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INSTITUTE OF NUCLEAR PHYSICS
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FIT OF EXPERIMENTAL POINTS TO THE SUM OF TWO (OR ONE) EXPONENTIALS WITH BACKGROUND

PROGRAM FOR ODRA 1305 COMPUTER

PART II

For Time Analysers with Constant Dead Time after Each Registered Pulse (AC–256 Type)

KRZYSZTOF DROZDOWICZ
EWA KRYNICKA–DROZDOWICZ

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WYRÓWNYWANIE PUNKTÓW DOŚWIADCZALNYCH DO SUMY DWÓCH (LUB JEDNEJ) EKSPONENT Z TŁEM

PROGRAM DLA E.M.C. ODRA 1305

Część II: Dla analizatorów czasu ze stałym czasem martwym po każdym zarejestrowanym impulsie (typu AC-256)

УРАВНИВАНИЕ ЭКСПЕРИМЕНТАЛЬНЫХ ТОЧЕК СУММОЙ ДВУХ (ИЛИ ОДНОЙ) ЭКСПОНЕНЦИАЛЬНЫХ ФУНКЦИЙ С ФОНОМ

ПРОГРАММА ДЛЯ ВЫЧИСЛИТЕЛЬНОЙ МАШИНЫ ODRA 1305

Часть II: Для анализаторов времени с постоянным мертвым временем после каждого регистрованного импульса (типа АС-256)

Krzysztof Drozdowicz, Ewa Krynicka-Drozdowicz

Institute of Nuclear Physics

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ABSTRACT

The LAMA program (in FORTRAN 1900 language), which fits the set of decaying experimental values to the sum of the two (or one) exponentials with background, is described. The method of calculation and its accuracy and the interpretation of the program results are given in Part I of the paper. The changes and the extensions of the calculation, referred to the dead time effect taken into account for time analysers having the constant dead time after each registered pulse, are described.

STRESZCZENIE

W artykule przedstawiono program (napisany w języku FORTRAN 1900) dopasowujący funkcję zawierającą dwie lub jedną eksponentę i składową stałą do ciągu malejących wartości doświadczalnych. Metoda obliczeniowa, jej dokładność oraz interpretacja wyników programu zostały zaprezentowane w Części I artykułu. Tu opisano zmiany i uzupełnienia wprowadzone w związku z uwzględnieniem wpływu czasu martwego analizatorów czasu o stałym czasie martwym po każdym rejestrowanym impulsie.

РЕЗЮМЕ

В статьи представлена программа (на языке FORTRAN 1900), которая уравнивает кривую сложенную из двух или одной экспоненциальной функции и константы к последовательности уменшивающихся экспериментальных величин. Вычислительный метод, его точность и способ интерпретации результатов программы представлены в Части I. Здесь описаны добавления и изменения программы относящиеся к многоканальным анализаторам времени, в которых мертвое время постоянно после каждого регистированного импульса.

1. INTRODUCTION

The LAMA program fits the experimental data to the one exponential with background or to the sum of two exponentials with background, using the very same method as that presented in the description of the MYSZY program [1], but with taking into account the dead time effect for some other kind of the multichannel time analysers. In the LAMA program the count-loss correction due to the dead time is referred to the analysers having the constant dead time after each registered pulse. In such analysers the pulse arriving at the input is at once stored in the analyser memory and the time of this operation is just the dead time τ_d of analyser. The count-loss correction must be introduced to obtain the correct values λ^c of decay constants in this case. This correction depends upon the ratio of the dead time τ_d to the width of the time channel Δt [2] (the LAMA program can be used for any integer - - in microseconds - values of τ_d and Δt). Thus, the structure of the program is the completely new one.

In this part the formulae, which are new or different from those in Part I of this paper [1], will be presented. The symbols of quantities used here are the same as in [1]. The equations being taken from Part I will be marked as (No/I).

The fit for the case of the sum of two exponentials with a constant component will be shortly denoted as 2EXP+C and for the one exponential with background - as 1EXP+C.

2. CHANGES IN THE METHOD OF CALCULATION

2.1. Correction for dead time of analyser

The form of the correction in the case of analysers having the constant dead time after each registered pulse, is different depending upon whether or not the value of the ratio of the analyser dead time τ_d to the width Δt of time channel is greater than one.

For $\frac{\tau_d}{\Delta t} \geq 1$ the formula for the corrected number of counts N_i^c in the i-th channel of time analyser*) is given by [3, 2]:

$$N_i^c = - S \ln(1 - \frac{N_i}{S - K_i}) \quad , \qquad (1)$$

where

S - number of runs of analyser,

N_i - uncorrected (i.e. stored during the measurement) number of counts in i-th channel of time analyser,

$$K_i = \sum_{j=i-r}^{i-1} N_j + (\frac{\tau_d}{\Delta t} - r) N_{i-r-1} \quad , \qquad (2)$$

where

$$r = C(\frac{\tau_d}{\Delta t}) \quad - \text{max. integer**)} \quad . \qquad (3)$$

One can see from (1) and (2) that the corrected N_i^c values are obtained starting with the channel No $r+1$ or $r+2$.

For $\frac{\tau_d}{\Delta t} < 1$ the value of the N_i^c is calculated [2] as:

$$N_i^c = - S \, p_r \ln v_{0i} \quad , \qquad (4)$$

where

p_r follows from the ratio $\frac{\tau_d}{\Delta t} = \frac{q_r}{p_r}$, where q_r and p_r

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*) The superscript ^{c} at a symbol signifies the corrected value i.e. the value with the correction for the dead time of analyser taken into account.

**) $C(x) = r$: $r \leq x < r+1$, where x is real and r is integer.

are numbers which have not the common divisor,

v_{0i} - real root of equation:

$$v^{p_r} + \frac{N_{i-1}}{S - N_{i-1}} v^{p_r - q_r} - \frac{S - N_i}{S - N_{i-1}} = 0 \quad , \qquad (5)$$

$$0 < v_{0i} < 1 \quad .$$

The values of the corrected decay constants λ_j^c, amplitudes of exponentials α_j^c and background α_b^c are calculated utilising the dependences described in [1] but using the corrected numbers of counts N_i^c instead of the N_i counts.

2.2. <u>Standard deviations</u>

The standard deviation $\sigma(\lambda^c)$ of the calculated corrected decay constant λ^c was obtained by the variance method. A general relation for the λ^c value calculated with the Cornell´s method (see Eq.(3/I) and (11/I)) is given by:

$$\lambda^c = - \frac{1}{n\,\Delta t} \ln x^c \quad , \qquad (6)$$

where for 2EXP+C it is λ_j^c and x_j^c with $j=1,2$. The quantity x^c is a function of the sums S_q^c :

$$x^c = x^c(S_1^c, S_2^c, \ldots, S_p^c) \quad . \qquad (7)$$

For 2EXP+C the x_j^c are given as the roots of the quadratic equation (4/I). For 1EXP+C the x^c is given by the formula (12/I). The S_q^c values are calculated from the formulae:

$$S_q^c = \sum_{i=(q-1)n+i_o}^{qn-1+i_o} N_i^c \quad , \qquad (8)$$

$$q = 1, 2, \ldots, p$$

where

$$p = \begin{cases} 5 & \text{for 2EXP+C,} \\ 3 & \text{for 1EXP+C,} \end{cases}$$

n - number of components N_i^c in each sum S_q^c (see Eq. (2/I)),

i_o - number of the analyser channel which is the first channel of analysed time interval (the 2EXP+C or 1EXP+C fit is performed in the finite time interval of a constant length and at the begining in the channel No i_o, varying with a constant step - see paragraph 3.1 in [1]),

$$N_i^c = N_i^c(N_{i-r_1}; N_{i-r_1+1}, \ldots, N_{i-1}, N_i) \quad , \qquad (9)$$

where the form of the above function (9) for the corrected number of counts N_i^c depends upon the ratio $\frac{\tau_d}{\Delta t}$ (see Eqs. (1,4)) and the r_1 value is defined as:

$$r_1 = \begin{cases} r & \text{for } \frac{\tau_d}{\Delta t} - r = 0, \\ r+1 & \text{for } \frac{\tau_d}{\Delta t} - r > 0, \end{cases} \qquad (10)$$

(r is given by Eq. (3)).

The variance $V(\lambda^c)$ of the corrected decay constant λ^c calculated from Eq. (6) is given by:

$$V(\lambda^c) = \sum_{q=1}^{p} \left(\frac{\partial \lambda^c}{\partial S_q^c} \right)^2 V(S_q^c) + 2 \sum_{q=1}^{p} \sum_{t=q+1}^{p} \frac{\partial \lambda^c}{\partial S_q^c} \frac{\partial \lambda^c}{\partial S_t^c} \mathrm{Cov}(S_q^c, S_t^c) \,, \tag{11}$$

where derivatives are calculated in the point determined by the values of sums S_q^c : $S_1^c, S_2^c, \ldots, S_p^c$. The form of the Eq.(11) is valid for the decay constant λ^c for 2EXP+C and for 1EXP+C as well, and it is independent upon the r value. But the relations determining the respective terms in Eq.(11) are different in these two cases. It is illustrated in Fig.1, where the scheme for the four possible ways of the calculation is given.

The derivatives $\frac{\partial \lambda^c}{\partial S_q^c}$ in Eq.(11) are given by:

$$\frac{\partial \lambda^c}{\partial S_q^c} = - \frac{1}{n\Delta t} \frac{1}{x^c} \frac{\partial x^c}{\partial S_q^c} \,, \tag{12}$$

$$q = 1, 2, \ldots, p.$$

The formulae which determined the derivatives $\frac{\partial x^c}{\partial S_q^c}$ depending upon 2EXP+C or 1EXP+C are given in the Appendix in [1].

The forms of the formulae for the variances $V(S_q^c)$ and covariances $\mathrm{Cov}(S_q^c, S_t^c)$ of the sums S_q^c are dependent upon the ratio $\frac{\tau_d}{\Delta t}$. The assumption $n > r_1$ was accepted (it is easy to realise) and then $\mathrm{Cov}(S_q^c, S_t^c) = 0$ for $q-t > 1$, i.e. $\mathrm{Cov}(S_q^c, S_{q+1}^c)$ remains only.

Thus, in the case $\frac{\tau_d}{\Delta t} \geq 1$ the relations for the variances $V(S_q^c)$ and covariances $\mathrm{Cov}(S_q^c, S_{q+1}^c)$ are given by:

$$V(S_q^c) = \sum_{k=(q-1)n-r_1+i_0}^{qn-1+i_0} \left(\sum_{i=k}^{k+r} Z_i \right)^2 V(N_k) \,, \tag{13}$$

$$q = 1, 2, \ldots, p$$

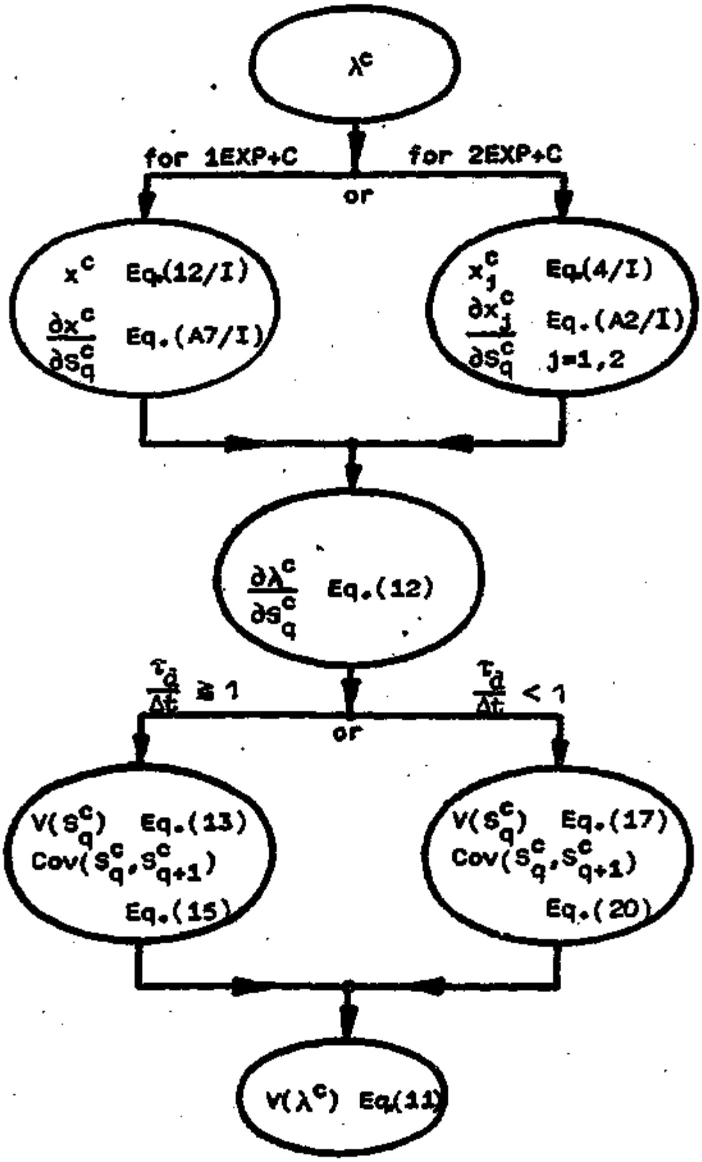

Fig.1. Scheme of different ways for calculation the variance $V(\lambda^c)$.

where

$$Z_i = \begin{cases} \frac{\partial N_i^q}{\partial N_k} & \text{for} \quad (q-1)n+i_o \leq i \leq qn-1+i_o \quad , \\ 0 & \text{for} \quad i < (q-1)n+i_o \quad \text{or} \quad i > qn-1+i_o \quad , \end{cases} \tag{14}$$

$$V(N_i) \approx N_i \quad .$$

$$Cov(S_q^c, S_{q+1}^c) = \sum_{k=qn-r_i+i_o}^{qn-1+i_o} \left(\sum_{i=k}^{qn-1+i_o} Z_i \sum_{i=qn+i_o}^{k+r_i} Z_i \right) V(N_k) \quad , \tag{15}$$

$$q = 1,\ 2,\ \ldots,\ (p-1)$$

where

$$Z_i = \frac{\partial N_i^c}{\partial N_k} \quad . \tag{16}$$

In the case $\frac{\tau_d}{\Delta t} < 1$ the relations for the variances and covariances are:

$$V(S_q^c) = \sum_{k=(q-1)n-1}^{qn-1} (W_k + Z_{k+1})^2 \, V(N_k) \quad , \tag{17}$$

$$q = 1,\ 2,\ \ldots,\ p$$

where:

$$W_k = \begin{cases} 0 & \text{for } k = (q-1)n-1 , \\ \frac{\partial N_k^c}{\partial N_k} & \text{for } k > (q-1)n-1 ; \end{cases} \tag{18}$$

$$Z_{k+1} = \begin{cases} \frac{\partial N_{k+1}^c}{\partial N_k} & \text{for } k < qn-1 , \\ 0 & \text{for } k = qn-1 . \end{cases} \tag{19}$$

$$Cov(S_q^c, S_{q+1}^c) = \left(\frac{\partial N_{qn-1}^c}{\partial N_{qn-1}} \right) \left(\frac{\partial N_{qn}^c}{\partial N_{qn-1}} \right) V(N_{qn-1}) \quad . \tag{20}$$

$$q = 1, 2, \ldots, (p-1).$$

The formulae for the derivatives $\frac{\partial N_i^c}{\partial N_k}$ for both cases of $\frac{\tau_d}{\Delta t}$ are given in the Appendix.

2.3. Mean of the decay constant

In the fitting procedure for the one exponential with background the λ_i^c values obtained for the i-th consecutive steps of the delay time have the same expectation value (cf paragraph 3.1 in [1]). The estimator $\overline{\lambda^c}$ of this expected value is thus obtained as the weighted mean:

$$\overline{\lambda^c} = \frac{\sum_{i=1}^{N} w_i \lambda_i^c}{\sum_{i=1}^{N} w_i} , \tag{21}$$

where

λ_i^c - value of decay constant obtained for i-th value of delay time,

w_i - weight of the λ_i^c value: $w_i = 1/\sigma^2(\lambda_i^c)$,

$\sigma(\lambda_i^c)$ - standard deviation of λ_i^c value,

N - total number of λ_i^c values.

The unbiased estimator $s^2(\lambda^c)$ of the variance $\sigma^2(\lambda^c)$, when the weights are present, is:

$$s^2(\lambda^c) = \frac{\sum_{i=1}^{N} w_i}{\left(\sum_{i=1}^{N} w_i\right)^2 - \sum_{i=1}^{N} w_i^2} \sum_{i=1}^{N} w_i \left(\lambda_i^c - \overline{\lambda^c}\right)^2 . \qquad (22)$$

3. PROGRAM OF CALCULATION

3.1. Description of the program

The calculation method used in the LAMA program is, in general, the same as that in the MYSZY program and the previous remarks [1] concerned with the accuracy of the method and with the interpretation of results can be referred to this case, too. But the substantial changes (due to the adaptation to the other type of time analysers), extensions and facilities are introduced. The LAMA program performs the fit of experimental points to the sum of the two exponentials with background and to the one exponential with background. The following values are obtained in function of delay time as the results of the program: decay constants of exponentials (from 2EXP+C and 1EXP+C fitting) with their standard deviations, the amplitudes of exponentials and the background; the count-loss correction

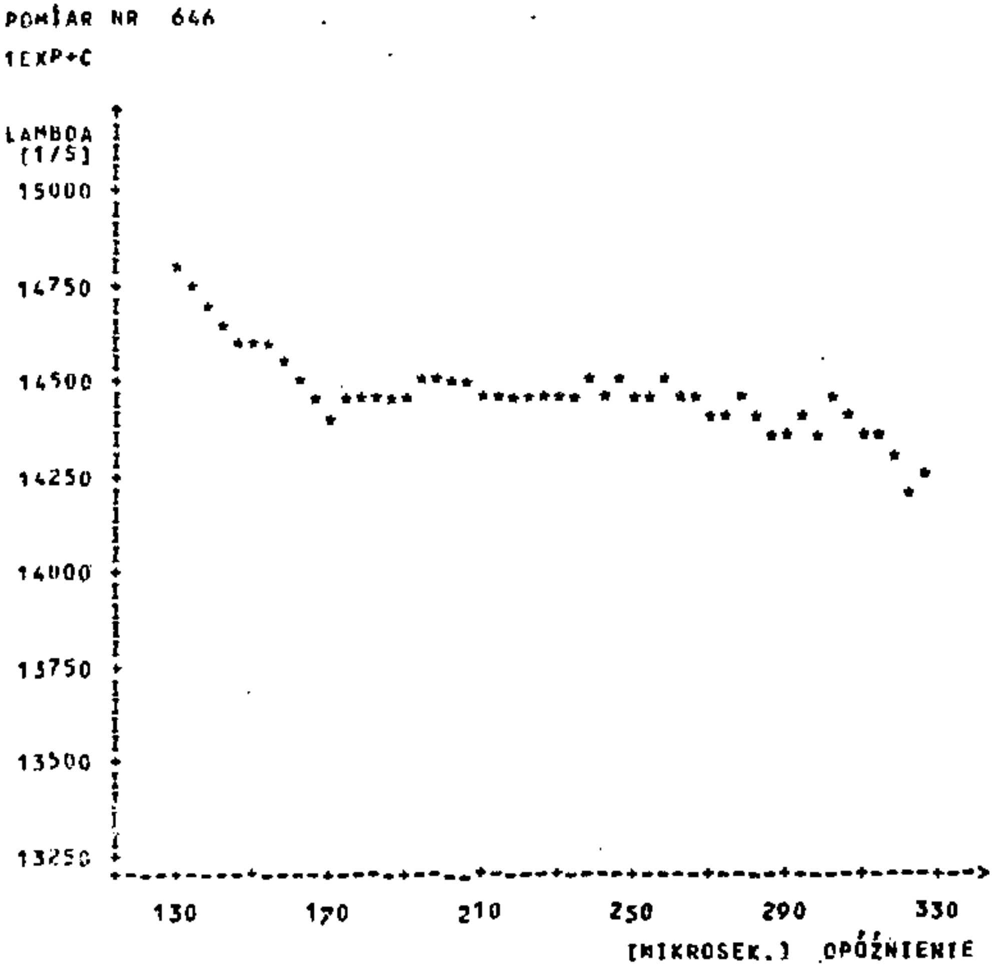

Fig.2. Plot of the decay constant vs delay time.

for time analysers, having the constant dead time after each registered pulse, is taken into account in the computation. The above mentioned values arising from the uncorrected data are computed, too, but without their standard deviations because the uncorrected results are auxiliary only in the interpretation of the final results.

The rough plot of the decay constant vs delay time is printed on the line printer. The typical plot is shown in Fig. 2, where the interval of the statistically constant values of the decay constant can be seen (the higher values, which are visible in the initial part of the plot, are due to the fact that the 1EXP+C model is inadequate in this range). The mean of the decay constant is calculated many times - from the successive λ_i^c value to the last one and it is easy to choose the right value of this mean by the comparison of the successive results and the plot.

In the main sequence of the program statements there are the relations for computing the values of some quantities being used in the further computation many times. Next there are the logical statements controlling the choice of computational ways and the statements calling the proper subroutines which perform the particular computations. For making clear the description of the program the list of these subroutines will be given first (Table 1), together with the short presentation of the results reached by each one.

The block diagram of the LAMA program is given in Fig.3. This general scheme of the program is very simple and it is not necessary to describe it; some short explanations will be only given.

The program runs using the FTRAP subroutine (see Table 1) and for this reason a non-fatal execution error, which can arrive, does not stop the computer work and the program can be continued (the information about the error is printed).

In the part denoted by "overflow" the value of the control variable NAD (see the NADM subroutine) is tested; if NAD=1

Table 1. List of subroutines

subroutine	result	formula () or reference []
BLAMBDA	decay constant λ	(11/I), (6)
COND	matrices being used in calculation of variances $V(S_q^c)$ and covariances $Cov(S_q^c, S_{q+1}^c)$ for the case $\frac{\tau_d}{\Delta t} \geq 1$	(14), (16) (A1) ÷ (A5)
DANE	print of the input matrix of numbers of counts N_i	
DRUK DRUK1 DRUKDO DRUKLPT	print of the results of calculation in tabular form	
F4BAIRSTOW	roots of polynomial with real coefficients	[4]
FTRAP	subroutine used to attach an own source monitoring program	[5]
INARRAY	translation of the data given in the odd code on the punched tape for ODRA 1305 computer	[6]
LALF2	decay constants λ_j (using the BLAMBDA function), amplitudes α_j and background α_0 - $j=1,2$ - for 2EXP+C; if $x_j \leq 0$ (for $j=1$ or $j=2$) then the λ_j value is assumed to be equal to zero	(3/I), (7/I), (8/I), (9/I)
LAMSR	weighted mean of decay constant with standard deviation for 1EXP+C	(21), (22)

Table 1 (continued)

subroutine	result	formula () or reference []
NADM	own source monitoring program: if a non-fatal execution error arrives in computation the NADM subr. (called then by the FTRAP subr.) assignes the number 1 to the control variable NAD; the number of the error is printed, too.	
SQQ	sums S_q	(2/I), (8)
VARLAM	standard deviations $\sigma(\lambda^c) = \sqrt{V(\lambda^c)}$	(11)
VARSQA	variances $V(S_q^c)$ and covariances $Cov(S_q^c, S_{q+1}^c)$ for the case $\frac{\tau_d}{\Delta t} \geq 1$ (using the COND subroutine)	(13), (15)
VARSQB	variances $V(S_q^c)$ and covariances $Cov(S_q^c, S_{q+1}^c)$ for the case $\frac{\tau_d}{\Delta t} < 1$	(17), (20)
WYKRES	print of the plot of decay constant λ^c vs delay time (for 1EXP+C)	
XLALF	decay constant λ (using the BLAMBDA subr.), amplitude α and background α_b for 1EXP+C; if $x \leq 0$ then the λ value is assumed to be equal to zero	(11/I), (13/I) (14/I), (6)
XX	roots x_j (j=1,2) of Eq.(4/I)	

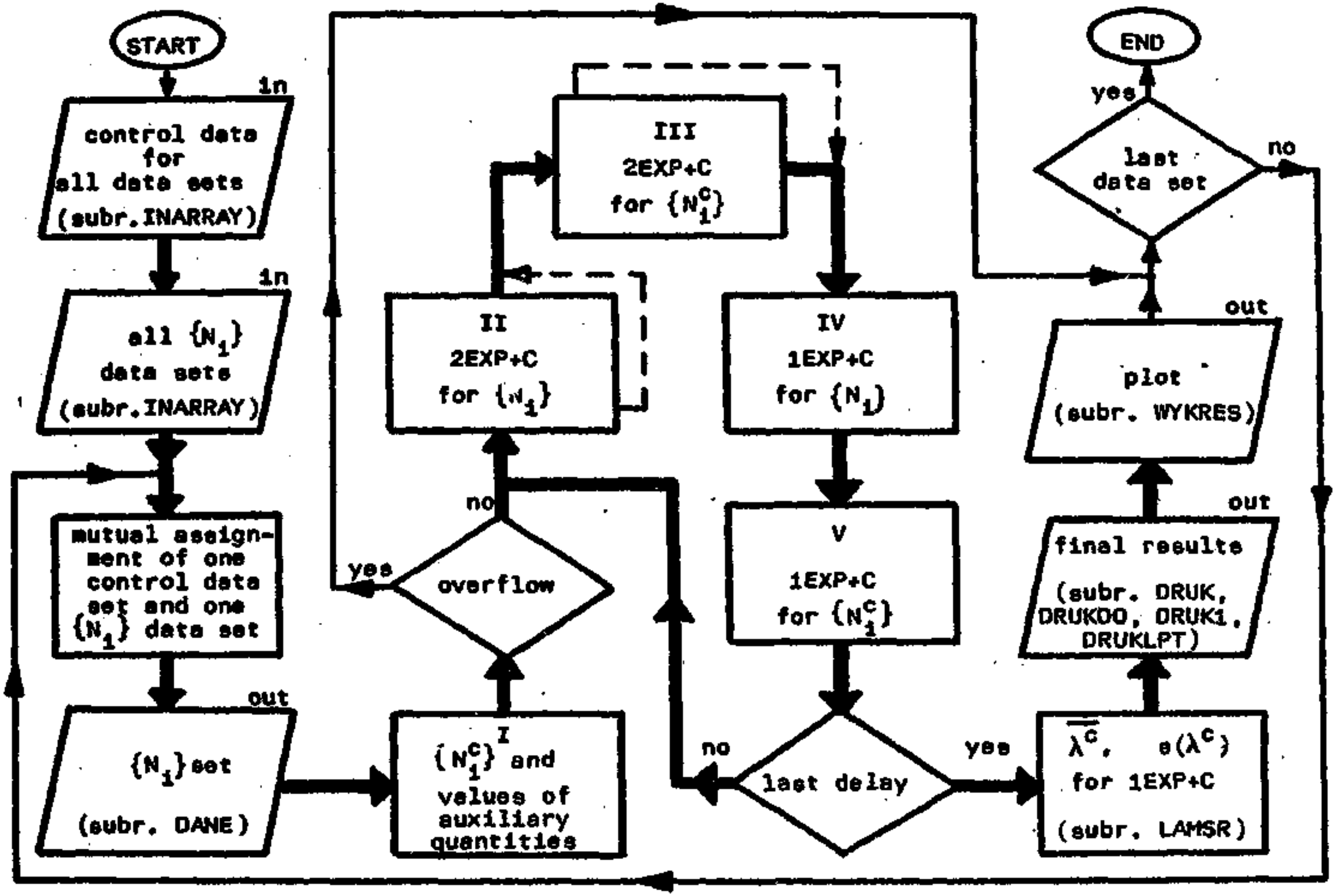

Fig.3. Block diagram of the LAMA program.

- due to some mistakes in the input data - all subsequent calculations for this data set are omitted.

The particular diagrams of the blocks marked with the Roman numbers and of the computational ways denoted with the broken lines are presented in Figs.4, 5, 6, 7.

The final results of the calculation for a consecutive value of the delay time are rounded off to the integers and stored in the matrices; after the computation is finished for the one data set these matrices contain the values of the required quantities in function of the delay time and they are printed in the tables. Then the program is repeated for the next data set.

In the current version of the LAMA program the matrices referred to the one N_I input data set can contain up to 256 elements and the matrices of the final results - up to 50 elements (as the 50 values for the consecutive values of delay time). The dimensions of these matrices can be easy increased in the proper specification statements.

3.2. Input and output data

The input data for the LAMA program have to be prepared on the punched tape in the odd code in IØ format with the comma as the separator (cf paragraph 3.1 in [1]). The specification of the input data is given in Table 2.

The quantities which values are the results of the program were mentioned in the begining of the description of the program (paragraph 3.1) and the example of the one page of output data is shown in Fig.8.

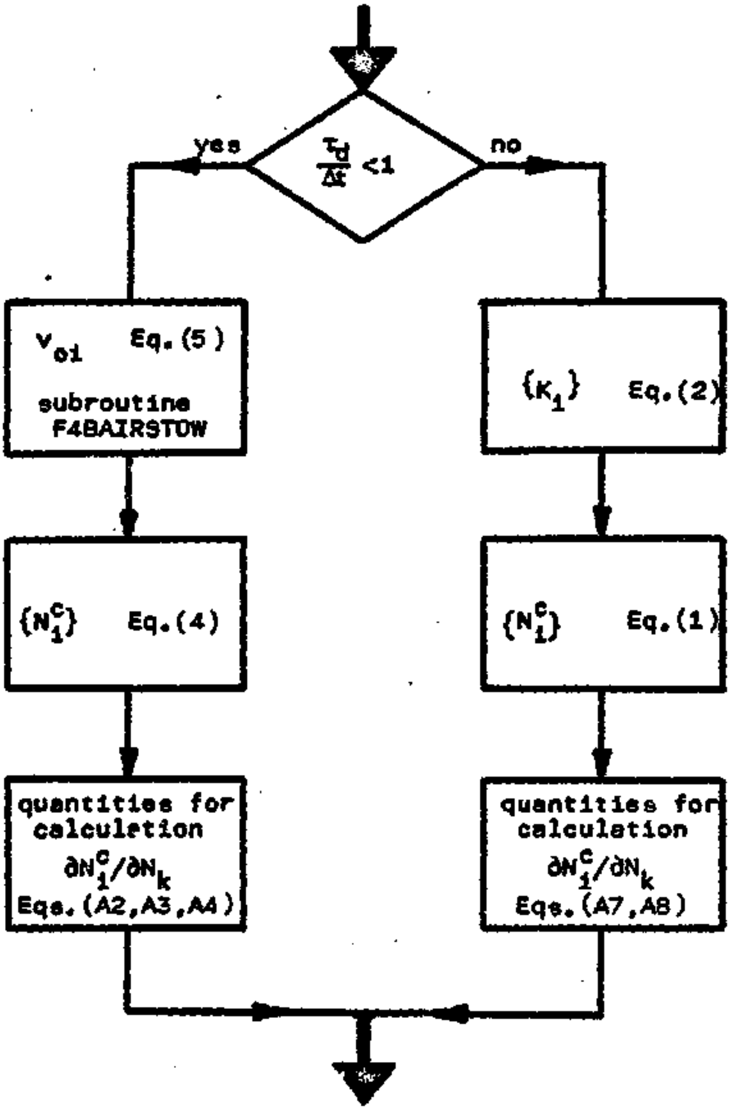

Fig.4. Diagram of the block I of the LAMA program.

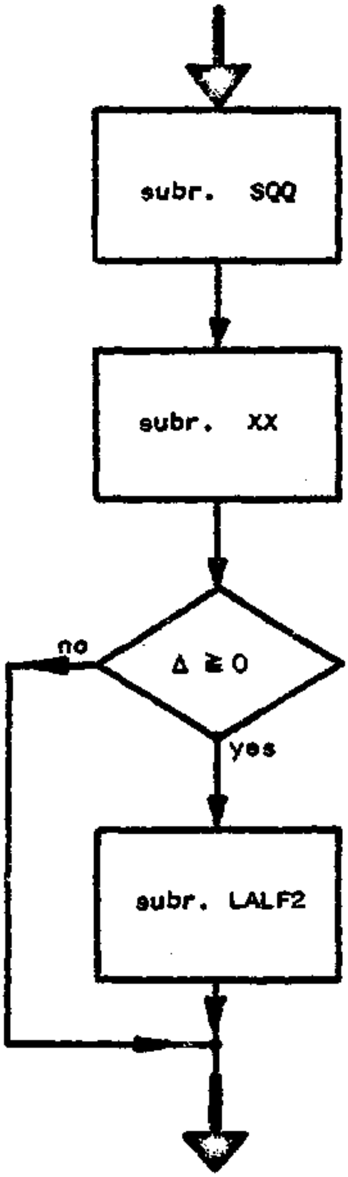

Fig.5. Diagram of the block II of the LAMA program.

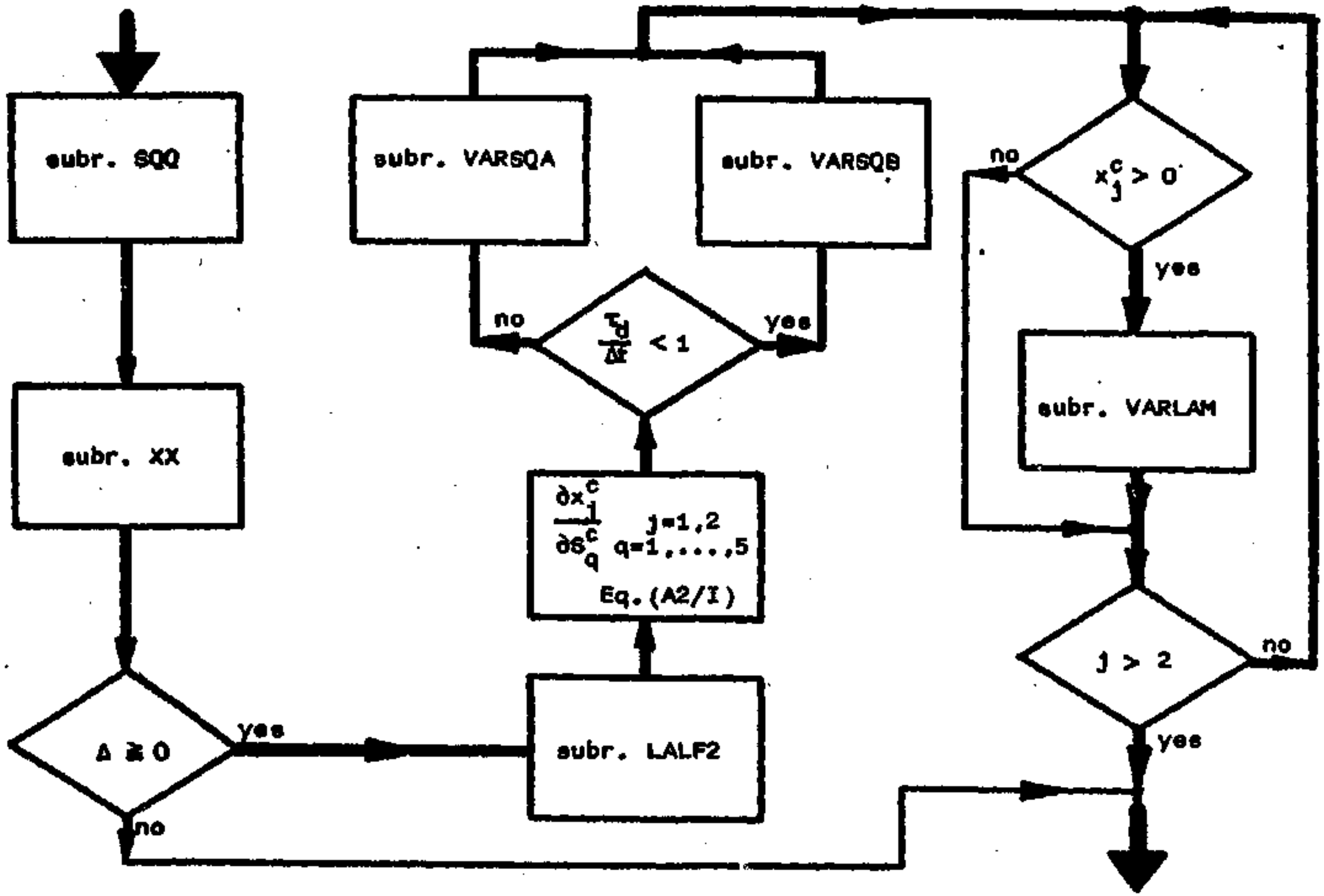

Fig.6. Diagram of the block III of the LAMA program.

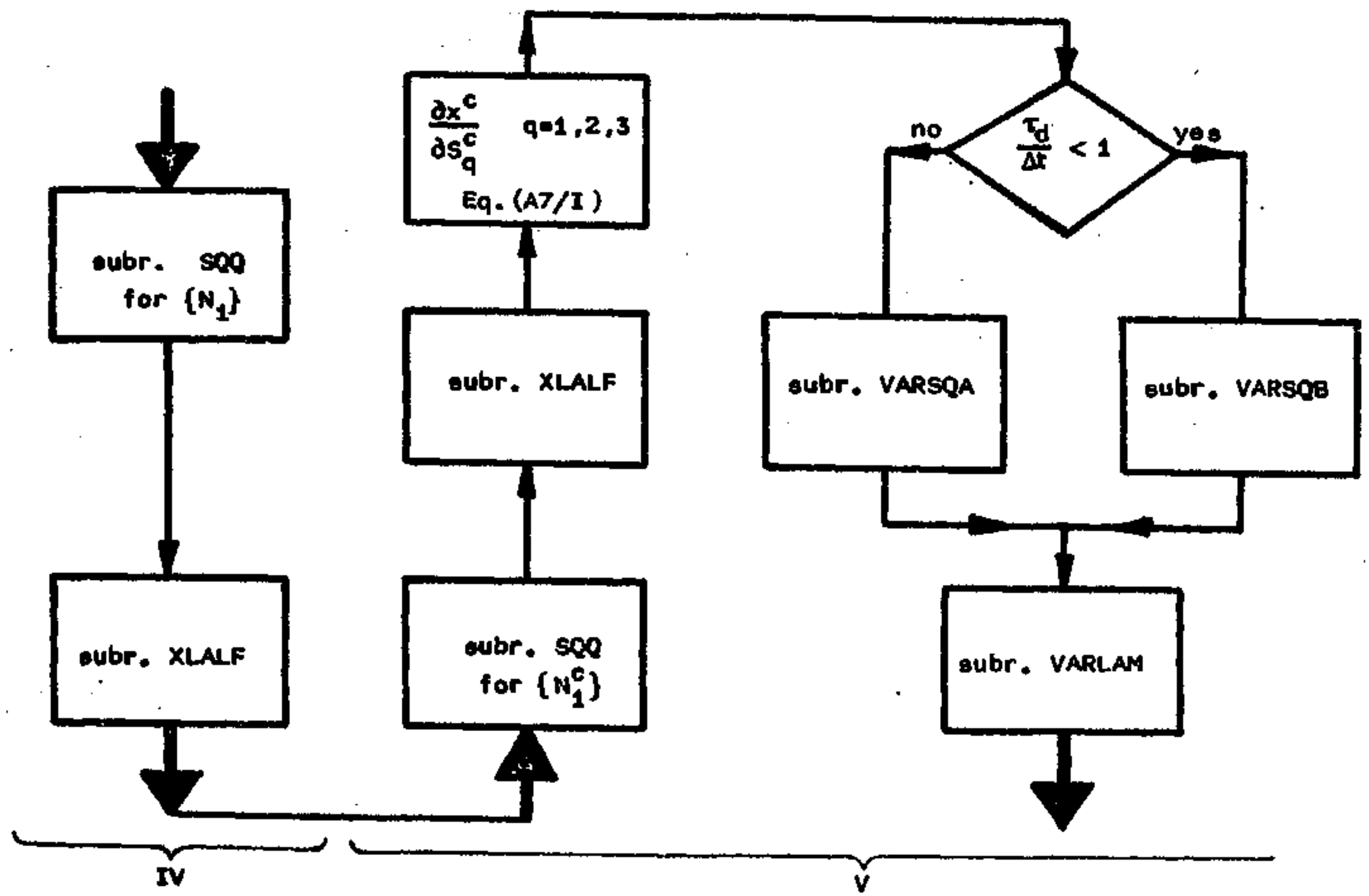

Fig.7. Diagram of the blocks IV and V of the LAMA program.

Table 2. Specification of the input data

No	Variable	Symbol in the program	Notes
I	number of data sets	LKD	It must be equal to the number of data sets taken really into account for the calculation and $LKD \leq 50$.
	about 15 spaces		
II	LKD sets of control data with the following structure of each one:		
1	number of measurement	NR	$NR \leq 9999$
2	number of the part of analyser memory	NR1	$NR1 \leq 9$
3	number of elements to be read from punched tape from analyser	LBN	$LBN_l \leq 256$ (see paragraph 3.1) $\sum_{l=1}^{LKD} LBN_l \leq 6400$
4	width of the time channel [in microseconds]	MDELT	

Table 2 (continued)

No	Variable	Symbol in the program	Notes
5	delay time of the start pulse for time analyser [in microseconds]	MTOS	
6	delay of the first group of time analyser from the start pulse [number from AC-256 analyser]	MTOA	*)
7	number of the channel taken as the first one for the calculation	NRKØ	$NRKØ > \begin{cases} \frac{\tau_d}{\Delta t} & \text{if } M(\frac{\tau_d}{\Delta t}) = 0 \\ C(\frac{\tau_d}{\Delta t})+1 & \text{if } M(\frac{\tau_d}{\Delta t}) > 0 \end{cases}$ **) a) (if the NRKØ is too small the minimum possible value of it is assumed by the program)
8	constant step of delay time [as the number of channels]	MSOP	MSOP > 0
9	number of the steps of delay time	LSOP	$0 \leq LSOP \leq 49$ (for LSOP>49 the program assumes LSOP=49)

Table 2 (continued)

No	Variable	Symbol in the program	Notes
10	length of the analysed time interval [as the number of channels]	L10P	divisible by 15, L10P ≥ 5a, where: $a = \begin{cases} \frac{\tau_d}{\Delta t} + 1 & \text{if } M(\frac{\tau_d}{\Delta t}) = 0 \\ C(\frac{\tau_d}{\Delta t}) + 2 & \text{if } M(\frac{\tau_d}{\Delta t}) > 0 \end{cases}$ **) b)
			ad No 8, 9, 10 : (NRKØ − 1) + L10P + LSOP·MSOP ≤ LBN
11	1/10 of the total number of runs of analyser	SS	
	about 15 spaces after the last set		

Table 2 (continued)

No	Variable	Symbol in the program	Notes
III	IKD sets of numbers of counts from time analyser	BN	
	about 15 spaces after the last set		

*) In the AC-256 time analyser the delay of the first group of channels from the start pulse is fixed by the following way: the number k ($k = 0, 1, 2, \ldots, 8$), which is mentioned in the point No 6, is chosen using the switch; the delay time t_d is enumerated $t_d = k \cdot 128 \cdot \Delta t$ (128 is the number of channels in the first group). It is easy to change this part of the program in order to adapt it to other time analyser.

**) $C(x)$ – max. integer contained in x (of Eq.3);
$M(x) = x - C(x)$.

a) The condition for NRKØ can be written as $NRKØ > r_1$ – using the symbols introduced in Eqs.(10,3).

b) The quantity a can be defined as $a = r_1 + 1$.

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OPÓŹN. ANALIZATORA 0 -
ODCINEK ANALIZY 270

LP.	1	2	3	4	5
NR KANAŁU POCZ.	6	8	10	12	14
NR KANAŁU KOŃC.	140	142	144	146	148
OPÓŹNIENIE (MIKROSEK.)	130	134	138	142	146
WARTOŚCI BEZ POPR.					
2EXP+C					
LAMBDA 2 (1/S)	14244	14430	14242	14457	14474
LAMBDA 1 (1/S)	36302	54803	34991	BRAK	BRAK
AMPLITUDA 2	45887	44292	40902	39673	37477
AMPLITUDA 1	2796	1450	1939		
TŁO	22	58	27		
1EXP+C					
LAMBDA (1/S)	14715	14658	14600	14555	14541
AMPLITUDA	47984	45122	42392	39904	37615
TŁO	135	113	98	84	81
WARTOŚCI Z POPR.					
2EXP+C					
LAMBDA 2 (1/S)	14252	14448	14268	14498	14318
ODCH.ST. (1/S)	590	353	685	118	97
LAMBDA 1 (1/S)	35552	47927	34233	BRAK	BRAK
ODCH.ST. (1/S)	32959	81785	43477		
AMPLITUDA 2	45972	44454	40955	39934	37728
AMPLITUDA 1	5369	1825	2407		
TŁO	22	60	27		
1EXP+C					
LAMBDA (1/S)	14806	14742	14678	14629	14611
ODCH.ST. (1/S)	40	41	42	43	44
AMPLITUDA	48522	45397	42811	40274	37944
TŁO	132	128	111	96	91
1EXP+C					
Z PUNKTÓW NR	1 - 1	1 - 2	1 - 3	1 - 4	1 - 5
LAMBDA ŚR. (1/S)			14743	14717	14698
ODCH.ST. (1/S)			63	74	81
Z PUNKTÓW NR	1 - 50	2 - 50	3 - 50	4 - 50	5 - 50
LAMBDA ŚR. (1/S)	14532	14515	14500	14480	14480
ODCH.ST. (1/S)	122	104	88	78	71

Fig.8. Typical first page of the LAMA outpu data.

3. Listing of the LAMA program

```
      LIST(LP)                                                          LAMA0001
      LIBRARY(SUBGROUPSREZ)                                             LAMA0002
      LIBRARY(SUBGROUPFSCF)                                             LAMA0003
      PROGRAM(LAMA)                                                     LAMA0004
      INPUT 6=TR0                                                       LAMA0005
      OUTPUT2=LP0                                                       LAMA0006

      MIXED SEGMENTS                                                    LAMA0008
      COMPRESS INTEGER AND LOGICAL                                      LAMA0009
      TRACE1                                                            LAMA0010
      END                                                               LAMA0011


      MASTER SZPAK                                                      LAMA0100
      DIMENSION A(11),AL(2),BK(256),BNC(256),C(4),CL(2),CW(11),CX(2),   LAMA0101
     A          DE1S(5),DE2S(5),DVM(256),DXS(2,5),DXS1(5),LAM(2,50),    LAMA0102
     B          LP(50),LPT(10),LSPD(50),LSRG(50),LU(50),L1(50),L1C(50), LAMA0103
     C          L2(50),L2C(50),MALFU(50),MALFUC(50),MALFUO(50),         LAMA0104
     D          MALFUOC(50),MALF1(50),MALF1C(50),MALF2(50),MALF2C(50),  LAMA0105
     E          MALFO(50),MALFOC(50),MDPOZ(50),MVLSPD(50),              LAMA0106
     F          MVLSKG(50),MVLUC(50),MVL1C(50),MVL2C(50),NRKK(50),      LAMA0107
     G          NRKP(50),V(256),VTH(10),VLAM(2),VLAMC(2),VRE(10),VSO(5),LAMA0108
     H          AA(550),BCN(6400),RQ(4)                                 LAMA0109
      DOUBLE PRECISION  MC(52)                                          LAMA0110
      COMMON /CMN1/MPP,N /CMN2/NRK,MR1 /CMN3/BN(256)                    LAMA0201
     A       /CMN4/ZZ(256),WW(256) /CMN5/S(5),DELT /CMN6/CX1,SS         LAMA0202
     B       /CMN7/MG1,LSOP1 /CMN8/K,RR /CMN9/LUC(50) /CMN10/NP,NAD     LAMA0203
      EQUIVALENCE (LP(1),MC(1)),(NRKP(1),BK(1)),(NRKK(1),V(1)),         LAMA0351
     A            (MDPOZ(1),DVM(1))                                     LAMA0352
      EXTERNAL  NADM                                                    LAMA0401

      CALL FIRAP(NADM)                                                  LAMA0601

C     0.7.  WCZYTYWANIE DANYCH                                          LAMA0700

C     0.7.1.  LICZBA KOMPLETOW DANYCH "LKD"                             LAMA0710

      CALL INARRAY(A,1,1)                                               LAMA0711
      LKD=A(1)                                                          LAMA0712

C     0.7.2.  ZBIOR "AA" TABLIC DANYCH STERUJACYCH "A"                  LAMA0720

      LAA=LKD*11                                                        LAMA0721
      CALL INARRAY (AA,LAA,LAA)                                         LAMA0722
```

```
C     0.7.3.  ZBIOR "BNN" TABLIC DANYCH Z ANALIZATORA "BN"          LAMA0730
      LBNN=0                                                        LAMA0731
      DO 6 I=3,LAA,11                                               LAMA0732
    6 LBNN=LBNN+AA(I)                                               LAMA0733
      CALL INARRAY (BNN,LBNN,LBNN)                                  LAMA0734
C     0.8.  POCZATEK OBLICZEN DLA "LKD" KOMPLETOW DANYCH            LAMA0800
      LBNN=0                                                        LAMA0801
      DO 1 JK=1,LKD                                                 LAMA0802
      MAD=0                                                         LAMA0803

C     1. OBLICZENIA DLA JEDNEGO KOMPLETU DANYCH                     LAMA0900
C     1.1.  PRZYPORZADKOWANIE DANYCH ZE ZBIORU "AA", "BNN"          LAMA1098
      DO 7 I=1,11                                                   LAMA1099
      II=I+(JK-1)*11                                                LAMA1100
    7 A(I)=AA(II)                                                   LAMA1101
      NR=A(1)                                                       LAMA1102
      NR1=A(2)                                                      LAMA1103
      LBN=A(3)                                                      LAMA1104
      DELT=A(4)*1.E-6                                               LAMA1105
      MDELT=A(4)                                                    LAMA1106
      MTOS=A(5)                                                     LAMA1107
      MTOA1=A(6)                                                    LAMA1108
      NRKO=A(7)                                                     LAMA1109
      MSOP=A(8)                                                     LAMA1110
      LSOP=A(9)                                                     LAMA1111
      L1OP=A(10)                                                    LAMA1112
      SS=A(11)*10                                                   LAMA1113
      DO 8 I=1,LBN                                                  LAMA1114
      II=I+LBNN                                                     LAMA1115
    8 BN(I)=BNN(II)                                                 LAMA1116
      LBNN=LBNN+LBN                                                 LAMA1117
C     1.2. DRUK ZAWARTOSCI ANALIZATORA                              LAMA1200
      WRITE(2,511) NR,MDELT,MTOA1,MTOS                              LAMA1201
      CALL DANE (LBN,BN)                                            LAMA1202
C     2. WIELKOSCI POMOCNICZE                                       LAMA2000
      MTAUM=8                                                       LAMA2001
      TAUM=MTAUM*1.E-6                                              LAMA2002
      MR=MTAUM/MDELT                                                LAMA2003
```

```
      K=MOD(MTAUH,MDELT)                                        LAMA2004
      RR=TAUM/DELT-MR                                           LAMA2005
      IF(K) 111,111,112                                         LAMA2006
  112 MR1=MR+2                                                  LAMA2007
      GO TO 113                                                 LAMA2008
  111 MR1=MR+1                                                  LAMA2009
  113 IF(NRKO.LT.MR1) NRKO=MR1                                  LAMA2010
      MTOA1S=MTOA1*128*MDELT                                    LAMA2011
      L1OPS=L1OP*MDELT                                          LAMA2012
      MSOPS=MSOP*MDELT                                          LAMA2013
      IF(LSOP.GT.49) LSOP=49                                    LAMA2014
      LSOP1=LSOP+1                                              LAMA2015
C     3. DANE POPRAWIONE BNC                                    LAMA3000
      DO 16 I=1,LRN                                             LAMA3001
   16 BNC(I)=0                                                  LAMA3002
      IF(MDELT.GT.MTAUM) GO TO 128                              LAMA3003
C     3.1. BNC DLA  DELT.LE.TAUM                                LAMA3100
      DO 11 I=MR1,LRN                                           LAMA3105
      DO 12 J=I-MR, I-1                                         LAMA3106
      RK(I)=0                                                   LAMA3107
   12 BK(I)=BK(I)+BN(J)                                         LAMA3108
      IF(K.GT.0) BK(I)=BK(I)+RR*BN(I-MR-1)                      LAMA3109
      BNC(I)=-SS*ALOG(1.-BN(I)/(SS-BK(I)))                      LAMA3111
      ZZ(I)=1./(SS-BK(I)-BN(I))                                 LAMA3112
   11 WW(I)=BN(I)/(SS-BK(I))                                    LAMA3113
      GO TO 129                                                 LAMA3114
                                                                LAMA3115
C     3.2. BNC DLA  DELT.GT.TAUM                                LAMA3200
C     3.2.1. USTALENIE  MP, MQ                                  LAMA3200
  128 MQ=MTAUM                                                  LAMA3201
      MP=MDELT                                                  LAMA3202
      DO 116 J=2,MTAUM                                          LAMA3203
  118 MA=MOD(MQ,J)                                              LAMA3204
      MB=MOD(MP,J)                                              LAMA3205
      IF(MA.EQ.0.AND.MB.EQ.0) GO TO 117                         LAMA3206
      GO TO 116                                                 LAMA3207
  117 MQ=MQ/J                                                   LAMA3208
      MP=MP/J                                                   LAMA3209
      IF(MQ.EQ.1) GO TO 119                                     LAMA3210
      GO TO 118                                                 LAMA3211
  116 CONTINUE                                                  LAMA3212
```

```
C       3.2.2. PRZYGOTOWANIE PARAMETROW AKTUALNYCH DO F4BAIRSTOW
119     MQ1=MP-MQ+1
        MP1=MP+1
        MP3=(MP+3)*4
        C(1)=1.E-16
        C(2)=1.E-13
        C(3)=1.62
        C(4)=5.
        C5=500
        CX(1)=1.01
        CX(2)=1.01
        DO 13 I=2,LBN
        DO 14 J=1,11
14      CW(J)=0.
        V(I)=0.
        CW(1)=(BN(I)-SS)/(SS-BN(I-1))
        CW(MQ1)=BN(I-1)/(SS-BN(I-1))
        CW(MP1)=1.

        CALL F4BAIRSTOW(MP,MP1,MP3,CW(1),MC(1),C,C5,CX,VRE(1),VIM(1),CL)
        DO 15 J=1,MP
        IF(VRE(J).LE.0..OR.VRE(J).GE.1.) GO TO 110
        CW(J)=ABS(VIM(J)/VRE(J))
        IF(CW(J).GE..001) GO TO 110
        V(I)=VRE(J)
        CW(11)=ALOG(VRE(J))
        BNC(I)=-SS*MP*CW(11)
110     IF(J.EQ.MP.AND.BNC(I).EQ.0.)  GO TO 120
        GO TO 15
120     WRITE(2,501) I
501     FORMAT(//1X,19HBRAK PIERWIASTKA V(,I3,1H))
15      CONTINUE
        DVM(I)=MP*(BN(I-1)-SS)*V(I)**MQ+(MQ-MP)*BN(I-1)
        WW(I)=1./(DVM(I)*V(I)**(MP-MQ))
13      ZZ(I)=(1.-V(I)**MQ)/DVM(I)
129     IF(NAD.EQ.1) GO TO 1
        DO 2 MOP=1, LSOP1
C       4. OBLICZENIA DLA JEDNEGO OPOZNIENIA
        NRK=NRK0+(MOP-1)*MSOP
        IF((NRK+L1OP-1).GT.LBN) GO TO 2
C       4.1. OBLICZENIA DLA  2EXP+C
        MPP=5
        N=L1OP/MPP
```

```
C       4.1.1. BEZ POPRAWKI                                              LAMA4103
        DO 17 J=1,2                                                      LAMA4104
17      LAM(J,MOP)=0                                                     LAMA4105
        CALL SQQ(BN,S)                                                   LAMA4106
        CALL XX(S,EM1,E1,EM2,E2,DE,CX)                                   LAMA4107
        IF(DE.LT.0.) GO TO 121                                           LAMA4108
        CALL LALF2(CX,CL,AL,ALO)                                         LAMA4109
        L1(MOP)=IFIX(CL(1)+.5)                                           LAMA4110
        L2(MOP)=IFIX(CL(2)+.5)                                           LAMA4111
        MALF1(MOP)=IFIX(AL(1)+.5)                                        LAMA4112
        MALF2(MOP)=IFIX(AL(2)+.5)                                        LAMA4113
        MALFO(MOP)=IFIX(ALO+.5)                                          LAMA4114
C       4.1.2. Z POPRAWKA                                                LAMA4115
121     DO 19 J=1,2                                                      LAMA4116
19      LAM(J,MOP)=0                                                     LAMA4117
        CALL SQQ(BNC,S)                                                  LAMA4118
        CALL XX(S,EM1,E1,EM2,E2,DE,CX)                                   LAMA4119
        IF(DE.LT.0.) GO TO 123                                           LAMA4120
        CALL LALF2(CX,CL,AL,ALO)                                         LAMA4121
            L1C(MOP)=IFIX(CL(1)+.5)                                      LAMA4122
            L2C(MOP)=IFIX(CL(2)+.5)                                      LAMA4123
        MALF1C(MOP)=IFIX(AL(1)+.5)                                       LAMA4124
        MALF2C(MOP)=IFIX(AL(2)+.5)                                       LAMA4125
        MALFOC(MOP)=IFIX(ALO+.5)                                         LAMA4126
C       4.1.2.1. ODCHYLENIA STANDARDOWE                                  LAMA4127
        G1=S(1)-S(2)                                                     LAMA4128
        G2=S(2)-S(3)                                                     LAMA4129
        G3=S(1)+S(2)-2.*S(3)                                             LAMA4130
        G4=2.*S(2)-S(3)-S(4)                                             LAMA4131
        G5=-S(2)+2.*S(3)-S(4)                                            LAMA4132
        DE1S(1)=S(4)-S(5)-E1*(S(3)-S(4))                                 LAMA4133
        DE1S(2)=-S(3)+S(5)+E1*G4                                         LAMA4134
        DE1S(3)=G5-E1*G3                                                 LAMA4135
        DE1S(4)=S(1)-S(3)+E1*G1                                          LAMA4136
        DE1S(5)=-G1                                                      LAMA4137
        DE2S(1)=G2*(S(4)-S(5)-E1*(S(3)-S(4)))/EM1-E2                     LAMA4138
        DE2S(2)=E1+E2-G2*(S(3)-S(5)-E1*G4)/EM1                           LAMA4139
        DE2S(3)=G2*(G5-E1*G3)/EM1-E1-1.                                  LAMA4140
        DE2S(4)=G2*(S(1)-S(3)+E1*G1)/EM1+1.                              LAMA4141
        DE2S(5)=-G1*G2/EM1                                               LAMA4142
        DO 22 MQQ=1,5                                                    LAMA4143
        DE1S(MQQ)=DE1S(MQQ)/EM1                                          LAMA4144
        DE2S(MQQ)=DE2S(MQQ)/(-EM2)                                       LAMA4145
        DO 23 J=1,2                                                      LAMA4146
```

```
23    DXS(J,MQQ)=(DE1S(MQQ)+(-1.)**J*(E1*DE1S(MQQ)-2.*DE2S(MQQ))/
     ASQRT(DE))/2.
22    CONTINUE
      IF(MDELT.GT.MTAUM) GO TO 122
      CALL VARSQA(VSQ,RQ)
      GO TO 126
122   CALL VARSQB(NRK,MP,VSQ,RQ)
126   DO 24 J=1,2
      IF(CX(J).LE.0.) GO TO 24
      DO 25 MQQ=1,MPP
25    DXS1(MQQ)=DXS(J,MQQ)
      CX1=CX(J)
      VLAMC(J)=VARLAM(RQ,VSQ,DXS1)
24    CONTINUE
      MVL1C(MOP)=IFIX(VLAMC(1)+.5)
      MVL2C(MOP)=IFIX(VLAMC(2)+.5)

C     4.2. OBLICZENIA DLA 1FXP+C

123   MPP=3
      N=L1OP/MPP

C     4.2.1. BEZ POPRAWKI
      CALL SQQ(HN,S)
      CALL XLALF(CX1,CL1,AL)
      LU(MOP)=IFIX(CL1+.5)
      MALFU (MOP)=IFIX(AL(1)+.5)
      MALFUO(MOP)=IFIX(AL(2)+.5)

C     4.2.2. Z POPRAWKA

      CALL SQQ(BNC,S)
      CALL XLALF(CX1,CL1,AL)
      LUC(MOP)=IFIX(CL1+.5)
      MALFUC (MOP)=IFIX(AL(1)+.5)
      MALFUOC(MOP)=IFIX(AL(2)+.5)

C     4.2.2.1. ODCHYLENIA STANDARDOWE

      G1=S(1)-S(2)
      DXS1(1)=-CX1/G1
      DXS1(2)=(S(1)-S(3))/G1**2
      DXS1(3)=-1./G1
      IF(MDELT.GT.MTAUM) GO TO 124
      CALL VARSQA(VSQ,RQ)
      GO TO 127
124   CALL VARSQB(NRK,MP,VSQ,RQ)
127   VLAM1C=VARLAM(RQ,VSQ,DXS1)
      MVLUC(MOP)=IFIX(VLAM1C+.5)
2     CONTINUE
```

```
C     5. OBLICZENIA LAMBD SREDNICH                                  LAMA5000
      DO 26 MOP=1,LSOP1                                             LAMA5002
      ZZ(MOP)=1./MVLUC(MOP)**2                                      LAMA5003
26    WW(MOP)=ZZ(MOP)**2                                            LAMA5004
      DO 27 MOP=1,LSOP1                                             LAMA5005
      LSRD(MOP),LSRG(MOP)=0                                         LAMA5006
      MG=MOP                                                        LAMA5007
      IF(MOP.LT.3) GO TO 130                                        LAMA5008
      CALL LAMSR(1,MG,LUCSR,MVLUCSR)                                LAMA5009
      LSRD(MOP)=LUCSR                                               LAMA5010
      MVLSRD(MOP)=MVLUCSR                                           LAMA5011
130   IF(MOP.GT.(LSOP1-2)) GO TO 27                                 LAMA5012
      CALL LAMSR(MG,LSOP1,LUCSR,MVLUCSR)                            LAMA5013
      LSRG(MOP)=LUCSR                                               LAMA5014
      MVLSRG(MOP)=MVLUCSR                                           LAMA5015
27    CONTINUE                                                      LAMA5016
C     6. DRUK WYNIKOW                                               LAMA6000
      DO 28 JJ=1,LSOP1                                              LAMA6003
      LP(JJ)=JJ                                                     LAMA6004
      NRKP(JJ)=NRKO+(JJ-1)*MSOP                                     LAMA6005
      NRKK(JJ)=NRKP(JJ)+L1OP-1                                      LAMA6006
28    MOPOZ(JJ)=MTOS+MTOA1S+(NRKP(JJ)-1)*MDELT                      LAMA6007
      WRITE(2,601) NR, NR1, MDELT, MTOS, MTOA1S, L1OPS              LAMA6008
      DO 29 JJ=1,10                                                 LAMA6009
      MG1=(JJ-1)*5+1                                                LAMA6010
      IF(MG1.GT.LSOP1) GO TO 132                                    LAMA6011
      IF(MG1.EQ.1) GO TO 131                                        LAMA6012
      WRITE(2,622)                                                  LAMA6013
131   IF((JJ*5).LE.LSOP1)  NN=10                                    LAMA6014
      IF((JJ*5).GT.LSOP1)  NN=2*(LSOP1-(JJ-1)*5)                    LAMA6015
      WRITE(2,602)                                                  LAMA6016
      WRITE(2,603)                                                  LAMA6017
      CALL DRUK(LP,0,0,0,L2,L2)                                     LAMA6018
      WRITE(2,604)                                                  LAMA6019
      CALL DRUK(NRKP,0,0,0,L2,L2)                                   LAMA6020
      WRITE(2,605)                                                  LAMA6021
      CALL DRUK(NRKK,0,0,0,L2,L2)                                   LAMA6022
      WRITE(2,606)                                                  LAMA6023
      CALL DRUK(MOPOZ,0,0,0,L2,L2)                                  LAMA6024
      WRITE(2,602)                                                  LAMA6025
      WRITE(2,607)                                                  LAMA6026
      WRITE(2,608)                                                  LAMA6027
      WRITE(2,609)                                                  LAMA6028
      CALL DRUK(L2,1,1,0,L2,L2)                                     LAMA6029
      WRITE(2,610)                                                  LAMA6030
      WRITE(2,611)                                                  LAMA6031
      CALL DRUK(L1,1,1,0,L1,L1)                                     LAMA6032
      WRITE(2,610)                                                  LAMA6033
```

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      WRITE(2,612)                                                      LAMA6034
      CALL DRUK(MALF2,1,0,0,L2,L2)                                      LAMA6035
      WRITE(2,613)                                                      LAMA6036
      CALL DRUK(MALF1,1,0,0,L1,L1)                                      LAMA6037
      WRITE(2,614)                                                      LAMA6038
      CALL DRUK(MALF0,0,0,1,L1,L2)                                      LAMA6039
      WRITE(2,615)                                                      LAMA6040
      WRITE(2,616)                                                      LAMA6041
      WRITE(2,617)                                                      LAMA6042
      CALL DRUK(LU,1,1,0,LU,LU)                                         LAMA6043
      WRITE(2,610)                                                      LAMA6044
      WRITE(2,618)                                                      LAMA6045
      CALL DRUK(MALFU,1,0,0,LU,LU)                                      LAMA6046
      WRITE(2,614)                                                      LAMA6047
      CALL DRUK(MALFU0,0,0,1,LU,LU)                                     LAMA6048
      WRITE(2,610)                                                      LAMA6049
      WRITE(2,602)                                                      LAMA6050
      WRITE(2,619)                                                      LAMA6051
      WRITE(2,608)                                                      LAMA6052
      WRITE(2,609)                                                      LAMA6053
      CALL DRUK(L2C,1,1,0,L2C,L2C)                                      LAMA6054
      WRITE(2,620)                                                      LAMA6055
      CALL DRUK(MVL2C,1,0,0,L2C,L2C)                                    LAMA6056
      WRITE(2,611)                                                      LAMA6057
      CALL DRUK(  L1C,1,1,0,L1C,L1C)                                    LAMA6058
      WRITE(2,620)                                                      LAMA6059
      CALL DRUK(MVL1C,1,0,0,L1C,L1C)                                    LAMA6060
      WRITE(2,612)                                                      LAMA6061
      CALL DRUK(MALF2C,1,0,0,L2C,L2C)                                   LAMA6062
      WRITE(2,613)                                                      LAMA6063
      CALL DRUK(MALF1C,1,0,0,L1C,L1C)                                   LAMA6064
      WRITE(2,614)                                                      LAMA6065
      CALL DRUK(MALF0C,0,0,1,L1C,L2C)                                   LAMA6066
      WRITE(2,615)                                                      LAMA6067
      WRITE(2,616)                                                      LAMA6068
      WRITE(2,617)                                                      LAMA6069
      CALL DRUK(LUC,1,1,0,LUC,LUC)                                      LAMA6070
      WRITE(2,620)                                                      LAMA6071
      CALL DRUK(MVLUC,1,0,0,LUC,LUC)                                    LAMA6072
      WRITE(2,618)                                                      LAMA6073
      CALL DRUK(MALFUC,1,0,0,LUC,LUC)                                   LAMA6074
      WRITE(2,614)                                                      LAMA6075
      CALL DRUK(MALFU0C,0,0,1,LUC,LUC)                                  LAMA6076
      WRITE(2,615)                                                      LAMA6077
      WRITE(2,616)                                                      LAMA6078
      WRITE(2,621)                                                      LAMA6079
      CALL DRUKD0(LSOP1,MG1)                                            LAMA6080
      CALL DRUK1 (LSOP1,MG1)                                            LAMA6081
      CALL DRUK(LP,0,0,0,L2,L2)                                         LAMA6082
      WRITE(2,623)                                                      LAMA6083
      CALL DRUK(LSRD,1,0,0,LSRD,LSRD)                                   LAMA6084
```

```
      WRITE(2,620)                                                      LAMA6085
      CALL DRUK(MVLSRD,1,0,0,LSRD,LSRD)                                 LAMA6086
      WRITE(2,610)                                                      LAMA6087
      WRITE(2,610)                                                      LAMA6088
      WRITE(2,621)                                                      LAMA6089
      CALL DRUKPO(LSOP1,MG1)                                            LAMA6090
      CALL DRUKLPT(LPT,NN,JJ,LSOP1)                                     LAMA6091
      WRITE(2,623)                                                      LAMA6092
      CALL DRUK(  LSRG,1,0,0,LSRG,LSRG)                                 LAMA6093
      WRITE(2,620)                                                      LAMA6094
      CALL DRUK(MVLSRG,1,0,0,LSRG,LSRG)                                 LAMA6095
      WRITE(2,610)                                                      LAMA6096
29    WRITE(2,602)                                                      LAMA6097

C     6.1. WYKRES LAMBDA(1EXP+C) = F(OPOZNIENIE)                        LAMA6100

132   WRITE(2,513) NR                                                   LAMA6101
      WRITE(2,616)                                                      LAMA6102
      CALL WYKRES (LUC,LSOP1,MOPOZ(1),MSOPS)                            LAMA6103

511   FORMAT(1H1///1X,9HPOMIAR NR,I5,45X,5HDN.   ,13(1H.)///36X,6HAC-256LAMA7001
     A,5(/),6X,12HDELTA T 1  =,I3,10H MIKROSEK.,8X,6HOP.1 =,I2/55X,6HOP.LAMA7002
     BS =,I4,10H MIKROSEK./6X,12HDELTA T 2  =,3X,10H MIKROSEK.,8X,6HOP.2LAMA7003
     C =//)                                                             LAMA7004
512   FORMAT(1H1////1X,9HPOMIAR NR,I5///33X,15HDANE POPRAWIONE//)       LAMA7005
513   FORMAT(1H1//1X,9HPOMIAR NR,I5/)                                   LAMA7005
601   FORMAT(1H1//41X,2H..,7X,1H./1X,9HPOMIAR NR,I5,I2,17X,18HSZEROKOSC LAMA7006
     K KANALOW,I4,10H MIKROSEK./34X,18HOPOZN. IMP. START.,I4,5X,1H"/    LAMA7007
     K34X,18HOPOZN. ANALIZATORA,I4,5X,1H"/34X,16HODCINEK  ANALIZY,I6,   LAMA7008
     K5X,1H",4(/))                                                      LAMA7009
602   FORMAT(1X,65(1H=))                                                LAMA7010
603   FORMAT(1X,3HLP.)                                                  LAMA7011
604   FORMAT(1X/1X,15HNR KANALU POCZ.)                                  LAMA7012
605   FORMAT(13X,1H./1X,15HNR KANALU KONC.)                             LAMA7013
606   FORMAT(3X,2H../1X,10HOPOZNIENIE/5X,11H[MIKROSEK.])                LAMA7014
607   FORMAT(6X,1H./1X,18HWARTOSCI BEZ POPR.)                           LAMA7015
608   FORMAT(1X,6H2EXP+C)                                               LAMA7016
609   FORMAT(2X,14HLAMBDA 2 [1/S])                                      LAMA7017
610   FORMAT(1X)                                                        LAMA7018
611   FORMAT(1X/2X,14HLAMBDA 1 [1/S])                                   LAMA7019
612   FORMAT(1X//2X,11HAMPLITUDA 2)                                     LAMA7020
613   FORMAT(2X,11HAMPLITUDA 1)                                         LAMA7021
614   FORMAT(2X,3HTLO)                                                  LAMA7022
615   FORMAT(1X/1X,65(1H-))                                             LAMA7023
616   FORMAT(1X,6H1EXP+C)                                               LAMA7024
617   FORMAT(2X,6HLAMBDA,3X,5H[1/S])                                    LAMA7025
618   FORMAT(1X//2X,9HAMPLITUDA)                                        LAMA7026
619   FORMAT(6X,1H./1X,16HWARTOSCI Z POPR.)                             LAMA7027
620   FORMAT(2X,14HODCH.ST. [1/S])                                      LAMA7028
621   FORMAT(1H*,8X,1H./2X,12H7 PUNKTOW NP)                             LAMA7029
```

```
622     FORMAT(1H1,3(/))                                                        LAMA7030
623     FORMAT(8X,1H,/1X,15HLAMBDA SR.[1/S])                                    LAMA7031

1       CONTINUE                                                                LAMA9001
        STOP                                                                    LAMA9002
        END                                                                     LAMA9003


        SUBROUTINE NADM(K)                                                      NADM 1
        COMMON /CMN10/ NR,NAD                                                   NADM 2
        WRITE(0,10) K, NR                                                       NADM 3
        NAD=1                                                                   NADM 4
   10   FORMAT(1X,27HUWAGA - EXECUTION ERROR NR ,I3,3X,8H(POMIAR ,I4,1H))       NADM 5
        RETURN                                                                  NADM 6
        END                                                                     NADM 7


        FUNCTION BLAMBDA (X,N,DELT)                                             BLAMBDA1
        BLAMBDA=-ALOG(X)/(N*DELT)                                               BLAMBDA2
        RETURN                                                                  BLAMBDA3
        END                                                                     BLAMBDA4


        FUNCTION VARLAM (RQ,VSQ,DXS1)                                           VARLAM 1
C       OBLICZANIE ODCHYLENIA STANDARDOWEGO LAMBDY                              VARLAM 2
        DIMENSION RQ(4),VSQ(5),DXS1(5)                                          VARLAM 3
        COMMON /CMN1/MPP,N /CMN5/S(5),DELT /CMN6/CX1,SS                         VARLAM 4
        VLAM=0.                                                                 VARLAM 5
        DO 81 MQQ=1,MPP                                                         VARLAM 6
        VLAM=VLAM+DXS1(MQQ)**2*VSQ(MQQ)                                         VARLAM 7
        IF(MQQ.EQ.MPP) GO TO 81                                                 VARLAM 8
        VLAM=VLAM+2*DXS1(MQQ)*DXS1(MQQ+1)*RQ(MQQ)                               VARLAM 9
81      CONTINUE                                                                VARLAM10
        IF(VLAM.LT.0.)VLAM=0.                                                   VARLAM11
        VARLAM=SS*SQRT(VLAM)/(N*DELT*CX1)                                       VARLAM12
        RETURN                                                                  VARLAM13
        END                                                                     VARLAM14
```

```
      SUBROUTINE SQQ (BN,S)
C     TWORZENIE SUM SQ
      DIMENSION S(5),BN(256)
      COMMON /CMN1/MPP,N /CMN2/NRK,MR1
      DO 51 MQQ=1,MPP
      S(MQQ)=0.
      MG1=(MQQ-1)*N+NRK
      MG2=MQQ*N-1+NRK
      DO 52 I=MG1,MG2
52    S(MQQ)=S(MQQ)+BN(I)
51    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE XX(S,EM1,E1,EM2,E2,DE,CX)
C     OBLICZANIE XJOT
      DIMENSION S(5),CX(2)
      EM1=S(1)*(S(3)-S(4))+S(2)*(S(3)+S(4)-S(2))-S(3)*S(3)
      E1=(S(1)*(S(4)-S(5))+S(2)*(S(5)-S(3))+S(3)*(S(3)-S(4)))/EM1
      EM2=S(2)-S(1)
      E2=(S(3)-S(4)+E1*(S(3)-S(2)))/EM2
      DE=E1*E1-4.*E2
      IF(DE.GE.0.)GO TO 156
      CX(1),CX(2)=0.
      RETURN
156   DO 56 J=1,2
56    CX(J)=.5*(E1+(-1.)**J*SQRT(DE))
      RETURN
      END
```

```
      SUBROUTINE LALF2 (CX,CL,AL,AL0)
C     OBLICZANIE LAMBDAJOT, ALFAJOT, I ALFA0
      DIMENSION CX(2),CL(2),AL(2),C(2)
      COMMON /CMN1/MPP,N /CMN5/S(5),DELT
      AL0=0.
      DO 61 J=1,2
      CL(J),AL(J)=0.
      IF(CX(J).LE.0.) GO TO 61
      CL(J)=BLAMBDA(CX(J),N,DELT)
      J1=J+(-1)**(J+1)
      AL(J)=((S(2)-S(1))*(1.+CX(J1))-S(3)+S(1))*(1.-CX(J)**(1./N))/
     K((1.-CX(J))**2*(CX(J)-CX(J1)))
61    CONTINUE
      IF(CX(1).GT.0..AND.CX(2).GT.0.) GO TO 161
      RETURN
161   DO 62 J=1,2
62    C(J)=AL(J)*(1.-CX(J))/(1.-CX(J)**(1./N))
      AL0=(S(1)-C(1)-C(2))/N
      RETURN
      END
```

```
      SUBROUTINE XLALF (CX1,CL1,AL)
C     OBLICZANIE X, LAMBDA, ALFA, ALFA0
      DIMENSION AL(2)
      COMMON /CMN1/MPP,N/CMN5/S(5),DELT
      CL1=0.
      CX1=(S(2)-S(3))/(S(1)-S(2))
      IF(CX1.GT.0.) GO TO 166
      WRITE(2,551)
551   FORMAT(1X///17HBRAK X DLA 1EXP+C)
      RETURN
166   CL1=BLAMBDA(CX1,N,DELT)
      A1=S(1)-2.*S(2)+S(3)
      AL(1)=(S(1)-S(2))**3*(1.-CX1**(1./N))/A1**2
      AL(2)=(S(1)*S(3)-S(2)**2)/(N*A1)
      RETURN
      END
```

```
      SUBROUTINE COND (I,IK,FF)
C     USTALANIE WARTOSCI ELEMENTOW TABLIC POMOCNICZYCH DLA "VARSQA"
      DIMENSION W(256)
      COMMON/CMN2/NRK,MR1 /CMN4/ZZ(256),WW(256) /CMN8/K,RR
      IF(I.NE.IK) GO TO 171
      W(I)=ZZ(I)
      GO TO 172
171   W(I)=ZZ(I)*WW(I)
      IF(I.EQ.(IK+(MR1-1)).AND.K.NE.0) W(I)=W(I)*RR
172   FF=FF+W(I)
      RETURN
      END
```

```
      SUBROUTINE VARSQA (VSQ,RQ)
C     OBLICZANIE WARIANCJI I KOWARIANCJI SUM  SQ  (DELT.LE.TAUM)
      DIMENSION VSQ(5), RQ(4)
      COMMON /CMN1/MPP,N/CMN2/NRK,MR1/CMN3/BN(256)
      DO 71 MQQ=1,MPP
      VSQ(MQQ)=0
      MG1=(MQQ-1)*N-(MR1-1)+NRK
      MG2=MQQ*N-1+NRK
      DO 72 IK=MG1,MG2
      F=0.
      IK2=IK+(MR1-1)
      DO 73 I = IK,IK2
      IF(I.LT.(MG1+(MR1-1)).OR.I.GT.MG2) GO TO 73
      CALL COND (I,IK,F)
73    CONTINUE
72    VSQ(MQQ)=VSQ(MQQ)+F**2*BN(IK)
      IF(MQQ.EQ.MPP) GO TO 71
      RQ(MQQ)=0.
      MG1=MG1+N
      DO 74 IK=MG1,MG2
      F=0.
      DO 75 I=IK,MG2
      CALL COND (I,IK,F)
75    CONTINUE
      FF=0.
      MG10=MG1+(MR1-1)
      MG20=IK+(MR1-1)
      DO 76 I=MG10,MG20
      CALL COND (I,IK,FF)
76    CONTINUE
74    RQ(MQQ)=RQ(MQQ) +F*FF*BN(IK)
71    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VARSQR (NRK,MP,VSQ,RQ)
C     OBLICZANIE WARIANCJI I KOWARIANCJI SUM  SQ  (DELT.GT.TAUM)
      DIMENSION W(256),Z(257),VSQ(5),RQ(4)
      COMMON /CMN1/MPP,N /CMN4/ZZ(256),WW(256) /CMN3/BN(256)
      DO 86 MQQ=1,MPP
      VSQ(MQQ)=0.
      MG1=(MQQ-1)*N-1+NRK
      MG2=MQQ*N-1+NRK
      DO 87 IK=MG1,MG2
      W(IK),Z(IK+1)=0.
      IF(IK.NE.MG1) W(IK)=WW(IK)
      IF(IK.NE.MG2) Z(IK+1)=ZZ(IK+1)
   87 VSQ(MQQ)=VSQ(MQQ)+(W(IK)+Z(IK+1))**2*BN(IK)
      VSQ(MQQ)=MP**2*VSQ(MQQ)
      IF(MQQ.EQ.MPP) GO TO 86
      RQ(MQQ)=MP**2*WW(MG2)*ZZ(MG2+1)*BN(MG2)
   86 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LAMSR (MG1,MG2,LUCSR,MVLUCSR)
C     OBLICZANIE LAMBDY SREDNIEJ Z ODCHYLENIEM STANDARDOWYM
      COMMON /CMN4/ZZ(256),WW(256) /CMN9/LUC(50)
      W,WL=0.
      DO 91 I=MG1,MG2
      W=W+ZZ(I)
   91 WL=WL+ZZ(I)*LUC(I)
      WL=WL/W
      LUCSR=IFIX(WL+.5)
      WL,SW=0.
      DO 92 I=MG1,MG2
      WL=WL+ZZ(I)*(LUC(I)-LUCSR)**2
   92 SW=SW+WW(I)
      WL=SQRT(W/(W**2-SW)*WL)
      MVLUCSR=IFIX(WL+.5)
      RETURN
      END
```

```
      SUBROUTINE DRUK(MZ,K1,K2,K3,MW1,MW2)                              DRUK   1
      DIMENSION MW1(50), MW2(50), MZ(50), IFORM(8), IZ(5)               DRUK   2
      COMMON /CMN7/ MG1, LSOP1                                          DRUK   3
      DATA I1/4H(1H+/, I2/3H15X/, I8/4H)/, IOI/4H,I10/, IOA/4H,A10/,    DRUK   4
     A     IA/4H    /, IB/4HBRAK/                                       DRUK   5
      IFORM(1)=I1                                                       DRUK  11
      IFORM(2)=I2                                                       DRUK  12
      IFORM(8)=I8                                                       DRUK  13
      DO 97 KK=1,5                                                      DRUK  14
      IZ(KK)=IA                                                         DRUK  15
   97 IFORM(KK+2)=IOA                                                   DRUK  16
      MG4=MG1+4                                                         DRUK  21
      KK=1                                                              DRUK  22
      DO 96 II=MG1,MG4                                                  DRUK  23
      IF(II.GT.LSOP1) GO TO 96                                          DRUK  24
      IF(K3.EQ.1.AND.(MW1(II).EQ.0.OR.MW2(II).EQ.0)) GO TO 96           DRUK  25
      IF(K2.EQ.1.AND.MW1(II).EQ.0) GO TO 196                            DRUK  26
      IF(K1.EQ.1.AND.MW1(II).EQ.0)  GO TO 96                            DRUK  27
      IZ(KK)=MZ(II)                                                     DRUK  28
      IFORM(KK+2)=IOI                                                   DRUK  29
      GO TO 96                                                          DRUK  30
  196 IZ(KK)=IB                                                         DRUK  31
   96 KK=KK+1                                                           DRUK  32
      WRITE(0,IFORM) IZ                                                 DRUK  33
      RETURN                                                            DRUK  34
      END                                                               DRUK  35
```

```
      SUBROUTINE DRUKLPT(LPT,NN,JJ,LSOP1)                               DRUKPT 1
      DIMENSION LPT(NN)                                                 DRUKPT 2
      NN1=NN/2                                                          DRUKPT 3
      DO 97 J=1,NN1                                                     DRUKPT 4
      LPT(2*J-1)=(JJ-1)*5+J                                             DRUKPT 5
   97 LPT(2*J)=LSOP1                                                    DRUKPT 6
      WRITE(2,671) LPT                                                  DRUKPT 7
  671 FORMAT (1H+,15X,10I5)                                             DRUKPT 8
      RETURN                                                            DRUKPT 9
      END                                                               DRUKPT10
```

```
      SUBROUTINE DRUKDO(LSOP1,MG1)
      KK=LSOP1+1-MG1
      IF(KK.GT.5) KK=5
      GO TO (781,782,783,784,785),KK
  781 WRITE(2,681)
      RETURN
  782 WRITE(2,682)
      RETURN
  783 WRITE(2,683)
      RETURN
  784 WRITE(2,684)
      RETURN
  785 WRITE(2,685)
  681 FORMAT(1H+,21X,   1H-)
  682 FORMAT(1H+,21X,2(1H-,9X))
  683 FORMAT(1H+,21X,3(1H-,9X))
  684 FORMAT(1H+,21X,4(1H-,9X))
  685 FORMAT(1H+,21X,5(1H-,9X))
      RETURN
      END
```

```
      SUBROUTINE DRUK1(LSOP1,MG1)
      KK=LSOP1+1-MG1
      IF(KK.GT.5) KK=5
      GO TO (791,792,793,794,795),KK
  791 WRITE(2,691)
      RETURN
  792 WRITE(2,692)
      RETURN
  793 WRITE(2,693)
      RETURN
  794 WRITE(2,694)
      RETURN
  795 WRITE(2,695)
  691 FORMAT(1H+,19X,   1H1)
  692 FORMAT(1H+,19X,2(1H1,9X))
  693 FORMAT(1H+,19X,3(1H1,9X))
  694 FORMAT(1H+,19X,4(1H1,9X))
  695 FORMAT(1H+,19X,5(1H1,9X))
      RETURN
      END
```

```
      SUBROUTINE DANE(LB,B)                                    DANE    1
C     DRUK TABLICY DANYCH                                      DANE    2
      DIMENSION MB(256),B(LB)                                  DANE    3
      DO 98 I=1,LB                                             DANE    4
98    MB(I)=IFIX(B(I))                                         DANE    5
      WRITE(2,696) (MB(I),I=1,LB)                              DANE    6
696   FORMAT(1X//1X,10(/10I8))                                 DANE    7
      RETURN                                                   DANE    8
      END                                                      DANE    9
```

```
      SUBROUTINE WYKRES(L,LL,KX0,KDX)                          WYKRES 1
      DIMENSION A(6),L(LL),B(57),KX(6)                         WYKRES 2
      DATA A/1H*,1HI,1H+,1H-,1H ,1H>/                          WYKRES 3
      MAXL=L(1)                                                WYKRES 4
      DO 60 I=2,LL                                             WYKRES 5
   60 MAXL=MAX0(MAXL,L(I))                                     WYKRES 6
      N=50                                                     WYKRES 7
      IF(MAXL.GT.20000) N=100                                  WYKRES 8
      IF(MAXL.GT.40000) N=200                                  WYKRES 9
      R=N                                                      WYKRES10
      NN=5*N                                                   WYKRES11
      DO 51 I=1,LL                                             WYKRES14
   51 L(I)=(L(I)/N +IFIX(MOD(L(I), N)/ R +.5))*N               WYKRES15
      MINY,MAXY=L(1)                                           WYKRES16
      DO 58 I=2,LL                                             WYKRES17
      MINY=MIN0(L(I),MINY)                                     WYKRES18
   58 MAXY=MAX0(L(I),MAXY)                                     WYKRES19
  151 M=MOD(MAXY,NN)                                           WYKRES21
      IF(M.EQ.0) GO TO 152                                     WYKRES22
      MAXY=MAXY+N                                              WYKRES23
      GO TO 151                                                WYKRES24
  152 MY=MAXY                                                  WYKRES25
```

```
      K=5
      IF(LL.GT.11) K=2
      IF(LL.GT.26) K=1
      JJ=(MAXY-MINY)/N +20
      IF(JJ.GT.65) JJ=65
      WRITE(2,566)
      DO 52 J=1,JJ
      M=MOD(MY,NN)
      IF(M) 153, 153, 154
  153 WRITE(2,561) MY
      WRITE(2,562) A(3)
      GO TO 155
  154 WRITE(2,562) A(2)
  155 DO 59 I=1,57
   59 B(I)=A(5)
      DO 53 I=1,LL
      II=K*(I-1)+1
   53 IF(L(I).EQ.MY) B(II)=A(1)
      WRITE(2,563)B
   52 MY=MY-N
      WRITE(2,562) A(3)
      B(57)=A(6)
      DO 54 I=1,56
   54 B(I)=A(4)
      GO TO (156,157,157,157,156), K
  156 DO 55 I=4,54,5
   55 B(I)=A(3)
      GO TO 158
  157 DO 56 I=4,54,2
   56 B(I)=A(3)
  158 WRITE(2,564) B
      KX(1)=KX0
      DO 57 I=2,6
   57 KX(I)=KX(I-1)+10/K*KDX
      WRITE(2,565) KX
  561 FORMAT(1H+,I6)
  562 FORMAT(1H+,7X,A1)
  563 FORMAT(1H+,11X,57A1/)
  564 FORMAT(1H+,8X,57A1)
  565 FORMAT(1X/4X,6I10/57X,2H.,/42X,23H[MIKROSEK.]  OPOZNIENIE)
  566 FORMAT(1X//8X,1H+/1X,8HLAMBDA I/2X,7H[1/S] I/8X,1HI/)
      RETURN
      END
```

FINISH

LAMAY005

APPENDIX

Formulae for calculation of the derivatives $\frac{\partial N_i^c}{\partial N_k}$

The derivatives $\frac{\partial N_i^c}{\partial N_k}$ are calculated at the point determined by the set of the N_i values appeared in the equation for a given N_i^c value (cf Eqs.(1,4)). The corrected number of counts N_i^c in the i-th channel of the time analyser is the function of the set of the uncorrected counts N_k (k = = i, i-1, i-2, etc.) - depending upon the value of the ratio $\frac{\tau_d}{\Delta t}$.

I. The ratio $\frac{\tau_d}{\Delta t} \geq 1$.

In this case the value of the corrected number of counts N_i^c is calculated from Eq.(1). Starting from Eq.(1) and taking into account Eq.(2) one can obtain the derivatives:

1) for $k > i$

$$\frac{\partial N_i^c}{\partial N_k} = 0 \quad , \tag{A1}$$

2) for $k = i$

$$\frac{\partial N_i^c}{\partial N_i} = \frac{S}{S - K_i - N_i} \quad , \tag{A2}$$

where K_i is defined in Eq.(2),

3) for $i-r \leq k \leq i-1$

$$\frac{\partial N_i^c}{\partial N_k} = \frac{S}{S - K_i - N_i} \; \frac{N_i}{S - K_i} \quad , \tag{A3}$$

4) for $k = i-r-1$

$$\frac{\partial N_i^c}{\partial N_{i-r-1}} = \frac{S}{S - K_i - N_i} \left(\frac{\tau_d}{\Delta t} - r\right) \frac{N_i}{S - K_i} \quad , \qquad \text{(A4)}$$

(i.e. $\frac{\partial N_i^c}{\partial N_{i-r-1}} = 0$ for the ratio $\frac{\tau_d}{\Delta t}$ being integer),

5) for $k < i-r-1$

$$\frac{\partial N_i^c}{\partial N_k} = 0 \quad . \qquad \text{(A5)}$$

II. The ratio $\frac{\tau_d}{\Delta t} < 1$.

In this case the corrected number of counts N_i^c is given by Eq.(4) and the derivative $\frac{\partial N_i^c}{\partial N_k}$ has the form:

$$\frac{\partial N_i^c}{\partial N_k} = - S \, p_r \frac{1}{v_{0i}} \frac{\partial v_{0i}}{\partial N_k} \quad . \qquad \text{(A6)}$$

The determining of $\frac{\partial v_{0i}}{\partial N_k}$ from Eq.(5) yields:

$$\frac{1}{v_{0i}} \, \frac{\partial v_{0i}}{\partial N_i} = \frac{1}{m_i \, v_{0i}^{\,p_r - q_r}} \quad , \qquad \text{(A7)}$$

$$\frac{1}{v_{oi}} \frac{\partial v_{oi}}{\partial N_{i-1}} = \frac{1 - v_{oi}^{q_r}}{m_i} , \tag{A8}$$

where

$$m_i = - \left[p_r \, (S - N_{i-1}) \, v_{oi}^{q_r} + (p_r - q_r) \, N_{i-1} \right] \tag{A9}$$

and the other derivatives $\frac{\partial v_{oi}}{\partial N_k}$ are equal to zero. Thus, Eq.(6) gives the two following formulae:

$$\frac{\partial N_i^q}{\partial N_i} = - S \, p_r \, \frac{1}{m_i \, v_{oi}^{p_r - q_r}} , \tag{A10}$$

$$\frac{\partial N_i^q}{\partial N_{i-1}} = - S \, p_r \, \frac{1 - v_{oi}^{q_r}}{m_i} . \tag{A11}$$

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REFERENCES

[1] E.Krynicka-Drozdowicz: Fit of Experimental Points to the Sum of Two (or One) Exponentials with Background. Part I. Report INP No 1020/PM, Cracow 1978.

[2] S.Chwaszczewski, A.T.Mikulski, Nucl. Instr. Meth. 118, 227 (1974).

[3] M.R.Foster, R.Fritsche, W.R.Mills, Nucl. Instr. Meth. 59, 254 (1968).

[4] Oprogramowanie e.m.c. ODRA serii 1300, Publ. ELWRO No 13043/2, Wrocław 1971.

[5] Oprogramowanie e.m.c. ODRA serii 1300, Publ. ELWRO No 13044/4, Wrocław 1972.

[6] J.Kajfosz: Wykorzystanie maszyny liczącej ODRA 1305 do analizy widm. Report INP No 916/PM, Cracow 1976.