

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Report No. 32-962

*An Adaptive Numerical Integration
Routine for the IBM 1620 II*

E. H. Kopf, Jr.

FACILITY FORM	N66	30122	(ACCESSION NUMBER)	(THRU)
	22		(PAGE)	1
	CR-76110		(NASA CR OR TMX OR AD NUMBER)	08
				(CATEGORY)

GPO PRICE \$ _____

CFSTI PRICE(S) \$ _____

Hard copy (HC) 1.00

Microfiche (MF) 1.50

653 July 65

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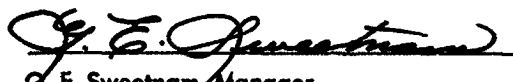
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Routine for the IBM 1620 II***

E. H. Kopf, Jr.


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Spacecraft Control Section

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Prepared Under Contract No. NAS 7-100
National Aeronautics & Space Administration

CONTENTS

I. General Description	1
II. Programming Considerations	3
III. Examples	4
References	6
Appendix: The Symbolic Programming System	7

FIGURES

1. Modified Adams integration with adaptive step size	2
2. Runge-Kutta-Gill integration	5

ABSTRACT

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This Report presents a Symbolic Programming System (SPS) coded numerical integration program designed to be used as a FORTRAN subroutine on the IBM 1620 II Computer. The program will solve differential equations by integration starting with known initial conditions. An adaptive option is available where the speed of integration is automatically varied in accordance with a predicted error.

I. GENERAL DESCRIPTION

This program is designed to solve, by integration, ordinary differential equations written in the form

$$\frac{dx}{dt} = f(t, x) \quad (1)$$

where x is an n vector and $f(t, x)$ is an n vector function of its arguments. The initial state

$$x(t_0) = x_0 \quad (2)$$

must be known.

Three options are available: (1) the Runge-Kutta-Gill integration method (Ref. 1), (2) the Adams method (Ref. 2), starting with the Runge-Kutta-Gill integration, and (3) the modified Adams or Moulton method with an adaptive step-size feature. In this last method, the solution is started by the Runge-Kutta-Gill method with automatic switching to the Adams method. The Adams method is used to predict the next point on the solution. This point is corrected by a closed-type formula (Ref. 2), and an error vector is formed from the absolute value of the difference between the predicted and corrected

values. This error vector is compared to upper and lower tolerance vectors supplied by the user. If any component of the error vector is greater than its respective upper tolerance, the step size is automatically halved. On the other hand, if each component of the error is smaller than its lower tolerance for three successive steps, the step size is doubled. This halving and doubling can continue until h is truncated at $h_{\max}$ or $h_{\min}$ which are user supplied bounds.

With any of these methods the user can change the step size at any time. This is possible because the routine detects this change and automatically restarts the Adams or modified Adams methods.

All three methods have h^5 error terms. The Runge-Kutta-Gill integration, however, is generally somewhat more accurate than the Adams method when each is using the same step size. Offsetting this is the higher speed of the Adams method which often takes only one-fourth the running time required by the Runge-Kutta-Gill method. It is difficult to give a time comparison for the modified Adams method because of the adaptive feature. If one set $h_{\max} = h_{\min}$, thus removing the adaptive feature, the routine would have about the same accuracy

as the Runge-Kutta-Gill method but would require about one-half the running time.

The adaptive feature of the modified Adams method permits one to start with a small initial step size and allow the routine to double the step size until it is the maximum which is consistent with a given accuracy. Figure 1 shows how the adaptive feature operates. In this example, x is the solution to

$$\frac{d^2x}{dt^2} + 0.6 \frac{dx}{dt} + 0.35 x^3 = u(t - 25) \quad (3)$$

where $u(\cdot)$ is the unit step function, and the initial conditions are

$$x(t = 0) = +0.2 \quad (4)$$

$$\frac{dx}{dt}(t = 0) = -0.1 \quad (5)$$

Notice that the initial step size of 0.5 sec was maintained until the time where dx/dt became large. At this point, the routine automatically reduced h to 0.125 to maintain accuracy. The step size h was later doubled and then doubled again as the truncation error decreased.

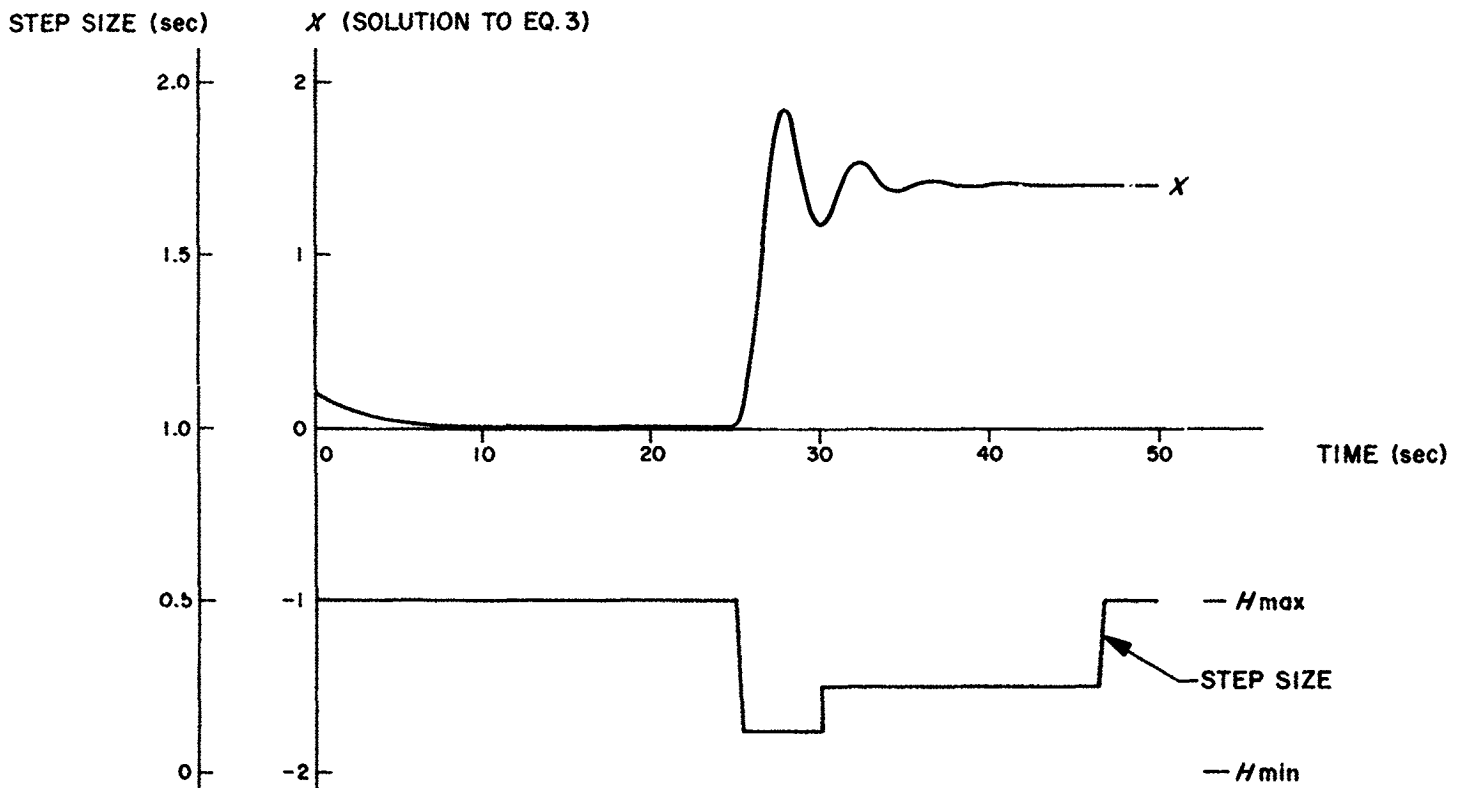


Fig. 1. Modified Adams integration with adaptive step size

II. PROGRAMMING CONSIDERATIONS

The user provides the information that the integration subroutine needs in the form of a derivative subroutine. This subroutine is written in the following manner. Let the differential equation to be integrated be

$$\dot{y} \triangleq \frac{dy}{dt} = f(t, y) \quad (6)$$

where

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}; \dot{y} = \begin{bmatrix} \dot{y}_1 \\ \dot{y}_2 \\ \vdots \\ \dot{y}_n \end{bmatrix} \quad (7)$$

$$f(t, y) = \begin{bmatrix} f_1(t, y) \\ f_2(t, y) \\ \vdots \\ f_n(t, y) \end{bmatrix} \quad (8)$$

Next, the time t and the step size h must be adjoined to the differential equations as shown below. Let the augmented state be x ; we then have

$$x \triangleq \begin{bmatrix} t \\ y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}; \dot{x} \triangleq \begin{bmatrix} h \\ \dot{y}_1 \\ \dot{y}_2 \\ \vdots \\ \dot{y}_n \end{bmatrix} \quad (9)$$

The purpose of the derivative subroutine is to calculate the derivative vector components $\dot{x}_2$ through $\dot{x}_{n+1}$ each time it is called. Since this subroutine is called by the integration routine, it can have no arguments in the call statement and all variables $x, \dot{x}$, etc. must be transferred through a *COMMON* statement.

The name of the derivative subroutine is *DER* since this is the name compiled into the integration routine. The user may change this to any valid FORTRAN name by changing the alphameric characters in the fourth from last card in the integration subroutine (LENGTH) to the desired name.

The integration subroutine is called *MARK* and is called by a two-statement sequence:

CALL *DER*

CALL *MARK* (*X*, *XD*, *N*, *IND*, *EU*, *EL*, *HMAX*, *HMIN*, *TS*)

where

X = $n + 1$ state vector as in *DER*

XD = $n + 1$ derivative vector as in *DER*

N = order of the equation

IND = indicator to show what integration system is to be used. *IND* = 0, 1, 2 for Runge-Kutta-Gill, Adams, modified Adams, respectively

EU = upper bound vector dimensioned n used only for modified Adams; must be positive

EL = lower bound vector dimensioned n used only for modified Adams; must be positive

HMAX = upper limit on step size, modified Adams

HMIN = lower limit on step size, modified Adams

TS = temporary storage dimensioned $(n + 1)$, $(5n + 1)$, $(5n + 2)$ for Runge-Kutta-Gill, Adams, or modified Adams, respectively

In the foregoing, the usual fixed/floating variable name rules apply. When using Runge-Kutta-Gill or the Adams method, *EU*, *EL*, *HMAX*, *HMIN* are not used and may be replaced by zeros in the call statement. For initialization purposes, *TS* (1) *must* be set to zero. When using Runge-Kutta-Gill or the Adams method, the x vector is initialized including the initial time in x (1). Next, the step size to be used, h , is placed into *XD* (1). Now each time that the two-statement call sequence is executed, the solution x will be moved from $x(t)$ to $x(t + h)$.

When the modified Adams option is selected, the initialization is as above; but after the solution is started

(3 steps), the predicted-corrected error is compared to EU and EL . The error for $X(2)$ is compared to $EU(1)$ and $EL(1)$, and so on. The step size is then adjusted as

described before. $XD(1)$ always contains the step size which *will* be used, unless changed by the user, for the next step.

III. EXAMPLES

Equation (3) was written in state variable form

$$\dot{y}_1 = y_2 \quad (10)$$

$$\dot{y}_2 = -0.6 y_2 - 0.35 y_1^3 + u(t - 25) \quad (11)$$

where $y_1 = x$, $y_2 = \dot{x}$.

Time and step size were adjoined to obtain the proper form

$$\dot{Z}_2 = Z_3 \quad (12)$$

$$\dot{Z}_3 = -0.6 Z_3 - 0.35 Z_2^3 + u(Z_1 - 25) \quad (13)$$

and the derivative subroutine was written as:

```

1. SUBROUTINE DER
2. DIMENSION Z(3), ZD(3)
3. COMMON Z, ZD
4. IF (Z(1) - 25.) 5,7,7
5. U = 0.
6. GO TO 8
7. U = 1.
8. ZD(2) = Z(3)
9. ZD(3) = -0.6 * Z(3) - 0.35 * Z(2) ** 3 + U
10. RETURN
```

A main program, which will integrate these equations from 0 to 50 sec for the initial conditions $x = 0.2$ and

$\dot{x} = -0.1$, follows. The step size to be used is 0.1 sec, and the results are to be printed or plotted every 0.5 sec.

```

C
C RUNGE-KUTTA-GILL
C
1. DIMENSION Z(3), ZD(3), TS(3)
2. COMMON Z, ZD
3. TS(1) = 0
4. ZD(1) = 0.1
5. Z(1) = 0
6. Z(2) = -0.2
7. Z(3) = -0.1
8. DO 11 J = 1,100
9. DO 11 I = 1,5
10. CALL DER
11. CALL MARK(Z, ZD, 3, 0, 0., 0., 0., 0., TS)
.
.
. Output Routine
.
.
12. CONTINUE
13. CALL EXIT
```

The result of an integration of this type and one where h was increased to 0.5 sec, where a noticeable error occurred, are shown in Fig. 2.

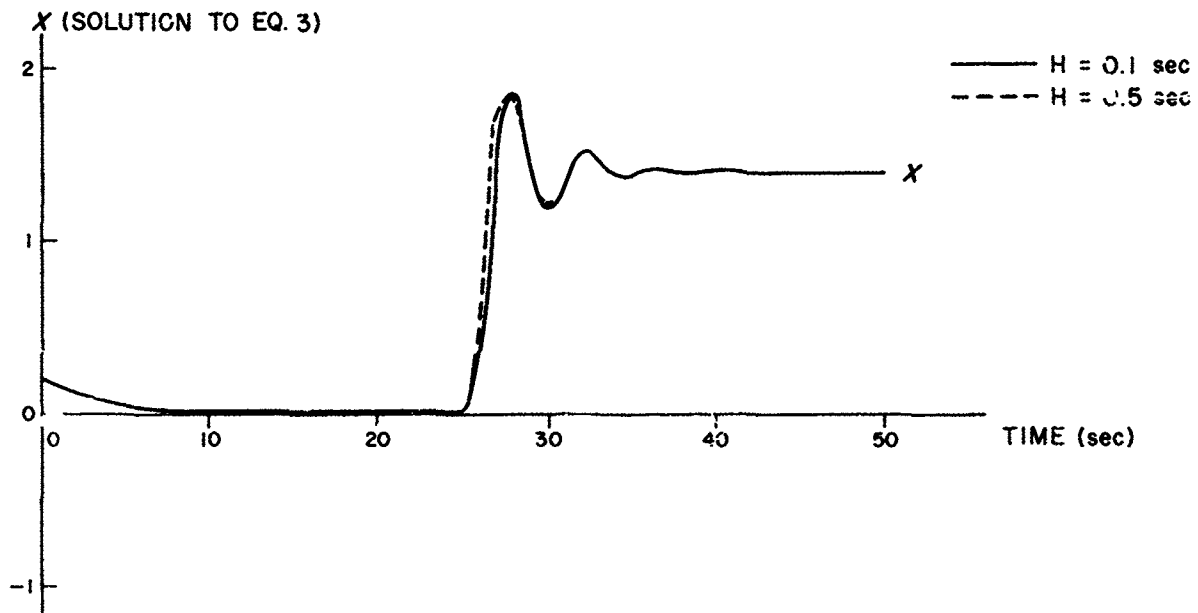


Fig. 2. Runge-Kutta-Gill integration

Returning back to Fig. 1, this was the result of a main program which forces the adaptive step-size feature to produce values at 0.5-sec intervals. This technique is illustrated below.

```

1. DIMENSION Z (3), ZD (3), TS (12), EU (2), EL (2)
2. COMMON Z, ZD
3. TS (1) = 0.
4. Z (1) = 0.
5. Z (2) = 0.2
6. Z (3) = -0.1
7. RESTOR = 0.5
8. DO 24 J = 1,100
9. T = Z (1)
10. DO 12 I = 1,2
11. EU (I) = 0.001 * ABSF (Z (I + 1)) + 0.001
12. EL (I) = 0.00001 * ABSF (Z (I + 1)) + 0.00001
13. ZD (1) = RESTOR
14. CALL DER
15. CALL MARK (Z, ZD, 2, 2, EU, EL, 0.5, 0.01, TS)
16. IF (ABSF (T + 0.5 - Z (1)) - 0.00001) 23, 23, 17
17. IF (T + 0.5 - Z (1) - ZD (1)) 18, 21, 21
18. RESTOR = XD (1)
19. XD (1) = T + 0.5 - X (1)
20. GO TO 14
21. RESTOR = XD (1)
22. GO TO 14
23. --- Output Routine ---
24. CONTINUE

```

As a comparison of running time, the integration using the Runge-Kutta-Gill method took 35 sec, while the modified Adams integration took 32 sec. Both yielded the same accuracy. Included in these times is a fixed time of 22 sec required to plot the output.

REFERENCES

1. *Mathematical Methods for Digital Computers*, Ralston, A., and H. Wilf (Ed.), New York: John Wiley, 1962, p. 115, Eq. 26.
2. Hildebrand, F., *Introduction to Numerical Analysis*, New York: McGraw-Hill, 1956, p. 198.

APPENDIX

The Symbolic Programming System

The following pages contain sequential facsimiles of the Symbolic Programming System (SPS) as used in this Report.

8

0000	LD	0000	0000
0001	LD	0001	0001
0002	LD	0002	0002
0003	LD	0003	0003
0004	LD	0004	0004
0005	LD	0005	0005
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0079	LD	0079	0079
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007B	LD	007B	007B
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00FF	LD	00FF	00FF

10

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53	FM01	K-PC5	01850	-L	04121	04131
54	TFL	AC,AD2,11	01862	-0	04071	04100
55	FALL	AC,PC0	01874	-L	04071	04191
56	PA00	AC,Y	01886	-J	04071	04121
57	TFL	AD2,AC,0	01898	-0	04100	04071
58	AM	AD2,10,10	01910	J1	04101	04000
59	BCKH	AS,1,011	01922	04	01754	0-0001
60	TFL	AC,AD2,11	01934	-0	04071	04010
61	FALL	AC,11,11F	01946	-L	04071	04131
62	PA00	XA,AC,0	01958	-J	04071	04071
63	STA	DER,#+12	01970	J1	04348	-1982
64	OLA	#+12,n(4)	01982	04	01954	0-0020
65	TF	ADR,XDA	01994	K0	04091	04010
66	TF	AD1,KA	02006	K0	04095	04010
67	TF	AD2,AC,0	02018	K0	04101	04086
68	AA	AD1,10,10	02030	J1	04091	04000
69	AA	AD1,10,10	02042	J1	04095	04000
70	TFL	AC,ADR,11	02054	-0	04071	0409J
71	BNUL	AC,XDA,11	02066	-L	04071	04010
72	FSUB	AC,AD2,11	02078	-K	04071	0410J
73	FSUB	AC,AD2,11	02090	-K	04071	0410J
74	BNUL	AC,PC7	02102	-L	04071	04201
75	PA00	AD1,AC,0	02114	-J	04090	04071
76	AM	AD2,10,10	02126	J1	04101	04000
77	BCKH	AS,1,011	02138	04	0-030	0-0001
78	ST	EXIT	02150	H9	04318	06000
1	*					
2	*	ADULTON OR ADAMS OPTION				
3	*					
4	MA	TF	ADR,XDA	02158	K0	04091
5	AD1	BLK	#+12,n(4)	02170	UM	02182
6	AS	ADR,10,10	02182	J1	04091	04000
7	TF	AD1,DCA	02194	K0	04096	04206
8	TF	AD2,DIA	02206	K0	04101	04211
9	TF	AD3,F23	02218	K0	04106	04216
10	TF	AD4,033	02230	K0	04111	04221
11	TF	TS,XDA,611	02242	-0	04098	04010
12	TFL	AC,ADR,11	02254	-0	04071	0409J
13	FSUB	AC,AD1,11	02266	-K	04071	0409J
14	TFL	ST0,AC	02278	-0	04081	04071
15	TFL	AD1,ADR,611	02290	-0	04050	0409J
16	FSUB	AC,AD2,11	02302	-K	04071	0410J
17	TFL	AD2,ST0,6	02314	-0	04101	04081
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19	FSUB	AC,AD3,11	02338	-K	04071	04100
20	TF	AD4,AC,6	02350	-0	04111	04071
21	TFL	AD3,ST0,6	02362	-0	04100	04081
22	AM	ADR,10,10	02374	J1	04091	04000
23	AM	AD1,10,10	02386	J1	04096	04000
24	AM	AD2,10,10	02398	J1	04101	04000
25	AM	AD3,10,10	02410	J1	04106	04000
26	AM	AD4,10,10	02422	J1	04111	04000
27	BLK	AS,1,011	02434	04	0-030	0-0001
28	ST	EXIT	02446	H9	04318	06000
29						
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6	STORX	TF	AC,10	02470	K0	04071	04070
7		ARE	AC,1,10	02482	J1	04071	04071
8		BLX	**12,AC(4)	02494	J1	04071	04071
9		TF	ADR,XA	02506	K0	04071	04071
10		TF	AD1,ADR	02518	K0	04071	04071
11	*						
12	*						
13	*						
14	*						
15	*						
16	C1	TFL	AD1,ADR,01	02531	-J	04071	04071
17		AD	ADR,10,10	02542	J1	04071	04071
18		AD	AD1,10,10	02554	J1	04071	04071
19		CCAS	01,1,011	02566	K0	04071	04071
20	ADRS	TF	AD1,00A	02578	K0	04071	04071
21		TF	AD2,01A	02590	K0	04071	04071
22		TF	AD3,02A	02602	K0	04071	04071
23		TF	AD4,03A	02614	K0	04071	04071
24		TF	ADR,XA	02626	K0	04071	04071
25		AM	ADR,1,10	02638	J1	04071	04071
26		FADD	XA,XDA,011	02650	-J	04071	04071
27		BLX	**12,01(4)	02662	K0	04071	04071
28	C2	TFL	AC,1,01	02674	-J	04071	04071
29		FADD	AC,AD4,11	02686	-L	04071	04071
30		TFL	STG,012	02698	-L	04071	04071
31		FADD	STG,AD5,1	02710	-L	04071	04071
32		FADD	AC,STG	02722	-J	04071	04071
33		TFL	STG,012	02734	-J	04071	04071
34		FADD	STG,AD2,11	02746	-L	04071	04071
35		FADD	AC,STG	02758	-J	04071	04071
36		FADD	AC,AD1,11	02770	-J	04071	04071
37		FADD	AC,AD1,11	02782	-L	04071	04071
38		FADD	AD1,AD1,0	02794	-J	04071	04071
39		AD	AD1,10,10	02806	J1	04071	04071
40		AD	AD1,10,10	02818	J1	04071	04071
41		AD	AD2,10,10	02830	J1	04071	04071
42		AD	AD3,10,10	02842	J1	04071	04071
43		AD	AD4,10,10	02854	J1	04071	04071
44		CCAS	02,1,011	02866	J4	04071	04071
45		CC	ADR,1,10	02878	J4	04071	04071
46		CC	EX11	02890	J4	04071	04071
1	*						
2	*						
3	*						
4		STG	DER,**12	02902	J0	04346	04346
5		TFH	EL1,0,10	02914	J6	04350	04350
6		TFH	EL1,0,10	02926	J6	04352	04352
7		BLX	**12,01(4)	02938	K0	04350	04350
8		TF	ADR,XDA	02950	K0	04351	04351
9		AD	ADR,10,10	02962	J1	04351	04351
10		TF	AD1,00A	02974	K0	04356	04356
11		TF	AD2,01A	02986	K0	04356	04356
12		TF	AD3,02A	02998	K0	04356	04356
13		TF	AD4,ADR	03010	K0	04356	04356
14		TF	AD5,XA	03022	K0	04356	04356
15		TF	ELAS,ELAS	03034	K0	04356	04356
16		TF	ELAS,ELAS	03046	K0	04356	04356
17		AM	AD1,10,10	03058	J1	04356	04356
18		AM	AD5,10,10	03070	J1	04356	04356
19	E1	TFL	AC,ADR,11	03082	-J	04071	04071

20	PSUB AC,AD1,11	03094 -R 04071 04090
21	TEL AC,AD1,11	03106 -O 04262 04071
22	PSUB AC,AD2,11	03118 -K 04071 04100
23	TEL AC,AD2,11	03130 -O 04272 04071
24	PSUB AC,AD3,11	03142 -K 04071 04100
25	TEL AC,AD3,11	03154 -O 04282 04071
26	TEL AC,AD3,11	
27	TEL AC,AD3,11	
28	TEL AC,AD3,11	
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76	TEL AC,AD3,11	
77	TEL AC,AD3,11	
78	TEL AC,AD3,11	

79		AN	DPLG,1,10	03758	01	04248	000-1
80		CH	DPLG,0,10	03758	01	04248	000-2
81		DNZ	EXIT	03758	01	04248	01250
82		TFM	LFLG,0,10	03758	01	04248	000-0
83		TFL	AC,ADA,11	03758	01	04071	04010
84		PADU	AC,ADA,11	03758	01	04071	04010
85		TFL	STU,AC	03758	01	04071	04071
86		FUOL	AC,MAX	03758	01	04071	04071
87		BNL	06	03758	01	04071	04071
88		TFL	ADA,STU,0	03758	01	04071	04071
89		BY	EXIT	03758	01	04071	04071
90	06	TFL	ADA,MAX,6	03758	01	04071	04071
91		BY	EXIT	03758	01	04071	04071
92	MAX	IF	AC,1	03758	01	04071	04071
93		AN	AC,1,10	03758	01	04071	04071
94		BLA	*+12,AC,1	03758	01	04071	04071
95		TF	ADA,KA	03758	01	04071	04071
96		TF	AD1,AD2	03758	01	04071	04071
97	03	TFL	AD1,AD1,1011	03758	01	04071	04071
98		AN	AD1,AD1,10	03758	01	04071	04071
99		AN	AD1,AD1,10	03758	01	04071	04071
100		CCM	07,1,111	03758	01	04071	04071
101		BY	EXIT	03758	01	04071	04071
102	CLM	TFM	DPLG,0,10	03758	01	04248	000-0
103		BY	EXIT	03758	01	04248	000-0
1	*						
2	*		STORAGE AREA				
3	*						
4		INOP	DS 5	04005	00005		
5		KA	DS 5	04010	00010		
6		ADA	DS 5	04015	00015		
7		DA	DS 5	04020	00020		
8		LPA	DS 4	04024	00024		
9		EUA	DS 6	04028	00028		
10		BLA	DS 5	04034	00034		
11		MAX	DS 10	04044	00044		
12		STU	DS 10	04054	00054		
13		ISA	DS 5	04059	00059		
14		PLG	DC 2,1	04063	00063		
15		AT	DS 10	04071	00071		
16		STU	DS 10	04071	00071		
17		AD1	DS 5	04071	00071		
18		AD2	DS 5	04071	00071		
19		AD3	DS 5	04071	00071		
20		AD4	DS 5	04071	00071		
21		AD5	DS 5	04071	00071		
22		AD6	DS 5	04071	00071		
23		AD7	DS 5	04071	00071		
24		AD8	DS 5	04071	00071		
25		AD9	DS 5	04071	00071		
26		AD10	DS 5	04071	00071		
27		AD11	DS 5	04071	00071		
28		AD12	DS 5	04071	00071		
29		AD13	DS 5	04071	00071		
30		AD14	DS 5	04071	00071		
31		AD15	DS 5	04071	00071		
32		AD16	DS 5	04071	00071		
33		AD17	DS 5	04071	00071		
34		AD18	DS 5	04071	00071		
35		AD19	DS 5	04071	00071		
36		AD20	DS 5	04071	00071		
37		AD21	DS 5	04071	00071		
38		AD22	DS 5	04071	00071		
39		AD23	DS 5	04071	00071		
40		AD24	DS 5	04071	00071		
41		AD25	DS 5	04071	00071		
42		AD26	DS 5	04071	00071		
43		AD27	DS 5	04071	00071		
44		AD28	DS 5	04071	00071		
45		AD29	DS 5	04071	00071		
46		AD30	DS 5	04071	00071		
47		AD31	DS 5	04071	00071		
48		AD32	DS 5	04071	00071		
49		AD33	DS 5	04071	00071		
50		AD34	DS 5	04071	00071		
51		AD35	DS 5	04071	00071		
52		AD36	DS 5	04071	00071		
53		AD37	DS 5	04071	00071		
54		AD38	DS 5	04071	00071		
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56		AD40	DS 5	04071	00071		
57		AD41	DS 5	04071	00071		
58		AD42	DS 5	04071	00071		
59		AD43	DS 5	04071	00071		
60		AD44	DS 5	04071	00071		
61		AD45	DS 5	04071	00071		
62		AD46	DS 5	04071	00071		
63		AD47	DS 5	04071	00071		
64		AD48	DS 5	04071	00071		
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66		AD50	DS 5	04071	00071		
67		AD51	DS 5	04071	00071		
68		AD52	DS 5	04071	00071		
69		AD53	DS 5	04071	00071		
70		AD54	DS 5	04071	00071		
71		AD55	DS 5	04071	00071		
72		AD56	DS 5	04071	00071		
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74		AD58	DS 5	04071	00071		
75		AD59	DS 5	04071	00071		
76		AD60	DS 5	04071	00071		
77		AD61	DS 5	04071	00071		
78		AD62	DS 5	04071	00071		
79		AD63	DS 5	04071	00071		
80		AD64	DS 5	04071	00071		
81		AD65	DS 5	04071	00071		
82		AD66	DS 5	04071	00071		
83		AD67	DS 5	04071	00071		
84		AD68	DS 5	04071	00071		
85		AD69	DS 5	04071	00071		
86		AD70	DS 5	04071	00071		
87		AD71	DS 5	04071	00071		
88		AD72	DS 5	04071	00071		
89		AD73	DS 5	04071	00071		
90		AD74	DS 5	04071	00071		
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93		AD77	DS 5	04071	00071		
94		AD78	DS 5	04071	00071		
95		AD79	DS 5	04071	00071		
96		AD80	DS 5	04071	00071		
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102		AD86	DS 5	04071	00071		
103		AD87	DS 5	04071	00071		
104		AD88	DS 5	04071	00071		
105		AD89	DS 5	04071	00071		
106		AD90	DS 5	04071	00071		
107		AD91	DS 5	04071	00071		
108		AD92	DS 5	04071	00071		
109		AD93	DS 5	04071	00071		
110		AD94	DS 5	04071	00071		
111		AD95	DS 5	04071	00071		
112		AD96	DS 5	04071	00071		
113		AD97	DS 5	04071	00071		
114		AD98	DS 5	04071	00071		
115		AD99	DS 5	04071	00071		
116		AD100	DS 5	04071	00071		
117		AD101	DS 5	04071	00071		
118		AD102	DS 5	04071	00071		
119		AD103	DS 5	04071	00071		
120		AD104	DS 5	04071	00071		
121		AD105	DS 5	04071	00071		
122		AD106	DS 5	04071	00071		
123		AD107	DS 5	04071	00071		
124		AD108	DS 5	04071	00071		
125		AD109	DS 5	04071	00071		
126		AD110	DS 5	04071	00071		
127		AD111	DS 5	04071	00071		
128		AD112	DS 5	04071	00071		
129		AD113	DS 5	04071	00071		
130		AD114	DS 5	04071	00071		
131		AD115	DS 5	04071	00071		
132		AD116	DS 5	04071	00071		
133		AD117	DS 5	04071	00071		
134		AD118	DS 5	04071	00071		
135		AD119	DS 5	04071	00071		
136		AD120	DS 5	04071	00071		
137		AD121	DS 5	04071	00071		
138		AD122	DS 5	04071	00071		
139		AD123	DS 5	04071	00071		
140		AD124	DS 5	04071	00071		
141		AD125	DS 5	04071	00071		
142		AD126	DS 5	04071	00071		
143		AD127	DS 5	04071	00071		
144		AD128	DS 5	04071	00071		
145		AD129	DS 5	04071	00071		
146		AD130	DS 5	04071	00071		
147		AD131	DS 5	04071	00071		
148		AD132	DS 5	04071	00071		
149		AD133	DS 5	04071	00071		
150		AD134	DS 5	04071	00071		
151		AD135	DS 5	04071	00071		
152		AD136	DS 5	04071	00071		
153		AD137	DS 5	04071	00071		
154		AD138	DS 5	04071	00071		
155		AD139	DS 5	04071	00071		
156		AD140	DS 5	04071	00071		
157		AD141	DS 5	04071	00071		
158		AD142	DS 5	04071	00071		
159		AD143	DS 5	04071	00071		
160		AD144	DS 5	04071	00071		
161		AD145	DS 5	04071	00071		
162		AD146	DS 5	04071	00071		
163		AD147	DS 5	04071	00071		
164		AD148	DS 5	04071	00071		
165		AD149	DS 5	04071	00071		
166		AD150	DS 5	04071	00071		
167		AD151	DS 5	04071	00071		
168		AD152	DS 5	04071	00071		
169		AD153	DS 5	04071	00071		
170		AD154	DS 5	04071	00071		
171		AD155	DS 5	04071	00071		
172		AD156	DS 5	04071	00071		
173		AD157	DS 5	04071	00071		
174		AD158	DS 5	04071	00071		
175		AD159	DS 5	04071	00071		
176		AD16					

35	FC5	DC	2,1	04101 00002
36	FC5	DC	6,-+1215205	04184 00004
37	FC5	DC	2,1	04191 00002
38	FC5	DC	8,15666667	04199 00008
39	FC5	DC	2,1	04201 00002
40	FC5	DC	2	04206 00005
41	FC5	DC	1	04211 00005
42	FC5	DC	3	04215 00005
43	FC5	DC	3	04221 00005
44	FC5	DC	3	04229 00008
45	FC5	DC	6,57500000	04231 00002
46	FC5	DC	2,0	04239 00008
47	FC5	DC	6,41666667	04241 00002
48	FC5	DC	2,0	04246 00005
49	FC5	DC	3	04248 00002
50	FC5	DC	2	04250 00002
51	FC5	DC	2	04252 00002
52	FC5	DC	2	04252 00010
53	FC5	DC	2	04272 00010
54	FC5	DC	10	04282 00010
55	FC5	DC	10	04290 00009
56	FC5	DC	10	04292 00002
57	FC5	DC	8,03333333	04300 00008
58	FC5	DC	2,-1	04302 00002
59	FC5	DC	8,41666667	04307 00005
60	FC5	DC	2,-1	04312 00005
61	FC5	DC	3	04317 00005
62	FC5	DC	3	
63	FC5	DC	3	
1	*			
2	*	EXIT		
3	*			
4	EXIT	BLX	*+12,INDEX(4)	04318 01 04320 00005
5	B	RA,10		04330 09 04240 00000
6	*			
7	*	CALL DE		
8	*			
9	DER	BTM	*+11	04346 00005
10	B	DER=17,6		04348 JR 04348 -4329
11	*			04360 09 04348 00000
12	*			
13	*	TRAILING CARDS		
14	*			
15	LENGTH	OAC	6,DER	04373 00012
16	OVLC	5,DER+5		04380 00005
17	OC	2,0		04390 00002
18	GENB			00000
19	DER	BTM	*+11	
20	B	DER=17,6		
21	*			
22	*			
23	*			
24	*			
25	*			
26	*			
27	*			
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