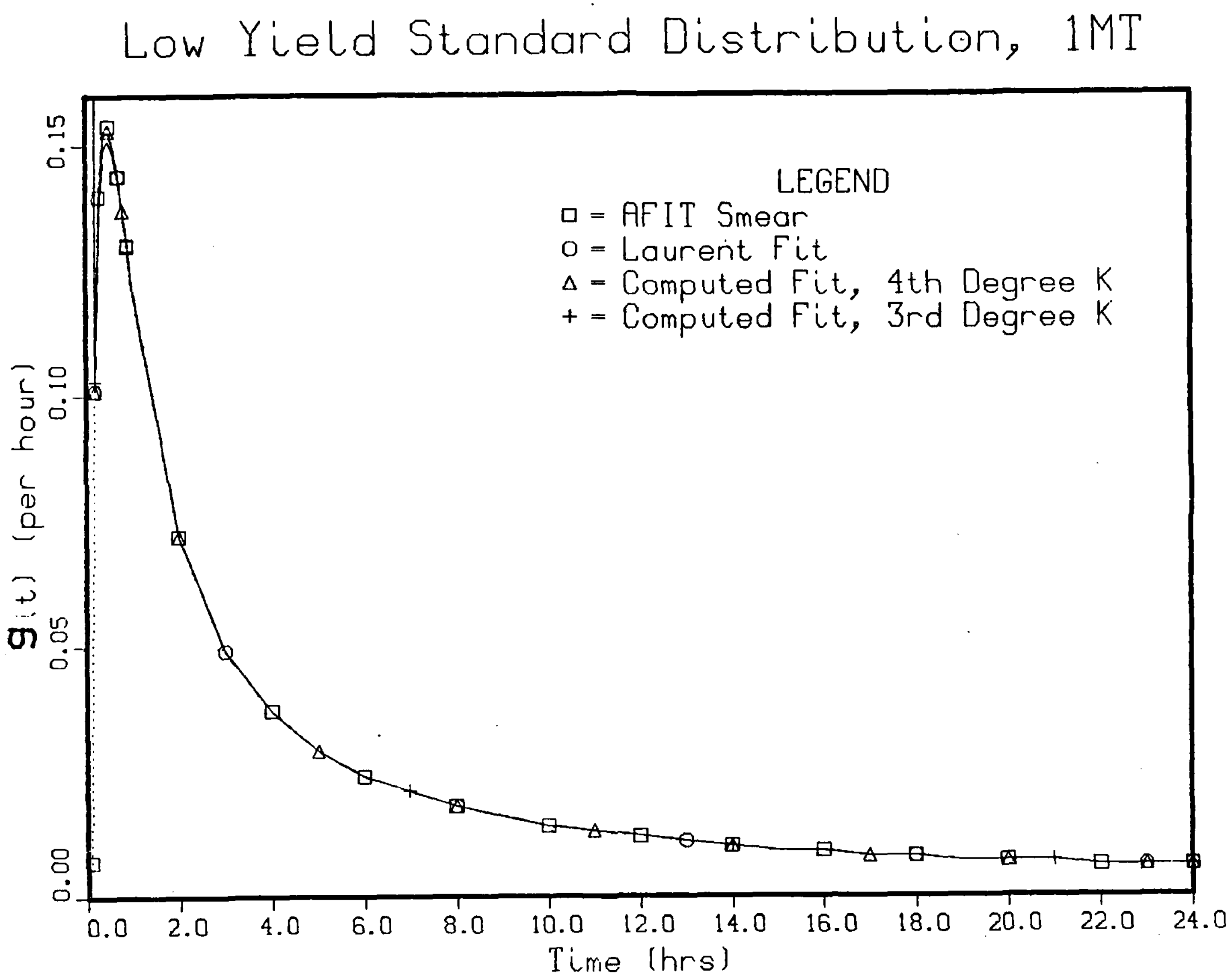

Fig. B-12 Low Yield Standard g(t), 1MT

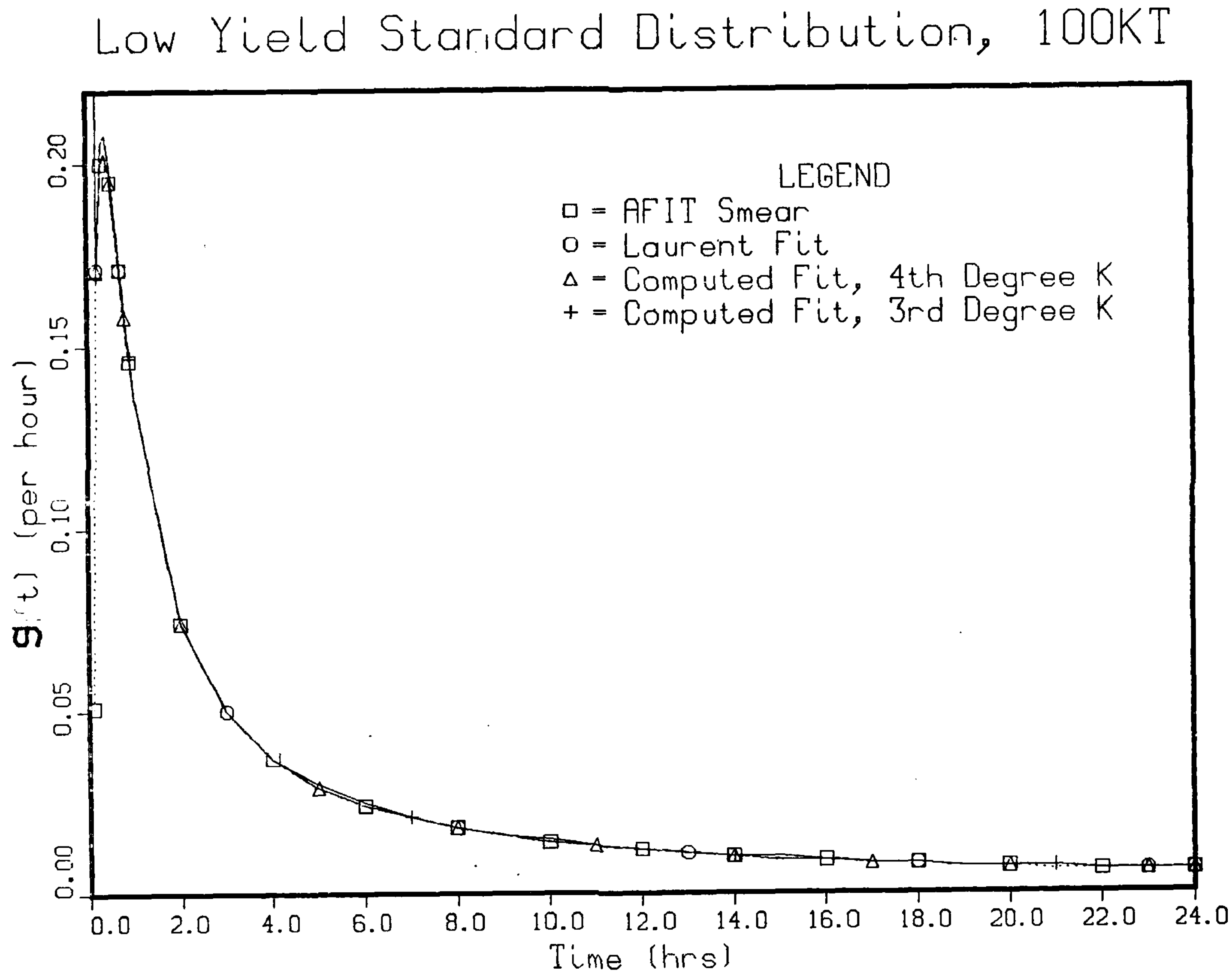

Fig. B-13 Low Yield Standard g(t), 100KT

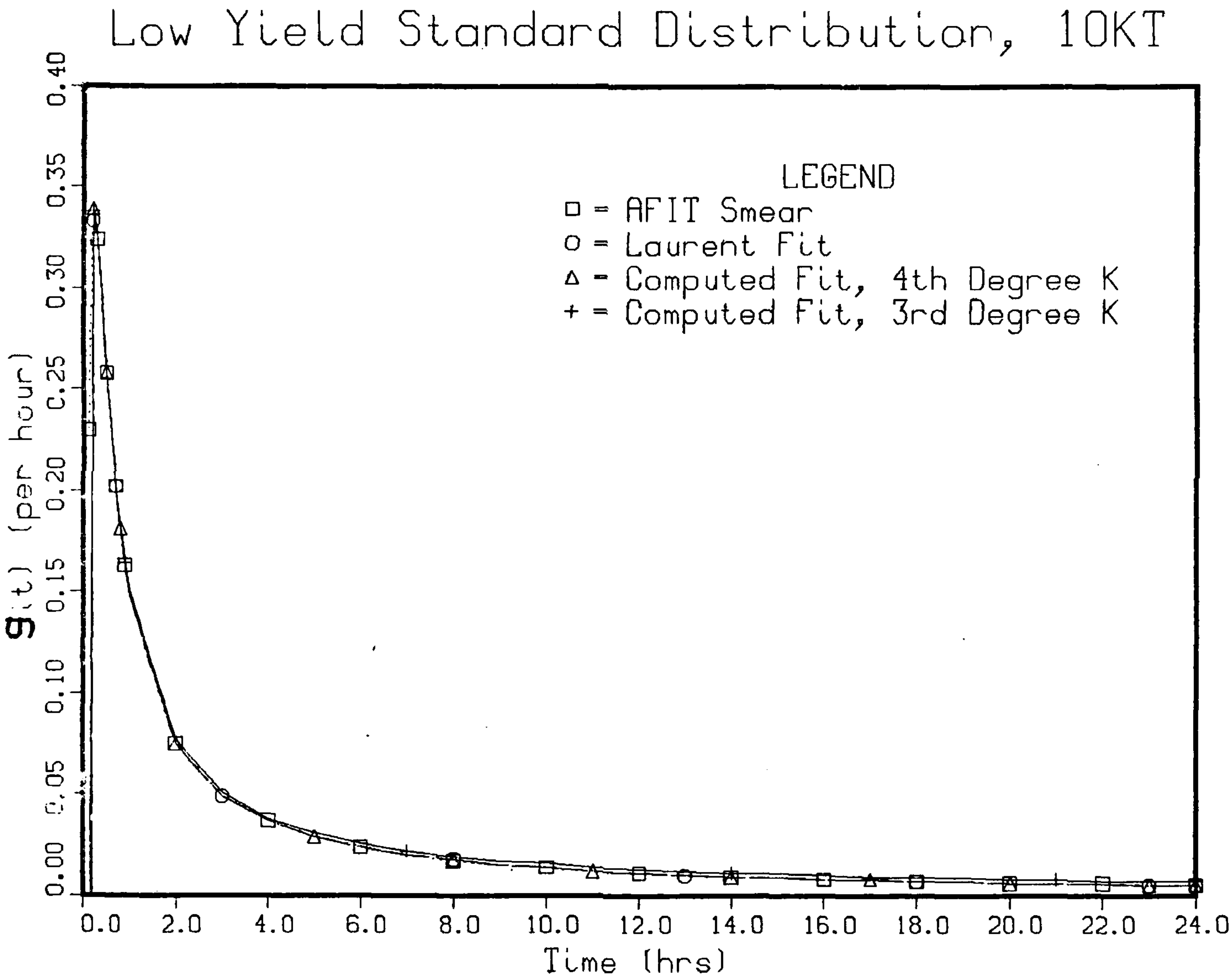

Fig. B-14 Low Yield Standard g(t), 10KT

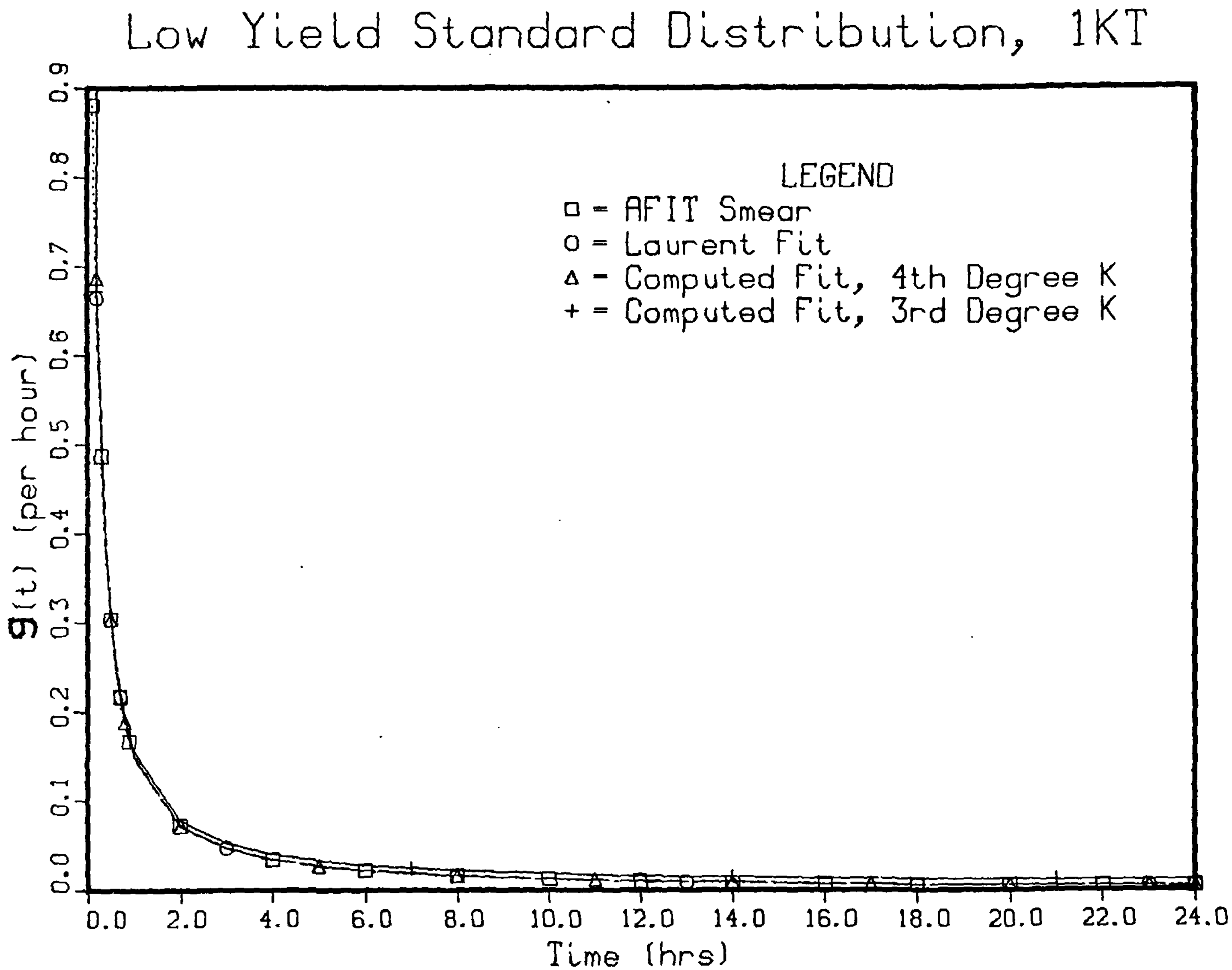

Fig. B-15 Low Yield Standard g(t), 1KT

NRDL-C61 Distribution

Table B-11
Laurent Coefficients for
NRDL-C61 Distribution

Yield	C1	C2	C3	C4	C5	C6	C7
15MT	-.00042768	.07954788	.21640942	-.15263025	.05060755	-.00823838	.00051744
1MT	-.00042774	.07708753	.19336201	-.11781905	.03403216	-.00485396	.00026950
100KT	-.00053048	.07789727	.14798938	-.06772837	.01425238	-.00137212	.00004240
10KT	-.00064791	.07547278	.09520249	-.02767826	.00393797	-.00029410	.00000965
1KT	-.00065898	.06384791	.06382661	-.02900744	.01095051	-.00215585	.00016055

Table B-12
4th Degree Polynomial Coefficients
for NRDL-C61 Distribution

C	K1	K2	K3	K4	K5
1	-.00042774	.00006306	-.00000950	-.00000423	-.00000032
2	.07708753	-.00022339	.00023127	.00007521	-.00000045
3	.19336201	.01532113	-.00230377	-.00012968	.00001910
4	-.11781905	-.01982045	.00167190	.00034810	-.00000577
5	.03403216	.00888199	-.00034683	-.00022532	-.00000854
6	-.00485396	-.00172161	.00001090	.00005163	.00000321
7	.00026950	.00012071	.00000208	-.00000394	-.00000030

Table P-13
3rd Degree Polynomial Coefficients
for NRDL-C61 Distribution

C	K1	K2	K3	K4
1	-.00044029	.00004007	-.00000866	-.00000150
2	.07706955	-.00025634	.00023248	.00007912
3	.19412189	.01671333	-.00235472	-.00023520
4	-.11804871	-.02024122	.00168730	.00039312
5	.03369236	.00825943	-.00032405	-.00015130
6	-.00472635	-.00148780	.00000235	.00002383
7	.00025773	.00009914	.00000287	-.00000138

Table P-14
2nd Degree Polynomial Coefficients
for NRDL-C61 Distribution

C	K1	K2	K3
1	-.00049035	.00003011	.00000078
2	.07970812	.00026900	-.00025483
3	.18427774	.01475334	-.00049935
4	-.10477230	-.01759786	-.00031497
5	.02864695	.00725488	.00062689
6	-.00393167	-.00132958	-.00014743
7	.00021180	.00008999	.00001153

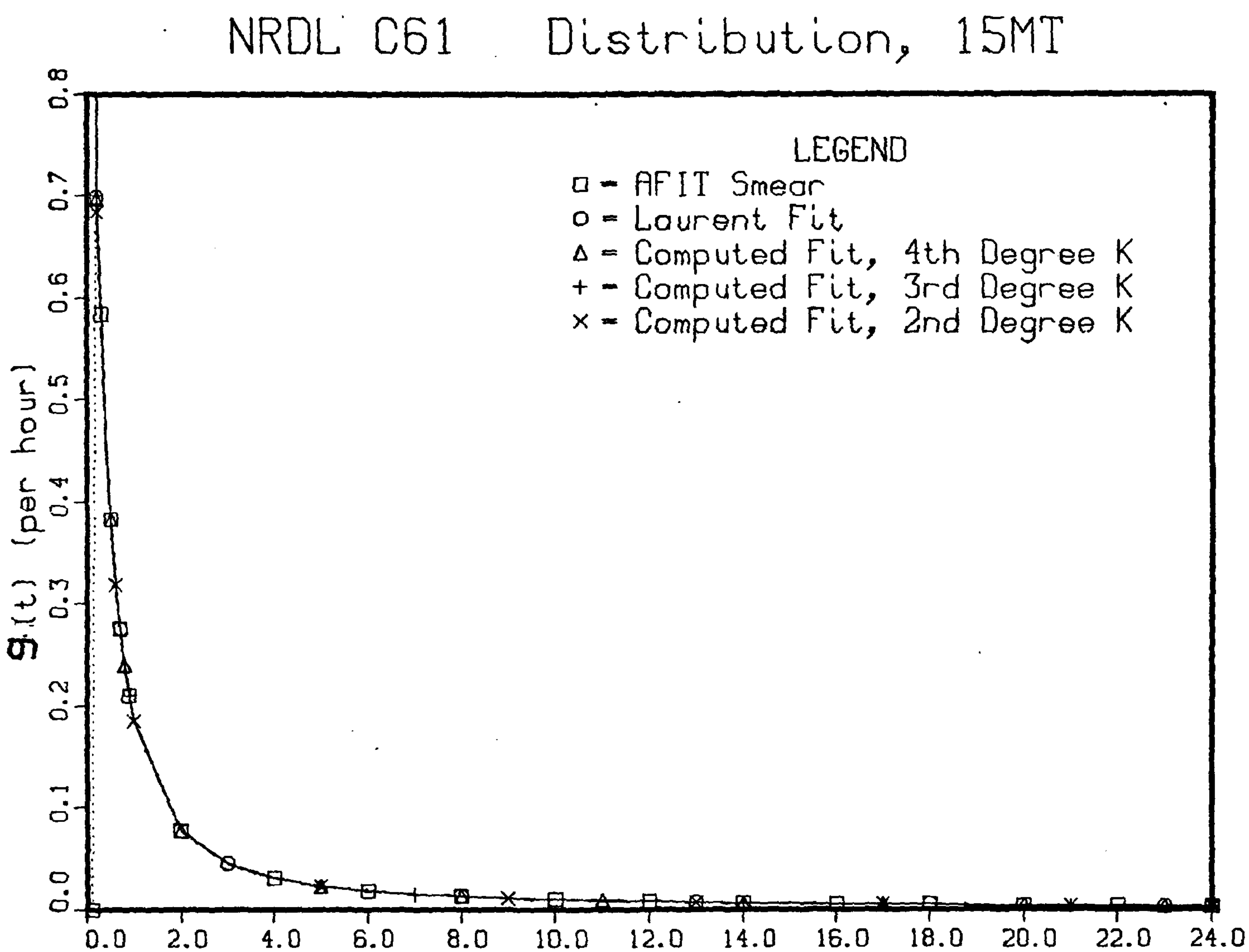

Fig. B-16 NRDL-C61 g(t), 15MT

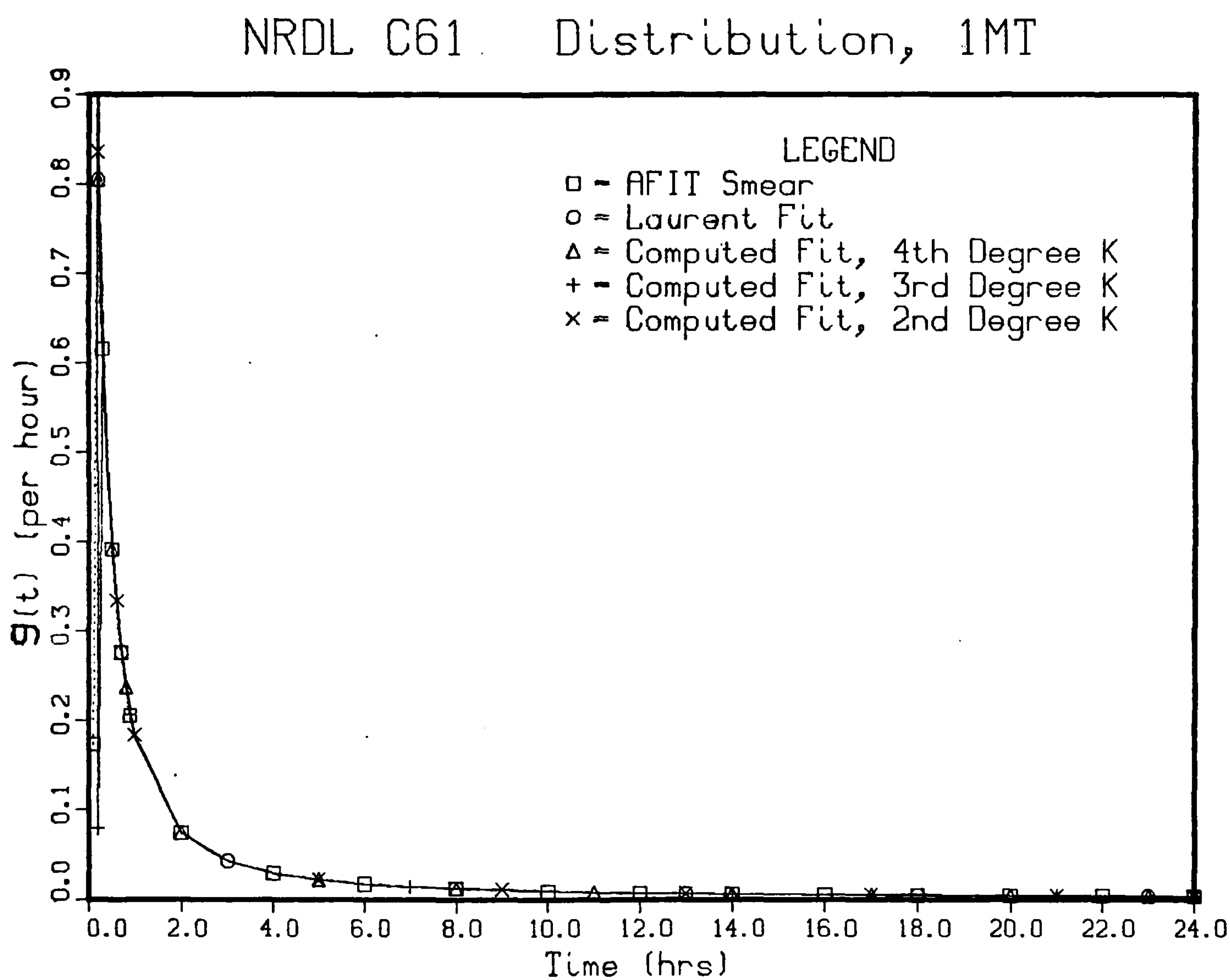

Fig. B-17 NRDL-C61 g(t), 1MT

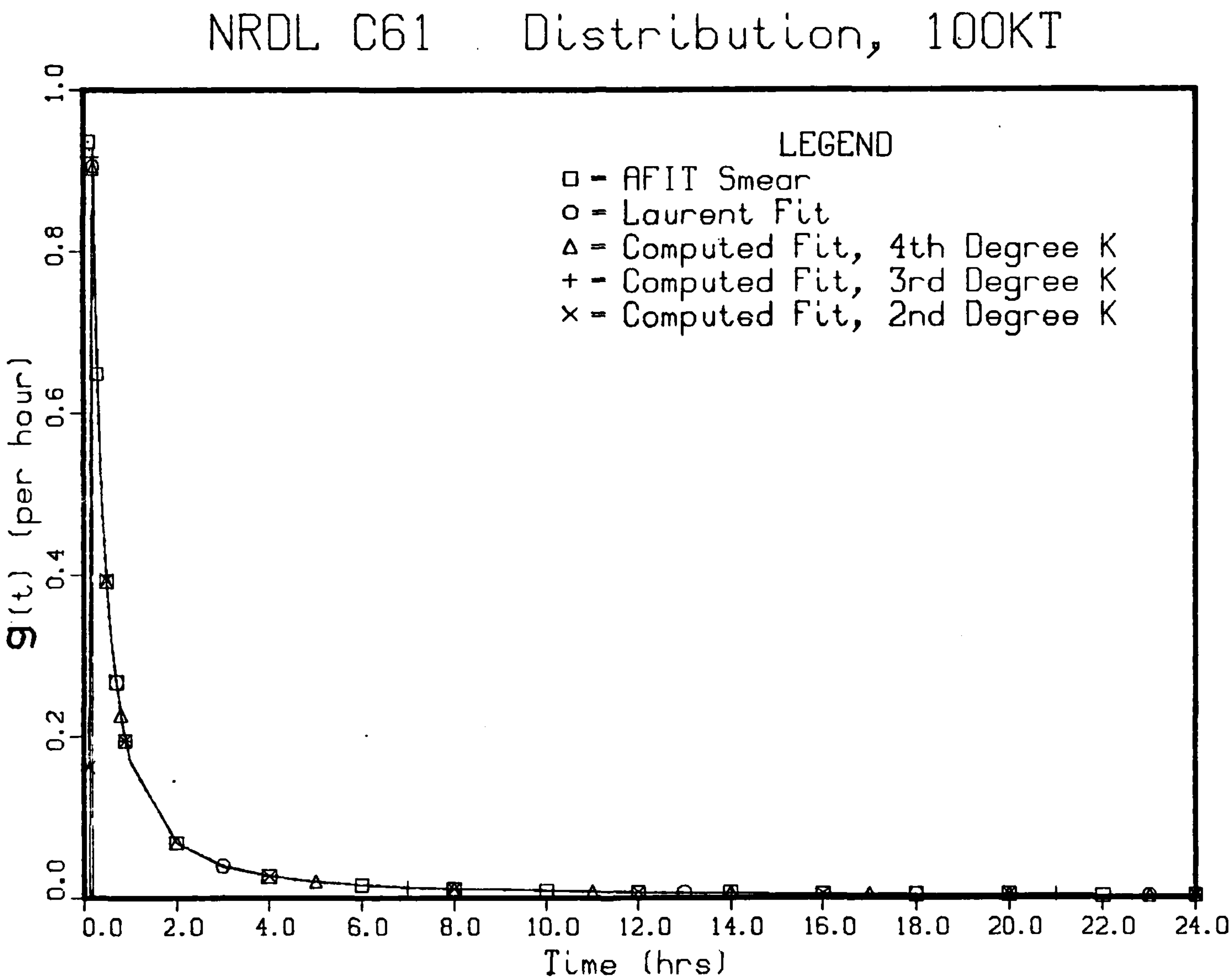

Fig. B-18 NRDL-C61 g(t), 100KT

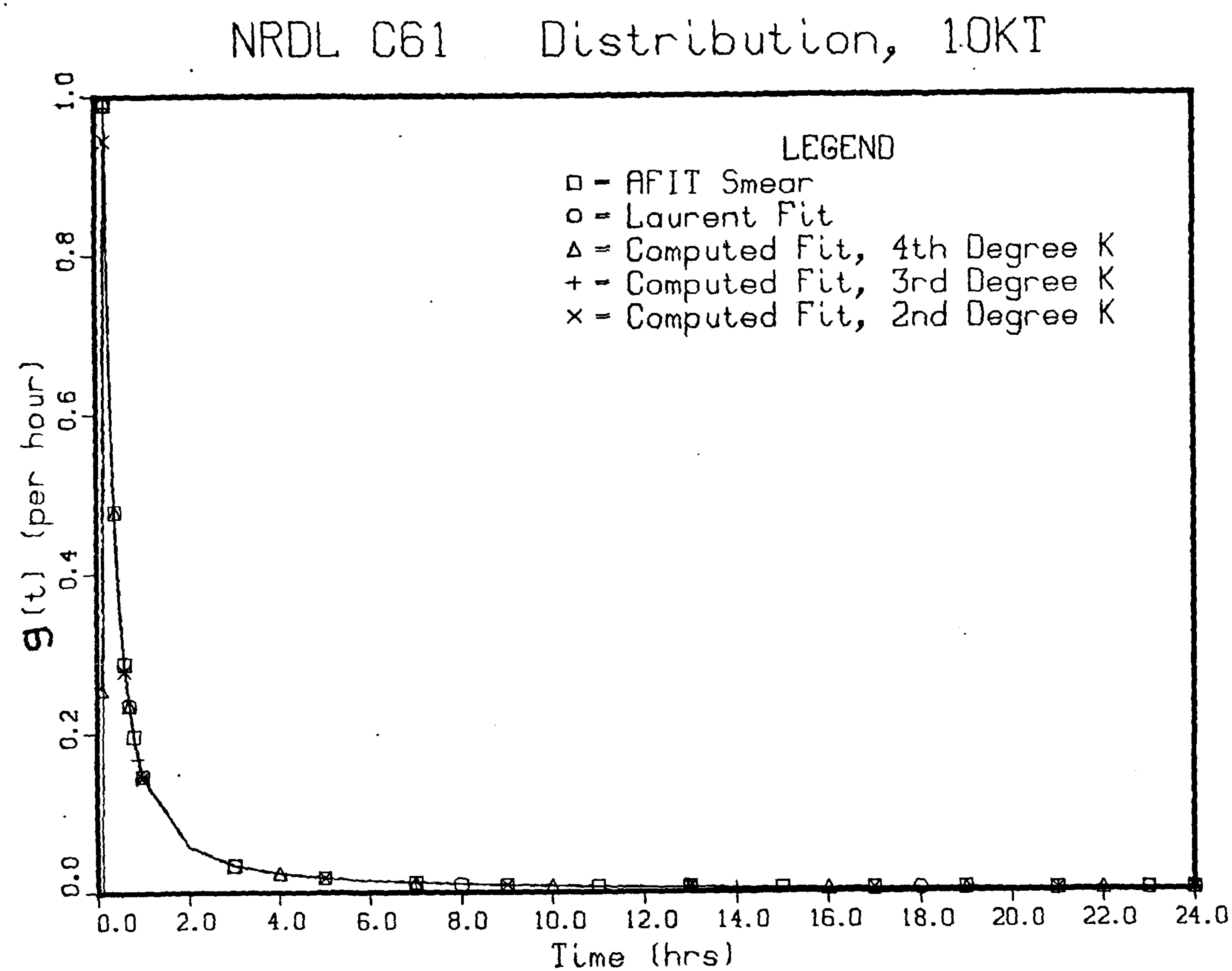

Fig. B-19 NRDL-C61 g(t), 1oKT

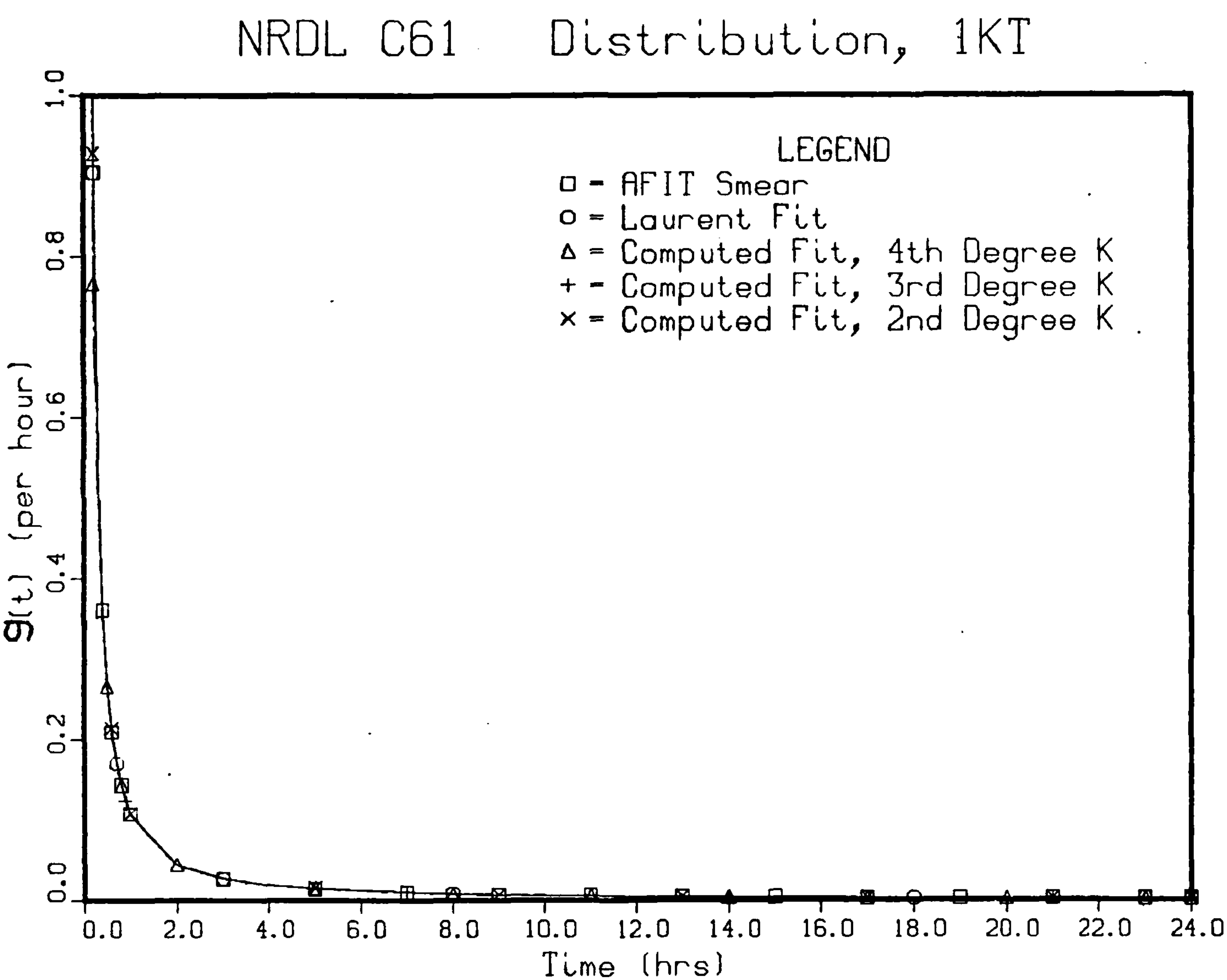

Fig. B-20 NRDL-C61 q(t), 1KT

Vita

LCDR James Henry Gogolin was born on March 5, 1943 in Harrold, SD. He was graduated from Rapid City High School, Rapid City, SD in 1961. He enlisted in the United States Navy in 1963 and served as a nuclear reactor operator in USS Bainbridge (CLGN-25). He is married to the former Linda Winterstein of Bel Air, MD. He attended North Carolina State University, Raleigh, NC under the Navy Enlisted Scientific Education Program where he received the degree of Bachelor of Science (Nuclear Engineering) in December, 1971, and was commissioned an Ensign. After completion of Naval Flight Officer training at NAS Pensacola, FL and NAS Glynco, GA he entered training in carrier based aviation antisubmarine warfare. LCDR Gogolin was assigned to Air Antisubmarine Squadron Twenty-Nine from 1972 to 1976 where he achieved qualification as Tactical Commander and Mission Commander in S-3A Viking aircraft. From 1977 to 1980 he served as Operational Test Director in Operational Test and Development Squadron One, NAS Patuxent River, MD. From 1980 to 1982 he served as Ordnance Officer in USS Midway (CV-41). LCDR Gogolin entered the Graduate Nuclear Effects program, School of Engineering, Air Force Institute of Technology in August, 1982.

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A set of empirical equations is produced to calculate the fractional arrival rate of radioactivity on the ground where the radioactivity is the result of a nuclear surface burst. A total of 20 such equations are given for four log-normal particle size distributions and five nuclear yields from 1KT to 15MT. The fractional arrival rate of radioactivity on the ground, $g(t)$, data for the 20 cases were generated by a fast running fallout smearing code. The results were fit with a sixth degree Laurent series for each of five particular yields. For each size distribution the Laurent series coefficients for the five yields were then fit with a polynomial function of yield to enable computation of $g(t)$ data for any arbitrary yield between 1KT and 15MT. Calculation of $g(t)$ data with these empirical equations may be accomplished on a hand held calculator and produce results which are accurate to within at least 4 percent of the fallout smearing computer code data.

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