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**DATA REDUCTION SCHEME
FOR LASER DOPPLER INTERFEROMETERS**

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DATA REDUCTION SCHEME FOR LASER DOPPLER INTERFEROMETERS

ABSTRACT

A data reduction scheme for laser Doppler interferometers is described in this report. The computer algorithm is built on the assumption that the fringe pattern of the interferometer is given by

$$I = A \cos^2 \left(\phi_0 + \frac{2\pi\tau U}{\lambda_0} \right),$$

where τ is the transit time along the optical delay, and λ_0 the wavelength. The fringe data from the interferometric measurements is analyzed by segments. At every point where the slope of the fringe pattern is radically altered, a reading is taken according to the formats which are attached to the report. The data correction and then the conversion of the data into velocity plots are performed on a 7600 computer. In order to demonstrate the applicability of the scheme, the data on the interferometric measurement of aluminum free surface velocities is processed by the prescribed method. The computer programs are attached for the convenience of the user.

I. INTRODUCTION

The laser Doppler interferometer has been recognized as an excellent instrument for shock wave studies.¹⁻⁴ There are two reasons for the increasing demand for this type of precision instrument. First of all, as a result of the great advancement in computational scheme, a higher order of accuracy is required for the data. Secondly, the rapid development in laser and electronic technologies (for example, subnanosecond response time) affords such precision in measurements.

The objective of this report is to describe a data-reduction scheme for the Doppler interferometers which have been developed in B-Division. The scheme is described in the systematic order of the procedure by which the film records of the interferometric data are converted into velocity plots.*

*Instructions on the steps to be taken for data reduction are given in the Summary, p. 15.

II. METHOD OF DIGITIZING FILM RECORDS

The computer algorithm is developed on the assumption that the fringe pattern on the Doppler interferometers is given by

$$I = A \cos^2 \left(\phi_0 + \frac{2\pi\tau U_t}{\lambda_0} \right), \quad (1)$$

which results from a plane-wave analysis of the interferometric process.⁵ τ is a transit time along the optical delay path, and λ_0 is the wavelength. Figure 1 shows an example of the typical interferometric data which we may expect to see. In digitizing the records, readings are taken at every point where the slope is radically altered. The determination of such points is made strictly by subjective judgment.

Let F_n be the phase of the cosine function expressed in units of π at the n th point; then the incremental change in phase between the $n-1$ th and n th points is

$$\Delta F_n = \frac{2\pi}{\lambda_0} \Delta U_n. \quad (2)$$

Figure 1 shows all the representative examples of ΔF_n . All the cases except ΔF_h are self-explanatory. A fractional fringe such as ΔF_h is calculated using a fringe-amplitude calibration. The fringe amplitude is calibrated by determining the minimum point and the maximum point on the fringe in this order in the region of interest. Also, the quadrant in which the point h is found is put into an appropriate column on these calibration cards. (Refer to FORTRAN Statement 2, p. 7).

Since the absolute time must be determined at every point, a time base calibration of a known frequency is recorded on the data film itself in order to correct for nonlinearity of the CRT trace. This is done immediately following the experiment. Absolute timing is further guaranteed through the addition of a timing fiducial to the data and monitor signal channels. When the data are being digitized, a time calibration is made right after the first data point on the film is read. X-readings are taken for two successive points, either at the peaks or at the troughs on the calibration signal in a positive direction in time. The interval time, K , between the two points is recorded in an appropriate column on these cards so that the calibration factor can be calculated by

$$0.1K / (X_2 - X_1). \quad (\text{Refer to FORTRAN Statement 2, p. 7}).$$

The time calibration is repeated at the beginning of every scope trace to be analyzed. If higher accuracy is required, the time calibration may be repeated more frequently. The calculation of the velocity and time is explained in the next section.

The beam intensity is monitored while the data is being taken so that any fluctuations on the beam intensity (i.e., those fluctuations not associated with a velocity

$$\Delta F_a = 0.5$$

$$\Delta F_b = 0.25$$

$$\Delta F_c = 0.25 - \Delta F_d - 1$$

$$\Delta F_h = \text{Calculated using fringe-amplitude calibration}$$

$$\Delta F_d = 0.5 - \Delta F_d - 1$$

$$\Delta F_e = 0$$

$$\Delta F_g = -\Delta F_f \text{ (velocity inflection)}$$

Fig. 1. Example of fringe pattern.

change) which occurred during the measurement are recorded and later used for corrections to be made on the data. Figure 2 shows an example of such intensity fluctuations. Superimposed on the data and monitor records are vertical calibrations with known voltages. In practice, these vertical calibrations may be recorded on separate films in order to avoid the accidental destruction of the data or the intensity monitor records.

The data correction is made in the following manner (refer to Fig. 2): The voltages for the points $\bar{Y}_1$ and $\bar{Y}_N$ in the monitor record are given by

$$\bar{V}_1 = \frac{\bar{V}_{\max} - \bar{V}_{\min}}{\bar{Y}_{\max} - \bar{Y}_{\min}} (\bar{Y}_1 - \bar{Y}_{\min}) + \bar{V}_{\min}$$

and

$$\bar{V}_N = \frac{\bar{V}_{\max} - \bar{V}_{\min}}{\bar{Y}_{\max} - \bar{Y}_{\min}} (\bar{Y}_N - \bar{Y}_{\min}) + \bar{V}_{\min}$$

The voltages for the point Y_N and the base line in the fringe record are similarly given by

$$V_N = \frac{V_{\max} - V_{\min}}{Y_{\max} - Y_{\min}} (Y_N - Y_{\min}) + V_{\min}$$

and

$$V_B = \frac{V_{\max} - V_{\min}}{Y_{\max} - Y_{\min}} (Y_B - Y_{\min}) + V_{\min}$$

Then the correction on V_N is made by

$$V_N^c = V_N \frac{\bar{V}_1}{\bar{V}_N}$$

Thus, the corrected amplitude reading for the point Y_N is given by

$$Y_N^c = (V_N^c - V_B) \frac{Y_{\max} - Y_{\min}}{V_{\max} - V_{\min}} + Y_B \quad (3)$$

The data is digitized according to the formats which are shown in FORTRAN Statements 1 and 2 (p. 7). The time and fringe-amplitude calibration are taken along with the data and inserted in appropriate places. The data amplitude correction is made only when the monitor indicates that the intensity fluctuations perturbed the

Fig. 2. Calibration and correction of data.

essential data. For the data correction, the monitor and other pertinent information are read out in the formats given by FORTRAN Statements 3, 4, and 5 (pp. 8 and 9).

The deck, which consists of the data points including the time and amplitude calibrations, the intensity monitor points, and other associated cards for data correction, is called DATA. DATA deck is arranged in the following order:

1. Data points including the time and amplitude calibration cards;
2. Monitor readings for data correction;
3. Base-line reading on the data film;
4. Base-line reading on the monitor film;
5. The minimum, maximum, and base-line readings, in that order, for the vertical calibration on the data scope;
6. The minimum, maximum, and base-line readings, in that order, for the vertical calibration on the monitor scope;
7. END card.

When we have more than one experiment to analyze, all the decks may be stacked together. However, there should be only one END card, marking the end of the entire deck.

The first operation to be performed on DATA deck is the data correction using the intensity monitor reading. The procedure is as follows:

1. Read DATA deck into a 7600;
2. Read out a program, INCOCTR, from a photostore or other appropriate storage;
3. Operate INCOCTR on DATA by the standard method, INCOCTR / T V .

The results are put out in two separate files: DAC $\emptyset$, which can be sent out to HSP or FR8 $\emptyset$; and DX-file, which can be viewed on a screen and sent out to CRT or RJET. DAC $\emptyset$ gives the corrected data points, and the DX-file shows the CRT plots. The corrected data points are replaced by the new cards. Once the data correction is completed, the monitor reading and the other associated cards are removed from the deck. The next step is the conversion of the data into velocity plots, which is explained in the next section. The program INCO is given in the Appendix of this report.

If the essential data is unperturbed by the intensity fluctuations, the data correction is not required. In this case only the data is digitized and, with the appropriate time and amplitude calibrations, the velocity conversion can be performed immediately.

FOR COMMENT						DATA POINTS												FORTRAN STATEMENT 1																																																				
STATEMENT NUMBER	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
																																				I = 0	$\Delta F_n = 0.$																																	
XXXXXXX						YYYYYYY																													= 1	$\Delta F_n = .25$																																		
(Time)						(Amplitude)																													= 2	$\Delta F_n = .5$																																		
																																			= 3	$\Delta F_n = \Delta F_{n-1}$																																		
																																			= 4	$\Delta F_n = .25 - \Delta F_{n-1}$																																		
																																			= 5	$\Delta F_n = .5 - \Delta F_{n-1}$																																		
																																			= 6	See the next two cards for the calibration of time or amplitude to calculate ΔF_n																																		
																																			= 7	Calibration for time or amplitude*																																		
																																			= 8	Data correction to be made on amplitude using intensity monitor*																																		
																																			= 9	Vertical calibration to be used for data correction*																																		
																																			J = 0	+ ΔU (positive velocity)																																		
																																			= 1	- ΔU (negative velocity)																																		
																																			K =	Time calibration, $.1xK/(x_2 - x_1)$, in $\mu s/\text{unit } x$																																		
																																				except I = 7 where calibration is for time or amplitude.																																		
																																			L = 0	Reading continues																																		
																																			= 1	End of the data points																																		

*The meanings of J, K, L for these 3 cases are defined on the next 3 pages.

†X-reading decreases in the positive direction in time, and Y-reading increases in the positive direction in amplitude.

FOR COMMENT						TIME OR FRINGE AMPLITUDE CALIBRATION												FORTRAN STATEMENT 2																																																				
STATEMENT NUMBER	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
																																			I = 7																																			
XXXXXXX						YYYYYYY																													J = 0	+ ΔU (positive velocity)																																		
(Time)						(Amplitude)																													= 1	- ΔU (negative velocity)																																		
																																			L = 0	Time calibration. Calibration factor = $.1 \times K / (x_2 - x_1)$																																		
																																			= 1	Amplitude calibration																																		
																																				K = 1, 2, 3 or 4 quadrant of $\cos^2$																																		

Comment:

Time calibration (L = 0)

At the beginning of every scope trace to be analyzed, a time calibration is made. Two readings (X_1 , Y_1) and (X_2 , Y_2) are taken in a positive direction in time. A calibration factor is calculated by

$$.1 \times K / (x_2 - x_1).$$

Fringe amplitude calibration (L = 1)

ΔF_n can be calculated using two calibration points on the fringe amplitude. The readings are taken at the minimum point and the maximum point on a fringe in this order in the region of interest.

FOR COMMENT		C O N T		DATA CORRECTION CARDS																												FORTRAN STATEMENT 3																																												
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72					
				*																																																																								
XXXXXX				YYYYYY	I JKL	NNNN	-- DATA POINTS																																																																					
(Time)				(Amplitude)		(Event)																																																																						
						I = 8																																																																						
						J = 0																																																																						
						K = Time calibration factor given by $.1 \times K / (x_2 - x_1)$																																																																						
						L = 0	Reading continues																																																																					
						L = 1	End of the data																																																																					
				*																																																																								
XXXXXX				YYYYYY	I JKL		-- MONITOR POINTS																																																																					
(Time)				(Amplitude)		I = 8																																																																						
						J = 1																																																																						
						K = Time calibration factor given by $.1 \times K / (x_2 - x_1)$																																																																						
						L = 0																																																																						
999999				YYYYYY	I JKL		-- BASE-LINE READING ON THE DATA RECORD																																																																					
				(Amplitude)		I = 8																																																																						
						J = 0																																																																						
						K, L = same as above																																																																						
999999				YYYYYY	I JKL		-- BASE-LINE READING ON THE MONITOR RECORD																																																																					
				(Amplitude)		I = 8																																																																						
						J = 1																																																																						
						K, L = same as above																																																																						
*These two X-readings must represent the same point in time in the data and monitor traces.																																																																												

FOR COMMENT		C O N T		VERTICAL CALIBRATION FOR SCOPES																												FORTRAN STATEMENT 4																																												
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72					
				*																																																																								
VVVVVV				YYYYYY	I JKL		-- VERTICAL CALIBRATION FOR DATA SCOPE																																																																					
(Voltage)				(Amplitude)		I = 9																																																																						
						J = 0																																																																						
						K = Time calibration factor given by $.1 \times K / (x_2 - x_1)$																																																																						
						L = 0																																																																						
999999				YYYYYY	I JKL		-- BASE-LINE READING ON VERTICAL CALIBRATION FOR DATA SCOPE																																																																					
				(Amplitude)		I = 9																																																																						
						J = 0																																																																						
						K, L = same as above																																																																						
				*																																																																								
VVVVVV				YYYYYY	I JKL		-- VERTICAL CALIBRATION FOR MONITOR SCOPE																																																																					
(Voltage)				(Amplitude)		I = 9																																																																						
						J = 1																																																																						
						K, L = same as above																																																																						
999999				YYYYYY	I JKL		-- BASE-LINE READING ON VERTICAL CALIBRATION FOR MONITOR SCOPE																																																																					
				(Amplitude)		I = 9																																																																						
						J = 1																																																																						
						K, L = same as above																																																																						
*Read two cards, V _{min} and V _{max} in this order.

Fig. 3. $\cos^2$ function.

a fringe and at the point h respectively. Then the amplitude calibration factor, YCA, is

$$YCA = 1./(Y_2 - Y_1).$$

Thus, ΔF_h in various quadrants is given by

$$1. \quad K = 1$$

$$\Delta F_h = [\text{arc cos } \sqrt{(Y_h - Y_1)YCA}]/\pi$$

$$2. \quad K = 2$$

$$\Delta F_h = \{[\text{arc cos } \sqrt{(Y_h - Y_1)YCA}]/\pi\} - 0.25$$

$$3. \quad K = 3$$

$$\Delta F_h = \{[\text{arc cos } -\sqrt{(Y_h - Y_1)YCA}]/\pi\} - 0.5$$

$$4. \quad K = 4$$

$$\Delta F_h = \{[\text{arc cos } -\sqrt{(Y_h - Y_1)YCA}]/\pi\} - 0.75$$

These equations are valid everywhere on the fringe except when ΔF_h is found at the beginning of the trace. This is a special case in which ΔF_h is calculated by

$$1. \quad K = 1$$

$$\Delta F_h = 0.25 - \{[\text{arc cos } \sqrt{(Y_{h-1} - Y_1)YCA}]/\pi\}$$

$$2. \quad K = 2$$

$$\Delta F_h = 0.5 - \{[\text{arc cos } \sqrt{(Y_{h-1} - Y_1)YCA}]/\pi\}$$

$$3. \quad K = 3$$

$$\Delta F_h = 0.75 - \{[\text{arc cos } -\sqrt{(Y_{h-1} - Y_1)YCA}]/\pi\}$$

$$4. \quad K = 4$$

$$\Delta F_h = 1.0 - \{[\text{arc cos } -\sqrt{(Y_{h-1} - Y_1)YCA}]/\pi\}$$

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Fig. 4. Measurement of the free-surface velocity for aluminum.

IV. SUMMARY

The data reduction for laser Doppler interferometers is a laborious process. The intention of this report is to bring about some orderly method of data reduction with the aid of a computer. The procedure is outlined as follows:

1. Digitizing the Data

Digitize the data at the points where the slope changes (see Fig. 1) according to FORTRAN Statements 1 and 2. A time-calibration is made at the beginning of every scope trace to be analyzed. If a fractional fringe has to be determined, the fringe amplitude must be calibrated.

2. Digitizing the Monitor

This is necessary only when intensity fluctuations appear to have perturbed the essential data. Digitize the intensity monitor according to FORTRAN Statements 3, 4, and 5, including the readings on the vertical scope calibration.

3. Data Corrections for Intensity Fluctuations

The corrections are made only when the essential data have been perturbed. Arrange DATA deck (refer to Section II). The correction is performed by INCOCTR on DATA deck. After the correction is completed, replace the corrected data points and remove all the cards except the data points and the time and fringe-amplitude calibration cards.

4. Conversion to Velocity Plots

Arrange DADE deck (refer to Section III). Input the wavelength and the transit time. The velocity conversion is performed by DOPICTR on DADE deck.

The scheme described in this report certainly expedites the data reduction, although it still does not eliminate a very tedious process of digitizing the records with a film reader. Automating such a process would require an investment in very expensive electro-optical equipment which is probably beyond our current needs.

ACKNOWLEDGMENT

The scheme described in this report was first suggested to us by W. Isbell of H-Division. R. Bailey of B-Division wrote the computer programs.

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APPENDIX: INCO AND DOPI

```

1 *ID 1858CH INCO KAMEGAI BOXC61020001
2 * PRINT
3 * LOD 30000-
4 * XEQ
5 * LISTB
6 * FORTRAN
7 PROGRAM NAME(TAPE5, TAPE3)
8 CODE ANALYSIS
9 INTEGER DATA, BX80, BY80, BX81, BY81
10 DIMENSION DAT8(1000), DAT9(100), DATA(4), DX9(6), DY9(6), DX80(1000),
11 2 DY80(1000), DX81(1000), DY81(1000)
12 3, YNC(1000)
13 CALL KEEPAR(1)
14 CALL ASSIGN(5, 0.4RDATA)
15 CALL ASSIGN(3, 4RDAC0)
16 CALL CRTID(2H00, 1, 1)
17 CALL FRAME(1)
18 DATA(LAB2=4HTIME), (LAB1=3HYNC)
19 CHK8=0
20 J0G=JAG=0
21 STRT READ(5, 112)(DATA(I), I=1, 4)
22 112 FORMAT(16, 1X, 16, 1X, 211)
23 IF(DATA(1).EQ.999999)GO TO FIN
24 IF(DATA(3).LT.A)GO TO STRT
25 IF(DATA(3).EQ.0) ,9
26 IF(CHK8.EQ.1)GO TO FR
27 IF(DATA(4).EQ.0) ,A8
28 J0G=J0G+1
29 DX80(J0G)=DATA(1)
30 DY80(J0G)=DATA(2)
31 GO TO STRT
32 A8 DO 20 I=1, J0G
33 IF(1.EQ.1)GO TO 22
34 READ(5, 112)(DATA(K), K=1, 2)
35 22 DX81(I)=DATA(1)
36 20 DY81(I)=DATA(2)
37 READ(5, 112)BX80, BY80
38 READ(5, 112)BX81, BY81
39 CHK8=1
40 GO TO STRT
41 9 JAG=JAG+1
42 IF(DATA(4).EQ.0) ,A9
43 DX9(JAG) = DATA(1)
44 DY9(JAG) = DATA(2)
45 IF(JAG.GT.3)GO TO ERR
46 GO TO STRT
47 A9 IF(CHK8.EQ.0)GO TO ERR
48 DX9(JAG) = DATA(1)
49 DY9(JAG) = DATA(2)
50 IF(JAG.EQ.6)CALC, STRT
51 ERR WRITE(59, 101)
52 101 FORMAT(26HDATA CARDS OUT OF SEQUENCE)
53 C J0G= NUM OF 80 & 81 YOU NEED TO PROCESS.
54 CALC CHK8=0
55 WRITE(3, 103)(DX80(K), K=1, J0G)
56 WRITE(3, 104)(DY80(K), K=1, J0G)
57 WRITE(3, 105)BY80, BY81
58 WRITE(3, 106)(DX81(K), K=1, J0G)
59 WRITE(3, 107)(DY81(K), K=1, J0G)
60 WRITE(3, 108)(DX9(K), K=1, JAG)
61 WRITE(3, 109)(DY9(K), K=1, JAG)
62 103 FORMAT(5HDX80=, F10.0)
63 104 FORMAT(5HDY80=, F10.0)
64 105 FORMAT(5HBY80=, 16, 2X, 5HBY81=, 15)
65 106 FORMAT(5HDX81=, F10.0)
66 107 FORMAT(5HDY81=, F10.0)
67 108 FORMAT(4HDX9=, F10.0)
68 109 FORMAT(4HDY9=, F10.0)
69 DO 21 N=1, J0G
70 VYBAR = (DX9(5) - DX9(4))/(DY9(5) - DY9(4))
71 VBBAR = VYBAR*(DY9(6) - DY9(4)) + DX9(4)
72 V1BAR = VYBAR*(DY81(1) - BY81) + VBBAR
73 VNBAR = VYBAR*(DY81(N) - BY81) + VBBAR
74 VY = (DX9(2) - DX9(1))/(DY9(2) - DY9(1))
75 VB = VY*(DY9(3) - DY9(1)) + DX9(1)
76 VN = VY*(DY80(N) - BY80) + VB
77 VNC = VNBAR/V1BAR
78 YNC(N) = (VNC - VB)/VY + BY80

```

```

79      WRITE(3,102)DX80(N),YNC(N)
80      IF(N.EQ.1) .23
81      CALL AMINMX(YNC,1,JOG,1,YMIN,YMAX)
82      CALL AMINMX(DX80,1,JOG,1,XMIN,XMAX)
83      YMAX=YMAX * 1.1
84      CALL MAPG(XMIN,XMAX,YMIN,YMAX,.11328, 1., .11328, .95)
85      CALL SETCH(1.,21.,1.0,1.1,0)
86      WRITE(100,110)LAB1
87      CALL SETCH(7.,0.5,1.0,1.0,0)
88      WRITE(100,110)LAB2
89      110 FORMAT(20X,R10)
90      23 CALL SETCRT(DX80,YNC,1,1023)
91      CALL POINTC(1HX,DX80(N),YNC(N),1)
92      102 FORMAT(6HDXB0= ,E14.6,2X,5HYNC= ,E14.6)
93      21 CONTINUE
94      YMAX=0.0
95      CALL FRAME(1)
96      WRITE(59,200)JUG JAG
97      200 FORMAT(215)
98      JOG=JAG=0
99      GO TO STRT
100     FIN CALL EXIT
101     END
102 *     DATA

```

```

1 *ID 106BCH DOPI KAMEGAI BOXC61 001
2 * PRINT
3 * DUMP (OCT)
4 * LOD 30000-
5 * XEQ
6 * LIST0
7 * FORTRAN
8     PROGRAM NAME(TAPE5,TAPE3,PUNCH)
9     CODE ANALYSIS
10    DIMENSION IDATA(7,1000),T(1000),V(1000),HT(1000),HV(1000),
11    1HF(1000)
12    CALL KEEP00(1)
13    CALL ASSIGN(5.0,4RDADE)
14    CALL ASSIGN(3.4ROUT0)
15    CALL CRTID(2H00,1,1)
16    CALL FRAME(1)
17    DATA(LAB2=4HTIME),(LAB1=3HVEL)
18    STRT READ(5,102)ALAM
19    IF(ALAM.EQ.0)GO TO FINN
20    READ(5,102)TA0
21    103 FORMAT(16,1X,16,1X,411,1X,14)
22    102 FORMAT(E11,4)
23    DO 10 J=1,1000
24    READ(5,103)(IDATA(I,J),I=1,7)
25    IF(IDATA(6,J).EQ.1) .10
26    IF(IDATA(3,J).EQ.7) .CALC
27    10 CONTINUE
28    CALC V(1)=0.0
29    T(1)=0.
30    HF(1)=0.
31    DO 11 N=1,J
32    IF(IDATA(3,N).EQ.0)GO TO 12
33    GO TO(1,2,3,4,5,6)IDATA(3,N)
34    12 DFN = 0.
35    GO TO 50
36    1 DFN = .25
37    GO TO 50
38    2 DFN = .5
39    GO TO 50
40    3 DFN = HDEFN
41    GO TO 50
42    4 DFN = .25 - HDEFN
43    GO TO 50
44    5 DFN = .5 - HDEFN
45    GO TO 50
46    6 IF(IDATA(6,N+1).EQ.0) .60
47    XCA=IDATA(5,N+2)*.1/(IDATA(1,N+2)-IDATA(1,N+1))
48    IF(N.EQ.1)GO TO 97
49    IF(IDATA(3,N-1).EQ.7) .7
50    V(N)=V(N-3)
51    T(N)=T(N-3)
52    GO TO 97
53    7 V(N)=V(N-1)
54    T(N)=T(N-1)
55    GO TO 97
56    60 YCA = 1./((IDATA(2,N+2) - IDATA(2,N+1))
57    IF(IDATA(3,N-1).EQ.7) .70
58    A1 = IDATA(2,N)-IDATA(2,N+1)

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59      IF(A1).51.51
60      A1 = 0.
61      51 SRTN = SQRTF(A1*YCA)
62      IF(SRTN.GT.1.)61
63      SRTN = 1.
64      61 A2 = IDATA(2,N-3)-IDATA(2,N+1)
65      IF(A2).52.52
66      A2 = 0.
67      52 SRTM = SQRTF(A2*YCA)
68      IF(SRTM.GT.1.)62
69      SRTM = 1.
70      62 GO TO(71,71,73,73) IDATA(5,N+1)
71      71 DFN = (ACOSF(SRTN) - ACOSF(SRTM))/3.1416
72      GO TO 50
73      73 DFN = (ACOSF(SRTM) - ACOSF(SRTN))/3.1416
74      GO TO 50
75      70 B1 = IDATA(2,N)-IDATA(2,N+1)
76      IF(B1).53.53
77      B1 = 0.
78      53 SRTN = SQRTF(B1*YCA)
79      IF(SRTN.GT.1.)63
80      SRTN = 1.
81      63 B2 = IDATA(2,N-1)-IDATA(2,N+1)
82      IF(B2).54.54
83      B2 = 0.
84      54 SRTM = SQRTF(B2*YCA)
85      IF(SRTM.GT.1.)64
86      SRTM = 1.
87      64 GO TO(71,71,73,73) IDATA(5,N+1)
88      50 HDEFN=DFN
89      IF(IDATA(4,N).EQ.0)90.
90      DFN=-DFN
91      90 IF(IDATA(3,N-1).EQ.7)92.
92      DTN = XCA*(IDATA(1,N) - IDATA(1,N-1))
93      T(N) = T(N-1) + DTN
94      IF(T(N).GE.TAO)55.
95      HF(N) = HF(N-1)+DFN
96      V(N) = .5*ALAM*HF(N)/T(N)
97      GO TO 65
98      55 V(N) = V(N-1)+.5*ALAM*DFN/TAO
99      65 HT(N) = T(N)
100     HV(N) = V(N)
101     94 GO TO 13
102     92 DTN = XCA*(IDATA(1,N)-IDATA(1,N-3))
103     T(N) = T(N-3)+DTN
104     IF(T(N).GE.TAO)56.
105     HF(N) = HF(N-3)+DFN
106     V(N) = .5*ALAM*HF(N)/T(N)
107     GO TO 97
108     56 V(N) = V(N-3)+.5*ALAM*DFN/TAO
109     97 HT(N) = T(N)
110     HV(N) = V(N)
111     13 IF(IDATA(3,N).EQ.6)N=N+2
112     11 CONTINUE
113     DO 91 N=1,J
114     WRITE(3,101)HT(N),HV(N)
115     101 FORMAT(3HT= ,E13.5,2X,3HV= ,E13.5)
116     IF(N.EQ.1) ,23
117     CALL AMINMX(HV,1,J,1,YMIN,YMAX)
118     CALL AMINMX(HT,1,J,1,XMIN,XMAX)
119     CALL MAPG(XMIN,XMAX,YMIN,YMAX,.11320, 1., .11320, .95)
120     CALL SETCH(1.,21.,1.0,1.1,0)
121     WRITE(100,110)LAB1
122     CALL SETCH(7.,0.5,1.0,1.0,0)
123     WRITE(100,110)LAB2
124     110 FORMAT(20X,R10)
125     23 CALL SETCRT(HT,HV,1,1023)
126     CALL POINTC(1HX,HT(N),HV(N),1)
127     91 CONTINUE
128     CALL FRAME(1)
129     DO 96 N=1,J,4
130     PUNCH 104, ((HT(JJ),HV(JJ)),JJ=N,N+3)
131     WRITE(3,104)((HT(JJ),HV(JJ)),JJ=N,N+3)
132     96 CONTINUE
133     104 FORMAT(8F9.6)
134     DO 80 I=1,1000
135     80 HF(I)-T(I)-V(I)-HT(I)-HV(I)-0.0
136     GO TO STRT
137     FINN CALL EXIT
138     END
139 *      IDATA

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