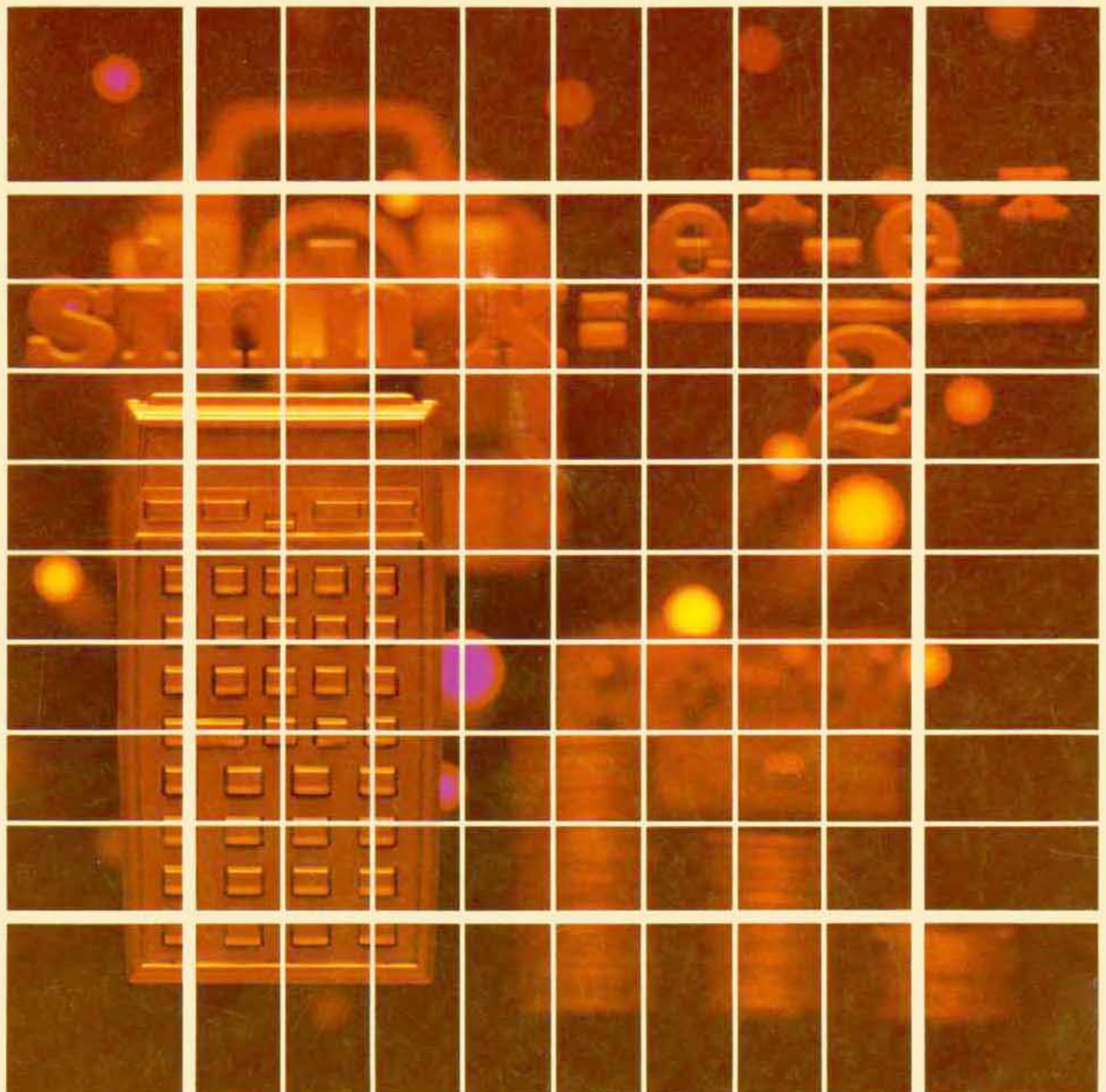


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HP-41C

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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 † character in the program listing is an indication of the **APPEND** function. When you see †, 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

```

01♦LBL "SAM
PLE"
02 "THIS IS
A "
03 "†SAMPLE
"
04 AVIEW
05 6
06 ENTER†
07 -2
08 /
09 ABS
10 STO IND
L
11 "R3="
12 ARCL 03
13 AVIEW
14 RTN

```

Keystrokes

```

■ LBL ALPHA SAMPLE ALPHA
ALPHA THIS IS A ALPHA
ALPHA ■ APPEND SAMPLE
■ AVIEW ALPHA
6
ENTER+
2 CHS
÷
XEQ ALPHA ABS ALPHA
STO ■ L
ALPHA R3= ■ ARCL 03
■ AVIEW
ALPHA
■ RTN

```

Display

```

01 LBLT SAMPLE
02T THIS IS A
03T † SAMPLE
04 AVIEW
05 6
06 ENTER /
07 -2
08 /
09 ABS
10 STO IND L
11T R3=
12 ARCL 03
13 AVIEW
14 RTN

```


TABLE OF CONTENTS

1.	PULMONARY FUNCTIONS/VITAL CAPACITY	1
	This program calculates normal values and percent of predicted values for the results of spirometry tests. (Note: This program requires one memory module.)	
2.	LUNG DIFFUSION AND ARTERIAL CO ₂ NORMALIZATION	9
	Calculates lung diffusion capacity from the carbon monoxide diffusion test and necessary additional dead space to compensate for a hypocapnic ventilator patient.	
3.	VENTILATOR SETUP AND CORRECTIONS (RADFORD)	17
	Initial tidal volume is calculated (according to the Radford Nomogram) and corrected for dead space volume, activity, body temperature, altitude, use of a tracheotomy tube or metabolic acidosis.	
4.	BLOOD CHEMISTRY I	23
	Calculates total plasma CO ₂ and base excess from PCO ₂ , pH and hemoglobin and calculates virtual O ₂ tension and % O ₂ saturation from the hemoglobin dissociation curve.	
5.	BLOOD CHEMISTRY II	32
	Corrects PCO ₂ and pH for anaerobic temperature change and corrects PO ₂ , at 37°C, to body temperature.	
6.	BODY SURFACE AREA FOR CARDIO PULMONARY PROGRAMS	37
	This program calculates body surface area by either the Du Bois or Boyd methods. In addition it calculates cardiac index if cardiac output is known.	
7.	CARDIAC OUTPUTS	42
	Calculates outputs from measurements during a dye dilution, cardiac output maneuver or by the Fick method, given arterial and venous blood O ₂ content.	
8.	VALVE AREA	50
	This program calculates the areas of heart valves across which the pressure gradient has been measured.	
9.	CARDIAC SHUNTS	55
	Calculates anatomic and/or physiologic shunts. Also calculates Fick cardiac output.	

10. CONTRACTILITY AND STROKE WORK 63

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.
 FEV₁ = 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_{25%-75%}) in liters/sec.

MALE

VC = (.058·Ht) - (.025·age) - 4.24
 FEV₁ = (.036·Ht) - (.032·age) - 1.26
 MEFR = (.043·Ht) - (.047·age) + 2.07
 MVV = (.9·Ht) - (1.51·age) + 27
 RV = (.03·Ht) + (.015·age) - 3.75
 TLC = (.094·Ht) - (.015·age) - 9.17
 FRC = (.051·Ht) - 5.05
 FEF = (.02·Ht) - (.04·age) + 2

FEMALE

VC = (.045·Ht) - (.024·age) - 2.852
 FEV₁ = (.035·Ht) - (.025·age) - 1.932
 MEFR = (.057·Ht) - (.036·age) - 2.532
 MVV = (.762·Ht) - (.81·age) - 6.29
 RV = (.024·Ht) + (.012·age) - 2.63
 TCL* = (.078·Ht) - (.01·age) - 7.36
 FRC = (.047·Ht) - 4.86
 FEF = (.02·Ht) - (.03·age) - (.00006·age²) + 1.3

where Ht is in cm and age in years.

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

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

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

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

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
 MEF=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

3

				SIZE: 008
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Begin program execution.		[XEQ] VITCAP	M/F?
3	Input M for make, 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 _{meas})	[XEQ] VC	
			or [A]	VC=
	Predicted FEV ₁	(FEV _{meas})	[XEQ] FEV1	
			or [B]	FEV1=
	Predicted MEFR	(MEFR _{meas})	[XEQ] MEFR	
			or [C]	MEFR=
	Predicted MVV	(MVV _{meas})	[XEQ] MVV	
			or [D]	MVV=
	Predicted RV	(RV _{meas})	[XEQ] RV	
			or [E]	RV=
	Predicted TLC	(TLC _{meas})	[XEQ] TLC	
			or [F]	TLV=
	Predicted FRC	(FRC _{meas})	[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 _{meas})	[XEQ] FEF	
			or [H]	FEF=
	*This [R/S] not needed if calculator is used with printer.			

[illegible]

Program Listings

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

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	----- Calculate LC
118 *		"	
119 "% PRED"		168 "TLC"	
120♦LBL 10	----- Output subroutine	169 FS? 00	
121 "F="		170 GTO 00	
122 ARCL %		171 .094	
123 AVIEW		172 STO 05	
124 RTN	----- Calculate MVV	173 .015	
125♦LBL D		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	----- Calculate FR
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	----- Calculate RV	194 STO 06	
146♦LBL E		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	
205 4.86		254 GTO 07	Calc. % predicted
206 STO 07		255♦LBL 09	FEF Calc.
207 GTO 01		256 FC? 00	Male?
208♦LBL H		257 RTN	Yes, RTN.
209♦LBL "FEF	Calculate FEF	258 6 E-5	Female, alternate
"		259 RCL 01	calculation.
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 /			
232 "25% VC"	Output 25% VC		
233 XEQ 10			
234 "T25%=?"	Input time at		
235 PROMPT	25% VC	90	
236 STO 03			
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	

10

LUNG DIFFUSION AND ARTERIAL CO₂ 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_ICO) is assumed to be 0.3%. If a different standard value for F_ICO is desired, it may be entered.

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

Arterial CO₂ Normalization: This portion of the program calculates the additional dead space (DS_{add}) needed in a hypocapnic ventilator patient's breathing circuit to raise the arterial CO₂ partial pressure (P_aCO₂) to 40 millimeters of mercury (mmHg).

Equations used:

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

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

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

where DS_p = dead space.

Detailed Instructions for Arterial CO₂ Normalization calculation:

Input the patient's weight in kilograms, or in pounds followed by [CHS]. Then input the P_aCO₂ in mmHg. If the patient's lung status is abnormal answer the question LUNG NORMAL? by inputting N and then inputting P_ECO₂ (the mixed expired CO₂ partial pressure). If lung condition is normal answer Y (P_ECO₂ 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_aCO₂ 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 CO₂ 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 CO₂ Normalization

Example:

Calculate the additional dead space required by a 50 kilogram patient with a PaCO₂ 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 ₂ 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 _I CO	[R/S]	FICAR=?
	Otherwise, press [R/S] <i>without data entry</i> .		[R/S]	FICAR=?
4	Input initial concentration of carrier and alveolar carrier concentration.	F _I 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 ₂ 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 ₂ =?
8	Input the arterial CO ₂ partial pressure.	PaCO ₂	[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 ₂ (mixed expired CO ₂ partial pressure).	N	[R/S]	PeCO ₂ =?
		PeCO ₂	[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=

[illegible]

Program Listings

01♦LBL "DLC 0"	DLCO Calc	45 PROMPT	X + or -
02♦LBL A	Initialization	46 X>0?	+
03 FIX 2		47 GTO 00	-
04 SF 21		48 CHS	Convert to kg
05 SF 27		49 2.205	
06 .3		50 /	
07 "FICO=.3 ?"	Is $F_{ICO}=.3\%$?	51♦LBL 00	
08 PROMPT	Input other F_{ICO}	52 STO 06	Sto wt in kg
09 STO 00		53 "PaCO2=? "	Input PaCO ₂
10 "FICAR=? "	Input $F_{I CAR}$	54 PROMPT	
11 PROMPT	&	55 STO 01	Calc. normal
12 STO 01		56 5	PeCO ₂ & store
13 "FACAR=? "	$F_A CAR$	57 -	
14 PROMPT	&	58 STO 08	
15 STO 02	$F_A CO$	59 "Y"	
16 "FACO=?"		60 ASTO Y	LUNG NORMAL?
17 PROMPT	&	61 "LUNG NO RMAL?"	
18 STO 03		62 AON	
19 "BHT=?"	Breath hold-time	63 PROMPT	
20 PROMPT	&	64 AOFF	
21 STO 08		65 ASTO X	Yes or no
22 "VA=?"	Alveolar volume	66 X=Y?	Yes, normal
23 PROMPT		67 GTO 01	No, input PeCO ₂
24 .084		68 "PeCO2=? "	
25 *		69 PROMPT	
26 X<>Y	Calculate DLCO	70 STO 08	Input tidal vol
27 /		71♦LBL 01	
28 RCL 02		72 "TV=?"	
29 RCL 01		73 PROMPT	&
30 /		74 STO 07	Present dead
31 RCL 00		75 "DSP=?"	space
32 RCL 03		76 PROMPT	
33 /		77 RCL 06	
34 *		78 1.47	Calculate
35 LN		79 *	
36 *		80 +	additional
37 "DLCO"	Display DLCO	81 RCL 07	
38 GTO 10	CO ₂ normalization	82 X<>Y	dead space
39♦LBL "NOR M"		83 -	
40♦LBL B	Initialization	84 40	
41 FIX 2		85 RCL 01	
42 SF 21		86 RCL 08	
43 SF 27		87 -	
44 "WT=?"	Input weight	88 -	
		89 /	
		90 40	
		91 RCL 01	

Program Listings

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

[illegible]

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:

$$\begin{aligned}
 V_A &= \text{Alveolar minute volume} = 10^{(C_1 \text{LOG WT} + C_2)/100} \text{ ml/min} \\
 TV_A &= \text{Alveolar tidal volume} = \frac{V_A}{r} \text{ ml} \\
 TV_{\text{bas}} &= \text{Basal tidal volume} = (V_{TA} + \text{Wt (lbs)}) \text{ ml} \\
 TV_{\text{corr}} &= \text{Basal tidal volume} + \text{ventilator dead space}
 \end{aligned}$$

where:

r = Breathing rate (breaths per minute)

For Females:

$$\begin{aligned}
 &124; \text{Wt} \leq 8\text{kg} \\
 C_1 = &61; 8\text{kg} < \text{Wt} \leq 23\text{kg} \\
 &44.2; \text{Wt} > 23\text{kg} \\
 &193; \text{Wt} \leq 8\text{kg} \\
 C_2 = &249; 8\text{kg} < \text{Wt} \leq 23\text{kg} \\
 &272; \text{Wt} > 23\text{kg}
 \end{aligned}$$

Corrections:

Temperature: +5% per °F above 99° (rectal)
 Altitude: +5% per 2000' above sea level
 Activity: +10%
 Tracheotomy: $-\frac{1}{2}$ body weight in pounds
 Metabolic acidosis in anesthesia: +20%

For Males:

$$\begin{aligned}
 &124; \text{Wt} \leq 8\text{kg} \\
 C_1 = &61; \text{Wt} > 8\text{kg} \\
 &193; \text{Wt} \leq 8\text{kg} \\
 C_2 = &249; \text{Wt} > 8\text{kg}
 \end{aligned}$$

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:

[XEQ] [ALPHA] SIZE [ALPHA] 009

[XEQ] [ALPHA] VENT [ALPHA]

170 [CHS] [R/S]

M [R/S]

15 [R/S]

[R/S]

25 [R/S]

[R/S]

101 [CHS] [R/S]

[R/S]

500 [CHS] [R/S]

[XEQ] [ALPHA] METACID [ALPHA]

Display:

WT=?

M/F?

BR=?

BASAL TV=461.74

DSV=?

DSV CORR TV=486.74

BT=?

TEMP CORR TV=535.42

ALT=?

ALT CORR TV=542.11

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,	Kg	[R/S]	
	in pounds.	lb	[CHS] [R/S]	M/F ?
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		[R/S]*	DSV=?
	dead space corrected tidal volume.	DS _v ,ml	[R/S]	DSV CORR TV=
6	To correct for temperature:		[R/S]*	BT=?
	Input patient temperature in °C	°C	[R/S]	
	(or °F [CHS]).	°F	[CHS] [R/S]	TEMP CORR TV=
7	To correct for altitude: Input the		[R/S]*	ALT=?
	altitude in meters	m	[R/S]	
	(or, in feet).	ft	[CHS] [R/S]	ALT CORR TV=
	The following steps are optional:			
8	To correct for minor daytime activity		[XEQ] ACTIVE	
	(noncomatose patient).		or [B]	ACTIVITY CORR TV=
9	To correct for use of a tracheotomy tube		[XEQ] TRACH	
			or [C]	TRACH CORR TV=
10	To correct for metabolic acidosis during		[XEQ] METACID	
	anesthesia		or [D]	ACIDOSIS CORR TV=
11	For a new case, press [A] and go to step 2.		[A]	WT = ?
	*This [R/S] not needed if calculator is used with printer.			

Program Listings

01♦LBL "VENT"	Ventilator corr.	50 44.2	Common male/female calc.
02 FIX 2	Initialize	51♦LBL 04	
03 SF 21		52 RCL 06	
04 SF 27		53 LOG	
05♦LBL A	Input wt.	54 *	
06 "WT=?"		55 +	
07 PROMPT		56 E2	
08 X>0?		57 /	
09 GTO 00	Convert to kg	58 10↑X	
10 -2.205		59 RCL 08	
11 /		60 /	
12♦LBL 00	STO wt	61 RCL 06	
13 STO 06		62 2.205	
14 "M"	Male or female?	63 *	Output basal
15 ASTO Y		64 +	
16 "M/F?"		65 STO 01	
17 CF 01		66 "BASAL"	Input dead space
18 AON		67 XEQ 10	
19 PROMPT		68 "DSV=?"	
20 AOFF		69 PROMPT	
21 ASTO X	X="M"?	70 ST+ 01	
22 X=Y?	Yes, male	71 RCL 01	Output DSV corr.
23 SF 01		72 "DSV"	Input body temp.
24 "BR=?"	Input breathing rate	73 XEQ 07	
25 PROMPT	Female?	74 "BT=?"	
26 STO 08	Yes, GTO female calc.	75 PROMPT	
27 FC?C 01	Male calc.	76 X<0?	Convert to °F
28 GTO 01		77 GTO 01	
29♦LBL 05		78 1.8	
30 8		79 *	
31 RCL 06		80 32	
32 X<=Y?		81 +	
33 GTO 03	Input constants	82 CHS	
34 249		83♦LBL 01	BT-99°
35 ENTER↑		84 CHS	
36 61		85 99	
37 GTO 04		86 -	No corr. if BT≤99°F
38♦LBL 03		87 X<=0?	Correct for BT>99°F
39 193		88 GTO 02	
40 ENTER↑		89 .05	
41 124		90 *	
42 GTO 04		91 RCL 01	
43♦LBL 01	Female constants	92 *	Output temp.
44 23		93 ST+ 01	
45 RCL 06		94♦LBL 02	
46 X<=Y?		95 RCL 01	
47 GTO 05		96 "TEMP"	Input altitude
48 272		97 XEQ 07	
49 ENTER↑		98 "ALT=?"	
		99 PROMPT	

Program Listings

100 X<0?		145♦LBL 10	Output routing
101 GTO 02	Convert to feet	146 "F TV="	
102 -3.28		147 ARCL X	
103 *		148 AVIEW	
104♦LBL 02	Altitude corr.	149 END	
105 CHS			
106 2 E3			
107 /			
108 RCL 01			
109 *		60	
110 .05			
111 *			
112 ST+ 01			
113 RCL 01			
114 "ALT"			
115 GTO 07	Output ALT corr.		
116♦LBL "ACT	TV		
IVE"	Activity correc.		
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 acido-		
ACID"	sis corr.	90	
136♦LBL D			
137 RCL 01			
138 .2			
139 *			
140 ST+ 01			
141 RCL 01			
142 "ACIDOSI			
S"			
143♦LBL 07			
144 "F CORR"	Output corr. TV	00	

BLOOD CHEMISTRY I

BLOOD ACID - BASE STATUS

VIRTUAL PO₂ AND O₂ SATURATION AND CONTENT

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

Blood-Acid Base Status

This program computes total plasma CO₂ and base excess from PCO₂, pH and hemoglobin concentration.

Equations:

Total plasma CO₂ is calculated from the Henderson-Hasselbalch equation:

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

where

TCO₂ = total CO₂ in plasma, mmol/l

s = solubility of CO₂ in plasma, mmol/l (taken to be 0.0307)

PCO₂ = partial pressure of CO₂ 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 TCO₂ will be most accurate if 37° C values for PCO₂ 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]_b = Base Excess in meq/l of blood

Hgb = Hemoglobin concentration in g/100 ml

and plasma [HCO₃] 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 PCO₂ 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 PCO₂ 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]_b, to within ± 1 meq/l in most cases.

VIRTUAL PO₂ AND O₂ SATURATION CONTENT:

The first part of this program computes virtual PO₂ for use in estimating O₂ 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:

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

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 O₂ saturation of blood from virtual PO₂ and computes O₂ content. If the actual O₂ saturation is known, O₂ content may be computed directly.

EQUATIONS:

The part of the program for estimating O₂ saturation is based on the polynomial curve fit of Thomas, where VPO₂ 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 O₂ content is computed from:

$$C_{xO_2} (\text{Vol.}\%) = 1.34 \cdot \frac{\text{SAT}(\%)}{100} \cdot \text{Hgb} (\text{g}/100\text{ml}) + 0.0031 PO_2 (\text{mmHg})$$

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 $37^\circ C$. 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 CO_2 , base excess, and plasma $[\text{HCO}_3^-]$. Also calculate virtual PO_2 and estimated O_2 saturation and content. Store the value as venous O_2 content.

$\text{PO}_2 = 75 \text{ mmHg}$	$\text{BT} = 40^\circ\text{C}$
$\text{PCO}_2 = 45 \text{ mmHg}$	$\text{Hgb} = 16 \text{ g/100ml}$
$\text{pH} = 7.35$	

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?
VPO2=59.70
%SAT=90.92
%SAT=90.92
HGB=16.00?
O2 CONT=19.68
19.68      (stored as venous)
```

Example 2:

Assuming that VPO_2 is actually 75 mmHg, calculate the estimated O_2 saturation and 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 ₂ and O ₂ 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] <i>without data entry</i> . 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)
			[R/S]	HCO3- =mmol/l
	VIRTUAL PO ₂ and O ₂ SATURATION AND CONTENT:			
4	Begin the program.		[XEQ] PO2	PO2=()?
	Values for the following variables are recalled. If correct, press [R/S] <i>without prior data entry</i> . 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

				SIZE :
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]	%SAT	[R/S]	HGB=()?
	if displayed figure is correct. Previously			
	stored hemoglobin is displayed.			
6b	Input correct hemoglobin, or press [R/S]	Hgb (gm/100ml)	[R/S]	O2 CONT=(%)
	if displayed hemoglobin is correct. Oxygen			
	content is calculated.			
7	Store oxygen content:			
	As arterial (CaO ₂) or,		[E]	(O ₂ cont.)
	As venous (CvO ₂)		[///]	(O ₂ cont.)
8	To calculate a different Blood Acid-base		[A]	PCO ₂ =()?
	status, press [A] and go to step 2.			
9	To calculate another virtual PO ₂ press,		[B]	PO ₂ =()?
	[B] and go to step 4.			
10	To calculate another % saturation input			
	correct virtual PO ₂	VP0 ₂ (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"		49 FIX 2	
02 FIX 2	Initialize	50 SF 21	
03 SF 21	Blood-Acid base	51 SF 27	
04 SF 27		52♦LBL B	RCL PO ₂
05♦LBL A	RCL PCO ₂	53 XEQ 01	RCL PCO ₂
06 XEQ 02	RCL pH	54 XEQ 02	RCL pH
07 XEQ 03	RCL HGB	55 XEQ 03	
08 XEQ 04		56 RCL 11	RCL BT
09 RCL 06	Calc. total	57 "BT"	
10 6.11	plasma CO ₂	58 XEQ 09	
11 -		59 STO 11	Calc. VPO ₂
12 10↑X		60 37	
13 RCL 05		61 X<>Y	
14 32.57		62 -	
15 /		63 .024	
16 *		64 *	
17 STO 02		65 RCL 06	
18 LASTX		66 7.4	
19 +	Display TCO ₂	67 -	
20 "TCO2"	Calc. base excess	68 .48	
21 XEQ 10		69 *	
22 RCL 09		70 +	
23 1.63		71 40	
24 *		72 RCL 05	
25 9.5		73 /	
26 +		74 LOG	
27 RCL 06		75 .06	
28 7.4		76 *	
29 -		77 +	
30 *		78 10↑X	
31 RCL 02		79 RCL 10	
32 +		80 *	
33 24		81 STO 01	Display VPO ₂
34 -		82 "VPO2"	Calc. % SAT
35 1		83 XEQ 10	
36 RCL 09		84♦LBL C	
37 70		85 STO 01	
38 /		86 ENTER↑	
39 -		87 ENTER↑	
40 *		88 ENTER↑	
41 "BE"	Display B E	89 15	
42 XEQ 10	Printer?	90 -	
43 FS? 55	Yes	91 *	
44 STOP		92 2045	
45 RCL 02	RCL HCO ₃ ⁻	93 +	
46 "HCO3-"	Display HCO ₃ ²	94 *	
47 GTO 10	Initialize	95 2 E3	
48♦LBL "PO2"	VPO ₂ & O ₂ SAT	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 ₂
110 +		160 RCL 10	
111 1 E2		161 "PO2"	
112 /		162 XEQ 09	
113 ST/ 08	Display % SAT	163 STO 10	
114 RCL 08		164 RTN	
115 "% SAT"	Calc. O ₂ content	165♦LBL 10	Display routine
116 GTO 10		166 "I="	
117♦LBL D		167 ARCL X	
118 RCL 08	RCL % SAT	168 AVIEW	
119 "% SAT"		169 RTN	
120 XEQ 09		170♦LBL 09	RCL routine
121 STO 08		171 "I="	
122 XEQ 04		172 ARCL X	
123 RCL 08		173 "I?"	
124 *		174 PROMPT	
125 134		175 END	
126 *			
127 RCL 01			
128 31			
129 *			
130 +			
131 1 E4			
132 /			
133 "O2 CONT			
"			
134 GTO 10	Display O ₂ cont.		
135♦LBL E			
136 STO 04	Store as C _A O ₂		
137 RTN			
138♦LBL e	Store as C _V O ₂		
139 STO 03			
140 RTN			
141♦LBL 02	RCL PCO ₂		
142 RCL 05			
143 "PCO2"			
144 XEQ 09			
145 STO 05			
146 RTN			
147♦LBL 03	RCL pH		
148 RCL 06			
149 "PH"			
150 XEQ 09			

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

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

BLOOD CHEMISTRY II

ANAEROBIC PCO₂ AND pH CHANGE AND ANAEROBIC PO₂ CHANGE

Corrections of PCO₂ and pH for anaerobic temperature change are calculated by this program. In addition, PO₂ measured at 37°C is corrected to body temperature.

Anaerobic PCO₂ and pH Change:

Corrections of PCO₂ 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 PO₂ Change:

This program corrects PO₂, measured at 37°C, to Body Temperature.

Equation Used: Correction of PO₂ for anaerobic temperature change is calculated taking into account the exchange of oxygen between HgbO₂ 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:

PO₂(BT) replaces the 37°C value in memory with the body temperature value. Therefore, calculation based on the 37°C values in programs for virtual PO₂ and O₂ saturation & content should be accomplished before this program is run. If O₂ saturation has not been measured, it should be estimated by using program for "Virtual PO₂ and O₂ Saturation and Content."

This program may also be used to convert PO₂ between any two temperatures, for example, from body temperature to 37°C. To do this, first determine what the desired temperature change is in °C. Add this to 37°C algebraically, and enter the result as BT. For example, suppose values known at 41°C are to be converted to 37°C. The temperature change is -4°C. Add this to 37°C, resulting 33°C. Executing the program with BT=33°C will then result in the 37°C value for PO₂.

Example:

For a patient with PCO₂ of 45mmHg and a pH of 7.35 at 40°C, calculate corrected values for PCO₂ and pH. If the patient's PO₂ is 75mmHg and % saturation is 90, what is the corrected PO₂?

Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 012

[XEQ] [ALPHA] ANRB [ALPHA]

[A]

45 [R/S]

7.35 [R/S]

40 [R/S]

[R/S]

[B]

90 [R/S]

75 [R/S]

[R/S]

Display:

0.00

PCO2=0.00?

PCO2=0.00?

PH=0.00?

BT=0.00?

PCO2 CORR.=51.31

PH CORR.=7.31

% SAT=0.00?

PO2=0.00?

BT=40.00?

PO2 CORR.=92.31

User Instructions

				SIZE: 012
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program and begin execution.		[XEQ] ANRB	PCO2=()?
2	For anaerobic PCO ₂ and pH change go to step 3. For anaerobic PO ₂ go to step 5.			
	ANAEROBIC PCO ₂ AND pH CHANGE:			
3	Input correct PCO ₂ or press [R/S] if displayed PCO ₂ is correct.	PCO ₂ (mmHg)	[R/S]	PH=()?
3a	Input correct pH or press [R/S] if displayed pH is correct.	pH	[R/S]	BT=()?
3b	Input correct body temperature or press [R/S] if displayed body temperature is correct. Anaerobic PCO ₂ is calculated.	BT(°C)	[R/S]	PCO2 CORR.=
4	Calculate pH (BT).		[R/S]	PH CORR.=
	ANAEROBIC PO ₂ :			
5	Recall % saturation if stored.		[B]	%SAT=()?
5a	Input correct % saturation or press [R/S] if displayed value is correct.	%SAT	[R/S]	PO2=()?
5b	Input correct PO ₂ or press [R/S] if displayed PO ₂ is correct.	PO ₂ (mmHg)	[R/S]	BT=()?
5c	Input correct body temperature or press [R/S] if displayed value is correct.	BT(°C)	[R/S]	PO2 CORR. (mmHg)
6	For a new PCO ₂ or pH press [A] and go to step 3. For a new PO ₂ go to step 5.			

Program Listings

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

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

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

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

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 ℓ/min .

NOTE: The DuBois formula for BSA is undefined for children with a BSA less than $0.6 m^2$. 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

[illegible]

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=?"	Input HT	55 .0188	
07 PROMPT	Metric?	56 *	
08 X>0?	Yes	57 .7285	
09 GTO 01	No, convert to cm	58 -	
10 CHS		59 Y↑X	
11 2.54		60 /	
12 *		61 3118	
13♦LBL 01	STO HT	62 /	
14 STO 05	Input WT	63 STO 07	STO Boyd BSA
15 "WT=?"		64 "BOYD BS	
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 C0
20 2.205		68 "C0"	
21 /		69 XEQ 09	
22♦LBL 02	STO WT	70 STO 08	STO new C0
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	Display routine
27 "H-A"		75 "H="	
28 AOFF		76 ARCL X	
29 ASTO X		77 AVIEW	
30 GTO IND	Go to calc.	78 RTN	
X	routine	79♦LBL 09	Recall stored C0
31♦LBL D		80 "H="	
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	

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

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

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.

$$\text{Equations Used: } CO(\ell/\text{min}) = \frac{VO_2 (\text{ml}/\text{min STPD}) \cdot 100(\%)}{(C_aO_2 - C_vO_2)(\text{vol.}\%) \cdot 1000(\text{ml}/\ell)}$$

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

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

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

Detailed Instructions for Fick Output:

If the Virtual PO_2 and O_2 Saturation and Content has just been run either or both CaO_2 and C_vO_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 VO_2 is in ml/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:

$CaO_2 = 18 \text{ vol.}\%$
 $CvO_2 = 15 \text{ vol.}\%$
 $VO_2 = 250 \text{ ml/min.STPD}$
 $BSA = 2\text{m}^2$
 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:

CaO2=()?
 CvO2=()?
 VO2=()?
 CO=8.33
 BSA=()?
 CI=4.17
 HEART BPM=?
 SV=138.83
 SI=69.42

User Instructions

45

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 $DC \leq 45\%$ of peak, area is calculated.			AREA=
6	Input calibration.		[R/S]*	CAL=?
		CAL (mg/(l 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	CaO2=()?
9	Stored CaO ₂ is displayed. Input correct			
	CaO ₂ or, if correct, press [R/S].	CaO ₂	[R/S]	CV02=()?
10	Stored C _v O ₂ is displayed. Input correct			
	C _v O ₂ or, if correct, press [R/S].	C _v O ₂	[R/S]	VO2=()?
11	Stored VO ₂ is displayed. Input correct			
	VO ₂ or, if correct, press [R/S]. Fick			
	Cardiac Output is calculated and displayed.	VO ₂	[R/S]	CO=
12	Recall stored BSA. Input correct BSA or,		[R/S]*	BSA=()?
	if correct, press [R/S]. Cardiac index	BSA	[R/S]	CI=
	is calculated and displayed.		[R/S]*	HEART BPM=?
	*This [R/S] not necessary if calculator is used with printer.			

[illegible]

Program Listings

01♦LBL "DYE "	Dye Curve C0	51 .45	Do 45% test
02♦LBL A		52 *	
03 FIX 2	Initialization	53 X<=Y?	If not past 45%
04 CF 01		54 GTO 08	Display negative
05 SF 21		55 RDN	count else
06 SF 27		56 STO 02	calculate
07 CLX		57 RCL 04	exponential area
08 STO 00		58 RCL 00	
09 STO 01		59 -	
10 STO 02		60 RCL 03	
11 "TIME=?"	Input time int.	61 RCL 02	
12 PROMPT		62 /	
13 STO 10		63 LN	
14♦LBL 00	Input dye curve	64 /	
15 "DC=?"	values	65 .5	
16 PROMPT	Count entries	66 -	
17 DSE 00		67 *	
18♦LBL 11		68 RCL 01	
19 ST+ 01	Integrate	69 +	
20 RCL 02	New Peak?	70 RCL 10	
21 X>Y?	No	71 *	
22 GTO 01	Yes	72 CF 01	
23 X<>Y		73 STO 02	
24 STO 02		74 "AREA"	Display area
25 X<>Y		75 XEQ 10	
26 CF 01	Clear 65% flag	76 "CAL=?"	Input calibration
27♦LBL 01		77 PROMPT	
28 FS? 01		78 ST* 02	
29 GTO 02		79 "DOSE=?"	Input dose
30 .65		80 PROMPT	
31 *		81 RCL 02	Calculate C0
32 X>Y?	If past 65% GTO	82 /	
33 GTO 03	03 else display	83 60	
34 RCL 00	count	84 *	
35 CHS		85 RND	
36 PSE		86♦LBL 05	
37 GTO 00	Do 65% test	87 STO 08	Store and display
38♦LBL 03		88 "C0"	C0
39 X<>Y		89♦LBL 10	
40 STO 03		90 "F="	Display routine
41 RCL 00		91 ARCL X	
42 STO 04		92 AVIEW	
43 SF 01		93 RTN	
44 PSE		94♦LBL "FIC	
45 GTO 00		K"	Fick C0
46♦LBL 08	Display negative	95♦LBL F	
47 RCL 00	count	96 FIX 2	Initialize
48 PSE		97 SF 21	
49 GTO 00		98 SF 27	
50♦LBL 02		99 RCL 04	
		100 "CaO2"	RCL CaO ₂

Program Listings

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

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, (ΔP), 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 ΔP values will be displayed ($\overline{\Delta P}$). 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 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

[illegible]

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 C0
09 ASTO Y		55 "C0="	
10 "MITRAL?"	Mitral valve?	56 ARCL X	
"		57 "I?"	
11 AON		58 PROMPT	
12 PROMPT		59 STO 08	STO C0
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	Input ΔP	69 GT0 03	No
IFF=?"		70 .7	Mitral factor
23 PROMPT		71 /	
24 FC?C 22		72 "MITRAL	
25 GT0 02		"	
26 FS? 01		73♦LBL 03	
27 GT0 01		74 "I-VALVE	
28 STO 01	STO ΔP ₁	AREA"	
29 SF 01		75♦LBL 10	
30 1	STO M=1	76 "I="	
31 STO 00		77 ARCL X	Display routine
32 PSE		78 AVIEW	
33 GT0 00		79 END	
34♦LBL 01	ΔP ₂ - ΔP _n		
35 ST+ 01			
36 ISG 00			
37♦LBL 15			
38 RCL 00	Display n	90	
39 PSE			
40 GT0 00			
41♦LBL 02			
42 RCL 00			
43 ST/ 01	ΔP		
44 RCL 01			
45 "AVE PRE			
SS DIFF"			
46 XEQ 10	Display ΔP	00	

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:

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

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

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:

$$\text{Phys. Shunt} = \frac{C_{A\text{O}_2} - C_{a\text{O}_2}}{C_{A\text{O}_2} - C_{v\text{O}_2}}$$

$$\text{CO (l/min)} = \frac{\text{VO}_2 \text{ (ml/min STPD)} \cdot 100 (\%)}{(C_{a\text{O}_2} - C_{v\text{O}_2} \text{ (vol.\%)}) \cdot 1000 \text{ (ml/l)}}$$

These are the standard physiologic shunt and Fick cardiac output equations. If measured O₂ saturations are used, these equations will be accurate.

If the content values have been derived from saturation estimates on PO_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 CAO_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:

CAO_2 =()?

CaO_2 =()?

CVO_2 =()?

PHYS SHUNT=40.00

VO_2 =()?

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	[R/S]	CV02=?
		C_vO_2 or no input	[R/S]	PHYS SHUNT=
	Physiologic shunt is calculated.			
	<u>Fick Cardiac Output (Optional)</u>			
4	To calculate Fick Cardiac Output (if oxygen			

[illegible]

Program Listings

01♦LBL "ANATOM"	Anatomic shunts	47 XEQ 10	Yes, display shunt
02♦LBL A		48♦LBL 04	Toggle for
03 FIX 2		49 FS? 55	
04 SF 21	Initialize	50 STOP	
05 SF 27		51 GTO 00	
06 SF 01		52♦LBL 01	Display: no shunt
07 "R-SYST=?"		53 "F: NO S HUNT"	
08 PROMPT		54 AVIEW	
09 STO 00		55 FS? 01	Go to toggle
10 "R-PUL=?"	Input right and left pulmonary and systemic O_2 concentrations	56 GTO 04	
11 PROMPT		57 RTN	Display shunt
12 STO 02		58♦LBL 10	
13 "L-PUL=?"		59 "F SHUNT ="	
14 PROMPT		60 ARCL X	
15 STO 05		61 AVIEW	Go to toggle
16 "L-SYST=?"		62 FS? 01	
17 PROMPT		63 GTO 04	
18 STO 06		64 RTN	
19 SF 00		65♦LBL "PHYS"	Calc. physiological shunt
20♦LBL 00	Toggle for L-R to R-L calc.	66♦LBL C	
21 FS?C 00		67 FIX 2	Initialize
22 GTO 02		68 SF 21	
23 SF 00		69 SF 27	
24 RCL 05	Calc. R-L shunt	70 CF 01	
25 RCL 06		71 RCL 01	RCL $C_{A}O_2$
26 -		72 "CAO2"	STO $C_{A}O_2$
27 RCL 05		73 XEQ 09	RCL $C_{a}O_2$
28 RCL 00		74 STO 01	STO $C_{a}O_2$
29 -		75 RCL 04	RCL $C_{a}O_2$
30 /		76 "CaO2"	STO $C_{a}O_2$
31 "R-L"		77 XEQ 09	RCL $C_{V}O_2$
32 GTO 03		78 STO 04	STO $C_{V}O_2$
33♦LBL 02	Calc. L-R shunt	79 RCL 03	
34 RCL 02		80 "CVO2"	
35 RCL 00		81 XEQ 09	STO $C_{V}O_2$
36 -		82 STO 03	Calculate shunt
37 RCL 05		83 RCL 01	
38 RCL 00		84 RCL 04	
39 -		85 -	
40 /		86 RCL 01	
41 "L-R"		87 RCL 03	
42♦LBL 03		88 -	
43 1 E2		89 /	
44 *		90 1 E2	
45 X<=0?	Is result pos. No	91 *	
46 GTO 01		92 "PHYS"	
		93 X<=0?	No shunt
		94 GTO 01	

Program Listings

95 GTO 10	Display shunt	51	
96♦LBL F	Calc. Fick CO		
97 RCL 02			
98 "VO2"			
99 XEQ 09	RCL VO ₂		
100 STO 02	STO VO ₂		
101 RCL 04			
102 RCL 03			
103 -	Calc. CO		
104 /		60	
105 10			
106 /			
107 STO 08			
108 "FICK CO			
"=			
109 ARCL X			
110 AVIEW	Output Fick CO		
111 RTN			
112♦LBL 09			
113 "F="	Display of	70	
114 ARCL X	recalled data		
115 "F?"			
116 PROMPT			
117 END			
30		80	
40		90	
50		00	

[illegible]

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

Δt = time interval between pressure measurements (sec)

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

ΔP = $P_N - P_{N-1}$

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

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

$dP/dt/P = \frac{dP/dt}{P_p} \text{ sec}^{-1}$

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 Δt . 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, Δt , 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:

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

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

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.	ΔT (sec)	[R/S]	P1=?
4	Input first pressure reading.	P1 (mmHg)	[R/S]	P(n)=?
5	Input next pressure reading.	P2 (mmHg)	[R/S]	(dP/dt/P)
	(dP/dt/P for two most recent points is			P(n+1)=?
	displayed with a pause).			
6	Repeat step 5 for remainder of pressure			
	readings. When all readings are input,			
	press [R/S] <i>without prior data entry</i> .	no entry	[R/S]	MAX dP/dT =
	Maximum dP/dt (mmHg/sec) is displayed.			
7	Calculate maximum dP/dt/P(sec ⁻¹) and Vmax		[R/S]*	MAX dP/dT/P =
	(circ/sec).		[R/S]*	VMAX=
	STROKE WORK			
8	Begin stroke work calculation.		[XEQ] WORK	PSYST=?
9	Input systolic pressure.	P _{sys} (mmHg)	[R/S]	PSYST=?
10	Repeat step 9 for all values of Psys.			
	After all values have been input press			
	[R/S] <i>without prior data entry</i> .	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.			

[illegible]

Program Listings

01*LBL "VMA X"	Contractility Initialization	50 FIX 2	Display dP/dt/P
02*LBL A		51 PSE	
03 SF 21		52 X<=Y?	
04 SF 27		53 GTO 00	
05 "TIME IN T.=?"	ΔT input	54 STO 04	
06 PROMPT		55 LASTX	
07 STO 06		56 STO 05	
08 CLX		57 RDN	
09 STO 00		58 GTO 00	
10 STO 01		59*LBL 01	
11 STO 03		60 RCL 03	
12 STO 04		61 "MAX dP/ dT"	
13 STO 05		62 ASTO 10	Display MAX dP/dt
14 CF 22		63 XEQ 10	
15*LBL 00		64 SF 29	
16 ISG 00		65 RCL 04	
17*LBL 11		66 FIX 1	
18 CLX		67 CLA	
19 FIX 0		68 ARCL 10	
20 CF 29		69 "F/dT/P"	Display MAX dP/dt/P
21 "P"		70 XEQ 10	
22 ARCL 00	Input P_{1--m}	71 RCL 09	
23 "F=?"		72 RCL 04	
24 PROMPT		73 *	Calc V_{max}
25 FC?C 22		74 RCL 05	
26 GTO 01		75 RCL 02	
27 ENTER↑		76 *	
28 X<> 01		77 -	
29 X=0?		78 RCL 09	
30 GTO 00		79 RCL 05	
31 -		80 -	
32 ENTER↑	Calc dP/dt	81 X≠0?	
33 ENTER↑		82 /	
34 RCL 06		83 30	
35 /		84 /	
36 RCL 03		85 FIX 2	
37 X<>Y		86 "VMAX"	Display VMAX
38 X>Y?		87*LBL 10	Display Routine
39 STO 03	Save MAX dP/dt	88 "F="	
40 RCL 01		89 ARCL X	
41 R↑		90 AVIEW	
42 2		91 RTN	WORK
43 /		92*LBL "WOR K"	
44 -	Save P_1	93*LBL 8	
45 STO 09		94 FIX 2	
46 /		95 CF 01	
47 STO 02		96 CF 22	Initialization
48 RCL 04		97 SF 21	
49 X<>Y		98 SF 27	

Program Listings

99 SF 29		149 /	
100 0		150 "SW INDE	Display stroke
101 STO 00	Input P _{syst}	X"	work index
102 LBL 02	Data input?	151 GTO 10	Recall stored
103 "PSYST"	No	152 LBL 09	data
104 "I=?"		153 "I="	
105 PROMPT	1st input	154 ARCL X	
106 FC?C 22	No	155 "I?"	
107 GTO 04		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			
125 "R-R=?"	Display AVE P		
126 PROMPT	Input R-R Int.		
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			
141 "STROKE			
WORK"	Display stroke		
142 XEQ 10	work		
143 RCL 07			
144 "BSA"	Recall BSA		
145 XEQ 09			
146 STO 07			
147 RCL 09			
148 X<>Y		00	

[illegible]

NOTES

NOTES

CARDIAC/PULMONARY

PULMONARY FUNCTIONS/VITAL CAPACITY
LUNG DIFFUSION AND ARTERIAL CO₂ 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



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