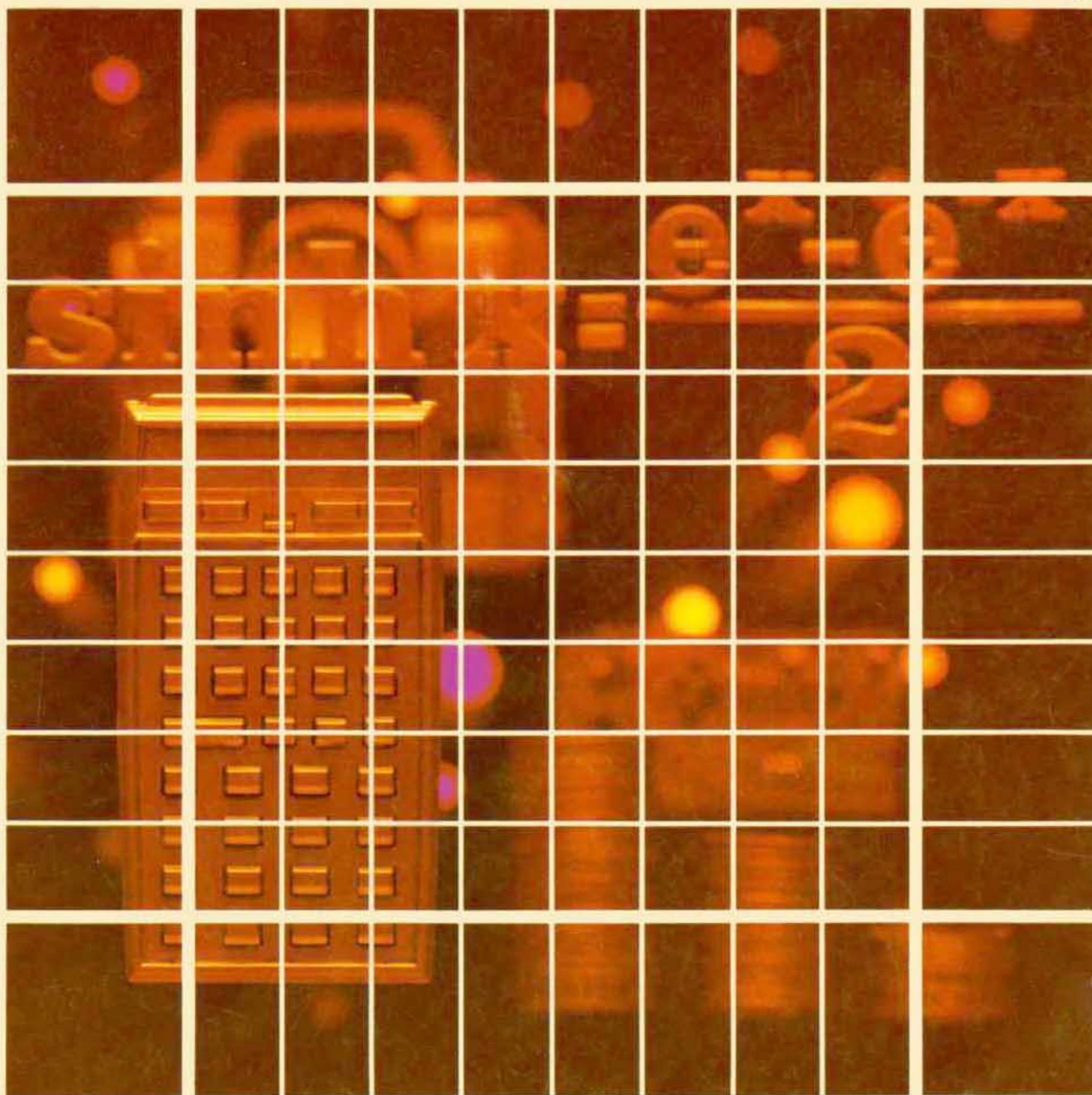


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\* Some books require additional memory modules to accomodate all programs.

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## INTRODUCTION

This HP-41C Solutions book was written to help you get the most from your calculator. The programs were chosen to provide useful calculations for many of the common problems encountered.

They will provide you with immediate capabilities in your everyday calculations and you will find them useful as guides to programming techniques for writing your own customized software. The comments on each program listing describe the approach used to reach the solution and help you follow the programmer's logic as you become an expert on your HP calculator.

## KEYING A PROGRAM INTO THE HP-41C

There are several things that you should keep in mind while you are keying in programs from the program listings provided in this book. The output from the HP 82143A printer provides a convenient way of listing and an easily understood method of keying in programs without showing every keystroke. This type of output is what appears in this handbook. Once you understand the procedure for keying programs in from the printed listings, you will find this method simple and fast. Here is the procedure:

1. At the end of each program listing is a listing of status information required to properly execute that program. Included is the SIZE allocation required. Before you begin keying in the program, press **XEQ ALPHA SIZE ALPHA** and specify the allocation (three digits; e.g., 10 should be specified as 010).  
Also included in the status information is the display format and status of flags important to the program. To ensure proper execution, check to see that the display status of the HP-41C is set as specified and check to see that all applicable flags are set or clear as specified.
2. Set the HP-41C to PRGM mode (press the **PRGM** key) and press **■ GTO • •** to prepare the calculator for the new program.
3. Begin keying in the program. Following is a list of hints that will help you when you key in your programs from the program listings in this handbook.
  - a. When you see " (quote marks) around a character or group of characters in the program listing, those characters are ALPHA. To key them in, simply press **ALPHA**, key in the characters, then press **ALPHA** again. So "SAMPLE" would be keyed in as **ALPHA "SAMPLE" ALPHA**.
  - b. The diamond in front of each LBL instruction is only a visual aid to help you locate labels in the program listings. When you key in a program, ignore the diamond.
  - c. The printer indication of divide sign is /. When you see / in the program listing, press **+**.
  - d. The printer indication of the multiply sign is \* . When you see \* in the program listing, press **×**.
  - e. The h character in the program listing is an indication of the **APPEND** function. When you see h, press **■ APPEND** in ALPHA mode (press **■** and the K key).
  - f. All operations requiring register addresses accept those addresses in these forms:  
nn (a two-digit number)  
IND nn (INDIRECT: **■**, followed by a two-digit number)  
X, Y, Z, T, or L (a STACK address: **■** followed by X, Y, Z, T, or L)  
IND X, Y, Z, T or L (INDIRECT stack: **■■** followed by X, Y, Z, T, or L)

Indirect addresses are specified by pressing **■** and then the indirect address. Stack addresses are specified by pressing **■** followed by X, Y, Z, T, or L. Indirect stack addresses are specified by pressing **■■** and X, Y, Z, T, or L.

Printer Listing	Keystrokes	Display
01 •LBL "SAM	<b>■ LBL ALPHA SAMPLE ALPHA</b>	01 LBL <sup>T</sup> SAMPLE
PLE"	<b>ALPHA THIS IS A ALPHA</b>	02 <sup>T</sup> THIS IS A
02 "THIS IS	<b>ALPHA ■ APPEND SAMPLE</b>	03 <sup>T</sup> h SAMPLE
A "	<b>■ AVIEW ALPHA</b>	04 AVIEW
03 "hSAMPLE	<b>6</b>	05 6
"	<b>ENTER</b>	06 ENTER /
04 AVIEW	<b>2 CHS</b>	07 -2
05 6	<b>+</b>	08 /
06 ENTER	<b>XEQ ALPHA ABS ALPHA</b>	09 ABS
07 -2	<b>STO ■ • L</b>	10 STO IND L
08 /	<b>ALPHA R3= ■ ARCL 03</b>	11 <sup>T</sup> R3=
09 ABS	<b>■ AVIEW</b>	12 ARCL 03
10 STO IND	<b>ALPHA</b>	13 AVIEW
L	<b>■ RTN</b>	14 RTN
11 "R3= "		
12 ARCL 03		
13 AVIEW		
14 RTN		

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Calculates indices of left ventricular contractility  
based on pressure rise during isovolumetric contractility.  
Also calculates stroke work and stroke work index.



## PULMONARY FUNCTIONS/VITAL CAPACITY

This program provides calculation of predicted and percent predicted values of the following functions:

VC = Vital capacity in liters.

FEV<sub>1</sub> = Forced expiratory volume after one second in liters.

MEFR = Maximum expiratory flow rate in liters/second.

MVV = Maximum ventilatory volume after 12 seconds in liters.

RV = Residual volume in liters.

TLC = Total lung capacity in liters.

FRC = Functional residual capacity in liters.

FEF = Forced expiratory flow from 25% to 75% (FEF<sub>25%-75%</sub>) in liters/sec.

### MALE

$$VC = (.058 \cdot Ht) - (.025 \cdot age) - 4.24$$

$$FEV_1 = (.036 \cdot Ht) - (.032 \cdot age) - 1.26$$

$$MEFR = (.043 \cdot Ht) - (.047 \cdot age) + 2.07$$

$$MVV = (.9 \cdot Ht) - (1.51 \cdot age) + 27$$

$$RV = (.03 \cdot Ht) + (.015 \cdot age) - 3.75$$

$$TLC = (.094 \cdot Ht) - (.015 \cdot age) - 9.17$$

$$FRC = (.051 \cdot Ht) - 5.05$$

$$FEF = (.02 \cdot Ht) - (.04 \cdot age) + 2$$

### FEMALE

$$VC = (.045 \cdot Ht) - (.024 \cdot age) - 2.852$$

$$FEV_1 = (.035 \cdot Ht) - (.025 \cdot age) - 1.932$$

$$MEFR = (.057 \cdot Ht) - (.036 \cdot age) - 2.532$$

$$MVV = (.762 \cdot Ht) - (.81 \cdot age) - 6.29$$

$$RV = (.024 \cdot Ht) + (.012 \cdot age) - 2.63$$

$$TCL^* = (.078 \cdot Ht) - (.01 \cdot age) - 7.36$$

$$FRC = (.047 \cdot Ht) - 4.86$$

$$FEF = (.02 \cdot Ht) - (.03 \cdot age) - (.00006 \cdot age^2) + 1.3$$

where Ht is in cm and age in years.

$$\text{Actual FEF} = (.5 \cdot VC) / \Delta t$$

$$\text{where } \Delta t = t_{75\%VC} - t_{25\%VC}$$

$$25\%VC = .25VC$$

$$75\%VC = .75VC$$

NOTE: This program requires one extra memory module in the HP-41C because of its length.

\*For females, if height is greater than 174 cm, 1 cm is added to the height before TLC is calculated.

References: This program is based on HP-67/97 Users' Library programs and on the HP-65 Medical Pac I.

Morris, J.F., Koski, A., & L.C. Johnson, *AM. REV. RESP. DIS.*, 57: 103 (1971).

Bates et.al., *RESP. FTN, IN DISEASE*, Saunders (1971).

Example:

For a male patient, height 72 in., age 28 the measured VC = 5.2 l. Calculate all predicted levels and % predicted for VC and FEF ( $t_{25\%} = .4$ ,  $t_{75\%} = 1.0$ ).

Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 008

[XEQ] [ALPHA] VITCAP [ALPHA]

M [R/S]

72 [CHS] [R/S]

28 [R/S]

5.2 [A]

[R/S]

[B]

[C]

[D]

[E]

[F]

[G]

[H]

[R/S]

[R/S]

.4 [R/S]

[R/S]

1 [R/S]

[R/S]

Display:

M/F?

HT=?

AGE=?

28.00

VC=5.67

%PRED=91.76

FEV1=4.43

MEFR=8.62

MVV=149.31

RV=2.16

TLC=7.60

FRC=4.28

FEF=4.54

25%VC=1.30

T25%=?

75%VC=3.90

T75%=?

ACT FEF=4.33

%PRED=95.50

# User Instructions

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Begin program execution.		[XEQ] VITCAP	M/F?
3	Input M for male, F for female.	M or F	[R/S]	HT=?
4	Input patient height (cm or — inches).	cm or -in	[R/S]	AGE=?
5	Input patient age.	yrs	[R/S]	
6	Input measured value (optional) and calculate:			
	Predicted VC	(VC <sub>meas</sub> )	[XEQ] VC	
			or [A]	VC=
	Predicted FEV <sub>1</sub>	(FEV <sub>meas</sub> )	[XEQ] FEV1	
			or [B]	FEV1=
	Predicted MEFR	(MEFR <sub>meas</sub> )	[XEQ] MEFR	
			or [C]	MEFR=
	Predicted MVV	(MVV <sub>meas</sub> )	[XEQ] MVV	
			or [D]	MVV=
	Predicted RV	(RV <sub>meas</sub> )	[XEQ] RV	
			or [E]	RV=
	Predicted TLC	(TLC <sub>meas</sub> )	[XEQ] TLC	
			or [F]	TLV=
	Predicted FRC	(FRC <sub>meas</sub> )	[XEQ] FRC	
			or [G]	FRC=
7	(Optional) If measured value was input obtain % predicted value.		[R/S]*	%PRED=
8	Input measured VC (not necessary if input above) and calculate predicted FEF.	(VC <sub>meas</sub> )	[XEQ] FEF	
			or [H]	FEF=
	*This [R/S] not needed if calculator is used with printer.			

# User Instructions

# Program Listings

01♦LBL "VIT CAP"		50 2.852 51 STO 07 52 GTO 01 53♦LBL B 54♦LBL "FEV	Go to calculation routine
02 SF 00	Initialize	1"	-----
03 CF 01		55 "FEV1"	Calculate FEV1
04 CF 02		56 FS? 00	
05 SF 21		57 GTO 00	
06 SF 27		58 .036	
07 FIX 2		59 STO 05	
08 "M"	-----	60 .032	
09 ASTO Y		61 STO 06	
10 "F/F?"	Male or female?	62 1.26	
11 RDN		63 STO 07	
12 PROMPT		64 GTO 01	
13 ROFF		65♦LBL 00	
14 ASTO X	M or F Male	66 .035	
15 CLA		67 STO 05	
16 X=Y?	-----	68 .025	
17 CF 00		69 STO 06	
18 "HT=?"	Input HT	70 1.932	
19 PROMPT	CM or inches	71 STO 07	
20 X>0?		72 GTO 01	
21 GTO 00		73♦LBL C	
22 2.54	Convert to CM	74♦LBL "MEF	
23 *		R"	
24 CHS		75 "MEFR"	
25♦LBL 00	-----	76 FS? 00	
26 STO 00	Input age	77 GTO 00	
27 "AGE=?"		78 .043	
28 PROMPT	-----	79 STO 05	
29 STO 01		80 .047	
30 STOP	Calculate vital capacity	81 STO 06	
31♦LBL A		82 -2.07	
32♦LBL "VC"	VC Input	83 STO 07	
33 "VC"		84 GTO 01	
34 FS? 22		85♦LBL 00	
35 STO 02	Female?	86 .057	
36 FS? 00	Yes	87 STO 05	
37 GTO 00	Male constants	88 .036	
38 .058		89 STO 06	
39 STO 05		90 2.532	
40 .025		91 STO 07	
41 STO 06		92♦LBL 01	
42 4.24		93 CF 03	Calculation subroutine
43 STO 07	Female constants	94 R↑	
44 GTO 01		95 RCL 00	
45♦LBL 00		96 FS?C 01	
46 .045		97 XEQ 08	
47 STO 05			
48 .024			
49 STO 06			

# Program Listings

98 RCL 05		148 "RV"
99 *		149 FS? 00
100 RCL 01		150 GTO 00
101 RCL 06		151 .03
102 *		152 STO 05
103 -		153 -.015
104 RCL 07		154 STO 06
105 -	FEF Calc.?	155 3.75
106 FS? 02	Yes	156 STO 07
107 XEQ 09	Was measured	157 GTO 01
108 FC?C 22	value input?	158♦LBL 00
109 SF 03		159 .024
110 XEQ 10		160 STO 05
111 FS?C 02	FEF Calc.?	161 -.012
112 RTN	Yes, stop	162 STO 06
113 FS? 03	No measured value	163 2.63
114 STOP	input. Stop	164 STO 07
115♦LBL 07	Calc. % of	165 GTO 01
116 /	predicted value	166♦LBL F
117 1 E2		167♦LBL "TLC
118 *		"
119 "% PRED"		168 "TLC"
120♦LBL 10	Output subroutine	169 FS? 00
121 "T="		170 GTO 00
122 ARCL X		171 .094
123 AVIEW		172 STO 05
124 RTN		173 .015
125♦LBL D	Calculate MVV	174 STO 06
126♦LBL "MVV		175 9.17
"		176 STO 07
127 "MVV"		177 GTO 01
128 FS? 00		178♦LBL 00
129 GTO 00		179 174
130 .9		180 RCL 00
131 STO 05		181 X>Y?
132 1.51		182 SF 01
133 STO 06		183 .078
134 27		184 STO 05
135 CHS		185 .01
136 STO 07		186 STO 06
137 GTO 01		187 7.36
138♦LBL 00		188 STO 07
139 .762		189 GTO 01
140 STO 05		190♦LBL G
141 .81		191♦LBL "FRC
142 STO 06		"
143 6.29		192 "FRC"
144 STO 07		193 CLX
145 GTO 01		194 STO 06
146♦LBL E	Calculate RV	195 FS? 00
147♦LBL "RV"		

# Program Listings

196 GTO 00		246 RCL 02	
197 .051		247 2	
198 STO 05		248 /	
199 5.05		249 X<>Y	
200 STO 07		250 /	
201 GTO 01		251 "ACT FEF	Output actual FEF
202♦LBL 00		"	
203 .047		252 XEQ 10	
204 STO 05		253 RCL 04	Calc. % predicted
205 4.86		254 GTO 07	FEF Calc.
206 STO 07		255♦LBL 09	Male?
207 GTO 01	-----	256 FC? 00	Yes, RTN.
208♦LBL H	Calculate FEF	257 RTN	Female, alternate
209♦LBL "FEF		258 6 E-5	calculation.
"		259 RCL 01	
210 "FEF"		260 X↑2	
211 SF 02		261 *	
212 .02		262 -	
213 STO 05		263 RTN	
214 FS? 00		264♦LBL 08	TLC, female
215 GTO 00		265 1	>174 cm.
216 .04		266 +	
217 STO 06		267 END	
218 -2			
219 STO 07			
220 GTO 02			
221♦LBL 00			
222 .03			
223 STO 06			
224 -1.3			
225 STO 07		80	
226♦LBL 02			
227 XEQ 01			
228 STO 04			
229 RCL 02			
230 4			
231 /	Output 25% VC		
232 "25% VC"			
233 XEQ 10			
234 "T25%=?"	Input time at		
235 PROMPT	25% VC		
236 STO 03		90	
237 X<>Y			
238 3			
239 *			
240 "75% VC"	Output 75% VC		
241 XEQ 10			
242 "T75%=?"	Input time at		
243 PROMPT	75% VC		
244 RCL 03			
245 -		00	

# 8 REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS				STATUS			
00	Height (cm)	50		SIZE	008	TOT. REG.	96
	Age (yrs)			ENG		SCI	USER MODE
	VCmeas			DEG	FIX 2	ON	OFF
	t 25%				RAD	GRAD	
	FEFPRED			FLAGS			
05	Coeff. A	55		#	INIT	SET INDICATES	
	Coeff. B				S/C	CLEAR INDICATES	
	Coeff. C			00	S	Female	Male
				01	C	Female 174 cm	Other
				02	C	FEF Calc.	Other
10		60		03	C	Meas. value input	No meas. value
				21	S	Display & Printer control	
				22	C	Data entry	No data entry
				27	S	User mode	
15		65					
20		70					
25		75					
30		80					
35		85		ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
40		90					
45		95					

## LUNG DIFFUSION AND ARTERIAL CO<sub>2</sub> NORMALIZATION

Lung Diffusion: This portion of the program evaluates the equation to calculate the lung diffusion capacity (DLCO) using the single breath method.

Equation used:

$$DLCO = \frac{V_A(0.084)}{BHT} \ln \frac{F_A CAR}{F_I CAR} \frac{0.3}{F_A CO}$$

Note: The initial concentration of carbon monoxide (F<sub>I</sub>CO) is assumed to be 0.3%. If a different standard value for F<sub>I</sub>CO is desired, it may be entered.

Reference: Comroe, et.al., *The Lung*, Year Book Medical Publishers Inc., 1962.

Arterial CO<sub>2</sub> Normalization: This portion of the program calculates the additional dead space (DS<sub>add</sub>) needed in a hypocapnic ventilator patient's breathing circuit to raise the arterial CO<sub>2</sub> partial pressure (P<sub>a</sub>CO<sub>2</sub>) to 40 millimeters of mercury (mmHg).

Equations used:

$$DS_{add} = \frac{TV - DS}{40 - \Delta P_{CO_2}} (40 - P_a CO_2)$$

$$\Delta P_{CO_2} = P_a CO_2 - P_E CO_2 \text{ (or } P_a CO_2 - 5 \text{ if } P_E CO_2 \text{ is not entered)}$$

$$TV - DS = TV - [1.47Wt(kg) + DS_p]$$

where DS<sub>p</sub> = dead space.

Detailed Instructions for Arterial CO<sub>2</sub> Normalization calculation:

Input the patient's weight in kilograms, or in pounds followed by [CHS]. Then input the P<sub>a</sub>CO<sub>2</sub> in mmHg. If the patient's lung status is abnormal answer the question LUNG NORMAL? by inputting N and then inputting P<sub>E</sub>CO<sub>2</sub> (the mixed expired CO<sub>2</sub> partial pressure). If lung condition is normal answer Y (P<sub>E</sub>CO<sub>2</sub> is not required). Then input the present tidal volume and ventilator dead space. The additional rebreathing dead space is calculated. This must be added to the patient's circuit to achieve P<sub>a</sub>CO<sub>2</sub> normalization.

Warning: The additional dead space required by this program must be inserted into the patient's breathing circuit *without* changing the ventilator rate or tidal volume.

Measure and input the mixed expired CO<sub>2</sub> partial pressure if lung function is abnormal.

References: Suwa, Kunio; Geffin, Bennie; Pontoppidan, Henning; Bendixen, Henry; "A Nomogram for Dead Space Requirement During Prolonged Artificial Ventilation", Anesthesiology, v. 29, 1968 Nov.-Dec.

### Lung Diffusion

#### Example 1:

Calculate the lung diffusing capacity using an initial helium carrier gas concentration of 10%, an alveolar helium concentration of 8%, an alveolar carbon monoxide concentration of 0.159%, an initial carbon monoxide concentration of 0.3%, a breath holding time of 10 seconds, and an alveolar volume of 4930 milliliters.

#### Example 2:

For the same data, calculate lung diffusing capacity assuming an initial carbon monoxide concentration of 0.45%.

#### Keystrokes: Example 1

[XEQ] [ALPHA] SIZE [ALPHA] 012  
 [XEQ] [ALPHA] DLCO [ALPHA]  
 [R/S]  
 10 [R/S]  
 8 [R/S]  
 .159 [R/S]  
 10 [R/S]  
 4930 [R/S]

#### Display:

FICO=.3?  
 FICAR=?  
 FACAR=?  
 FACO=?  
 BHT=?  
 VA=?  
 DLCO=17.05

#### Keystrokes: Example 2

[A]  
 .45 [R/S]  
 10 [R/S]  
 8 [R/S]  
 .159 [R/S]  
 10 [R/S]  
 4930 [R/S]

#### Display:

FICO=.3?  
 FICAR=?  
 FACAR=?  
 FACO=?  
 BHT=?  
 VA=?  
 DLCO=33.84

Arterial CO<sub>2</sub> Normalization

## Example:

Calculate the additional dead space required by a 50 kilogram patient with a PaCO<sub>2</sub> of 25 mmHg with normal lung status having a tidal volume of 900 ml and a present dead space of 25 ml.

## Keystrokes:

[XEQ] [ALPHA] NORM [ALPHA]  
50 [R/S]  
25 [R/S]  
Y [R/S]  
900 [R/S]  
25 [R/S]

## Display:

WT=?  
PaCO2=?  
LUNG NORMAL?  
TV=?  
DSP=?  
DSadd=343.50

# User Instructions

SIZE: 012

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program. Go to step 2 for lung diffusion (DLCO). Go to step 6 for Arterial CO <sub>2</sub> normalization.			
	LUNG DIFFUSION:			
2	Begin the lung diffusion calculation.		[XEQ] DLCO	FICO=.3?
3	If initial concentration of carbon monoxide is other than 0.3% input correct value.	F <sub>1</sub> CO	[R/S]	FICAR=?
	Otherwise, press [R/S] without data entry.		[R/S]	FICAR=?
4	Input initial concentration of carrier and alveolar carrier concentration.	F <sub>1</sub> CAR	[R/S]	FACAR=?
		FACAR	[R/S]	FACO=?
5	Input the arterial concentration of carbon monoxide, the breath holding time (in seconds) and the alveolar volume. The lung diffusion capacity (DLCO) is calculated.	FACO	[R/S]	BHT=?
		BHT	[R/S]	VA=?
		VA	[R/S]	DLCO=?
	ARTERIAL CO <sub>2</sub> NORMALIZATION:			
6	Begin the normalization calculation.		[XEQ] NORM	WT=?
7	Input the patient weight			
	-in Kg or,	Kg	[R/S]	
	-in pounds.	lb.	[CHS] [R/S]	PaCO <sub>2</sub> ?=?
8	Input the arterial CO <sub>2</sub> partial pressure.	PaCO <sub>2</sub>	[R/S]	LUNG NORM
9a	If lung is normal answer "Y" and go to step 10.	Y	[R/S]	TV=?
9b	If lung is abnormal answer "N" and then input PeCO <sub>2</sub> (mixed expired CO <sub>2</sub> partial pressure).	N	[R/S]	PeCO <sub>2</sub> ?=?
		PeCO <sub>2</sub>	[R/S]	TV=?
10	Input the tidal volume and present dead space. The additional dead space	TV(ml)	[R/S]	DSP=?
		DSp(ml)	[R/S]	DSadd=?

# User Instructions

# Program Listings

01♦LBL "DLC	DLCO Calc	45 PROMPT	X + or -
0"		46 X>0?	+
02♦LBL A	Initialization	47 GTO 00	-
03 FIX 2		48 CHS	Convert to kg
04 SF 21		49 2.205	
05 SF 27		50 /	
06 .3		51♦LBL 00	
07 "FICO=.3	Is F <sub>I</sub> CO=.3%?	52 STO 06	
?"		53 "PaCO <sub>2</sub> =?"	Sto wt in kg
08 PROMPT	Input other F <sub>I</sub> CO	54 PROMPT	Input PaCO <sub>2</sub>
09 STO 00		55 STO 01	
10 "FICAR=?	Input FI CAR	56 5	Calc. normal
"		57 -	PeCO <sub>2</sub> & store
11 PROMPT		58 STO 08	
12 STO 01		59 "Y"	
13 "FACAR=?	FA CAR	60 ASTO Y	LUNG NORMAL?
"		61 "LUNG NO	
14 PROMPT		62 AON	
15 STO 02		63 PROMPT	
16 "FACO=?"	FA CO	64 AOFF	
17 PROMPT		65 ASTO X	
18 STO 03		66 X=Y?	Yes or no
19 "BHT=?"	Breath hold-time	67 GTO 01	Yes, normal
20 PROMPT		68 "PeCO <sub>2</sub> =?"	No, input PeCO <sub>2</sub>
21 STO 08		69 PROMPT	
22 "VA=?"		70 STO 08	Input tidal vol
23 PROMPT	Alveolar volume	71♦LBL 01	
24 .884		72 "TV=?"	
25 *		73 PROMPT	
26 X<>Y	Calculate DLCO	74 STO 07	
27 /		75 "DSP=?"	Present dead
28 RCL 02		76 PROMPT	space
29 RCL 01		77 RCL 06	
30 /		78 1.47	Calculate
31 RCL 00		79 *	
32 RCL 03		80 +	additional
33 /		81 RCL 07	
34 *		82 X<>Y	dead space
35 LN		83 -	
36 *		84 40	
37 "DLCO"	Display DLCO	85 RCL 01	
38 GTO 10	CO <sub>2</sub> normalization	86 RCL 08	
39♦LBL "NOR		87 -	
M"		88 -	
40♦LBL B		89 /	
41 FIX 2	Initialization	90 40	
42 SF 21		91 RCL 01	
43 SF 27			
44 "WT=?"	Input weight		

# Program Listings

92 -	Display DS add Display routine	51	
93 *			
94 "DSadd"			
95♦LBL 10			
96 "T="			
97 ARCL X			
98 AVIEW			
99 END			
10		60	
20		70	
30		80	
40		90	
50		00	

# REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
00	.3 or F CO	50	SIZE 012 ENG _____ DEG _____	TOT. REG. 44 FIX 2 SCI _____ RAD _____ GRAD _____	USER MODE ON _____ OFF _____	
	F CAR/PaCO <sub>2</sub>				ON _____ OFF _____	
	F CAR				ON _____ OFF _____	
	F CO				ON _____ OFF _____	
05		55	FLAGS			
	WT (Kg)		#	INIT S/C	SET INDICATES	CLEAR INDICATES
	TV		21	S	Print & Display	Pause only
	BHT/PeCO <sub>2</sub>		27	S	User Mode	Reg. Mode
10		60				
15		65				
20		70				
25		75				
30		80				
35		85				
ASSIGNMENTS						
40		90	FUNCTION		FUNCTION	KEY
45		95				

## VENTILATOR SETUP AND CORRECTIONS

This program calculates the initial tidal volume for a ventilator patient. The first part calculates an approximation to the Radford nomogram tidal volume with correction for ventilator dead space only. The second part corrects the tidal volume for altitude, patient's temperature, daily activity, use of a tracheotomy tube, and metabolic acidosis in anesthesia.

Equations Used:

$$V_A = \text{Alveolar minute volume} = 10^{(C_1 \log \text{WT} + C_2)/100} \text{ ml/min}$$

$$TV_A = \text{Alveolar tidal volume} = \frac{V_A}{r} \text{ ml}$$

$$TV_{\text{bas}} = \text{Basal tidal volume} = (V_{T_A} + \text{WT (lbs)}) \text{ ml}$$

$$TV_{\text{corr}} = \text{Basal tidal volume} + \text{ventilator dead space}$$

where:

$r$  = Breathing rate (breaths per minute)

### For Females:

$$C_1 = \begin{cases} 124; & \text{WT} \leq 8\text{kg} \\ 61; & 8\text{kg} < \text{WT} \leq 23\text{kg} \\ 44.2; & \text{WT} > 23\text{kg} \end{cases}$$

$$C_2 = \begin{cases} 193; & \text{WT} \leq 8\text{kg} \\ 249; & 8\text{kg} < \text{WT} \leq 23\text{kg} \\ 272; & \text{WT} > 23\text{kg} \end{cases}$$

### Corrections:

$$\text{Temperature: } +5\% \text{ per } {}^{\circ}\text{F above } 99^{\circ} \text{ (rectal)}$$

$$\text{Altitude: } +5\% \text{ per } 2000' \text{ above sea level}$$

$$\text{Activity: } +10\%$$

$$\text{Tracheotomy: } -\frac{1}{2} \text{ body weight in pounds}$$

$$\text{Metabolic acidosis in anesthesia: } +20\%$$

### For Males:

$$C_1 = \begin{cases} 124; & \text{WT} \leq 8\text{kg} \\ 61; & \text{WT} > 8\text{kg} \end{cases}$$

$$C_2 = \begin{cases} 193; & \text{WT} \leq 8\text{kg} \\ 249; & \text{WT} > 8\text{kg} \end{cases}$$

Reference: Radford, Edward P., "Ventilation Standards for Use in Artificial Respiration", Journal of Applied Physiology, 7:451, 1955.

## Warning:

- This program yields an approximation to the Radford nomogram. The nomogram may not be applied with confidence to patients with muscular activity or abnormal lung function.
- Apply only the corrections which pertain to the patient for whom the program is being run.

## Example:

- 1) Calculate the predicted tidal volume for a 170 pound comatose male having a breath rate of 15 breaths per minute, ventilator dead space of 25 milliliters, fever of 101°F, who is located 500 feet above sea level.
- 2) What would be the corrected tidal volume if this patient were in metabolic acidosis?

## Keystrokes:

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 009	
[XEQ] [ALPHA] VENT [ALPHA]	WT=?
170 [CHS] [R/S]	M/F?
M [R/S]	BR=?
15 [R/S]	BASAL TV=461.74
[R/S]	DSV=?
25 [R/S]	DSV CORR TV=486.74
[R/S]	BT=?
101 [CHS] [R/S]	TEMP CORR TV=535.42
[R/S]	ALT=?
500 [CHS] [R/S]	ALT CORR TV=542.11
[XEQ] [ALPHA] METACID [ALPHA]	ACIDOSIS CORR
	TV=650.53

# User Instructions

SIZE: 009

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program and begin Ventilator Setup and Correction calculations.		[XEQ] VENT	WT = ?
2	Input the patient weight in Kg or, in pounds.	Kg lb	[R/S] [CHS] [R/S]	
3	If patient is a male input M or, if a female, F.	M or F	[R/S]	BR=?
4	Input the breathing rate and calculate basal tidal volume.	BR/min	[R/S]	BASAL TV=
5	To correct for ventilator dead space: Input ventilator dead space and calculate dead space corrected tidal volume.	DS <sub>V,ml</sub>	[R/S]*	DSV=?
6	To correct for temperature: Input patient temperature in °C (or °F [CHS]).	°C °F	[R/S]	TEMP CORR TV=
7	To correct for altitude: Input the altitude in meters (or, in feet).	m ft	[R/S] [CHS] [R/S]	ALT=? ALT CORR TV=
8	The following steps are optional: To correct for minor daytime activity (noncomatose patient).		[XEQ] ACTIVE or [B]	
9	To correct for use of a tracheotomy tube		[XEQ] TRACH or [C]	ACTIVITY CORR TV=
10	To correct for metabolic acidosis during anesthesia		[XEQ] METACID or [D]	TRACH CORR TV=
11	For a new case, press [A] and go to step 2.		[A]	ACIDOSIS CORR TV=
				WT = ?
	*This [R/S] not needed if calculator is used with printer.			

# Program Listings

01♦LBL "VEN T"	Ventilator corr.	50 44.2 51♦LBL 04 52 RCL 06 53 LOG 54 * 55 + 56 E2 57 / 58 10↑X 59 RCL 08 60 / 61 RCL 06 62 2.205 63 * 64 + 65 STO 01 66 "BASAL" 67 XEQ 10 68 "DSV=?" 69 PROMPT 70 ST+ 01 71 RCL 01 72 "DSV" 73 XEQ 07 74 "BT=?" 75 PROMPT 76 X<0? 77 GTO 01 78 1.8 79 * 80 32 81 + 82 CHS 83♦LBL 01 84 CHS 85 99 86 - 87 X<=0? 88 GTO 02 89 .05 90 * 91 RCL 01 92 * 93 ST+ 01 94♦LBL 02 95 RCL 01 96 "TEMP" 97 XEQ 07 98 "ALT=?" 99 PROMPT	Common male/female calc.
02 FIX 2	Initialize		
03 SF 21			
04 SF 27			
05♦LBL A	Input wt.		
06 "WT=?"			
07 PROMPT			
08 X>0?			
09 GTO 00			
10 -2.205	Convert to kg		
11 /			
12♦LBL 00	STO wt		
13 STO 06			
14 "M"	Male or female?	Output basal	
15 ASTO Y			
16 "M/F?"			
17 CF 01			
18 AON			
19 PROMPT			
20 AOFF			
21 ASTO X	X="M"?		
22 X=Y?	Yes, male		
23 SF 01			
24 "BR=?"	Input breathing rate		
25 PROMPT			
26 STO 08	Female?		
27 FC?C 01	Yes, GTO female calc.	Convert to °F	
28 GTO 01			
29♦LBL 05	Male calc.		
30 8			
31 RCL 06			
32 X<=Y?			
33 GTO 03			
34 249	Input constants	BT-99°	
35 ENTER↑			
36 61			
37 GTO 04			
38♦LBL 03			
39 193			
40 ENTER↑			
41 124			
42 GTO 04			
43♦LBL 01	Female constants		
44 23			
45 RCL 06			
46 X<=Y?			
47 GTO 05			
48 272			
49 ENTER↑			

# Program Listings

100 X<0?		145♦LBL 10	Output routing
101 GTO 02		146 "� TV="	
102 -3.28	Convert to feet	147 ARCL X	
103 *		148 AVIEW	
104♦LBL 02	Altitude corr.	149 END	
105 CHS			
106 2 E3			
107 /			
108 RCL 01		60	
109 *			
110 .05			
111 *			
112 ST+ 01			
113 RCL 01			
114 "ALT"			
115 GTO 07	Output ALT corr.		
116♦LBL "ACT			
IVE"			
117♦LBL B			
118 RCL 01		70	
119 .1			
120 *			
121 ST+ 01			
122 RCL 01			
123 "ACTIVIT			
Y"			
124 GTO 07			
125♦LBL "TRA	Tracheotomy corr.		
CH"			
126♦LBL C		80	
127 RCL 01			
128 RCL 06			
129 1.1023			
130 *			
131 -			
132 STO 01			
133 "TRACH"			
134 GTO 07			
135♦LBL "MET	Metabolic acidosis corr.	90	
ACID"			
136♦LBL D			
137 RCL 01			
138 .2			
139 *			
140 ST+ 01			
141 RCL 01			
142 "ACIDOSI			
S"			
143♦LBL 07			
144 "� CORR"	Output corr. TV	00	

22  
**REGISTERS, STATUS, FLAGS, ASSIGNMENTS**

DATA REGISTERS				STATUS			
00		50		SIZE 009	TOT. REG. 58	USER MODE	
	TV			ENG	FIX 2	SCI	ON OFF
				DEG	RAD	GRAD	
05		55		FLAGS			
	WT (kg)			#	INIT S/C	SET INDICATES	CLEAR INDICATES
	BR			01	C	Male	Female
				21	S	Print & Display	Pause only
	10	60		27	S	User mode	Reg. mode
15		65					
20		70					
25		75					
30		80					
35		85					
40		90		ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
45		95					

BLOOD CHEMISTRY I  
BLOOD ACID - BASE STATUS  
VIRTUAL PO<sub>2</sub> AND O<sub>2</sub> SATURATION AND CONTENT

These two programs perform various related blood chemistry and blood gas calculations.

Blood-Acid Base Status

This program computes total plasma CO<sub>2</sub> and base excess from PCO<sub>2</sub>, pH and hemoglobin concentration.

Equations:

Total plasma CO<sub>2</sub> is calculated from the Henderson-Hasselbalch equation:

$$TCO_2 = s \cdot PCO_2 [1 + 10^{pH-pK}]$$

where

TCO<sub>2</sub> = total CO<sub>2</sub> in plasma, mmol/l

s = solubility of CO<sub>2</sub> in plasma, mmol/l (taken to be 0.0307)

PCO<sub>2</sub> = partial pressure of CO<sub>2</sub> in the blood, mmHg

pK = 6.11

This does not take into account the small temperature dependence of both s and pK, nor the pH dependence of pK. For this reason the formula for TCO<sub>2</sub> will be most accurate if 37° C values for PCO<sub>2</sub> and pH are used.

The base excess is calculated from an equation suggested by Siggaard-Andersen:

$$[BE]_b = (1 - 0.0143Hgb) \cdot ([HCO_3] - (9.5 + 1.63Hgb)(7.4 - pH) - 24)$$

where

[BE]<sub>b</sub> = Base Excess in meq/l of blood

Hgb = Hemoglobin concentration in g/100 ml

and plasma [HCO<sub>3</sub>] is calculated from the Henderson-Hasselbalch equation in the form:

$$[HCO_3] = s \cdot PCO_2 \cdot 10^{pH-pK}$$

Siggaard-Andersen used 38°C values for PCO<sub>2</sub> and pH. Only small errors will result from using 37°C values, but body temperature corrected values should not be used if the patient has any significant hyper or hypothermia. In only body temperature values are known, the "Anaerobic PCO<sub>2</sub> and pH change" program may be used to correct them back to 37°C. (See special instructions for that program).

NOTE: While Thomas has shown that this equation may produce large errors for very abnormal conditions, it matches the Siggaard-Andersen nomogram for [BE]<sub>b</sub>, to within  $\pm 1$  meq/l in most cases.

#### VIRTUAL PO<sub>2</sub> AND O<sub>2</sub> SATURATION CONTENT:

The first part of this program computes virtual PO<sub>2</sub> for use in estimating O<sub>2</sub> saturation. Generally, it will be more convenient to calculate venous values first, as arterial values are frequently needed in other programs and, thus, will be left in the storage registers after both calculations.

The equation solved is:

$$VPO_2 = PO_2 \cdot 10^{[0.024(37-BT) + 0.48pH-7.4) + 0.06(\log PCO_2)]}$$

which is a hybrid of the equation used by Thomas and that used by Kelman. There is some disagreement regarding the best value of the pH multiplier, 0.48 being used by most workers, but see, for example, Kelman.

The second part of the program estimates O<sub>2</sub> saturation of blood from virtual PO<sub>2</sub> and computes O<sub>2</sub> content. If the actual O<sub>2</sub> saturation is known, O<sub>2</sub> content may be computed directly.

#### EQUATIONS:

The part of the program for estimating O<sub>2</sub> saturation is based on the polynomial curve fit of Thomas, where VPO<sub>2</sub> is in mmHg.

$$O_2 \text{ Sat} = \frac{(VPO_2)^4 - 15(VPO_2)^3 + 2045(VPO_2)^2 + 2000(VPO_2)}{(VPO_2)^4 - 15(VPO_2)^3 + 2400(VPO_2)^2 + 31,100(VPO_2) + 2,400,000}$$

This calculation assumes that the oxygen dissociation curve for the hemoglobin is normal. The O<sub>2</sub> content is computed from:

$$C_x O_2 (\text{Vol.}\%) = 1.34 \cdot \frac{\text{SAT}(\%)}{100} \cdot \text{Hgb(g/100ml)} + 0.0031 PO_2 (\text{mmHg})$$

NOTE: Virtual  $PO_2$  is not in any way a real physiologic  $PO_2$ . Its only function is for use in estimating  $O_2$  saturation, and it should never be confused with  $PO_2$  corrected to body temperature. Furthermore, it must always be calculated from blood parameters measured at or corrected to 37°C. The calculation will give inaccurate results for fetal hemoglobin, present in babies less than six months old, and for some abnormal adult hemoglobins and certain other blood conditions. The results of the estimation and any subsequent calculations based on it should be viewed with caution unless the dissociation curve has been previously established to be normal. If both  $PO_2$  and  $O_2$  saturation are measured, the program may be used as a convenient means to check for the normality of the dissociation curve.

References: Siggaard-Andersen, "Titratable Acid or Base of Body Fluids", Annals New York Academy of Sciences, 133: 41-48, 1966.

Thomas, L.J. Jr., "Algorithm for Selected Blood Acid-Base and Blood Gas Calculations", J. Appl. Physiol., 33: 154-158, 1972.

Kelman, G. Richard, "Digital Computer Subroutine for the Conversion of Oxygen Tension into Saturation", J. Appl. Physiol., 21: 1375-1376, 1966.

## Example 1:

From the following patient data calculate total plasma  $\text{CO}_2$ , base excess, and plasma  $[\text{HCO}_3]$ . Also calculate virtual  $\text{PO}_2$  and estimated  $\text{O}_2$  saturation and content. Store the value as venous  $\text{O}_2$  content.

$\text{PO}_2 = 75 \text{ mmHg}$   
 $\text{PCO}_2 = 45 \text{ mmHg}$   
 $\text{pH} = 7.35$

$\text{BT} = 40^\circ\text{C}$   
 $\text{Hgb} = 16 \text{ g/100ml}$

## Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 012  
[XEQ] [ALPHA] ACID [ALPHA]  
45 [R/S]  
7.35 [R/S]  
16 [R/S]  
[R/S]  
[R/S]  
[XEQ] [ALPHA] PO2 [ALPHA]  
75 [R/S]  
[R/S]  
[R/S]  
40 [R/S]  
[R/S]  
[D]  
[R/S]  
[R/S]  
[//] [E]

## Display:

PCO2=0.00?  
PH=0.00?  
HGB=0.00?  
TCO2=25.39  
BE=-1.36  
HCO3=-24.01  
PO2=0.00?  
PCO2=45.00?  
PH=7.35?  
BT=0.00?  
VP02=59.70  
%SAT=90.92  
%SAT=90.92  
HGB=16.00?  
O2 CONT=19.68  
19.68 (stored as venous)

## Example 2:

Assuming that  $\text{VP02}$  is actually 75 mmHg, calculate the estimated  $\text{O}_2$  saturation and  $\text{O}_2$  content.

## Keystrokes:

75 [C]  
[D]  
[R/S]  
[R/S]

## Display:

% SAT=95.08  
% SAT=95.08  
HGB=16.00?  
O2 CONT=20.62

# User Instructions

SIZE: 012

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program. For Blood-Acid Base Status calculation, go to step 2. For Virtual PO <sub>2</sub> and O <sub>2</sub> Saturation and Content calculation, go to step 4.			
	BLOOD ACID-BASE STATUS:			
2	Begin the program.		[XEQ] ACID	PCO2=( )?
	Values for the following variables are recalled. If correct, press [R/S] without data entry. Otherwise, input the correct value and press [R/S].			
	PCO2	(mmHg)	[R/S]	PH=( )?
	pH	pH	[R/S]	HGB=( )?
	Hemoglobin	Hgb (g/100ml)	[R/S]	TCO2=
	When these entries are completed TCO2 (in mmol/l) is calculated.			
3	Calculate base excess and, if desired, bicarbonate concentration.		[R/S]*	BE=(meg/l)
	VIRTUAL PO <sub>2</sub> and O <sub>2</sub> SATURATION AND CONTENT:		[R/S]	HCO3-=mmol/l
4	Begin the program.		[XEQ] PO2	PO2=( )?
	Values for the following variables are recalled. If correct, press [R/S] without prior data entry. Otherwise, input the correct value and press [R/S].			
	PCO2	(mmHg)	[R/S]	PH=( )?
	pH	pH	[R/S]	BT=( )?
	Body Temperature	BT(°C)	[R/S]	VPO2=

\*This [R/S] not necessary if calculator is used with printer.

# User Instructions

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
	When these entries are completed VP02 (in mmHg) is calculated.			
5	Calculate estimated % saturation.		[R/S]*	%SAT=
6	To calculate oxygen content in volume %.		[D]	%SAT=( )?
6a	Input correct % saturation, or press [R/S]  if displayed figure is correct. Previously stored hemoglobin is displayed.	%SAT	[R/S]	HGB=( )?
6b	Input correct hemoglobin, or press [R/S]  if displayed hemoglobin is correct. Oxygen content is calculated.	Hgb (gm/100ml)	[R/S]	O2 CONT=(%)
7	Store oxygen content:  As arterial (CaO <sub>2</sub> ) or,  As venous (CvO <sub>2</sub> )		[E]  [//]	(O <sub>2</sub> cont.)  (O <sub>2</sub> cont.)
8	To calculate a different Blood Acid-base status, press [A] and go to step 2.		[A]	PCO <sub>2</sub> =( )?
9	To calculate another virtual PO <sub>2</sub> press, [B] and go to step 4.		[B]	PO <sub>2</sub> =( )?
10	To calculate another % saturation input correct virtual PO <sub>2</sub>	VPO <sub>2</sub> (mmHg)	[C]	%SAT=
11.	To calculate another Oxygen content go to step 6.			
	*This [R/S] not necessary if calculator is used with printer.			

# Program Listings

01♦LBL "ACI D"		
02 FIX 2	Initialize	
03 SF 21	Blood-Acid base	
04 SF 27		
05♦LBL A	RCL PCO <sub>2</sub>	
06 XEQ 02	RCL pH	
07 XEQ 03	RCL HGB	
08 XEQ 04		
09 RCL 06	Calc. total	
10 6.11	plasma CO <sub>2</sub>	
11 -		
12 10↑X		
13 RCL 05		
14 32.57		
15 /		
16 *		
17 STO 02	Display TCO <sub>2</sub>	
18 LASTX		
19 +		
20 "TCO2"		
21 XEQ 10	Calc. base excess	
22 RCL 09		
23 1.63		
24 *		
25 9.5		
26 +		
27 RCL 06		
28 7.4		
29 -		
30 *		
31 RCL 02		
32 +		
33 24		
34 -		
35 1		
36 RCL 09		
37 70		
38 /		
39 -		
40 *		
41 "BE"	Display B E	
42 XEQ 10	Printer?	
43 FS? 55	Yes	
44 STOP		
45 RCL 02	RCL HCO <sub>3</sub>	
46 "HCO3-"	Display HCO <sub>3</sub> <sup>2</sup>	
47 GTO 10	Initialize	
48♦LBL "PO2	VPO <sub>2</sub> & O <sub>2</sub> SAT	
"		
49 FIX 2		
50 SF 21		
51 SF 27		
52♦LBL B		RCL PO <sub>2</sub>
53 XEQ 01		RCL PCO <sub>2</sub>
54 XEQ 02		RCL pH
55 XEQ 03		
56 RCL 11		RCL BT
57 "BT"		
58 XEQ 09		
59 STO 11		Calc. VPO <sub>2</sub>
60 37		
61 X<>Y		
62 -		
63 .024		
64 *		
65 RCL 06		
66 7.4		
67 -		
68 .48		
69 *		
70 +		
71 40		
72 RCL 05		
73 /		
74 LOG		
75 .06		
76 *		
77 +		
78 10↑X		
79 RCL 10		
80 *		
81 STO 01		Display VPO <sub>2</sub>
82 "VPO2"		
83 XEQ 10		Calc. % SAT
84♦LBL C		
85 STO 01		
86 ENTER↑		
87 ENTER↑		
88 ENTER↑		
89 15		
90 -		
91 *		
92 2045		
93 +		
94 *		
95 2 E3		
96 +		
97 *		
98 STO 08		
99 CLX		
100 15		

# Program Listings

101	-	151	STO 06	
102	*	152	RTN	
103	2400	153♦LBL 04		RCL HGB
104	+	154	RCL 09	
105	*	155	"HGB"	
106	31100	156	XEQ 09	
107	-	157	STO 09	
108	*	158	RTN	
109	24 E5	159♦LBL 01		RCL PO <sub>2</sub>
110	+	160	RCL 10	
111	1 E2	161	"PO2"	
112	/	162	XEQ 09	
113	ST/ 08	163	STO 10	
114	RCL 08	164	RTN	
115	"% SAT"	165♦LBL 10		Display routine
116	GTO 10	166	"T="	
117♦LBL D		167	ARCL X	
118	RCL 08	168	AVIEW	
119	"% SAT"	169	RTN	
120	XEQ 09	170♦LBL 09		RCL routine
121	STO 08	171	"T="	
122	XEQ 04	172	ARCL X	
123	RCL 08	173	"T?"	
124	*	174	PROMPT	
125	134	175	END	
126	*			
127	RCL 01			
128	31			
129	*			
130	+	80		
131	1 E4			
132	/			
133	"O2 CONT			
"				
134	GTO 10			
135♦LBL E				
136	STO 04			
137	RTN			
138♦LBL ε				
139	STO 03			
140	RTN			
141♦LBL 02				
142	RCL 05			
143	"PCO2"			
144	XEQ 09			
145	STO 05			
146	RTN			
147♦LBL 03				
148	RCL 06			
149	"PH"			
150	XEQ 09			
		00		

# REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
REG	NAME	VAL	STATUS			
			SIZE	012	TOT. REG.	61
00	HCO <sub>3</sub> <sup>-</sup> /VPO <sub>2</sub>	50	ENG		FIX	2
			DEG		SCI	
	CVO <sub>2</sub>				RAD	
	CAO <sub>2</sub>				GRAD	
05	PCO <sub>2</sub>	55	FLAGS			
	pH		#	INIT	SET INDICATES	CLEAR INDICATES
				S/C		
	Used/%SAT		21	S	Print & Display	Pause only
	HGB		27	S	User mode	Regular
10	PO <sub>2</sub>	60				
	BT					
15		65				
20		70				
25		75				
30		80				
35		85				
40		90	ASSIGNMENTS			
45		95	FUNCTION	KEY	FUNCTION	KEY

## BLOOD CHEMISTRY II

### ANAEROBIC PCO<sub>2</sub> AND pH CHANGE AND ANAEROBIC PO<sub>2</sub> CHANGE

Corrections of PCO<sub>2</sub> and pH for anaerobic temperature change are calculated by this program. In addition, PO<sub>2</sub> measured at 37°C is corrected to body temperature.

#### Anaerobic PCO<sub>2</sub> and pH Change:

Corrections of PCO<sub>2</sub> and pH for anaerobic temperature change are calculated. The equation for pH is a simplification of a formula from Severinghaus. It ignores the pH and BE dependent terms. This introduces a very small error except at extreme conditions of acid-base status and large temperature shifts. For example, at a pH of 7.2 or 7.6, the error is 0.0013 pH units per °C.

Equations Used:  $PCO_2(BT) = PCO_2(37) \cdot 10^{0.019(T-37)}$

 $pH(BT) = pH(37) - 0.0146(T-37)$

#### Anaerobic PO<sub>2</sub> Change:

This program corrects PO<sub>2</sub>, measured at 37°C, to Body Temperature.

Equation Used: Correction of PO<sub>2</sub> for anaerobic temperature change is calculated taking into account the exchange of oxygen between HgbO<sub>2</sub> and the dissolved state at high saturation. Below 80% Sat., the relation is approximately

$$\frac{\Delta \text{ Log PO}_2}{\Delta T} = 0.031$$

This factor falls at higher saturations, approaching 0.006 at 100% Sat. The curve given by Severinghaus has been approximated by the following equation in this program:

$$\frac{\Delta \log PO_2}{\Delta T} = \frac{3130 - 62.5 \text{ Sat} + 0.312008 \text{ Sat}^2}{100,000 - 1993 \text{ Sat} + 9.9313 \text{ Sat}^2}$$

Reference: Severinghaus, John W., *Blood Gas Calculator, J. Appl. Physiol.*, 21 (3): 1108-1116, 1966.

Detailed User Instructions:

$PO_2(BT)$  replaces the  $37^\circ C$  value in memory with the body temperature value. Therefore, calculation based on the  $37^\circ C$  values in programs for virtual  $PO_2$  and  $O_2$  saturation & content should be accomplished before this program is run. If  $O_2$  saturation has not been measured, it should be estimated by using program for "Virtual  $PO_2$  and  $O_2$  Saturation and Content."

This program may also be used to convert  $PO_2$  between any two temperatures, for example, from body temperature to  $37^\circ C$ . To do this, first determine what the desired temperature change is in  $^\circ C$ . Add this to  $37^\circ C$  algebraically, and enter the result as BT. For example, suppose values known at  $41^\circ C$  are to be converted to  $37^\circ C$ . The temperature change is  $-4^\circ C$ . Add this to  $37^\circ C$ , resulting  $33^\circ C$ . Executing the program with  $BT=33^\circ C$  will then result in the  $37^\circ C$  value for  $PO_2$ .

Example:

For a patient with  $PCO_2$  of 45mmHg and a pH of 7.35 at  $40^\circ C$ , calculate corrected values for  $PCO_2$  and pH. If the patient's  $PO_2$  is 75mmHg and % saturation is 90, what is the corrected  $PO_2$ ?

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 012	
[XEQ] [ALPHA] ANRB [ALPHA]	0.00
[A]	PCO2=0.00?
45 [R/S]	PCO2=0.00?
7.35 [R/S]	PH=0.00?
40 [R/S]	BT=0.00?
[R/S]	PCO2 CORR.=51.31
[B]	PH CORR.=7.31
90 [R/S]	% SAT=0.00?
75 [R/S]	PO2=0.00?
[R/S]	BT=40.00?
	PO2 CORR.=92.31

# User Instructions

SIZE: 012

# Program Listings

01♦LBL "ANR B"	Initialize	51 + 52 RCL 08 53 X↑2 54 9.9313 55 * 56 RCL 08 57 1993 58 * 59 - 60 1 E5 61 + 62 / 63 RCL 11 64 37 65 - 66 * 67 10↑X 68 RCL 10 69 * 70 STO 10 71 "PO2" 72♦LBL 10 73 "H CORR. ="	
02 FIX 2			Display PO <sub>2</sub> corr.
03 SF 21			
04 SF 27			
05♦LBL A			
06 RCL 05	RCL PCO <sub>2</sub>	74 ARCL X 75 AVIEW 76 RTN 77♦LBL 04 78 RCL 11 79 "BT" 80 XEQ 09 81 STO 11 82 RTN 83♦LBL 09 84 "H="	Display routine
07 "PCO2"			
08 XEQ 09			
09 STO 05			
10 RCL 06	RCL pH	85 ARCL X 86 "H?" 87 PROMPT 88 END	
11 "PH"			
12 XEQ 09			
13 STO 06	RCL BT		
14 XEQ 04			
15 37			
16 -			
17 STO 01	Calc. PCO <sub>2</sub> corr.		
18 .019			
19 *			
20 10↑X			
21 RCL 05			
22 *	Display PCO <sub>2</sub> corr.		
23 "PCO2"			
24 XEQ 10			
25 RCL 06	Calc. pH corr.		
26 RCL 01			
27 .0146			
28 *			
29 -			
30 "PH"	Display pH corr.		
31 GTO 10			
32♦LBL B	Calc. PO <sub>2</sub> corr.		
33 RCL 08			
34 "% SAT"	RCL % SAT		RCL routine
35 XEQ 09			
36 STO 08			
37 RCL 10	RCL PO <sub>2</sub>		
38 "PO2"			
39 XEQ 09			
40 STO 10	RCL BT		
41 XEQ 04			
42 RCL 08	Calc. PO <sub>2</sub> corr.		
43 X↑2			
44 .312008			
45 *			
46 RCL 08			
47 62.5			
48 *			
49 -			
50 3130		00	

# REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS				STATUS			
00		50		SIZE	012	TOT. REG.	39
	ΔT			ENG		FIX	2
				DEG		SCI	
						RAD	GRAD
05	PCO <sub>2</sub>	55		FLAGS			
	pH			#	INIT	SET INDICATES	CLEAR INDICATES
	%SAT				21	S Print & Display	Pause only
					27	S User mode	Reg. mode
10	PO <sub>2</sub>	60					
	BT						
15		65					
20		70					
25		75					
30		80					
35		85		ASSIGNMENTS			
40		90		FUNCTION	KEY	FUNCTION	KEY
45		95					

## BODY SURFACE AREA FOR CARDIO PULMONARY

This program calculates body surface area by either the method of DuBois or the method of Boyd. In both cases, the required inputs are height and weight, which may be input either in metric (cm, kg) or English (in, lb) units. Quantities in English units should be input as negative numbers. If cardiac output is given, the cardiac index can also be calculated.

Equations: Let  $Ht$  be height,  $Wt$  be weight, and  $BSA$  be the body surface area in  $\text{m}^2$ .

$$Ht \text{ (cm)} = 2.54 Ht \text{ (in.)}$$

$$Wt \text{ (kg)} = 0.45359237 Wt \text{ (lb.)}$$

DuBois:

$$BSA \text{ (m}^2\text{)} = Ht \text{ (cm)}^{0.725} \cdot Wt \text{ (kg)}^{0.425} \cdot 7.184 \cdot 10^{-3}$$

Boyd:  $BSA \text{ (m}^2\text{)} = Wt \text{ (g)}^{(0.7285 - 0.0188 \log Wt)} \cdot Ht \text{ (cm)}^{0.3} \cdot 3.207 \cdot 10^{-4}$

$$CI = \frac{CO}{BSA}$$

where  $CO$  is cardiac output in  $\ell/\text{min.}$

NOTE: The DuBois formula for BSA is undefined for children with a BSA less than  $0.6 \text{ m}^2$ . In such cases BSA should be calculated by the Boyd formula.

Reference: D. DuBois and E.F. DuBois, Clin. Cal. 10, Arch. Int. Med., 17, 863, 1916.

Edith Boyd, *Growth of the Surface Area of the Human Body*, U. of Minnesota Press, 1935, p. 132.

Example 1:

Patient is 176 cm in height and weights 63.5 kg. What is the body surface area by both the Du Bois and Boyd methods?

Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 012

[XEQ] [ALPHA] BSA [ALPHA]

176 [R/S]

63.5 [R/S]

D [R/S]

[B]

Display:

HT=?

WT=?

B/D?

DUBOIS BSA=1.78

BOYD BSA=1.76

## Example 2:

A patient 60 inches in height and 100 pounds in weight has a cardiac output of 5 l/min. Calculate the body surface area and cardiac index by Boyd. What is the cardiac index using the Du Bois BSA?

## Keystrokes:

[A]  
60 [CHS] [R/S]  
100 [CHS] [R/S]  
B [R/S]  
[C]  
5 [R/S]  
[D]  
[C]  
[R/S]

## Display:

HT=?  
WT=?  
B/D?  
BOYD BSA=1.40  
CO=( )?  
CI=3.58  
DUBOIS BSA=1.39  
CO=5.00?  
CI=3.60

# User Instructions

# Program Listings

01♦LBL "BSA"		49 Y↑X	
"		50 RCL 06	
02 FIX 2	Initialize	51 1 E3	
03 SF 21		52 *	
04 SF 27		53 ENTER↑	
05♦LBL A		54 LOG	
06 "HT=?"		55 .0188	
07 PROMPT	Input HT	56 *	
08 X>0?	Metric?	57 .7285	
09 GTO 01	Yes	58 -	
10 CHS	No, convert to cm	59 Y↑X	
11 2.54		60 /	
12 *		61 3118	
13♦LBL 01		62 /	
14 STO 05	STO HT	63 STO 07	STO Boyd BSA
15 "WT=?"	Input WT	64 "BOYD BSA	
16 PROMPT		A"	
17 X>0?	Metric	65 GTO 10	Display Boyd BSA
18 GTO 02	Yes	66♦LBL C	
19 CHS	No, convert to kg	67 RCL 08	Recall CO
20 2.205		68 "CO"	
21 /		69 XEQ 09	
22♦LBL 02	STO WT	70 STO 08	STO new CO
23 STO 06		71 RCL 07	
24 "B/D?"	Choose Boyd or	72 /	Calc. CI
25 AON	Du Bois	73 "CI"	
26 PROMPT		74♦LBL 10	
27 "HA"		75 "H=?"	Display routine
28 AOFF		76 ARCL X	
29 ASTO X		77 AVIEW	
30 GTO IND	Go to calc.	78 RTN	
X	routine	79♦LBL 09	
31♦LBL D		80 "H=?"	Recall stored CO
32♦LBL "DA"	Du Bois calc.	81 ARCL X	
33 RCL 05		82 "H?"	
34 .725		83 PROMPT	
35 Y↑X		84 END	
36 RCL 06			
37 .425			
38 Y↑X			
39 *			
40 139.2			
41 /			
42 STO 07	STO Du Bois BSA		
43 "DUBOIS			
BSA"			
44 GTO 10	Display Du Bois		
45♦LBL B	BSA		
46♦LBL "BA"	Boyd calc.		
47 RCL 05			
48 .3		00	

# REGISTERS, STATUS, FLAGS, ASSIGNMENTS

41

DATA REGISTERS				STATUS			
00		50		SIZE 012	TOT. REG. 40	USER MODE	
				ENG	FIX 2	SCI	ON OFF
				DEG	RAD	GRAD	
FLAGS				CLEAR INDICATES			
05	HT (cm)	55		# INIT	SET INDICATES	CLEAR INDICATES	
	WT (kg)			21 S	Print & Display	Pause only	
	BSA (m <sup>2</sup> )			27 S	User mode	Reg. mode	
	CO (l/min)						
10		60					
15		65					
20		70					
25		75					
30		80					
35		85					
ASSIGNMENTS							
40		90		FUNCTION	KEY	FUNCTION	KEY
45		95					

## CARDIAC OUTPUTS

### Dye Curve Cardiac Output:

This portion of the program calculates cardiac output from measurements taken directly from an indicator dilution curve. It computes the area of the first part of the curve by trapezoidal rule integration. The part after the last point is calculated from an exponential projection based on the first measured point below 65% of the peak measured point; and the first measured point after that which is below 45% of the peak. This not only avoids problems of indicator recirculation in most cases, but also limits the amount of data to be input. Thus it is important to have a measured point which is below 45% of the peak, but before recirculation becomes obvious. If this isn't possible, an approximation can be obtained by guessing at the curve without recirculation and entering values.

$$\text{Equation Used: } \text{CO}(\ell/\text{min}) = \frac{\text{DOSE (mg)} \cdot 60 \text{ (sec/min)}}{\text{CAL}(\text{mg}/(\ell \cdot \text{div})) \cdot \text{AREA (div} \cdot \text{sec})}$$

### Detailed Instructions for Dye Curve Output:

To obtain accurate results, it is important to measure the curve at frequent intervals. Generally, about ten points on the curve, equally spaced in time between onset and the 40%-of-peak point on the downslope, will be adequate. Choose and input a measurement time interval accordingly.

Input the values measured from the curve (DC) and press [R/S] after each. The units of measurement are arbitrary; for example, divisions on the paper or volts, so long as the same units are used in inputting the calibration. The values are measured relative to the baseline, or starting level, of the curve. After each input entry, the display will indicate the number of points input.

As points on the downslope are input, the program compares each with the peak value. When the first point whose value is less than 65% of the peak value is found, it is stored for later use in the exponential projection as indicated by a minus sign preceding the displayed value representing the number of points input.

When a point having a value less than 45% of the peak value is input, the program automatically makes the exponential projection and displays the area under the curve, rather than the number of points entered.

At this time, input the CAL value. If indocyanine green dye is being used, it will generally be measured as milligrams of dye per liter of the patient's blood per division or unit of curve measurement. For other indicators, equivalent calibration factors must be determined.

Finally, input the dose of indicator given (for dye, this will usually be in mg.). Cardiac output in liters/min. is calculated and stored in memory.

Fick Cardiac Output:

This portion of the program computes cardiac output, stroke volume, and cardiac index by the Fick method.

$$\text{Equations Used: } \text{CO}(\ell/\text{min}) = \frac{\text{VO}_2 \text{ (ml/min STPD)} \cdot 100(\%)}{(\text{CaO}_2 - \text{C}_v\text{O}_2)(\text{vol.}\%) \cdot 1000(\text{ml}/\ell)}$$

$$\text{SV}(\text{ml/beat}) = \frac{\text{CO}(\ell/\text{min}) \cdot 1000 \text{ (ml}/\ell)}{\text{HR} \text{ (beats/min)}}$$

$$\text{CI}(\ell/\text{min m}^2) = \frac{\text{CO}(\ell/\text{min})}{\text{BSA}(\text{m}^2)}$$

$$\text{SI}(\text{ml}/\text{m}^2) = \frac{\text{SV}(\text{ml})}{\text{BSA}(\text{m}^2)}$$

Detailed Instructions for Fick Output:

If the Virtual  $\text{PO}_2$  and  $\text{O}_2$  Saturation and Content has just been run either or both  $\text{CaO}_2$  and  $\text{C}_v\text{O}_2$  will be stored. The program will automatically recall these stored values for input. Proceed as usual by inputting values or accepting recalled values for each parameter. Be sure  $\text{VO}_2$  is in  $\text{ml}/\text{min STPD}$ .

To calculate cardiac index-assuming BSA has been previously stored, press [R/S] to recall BSA, or input the correct value. To calculate stroke volume input the heart rate. After calculating stroke volume pressing [R/S] will yield the stroke index. Pressing [R/S] again returns to the display of SV.

Example 1: (For dye curve CO)

Eight consecutive values are taken at one second intervals from an indicator dilution curve. They are as follows: 5, 20, 45, 60, 50, 38, 28, 20. The calibration is 0.2 mg/l/div. The dose is 3 mg. Calculate the cardiac output from the dye curve data.

Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 012

[XEQ] [ALPHA] DYE [ALPHA]

1 [R/S]

Display:

TIME=?

DC=?

5 [R/S]	(1.00)
	DC=?
20 [R/S]	(2.00)
	DC=?
45 [R/S]	(3.00)
	DC=?
60 [R/S]	(4.00)
	DC=?
50 [R/S]	(5.00)
	DC=?
38 [R/S]	(-6.00) past 65% point.
	DC=?
28 [R/S]	(-7.00)
	DC=?
20 [R/S]	AREA=318.32
[R/S]	CAL=?
.2 [R/S]	DOSE=?
3 [R/S]	CO=2.83

Example 2: (For Fick CO)

Calculate Fick cardiac output and index, and stroke volume and index from the following data:

$\text{CaO}_2 = 18 \text{ vol.\%}$   
 $\text{C}_v\text{O}_2 = 15 \text{ vol.\%}$   
 $\text{VO}_2 = 250 \text{ ml/min. STPD}$   
 $\text{BSA} = 2\text{m}^2$   
 Heart rate = 60 BPM

Keystrokes:

[XEQ] [ALPHA] FICK [ALPHA]  
 18 [R/S]  
 15 [R/S]  
 250 [R/S]  
 [R/S]  
 2 [R/S]  
 [R/S]  
 60 [R/S]  
 [R/S]

Display:

$\text{CaO}_2 = ( ) ?$   
 $\text{C}_v\text{O}_2 = ( ) ?$   
 $\text{VO}_2 = ( ) ?$   
 $\text{CO} = 8.33$   
 $\text{BSA} = ( ) ?$   
 $\text{CI} = 4.17$   
 $\text{HEART BPM} = ?$   
 $\text{SV} = 138.83$   
 $\text{SI} = 69.42$

# User Instructions

SIZE: 012

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program. For Dye Curve Cardiac			
	Output go to step 2. For Fick Cardiac			
	Output go to step 8.			
	DYE CURVE CARDIAC OUTPUT			
2	Begin Dye Curve Cardiac Output calculation.		[XEQ] DYE	TIME=?
3	Input the time interval.	Time (sec)	[R/S]	DC=?
4	Input the first value from the dye curve.	DC	[R/S]	(n or -n)
				DC=?
5	Repeat step 4 for all DC values. As soon as DC < 45% of peak, area is calculated.			AREA=?
6	Input calibration.		[R/S]*	CAL=?
		CAL (mg/(1 Div))	[R/S]	DOSE=?
7	Input dose of indicator. Cardiac Output is calculated and displayed.	Dose	[R/S]	CO=?
	FICK CARDIAC OUTPUT			
8	Begin Fick Cardiac Output calculation.		[XEQ] FICK	CaO <sub>2</sub> =( )?
9	Stored CaO <sub>2</sub> is displayed. Input correct CaO <sub>2</sub> or, if correct, press [R/S].	CaO <sub>2</sub>	[R/S]	CV <sub>O2</sub> =( )?
10	Stored C <sub>V</sub> O <sub>2</sub> is displayed. Input correct C <sub>V</sub> O <sub>2</sub> or, if correct, press [R/S].	C <sub>V</sub> O <sub>2</sub>	[R/S]	VO <sub>2</sub> =( )?
11	Stored VO <sub>2</sub> is displayed. Input correct VO <sub>2</sub> or, if correct, press [R/S]. Fick Cardiac Output is calculated and displayed.	VO <sub>2</sub>	[R/S]	CO=?
12	Recall stored BSA. Input correct BSA or, if correct, press [R/S]. Cardiac index is calculated and displayed.		[R/S]*	BSA=( )? CI=? HEART BPM=?

\*This [R/S] not necessary if calculator is used with printer.

# User Instructions

# Program Listings

01♦LBL "DYE	Dye Curve CO	51 .45	Do 45% test
"		52 *	If not past 45%
02♦LBL A		53 X<=Y?	Display negative
03 FIX 2		54 GTO 08	count else
04 CF 01		55 RDN	calculate
05 SF 21		56 STO 02	exponential area
06 SF 27		57 RCL 04	
07 CLX		58 RCL 00	
08 STO 00		59 -	
09 STO 01		60 RCL 03	
10 STO 02		61 RCL 02	
11 "TIME=?"	Input time int.	62 /	
12 PROMPT		63 LN	
13 STO 10		64 /	
14♦LBL 00	Input dye curve	65 .5	
15 "DC=?"	values	66 -	
16 PROMPT		67 *	
17 DSE 00	Count entries	68 RCL 01	
18♦LBL 11		69 +	
19 ST+ 01		70 RCL 10	
20 RCL 02	Integrate	71 *	
21 X>Y?	New Peak?	72 CF 01	
22 GTO 01	No	73 STO 02	
23 X<>Y	Yes	74 "AREA"	Display area
24 STO 02		75 XEQ 10	
25 X<>Y	Clear 65% flag	76 "CAL=?"	Input calibration
26 CF 01		77 PROMPT	
27♦LBL 01		78 ST* 02	
28 FS? 01		79 "DOSE=?"	Input dose
29 GTO 02		80 PROMPT	
30 .65		81 RCL 02	Calculate CO
31 *	If past 65% GTO	82 /	
32 X>Y?	03 else display	83 60	
33 GTO 03	count	84 *	
34 RCL 00		85 RND	
35 CHS		86♦LBL 05	
36 PSE		87 STO 08	Store and display
37 GTO 00	Do 65% test	88 "CO"	CO
38♦LBL 03		89♦LBL 10	
39 X<>Y		90 "I=?"	Display routine
40 STO 03		91 ARCL X	
41 RCL 00		92 AVIEW	
42 STO 04		93 RTN	
43 SF 01		94♦LBL "FIC	
44 PSE		K"	Fick CO
45 GTO 00		95♦LBL F	
46♦LBL 08	Display negative	96 FIX 2	Initialize
47 RCL 00	count	97 SF 21	
48 PSE		98 SF 27	
49 GTO 00		99 RCL 04	
50♦LBL 02		100 "CaO2"	RCL CaO <sub>2</sub>

# Program Listings

101	XEQ	09			151	PROMPT
102	STO	04	STO CaO <sub>2</sub>		152	END
103	RCL	03				
104	"CVO2"		RCL CVO <sub>2</sub>			
105	XEQ	09				
106	STO	03	STO CVO <sub>2</sub>			
107	RCL	02				
108	"VO2"		RCL VO <sub>2</sub>			
109	XEQ	09				
110	STO	02	STO VO <sub>2</sub>	60		
111	RCL	04				
112	RCL	03				
113	-		Call Fick CO			
114	.10					
115	*					
116	/					
117	RND					
118	XEQ	05	Display CO			
119	RCL	07				
120	"BSA"		RCL BSA	70		
121	XEQ	09				
122	STO	07	STO BSA			
123	RCL	08				
124	X<>Y					
125	/		Calc. and display			
126	"CI"		CI			
127	XEQ	10				
128	RCL	08				
129	"HEART B		Input Heart Rate			
PM=?"						
130	PROMPT			80		
131	/		Calculate			
132	1 E3					
133	*		&			
134	STO	01				
135	LBL	04	Display SV			
136	SF	21				
137	"SV"					
138	XEQ	10				
139	RCL	07	Calculate and			
140	/		display SI	90		
141	"SI"					
142	XEQ	10				
143	FS? 55		Repeat SV and			
144	STOP		SI display			
145	RCL	01				
146	GTO	04				
147	LBL	09	RCL and store			
148	"T=		routine			
149	ARCL	X				
150	"T?"			00		

# REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS				STATUS			
#	NAME	INIT	S/C	SET INDICATES		CLEAR INDICATES	
				01	C	Past 65% point	Not past 65%
00	Counter	50		21	S	Print & Display	Pause only
	SD/SV			27	S	User mode	Reg. mode
	Used/VO <sub>2</sub>						
	D65/C <sub>V</sub> O <sub>2</sub>						
	-N65/CaO <sub>2</sub>						
05		55					
10	ΔT	60					
15		65					
20		70					
25		75					
30		80					
35		85					
40		90					
45		95					

## VALVE AREA

This program calculates the areas of heart valves from measured pressure gradients.

Equations Used:

$$\text{Valve Area (cm}^2\text{)} = \frac{\text{Mean Flow}}{0.0445\sqrt{\text{mean gradient}}}$$

where

$$\text{Mean Flow (l/sec)} = \frac{\text{CO(l/min.)} \cdot \text{R-R(sec)}}{\text{Valve Open Time (sec/beat)} \cdot 60 \text{ (sec/min.)}}$$

$$\text{Mitral Valve Area only} = \frac{\text{Valve Area}}{0.7}$$

### Detailed User Instructions:

Choose whether the calculation is for mitral or aortic valve, then input the time duration, in seconds, of blood flow through the valve of interest; that is, the systolic ejection period (SEP) for outflow tract valves or the diastolic filling period (DFP) for A-V valves. Press [R/S].

This program permits averaging of a number of pressure gradients across the valve measured at different times while the valve is open. If the pressure gradient is to be measured at a number of different times, the time intervals should be equally spaced across the duration of the valve opening to obtain a true average. Simply input each value of pressure difference, ( $\Delta P$ ), in mmHg, and press [R/S] after each. The display will then show the number of input entries made. When all input entries have been made, press [R/S] without data entry. The average of all the  $\Delta P$  values will be displayed ( $\bar{\Delta P}$ ). If only one pressure gradient measurement is to be input, because averaging has been accomplished by some other means, simply input the value, press [R/S] and then press [R/S] without data entry. The input value will be displayed.

Input the R-R interval, in seconds, and press [R/S]. Cardiac output, if previously stored, will be recalled. If not, input it. Pressing [R/S] will display the valve area, in  $\text{cm}^2$ .

References: Gorlin, F., Gorlin, S.G., *Hydraulic Formula for Calculation of the Area of the Stenotic Mitral Valve, Other Cardiac Valves, and Central Circulatory Shunts*, American Heart Journal, Jan. 1957, VOL. 41, No. 1.

Hewlett-Packard Users' Library program #00207A.

## Example:

DFP (mitral valve) = 0.55 sec.

 $\Delta P$  = 10, 12, 8, 6, 2 mm Hg.

R-R = 0.94 sec.

CO = 5.73 l/min.

## Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 012

[XEQ] [ALPHA] VALVE [ALPHA]

Y [R/S]

.55 [R/S]

10 [R/S]

12 [R/S]

etc.

2 [R/S]

[R/S]

[R/S]

.94 [R/S]

5.73 [R/S]

## Display:

MITRAL?

TIME=?

PRESS DIFF=?

(1.00)

PRESS DIFF=?

(2.00)

PRESS DIFF=?

etc.

(5.00)

PRESS DIFF=?

AVE PRESS DIFF=7.60

R-R=?

CO=( )?

MITRAL VALVE AREA=1.90

# User Instructions

# Program Listings

01♦LBL "VAL VE"	Valve Area	47 RCL 09	
02♦LBL A		48 "R-R=?"	Input R-R
03 CF 00		49 PROMPT	
04 CF 01	Initialize	50 /	
05 SF 21		51 60	
06 SF 27		52 *	
07 FIX 2		53 STO 10	
08 "Y"		54 RCL 08	Recall CO
09 ASTO Y		55 "CO="	
10 "MITRAL?"	Mitral valve?	56 ARCL X	
"		57 "T?"	
11 AON		58 PROMPT	
12 PROMPT		59 STO 08	STO CO
13 AOFF		60 RCL 10	
14 ASTO X		61 /	Calc. area
15 X=Y?		62 .0445	
16 SF 00	Yes	63 /	
17 "TIME=?"		64 RCL 01	
18 PROMPT	Input SEP or DFP	65 SQRT	
19 STO 09		66 /	
20 CF 22		67 CLA	
21♦LBL 00		68 FC? 00	Mitral?
22 "PRESS D IFF=?"	Input ΔP	69 GTO 03	No
23 PROMPT		70 .7	
24 FC?C 22		71 /	Mitral factor
25 GTO 02		72 "MITRAL	
26 FS? 01		"	
27 GTO 01		73♦LBL 03	
28 STO 01	STO ΔP <sub>1</sub>	74 "T-VALVE	
29 SF 01		AREA"	
30 1	STO M=1	75♦LBL 10	
31 STO 00		76 "T="	
32 PSE		77 ARCL X	Display routine
33 GTO 00		78 AVIEW	
34♦LBL 01	ΔP <sub>2</sub> - ΔP <sub>n</sub>	79 END	
35 ST+ 01		90	
36 ISG 00			
37♦LBL 15	Display n		
38 RCL 00			
39 PSE			
40 GTO 00			
41♦LBL 02			
42 RCL 00			
43 ST/ 01	ΔP		
44 RCL 01			
45 "RVE PRE SS DIFF"	Display ΔP		
46 XEQ 10		00	

# REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS			STATUS			
00	n (counter) $\Sigma \Delta P$ , $\Delta P$	50	SIZE	012	TOT. REG.	39
			ENG		FIX	2
			DEG		SCI	
					RAD	GRAD
05		55	FLAGS			
			#	INIT S/C	SET INDICATES	CLEAR INDICATES
			00	C	Mitral Calc	Other valves
	CO		01	C	Other $\Delta P$	First $\Delta P$
	SEP or DFP		21	S	Print & Display	Pause only
10	S/M, A	60	27	S	User mode	Reg. mode
15		65				
20		70				
25		75				
30		80				
35		85				
ASSIGNMENTS						
40		90	FUNCTION	KEY	FUNCTION	KEY
45		95				

## CARDIAC SHUNTS

This program calculates anatomic shunts or a physiologic shunt from measured oxygen concentrations.

### Anatomic Shunts:

This routine calculates left-to-right and right-to-left shunts and displays them as a percentage. The program uses the method of allegations and can calculate bi-directional shunts.

### Equations Used:

$$R-L \text{ shunt } (\%) = \frac{(L-PUL) - (L-SYST)}{(L-PUL) - (R-SYST)} \cdot 100$$

$$L-R \text{ shunt } (\%) = \frac{(R-PUL) - (R-SYST)}{(L-PUL) - (R-SYST)} \cdot 100$$

The program assumes oxygen concentration values taken from four sites in the cardiovascular system. Since these sites may be various chambers in the heart or great vessels, they are labeled right systemic, right pulmonary, left pulmonary and left systemic. For example, suppose oxygen concentration values are known for the right atrium, pulmonary artery, left ventricle, and aorta; then the right systemic site would be the right atrium, the right pulmonary site would be the pulmonary artery, the left pulmonary site would be the left ventricle, and the left systemic site would be the aorta.

Note that it is possible to enter either oxygen contents or saturations, assuming hematocrit does not change during the sampling interval.

### Physiologic Shunt and Fick Cardiac Output:

The Fick cardiac output and physiologic shunt fraction are calculated from arterial, venous and alveolar oxygen concentration and oxygen intake.

### Equations Used:

$$\text{Phys. Shunt} = \frac{C_AO_2 - C_aO_2}{C_AO_2 - C_VO_2}$$

$$CO \text{ } (\ell/\text{min}) = \frac{VO_2 \text{ } (\text{ml/min STPD}) \cdot 100 (\%)}{(C_aO_2 - C_VO_2 \text{ (vol. \%)}) \cdot 1000 \text{ (ml/}\ell\text{)}}$$

These are the standard physiologic shunt and Fick cardiac output equations. If measured O<sub>2</sub> saturations are used, these equations will be accurate.

If the content values have been derived from saturation estimates on  $P_0_2$  measurements for arterial and venous blood, the results should be viewed with caution unless the patient's oxygen dissociation curve has been established to be normal.

After cardiac output is calculated, stroke volume may be calculated by heart rate and multiplying by 1000 (to convert from l to ml). Alternatively, cardiac index may be calculated by dividing by body surface area.

If the program is to be used to calculate output only, it is not necessary to input  $C_AO_2$ .

References: Zimmerman, H.A., *Intravascular Catheterization*, Charles C. Thomas, Springfield, IL, 1966.

Comroe, Julius H., Jr., et al. *The Lung*, 2nd ed., Year Book Medical Publishers, Inc., Chicago, 1962, p. 345.

Hang, Sing San, et al, *From Cardiac Catheterization Data to Hemodynamic Parameters*, F.A. Davis Co., Phil., 1972, p. 21.

## Example 1:

Calculate the left-to-right or right-to-left shunts for a patient having the following oxygen saturation values at the listed sites. Right atrium, 85%; pulmonary artery, 88%; left ventricle, 95%; left atrium, 93%.

## Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 012  
 [XEQ] [ALPHA] ANATOM [ALPHA]  
 85 [R/S]  
 88 [R/S]  
 95 [R/S]  
 93 [R/S]  
 [R/S]

## Display:

R-SYST=?  
 R-PUL=?  
 L-PUL=?  
 L-SYST=?  
 L-R SHUNT=30.00  
 R-L SHUNT=20.00

## Example 2:

Calculate physiologic shunt and Fick cardiac output from the following data:

$C_AO_2$  = 20 vol.%  
 $C_aO_2$  = 18 vol.%  
 $C_VO_2$  = 15 vol.%  
 $VO_2$  = 250 ml/min. STPD

## Keystrokes:

[XEQ] [ALPHA] PHYS [ALPHA]  
 20 [R/S]  
 18 [R/S]  
 15 [R/S]  
 [F]  
 250 [R/S]

## Display:

CAO2=( )?  
 CaO2=( )?  
 CVO2=( )?  
 PHYS SHUNT=40.00  
 VO2=( )?  
 FICK CO=8.33

# User Instructions

SIZE: 012

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program. To calculate anatomic shunts go to step 2. To calculate physiologic shunts go to step 3.			
	<u>Anatomic Shunts</u>			
2	Begin the anatomic shunt calculation		[XEQ] ANATOM	R-SYST=?
2a	Input the following oxygen concentrations:			
	Right-Systemic	R-syst	[R/S]	R-PUL=?
	Right-Pulmonary	R-pul	[R/S]	L-PUL=?
	Left-Pulmonary	L-pul	[R/S]	L-SYST=?
	Left-Systemic	L-syst	[R/S]	L-R SHUNT=
	and calculate the Left-to-Right Shunt			
2b	To calculate the Right-to-Left Shunt		[R/S]	R-L SHUNT=?
2c	If no shunt is calculated display so indicates		or,	L-R: NO SHUNT R-L: NO SHUNT
	<u>Physiologic Shunts</u>			
3	Begin the physiologic shunt calculation and see stored $C_AO_2$		[XEQ] PHYS	CAO2=?
3a	Input correct $C_AO_2$ , or if stored $C_AO_2$ is correct press [R/S] <u>without prior data entry</u>	$C_AO_2$ or no input	[R/S]	CaO2=?
3b	Repeat for $C_aO_2$ and $C_vO_2$	$C_aO_2$ or no input $C_vO_2$ or no input	[R/S]	CVO2=?
	Physiologic shunt is calculated.		[R/S]	PHYS SHUNT=?
	<u>Fick Cardiac Output (Optional)</u>			
4	To calculate Fick Cardiac Output (if oxygen			

# User Instructions

# Program Listings

01♦LBL "ANA TOM"	Anatomic shunts	47 XEQ 10 48♦LBL 04 49 FS? 55 50 STOP 51 GTO 00 52♦LBL 01 53 "F: NO S HUNT"	Yes, display shunt
02♦LBL A 03 FIX 2 04 SF 21 05 SF 27 06 SF 01 07 "R-SYST=?"	Initialize	54 AVIEW 55 FS? 01 56 GTO 04 57 RTN 58♦LBL 10 59 "F SHUNT = " 60 ARCL X 61 AVIEW 62 FS? 01 63 GTO 04 64 RTN 65♦LBL "PHY S"	Toggle for shunt
08 PROMPT 09 STO 00 10 "R-PUL=?" " 11 PROMPT 12 STO 02 13 "L-PUL=?" " 14 PROMPT 15 STO 05 16 "L-SYST=?" ?"	Input right and left pulmonary and systemic O <sub>2</sub> concentra- tions	66♦LBL C 67 FIX 2 68 SF 21 69 SF 27 70 CF 01 71 RCL 01 72 "CAO2" 73 XEQ 09 74 STO 01 75 RCL 04 76 "CaO2" 77 XEQ 09 78 STO 04 79 RCL 03 80 "CVO2" 81 XEQ 09 82 STO 03 83 RCL 01 84 RCL 04 85 - 86 RCL 01 87 RCL 03 88 - 89 /	Display: no shunt
17 PROMPT 18 STO 06 19 SF 00 20♦LBL 00 21 FS?C 00 22 GTO 02 23 SF 00 24 RCL 05 25 RCL 06 26 - 27 RCL 05 28 RCL 00 29 - 30 / 31 "R-L" 32 GTO 03 33♦LBL 02 34 RCL 02 35 RCL 00 36 - 37 RCL 05 38 RCL 00 39 - 40 / 41 "L-R" 42♦LBL 03 43 1 E2 44 * 45 X<=0? 46 GTO 01	Toggle for L-R to R-L calc. Calc. R-L shunt Calc. L-R shunt Is result pos. No	85 XEQ 10 86 GTO 04 87 STOP 88 GTO 00 89 52♦LBL 01 90 1 E2 91 * 92 "PHYS" 93 X<=0? 94 GTO 01	Go to toggle Display shunt Go to toggle Calc. physiological shunt Initialize RCL C <sub>A</sub> O <sub>2</sub> STO C <sub>A</sub> O <sub>2</sub> RCL C <sub>a</sub> O <sub>2</sub> STO C <sub>a</sub> O <sub>2</sub> RCL C <sub>V</sub> O <sub>2</sub> STO C <sub>V</sub> O <sub>2</sub> Calculate shunt No shunt

# Program Listings

```

95 GTO 10
96♦LBL F
97 RCL 02
98 "VO2"
99 XEQ 09
100 STO 02
101 RCL 04
102 RCL 03
103 -
104 /
105 10
106 /
107 STO 08
108 "FICK CO
= "
109 ARCL X
110 AVIEW
111 RTN
112♦LBL 09
113 "T="
114 ARCL X
115 "T?"
116 PROMPT
117 END

```

Display shunt  
Calc. Fick CO

RCL VO<sub>2</sub>  
STO VO<sub>2</sub>

Calc. CO

Output Fick CO

Display of  
recalled data

30

51

60

70

80

90

00

40

50

# REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS				STATUS			
#	INIT	FLAGS		SET INDICATES		CLEAR INDICATES	
		S/C					
00	R-Syst	50		SIZE 012	TOT. REG. 50	USER MODE	
	$C_aO_2$			ENG	FIX 2	ON	OFF
	R-Pulm/VO <sub>2</sub>			DEG	RAD	GRAD	
	$C_yO_2$						
	$C_aO_2$						
05	L-Pulm	55					
	L-Syst						
	BSA						
	CO						
10		60		00 S	L-R shunt calc.	R-L shunt calc.	
				01 S	Anatomic	Physiologic	
				21 S	Print & Display	Pause only	
				27 S	User mode	Reg. mode	
15		65					
20		70					
25		75					
30		80					
35		85					
ASSIGNMENTS							
40		90		FUNCTION	KEY	FUNCTION	KEY
45		95					

## CONTRACTILITY AND STROKE WORK

### Contractility:

This portion of the program, entitled "Vmax," calculates the indices of left ventricular contractility based on pressure rise during isovolumetric contraction.

### Equations Used:

$P_N$  = most recently entered pressure (mmHg)

$P_{N-1}$  = next previously entered pressure

$\Delta t$  = time interval between pressure measurements (sec)

$P_p$  = pressure at which  $dP/dt/P$  is calculated

$\Delta P$  =  $P_N - P_{N-1}$

$\frac{dP}{dt} = \frac{\Delta P}{\Delta t}$  mmHg/sec

$P_p = \frac{P_N + P_{N-1}}{2}$

$dP/dt/P = \frac{dP/dt}{P_p}$  sec<sup>-1</sup>

$P_M$  =  $P_p$  where  $dP/dt/P$  is a maximum

$V_{MAX} = \frac{1}{30} \frac{(P_p \text{ LAST} \cdot \text{MAX } dP/dt/P) - (P_M \cdot dP/dt/P \text{ LAST})}{P_p \text{ LAST} - P_M}$

$dP/dt$  is calculated as the difference between successive pressure inputs divided by the time interval  $\Delta t$ . The largest value found is stored as maximum  $dP/dt$ .

$dP/dt/P$  is calculated for each pair of successive inputs, by first determining  $dP/dt$  as above, then dividing by the mean of the two pressures. The largest value found is stored as maximum  $dP/dt/P$ .

$V_{MAX}$  is found in this program by a linear projection of the downslope of the  $dP/dt/P$  vs.  $P$  curve back to  $P = 0$ , and by dividing the resulting  $dP/dt/P$  by 30. The projection is based on the point at which the maximum  $dP/dt/P$  was found, and the last point input. The constant is controversial, values between about 28 and 32 having appeared in the literature. The value 30 is used in this program.

**Detailed Instructions:**

The indices of left ventricular contractility calculated by this program are based on the pressure rise during isovolumetric contraction. Measurements, equally spaced in time, should be input for the isovolumetric phase only. Inputting values from the systolic ejection period can cause significant errors. Generally, between 5 and 10 pressure measurements should be input, and the time interval between measurements,  $\Delta t$ , chosen accordingly. Too few measurements will cause the maximum values to be missed. Too many will introduce excessive "noise" resulting in errors.

After each input except the first,  $dP/dt/P$  for the two most recent points will be displayed with a pause. When all inputs have been made the results: maximum  $dP/dt$ , maximum  $dP/dt/P$  and  $V_{MAX}$ , maximum velocity of the contractile element at zero pressure in circumferences or lengths/sec., are displayed.

If the contractility parameters are to be calculated using developed pressure, or any pressure reference other than zero, perform the subtraction before entering pressure values.

**Stroke Work:**

This routine calculates stroke work (SW) and stroke work index (SWI). For stroke work based on systolic minus end-diastolic pressure, perform subtraction before data input.

**Equations Used:**

$$SW(gm \cdot m) = \frac{13.6 \cdot P(mmHg) \cdot CO(l/min) \cdot R-R(sec)}{60 \text{ (sec/min)}}$$

$$SWI(gm/m) = \frac{SW(gm \cdot m)}{BSA(m^2)}$$

**Detailed Instructions:**

The mean systolic pressure,  $\bar{P}$ , is required for stroke work calculation. The program will average pressures measured at equal time intervals through systole to obtain the mean. When all inputs have been made, press [R/S] without prior data entry to obtain the mean systolic pressure.

If averaging is accomplished by other means, only a single value is input. If an error is made in the pressure inputs, restart program by pressing [B] and rekey the input data.

Reference: Yang, Sing San, et al, *From Cardiac Catheterization Data to Hemodynamic Parameters*, F.A. Davis Co., Phil., 1972.

## Example 1:

Find maximum  $dP/dt$ , maximum  $dP/dt/P$  and maximum ventricular contractility if the time interval is 0.005 seconds and  $P_N$  is 10, 20, 40, 60, and 80 mmHg.

## Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 012  
 [XEQ] [ALPHA] VMAX [ALPHA]  
 .005 [R/S]  
 10 [R/S]  
 20 [R/S]  
 40 [R/S]  
 60 [R/S]  
 80 [R/S]  
 [R/S]  
 [R/S]  
 [R/S]

## Display:

TIME INT.=?  
 P1=?  
 P2=?  
 (133.33)  
 P3=?  
 (133.33)  
 P4=?  
 (80.00)  
 P5=?  
 (57.14)  
 P6=?  
 MAX  $dP/dT=4000$   
 MAX  $dP/dT/P=133.3$   
 VMAX=5.14

## Example 2:

$P_{SYS}$  = 100,110 mmHg  
 R-R = 1 sec  
 CO = 5 l/min.  
 BSA =  $2m^2$

## Keystrokes:

[XEQ] [ALPHA] WORK [ALPHA]  
 100 [R/S]  
 110 [R/S]  
 [R/S]  
 [R/S]  
 1 [R/S]  
 5 [R/S]  
 [R/S]  
 2 [R/S]

## Display:

PSYST=?  
 PSYST=?  
 PSYST=?  
 AVE P=105.00  
 R-R=?  
 CO=( )?  
 STROKE WORK=119.00  
 BSA=( )?  
 SW INDEX=59.50

# User Instructions

SIZE: 012

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program. For Contractibility (Vmax) calculation go to step 2. For stroke work go to step 8.			
	CONTRACTIBILITY			
2	Begin contractibility calculation.		[ XEQ ] VMAX	TIME INT.=?
3	Input the time interval.	$\Delta T$ (sec)	[ R/S ]	P1=?
4	Input first pressure reading.	P1 (mmHg)	[ R/S ]	P(n)=?
5	Input next pressure reading.  (dP/dt/P for two most recent points is displayed with a pause).	P2 (mmHg)	[ R/S ]	(dP/dt/P)
6	Repeat step 5 for remainder of pressure readings. When all readings are input, press [ R/S ] without prior data entry.	no entry	[ R/S ]	MAX dP/dT =
	Maximum dP/dt (mmHg/sec) is displayed.			
7	Calculate maximum dP/dt/P(sec <sup>-1</sup> ) and Vmax (circ/sec).		[ R/S ]*	MAX dP/dT/P =
	STROKE WORK		[ R/S ]*	VMAX=
8	Begin stroke work calculation.		[ XEQ ] WORK	PSYST=?
9	Input systolic pressure.	$P_{sys}$ (mmHg)	[ R/S ]	PSYST=?
10	Repeat step 9 for all valves of Psys.  After all valves have been input press [ R/S ] without prior data entry.	no entry	[ R/S ]	AVE P=
	Average Psys is displayed.			
11	Input R-R interval.		[ R/S ]	R-R=?
		R-R (sec)	[ R/S ]	CO=( )?
	*This [ R/S ] not necessary if calculator is used with printer.			

# User Instructions

# Program Listings

01♦LBL "VMA X"	Contractility Initialization	50 FIX 2 51 PSE 52 X<=Y? 53 GTO 00 54 STO 04 55 LASTX 56 STO 05 57 RDN 58 GTO 00 59♦LBL 01 60 RCL 03 61 "MAX dP/ dT"	Display dP/dt/P
02♦LBL A 03 SF 21 04 SF 27 05 "TIME IN T.=?" 06 PROMPT 07 STO 06 08 CLX 09 STO 00 10 STO 01 11 STO 03 12 STO 04 13 STO 05 14 CF 22 15♦LBL 00 16 ISG 00 17♦LBL 11 18 CLX 19 FIX 0 20 CF 29 21 "P" 22 ARCL 00 23 "T=?" 24 PROMPT 25 FC?C 22 26 GTO 01 27 ENTER↑ 28 X<> 01 29 X=0? 30 GTO 00 31 32 ENTER↑ 33 ENTER↑ 34 RCL 06 35 / 36 RCL 03 37 X<>Y 38 X>Y? 39 STO 03 40 RCL 01 41 R↑ 42 2 43 / 44 - 45 STO 09 46 / 47 STO 02 48 RCL 04 49 X<>Y	Input P <sub>1--m</sub>  Calc dP/dt  Save MAX dP/dt  Save P <sub>1</sub>	62 ASTO 10 63 XEQ 10 64 SF 29 65 RCL 04 66 FIX 1 67 CLA 68 ARCL 10 69 "T/dT/P" 70 XEQ 10 71 RCL 09 72 RCL 04 73 * 74 RCL 05 75 RCL 02 76 * 77 - 78 RCL 09 79 RCL 05 80 - 81 X=0? 82 / 83 30 84 / 85 FIX 2 86 "VMAX" 87♦LBL 10 88 "T=" 89 ARCL X 90 AVIEW 91 RTN 92♦LBL "WOR K" 93♦LBL B 94 FIX 2 95 CF 01 96 CF 22 97 SF 21 98 SF 27	Display MAX dP/dt Display MAX dP/dt/P Calc V <sub>max</sub> Display VMAX Display Routine WORK Initialization

# Program Listings

99 SF 29		149 /	
100 0		150 "SW INDE	Display stroke
101 STO 00		X"	work index
102♦LBL 02	Input P <sub>syst</sub>	151 GTO 10	Recall stored
103 "PSYST"	Data input?	152♦LBL 09	data
104 "T=?"	No	153 "T="	
105 PROMPT		154 ARCL X	
106 FC?C 22	1st input	155 "T?"	
107 GTO 04	No	156 PROMPT	
108 ISG 00		157 END	
109♦LBL 11	Initial input	..	
110 FS? 01			
111 GTO 03			
112 STO 01			
113 SF 01			
114 GTO 02			
115♦LBL 03			
116 ST+ 01			
117 GTO 02			
118♦LBL 04			
119 CF 01		70	
120 RCL 00			
121 ST/ 01	AVE P		
122 RCL 01			
123 "AVE P"			
124 XEQ 10	Display AVE P		
125 "R-R=?"	Input R-R Int.		
126 PROMPT			
127 STO 10			
128 RCL 08			
129 "CO"	Recall CO	80	
130 XEQ 09			
131 STO 08	Calc stroke work		
132 RCL 10			
133 *			
134 60			
135 /			
136 RCL 01			
137 *			
138 13.6			
139 *		90	
140 STO 09	Display stroke		
141 "STROKE	work		
WORK"			
142 XEQ 10	Recall BSA		
143 RCL 07			
144 "BSA"			
145 XEQ 09			
146 STO 07			
147 RCL 09			
148 X<>Y		00	

## REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS				STATUS			
00		50		SIZE	012	TOT. REG.	57
	Pn / $\Sigma P, \bar{P}$			ENG		FIX	2
	dP/dt/P			DEG		SCI	
	MAXdP/dt					RAD	GRAD
	MAX dP/dt/P			FLAGS			
05	Pn	55		#	INIT S/C	SET INDICATES	CLEAR INDICATES
	$\Delta t$			01	C	Input $P_2$ to Pn	First input
	BSA			21	S	Print display	Pause only
	CO			22	C	Digit entry	No digit entry
	Pp/SW			27	S	User mode	Reg. mode
10	USED/R-R	60		29	C	Radix	No Radix
15		65					
20		70					
25		75					
30		80					
35		85					
ASSIGNMENTS				FUNCTION	KEY	FUNCTION	K:Y
40		90					
45		95					

**NOTES**

**NOTES**

## CARDIAC/PULMONARY

PULMONARY FUNCTIONS/VITAL CAPACITY  
LUNG DIFFUSION AND ARTERIAL CO<sub>2</sub> NORMALIZATION  
VENTILATOR SETUP AND CORRECTIONS (RADFORD)  
BLOOD CHEMISTRY I  
BLOOD CHEMISTRY II  
BODY SURFACE AREA FOR CARDIO PULMONARY PROGRAMS  
CARDIAC OUTPUTS  
VALVE AREA  
CARDIAC SHUNTS  
CONTRACTILITY AND STROKE WORK

HEWLETT  PACKARD

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