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A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE--ETC(U)
JAN 80 S STEINBERG
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A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE CREWMEMBERS OF EXPOSURE TO CARBON MONOXIDE EMISSIONS,

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20. ABSTRACT (Continued)

and safety of any crewmember jeopardized. An appendix provides the reader with both a complete program listing (FORTRAN IV) and a sample presentation of a hypothetical mission for tank crewmembers.

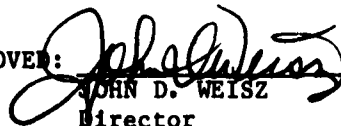
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A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE
CREWMEMBERS OF EXPOSURE TO CARBON MONOXIDE EMISSIONS

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January 1980

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A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE
CREWMEMBERS OF EXPOSURE TO CARBON MONOXIDE EMISSIONS

INTRODUCTION

The computer model described in this report was developed in December 1978 for use in analyzing data collected during Development Test II of the XM1 Main Battle Tank. The model was developed from an empirical equation (derived from reference 1 and detailed in reference 3) which predicts the amount of carboxyhemoglobin (COHb) in the blood of a person based upon both the cumulative COHb level prior to a period of exposure and the amount of carbon monoxide (CO) actually respired during the exposure. The amount of CO respired is a function only of the concentration level, the time duration of the exposure and the workload of the exposed individual during the period of exposure. Reference 3 explains that the percentage of COHb in a person's blood is the measure most closely related to the effects of CO exposure and that accounting for only CO exposure is unrealistic in that its effect upon both health and human performance are not adequately predicted based upon the evaluation method (4) and governing standards (2) presently used.

The computer program, described in the sections which follow, offers the evaluator a useful tool for determining whether or not a mission, comprised of numerous mission elements, can be accomplished without compromising system effectiveness or crew health and safety due to crew exposure to CO. The computer model is applicable to either the steady state or transient type exposure to CO. The steady state exposure is one of almost constant level (usually a value of less than 50 parts per million [ppm]) over a long time period such as the driver or passengers in a truck, traveling with a convoy, might experience. The transient type exposure is usually of short duration (2-3 minutes) as might result from firing weapons from either a stationary or moving vehicle (e.g., tanks, aircraft, armored personnel carrier). The crews of an artillery battery may also experience a transient type exposure to CO.

In the present case, the computer model calculates the instantaneous COHb blood content for each crew member (commander, driver, loader, gunner) at any time during the course of a mission. The calculated values of COHb can then be compared with the proposed limit values (3) (or alternate criteria) to determine what effects, if any, result from actual or projected exposures to CO.

The recommended limit for the COHb blood content (see reference 3 "Proposed Evaluation Scale") for the soldier population is 10 percent providing that the limit value is reached only occasionally. If exposure to a CO environment of greater than 50 ppm is a regular occurrence, the COHb average should not exceed 5 percent. Adherence to this evaluation scale should not compromise the health or safety of the soldiers, nor cause a decrement in crew performance.

EQUATION FOR DETERMINING PERCENT COHb IN BLOOD

The following equation is used in the computer mode to predict the COHb blood content of each crewmember at any time during a mission:

$$\text{COHb}_t = \text{COHb}_0 \{ e^{-\exp - (t/2398B)} \} + 218 \{ 1 - e^{-\exp - (t/2398B)} \} \times \{ .007B + (\text{ppm CO}/1316) \}$$

where COHb_0 = percentage of COHb in the blood at time 0

COHb_t = percentage of COHb at time t (t in minutes)

$B = 1/DL + (PB - 47)/VA$ where

DL = rate of diffusion of CO in the lungs

PB = barometric pressure in millimeters of mercury

VA = minute respiratory volume in milliliters

The term B is related directly to the physical exertion of the crewmember during the exposure period. For ease of application, the work effort has been simplified to five individual levels which are then related to DL and VA, the respiratory factors in the above equation. Table 1 defines the values of DL and VA.

TABLE 1
Definition of Values DL and VA

Work Effort	DL	VA
1. (Sedentary)	30	6000
2.	35	12000
3. (Light work)	40	18000
4.	50	24000
5. (Heavy work)	60	30000

COMPUTER PROGRAM DETAILS

General

The program was written specifically for application to the XM1 tank crew consisting of the commander, driver, loader and gunner, but it can be modified easily to be applicable to the crew of any surface vehicle or airplane by revising the column format (of the printout) to conform to the user's requirements. The program is written in the FORTRAN IV language and is usable with most digital computers. The complete program listing and printout of a sample problem are presented in the appendix.

Program Symbology Identification and Definitions

COHb1 -Program Name/Title

COO -Percentage of COHb in crewmember's blood at beginning of any mission segment, (input value at mission start).

COHBT -Cumulative percentage of COHb in crewmember's blood at the conclusion of any mission segment. Note that COHBT for any mission segment n, equals COO for segment n + 1.

PPM -Average carbon monoxide exposure level in parts per million, for any mission segment of time duration TI, in minutes. (Input data for each mission segment.)

IBWS -Work stress level for a crewmember for any mission segment (input data - integer [1, 2, 3, 4 or 5]).

DL -Rate of diffusion of CO in the lungs (input constants [real] [30, 35, 40, 50 or 60]) that is a function of work stress level.

VA -Minute respiratory volume in milliliters (input constants [real] [6000, 12000, 18000, 24000 or 30000]) that is a function of work stress level.

B -Calculated value of the work stress parameter that is a function of DL, VA and PB.

PB -Barometric pressure in millimeters of mercury.

TI -Time duration (minutes) of any mission segment.

HDR -Header (see detailed description below).

Header Details

The purpose of the header (HDR) is to provide the user with a heading (at the top of each page of computed/listed values) which describes (using up to 80 characters of alphanumeric) the mission scenario for the particular computations being made. In addition, HDR includes the column titles which identify both the input data (listed for convenience) and the calculated results. The column titles included CUM TIME (cumulative mission segment time) in HRS (hours) and MIN (minutes), D-TIME (mission segment time) in minutes, WE (level of work effort), CO-PPM (the CO exposure value) in parts per million, D-COHB (the calculated incremental value of COHB for each mission segment) in percent, T-COHB (the calculated cumulative value of COHB at the conclusion of any mission segment) in percent. The four column headings (i.e., WE, CO-PPM, D-COHB, T-COHB) are repeated for each crewmember. The program is written such that a maximum of 50 lines of calculations will be printed on each page.

Data Input Cards Format

The following are the formats for the input data cards:

Card Number	Symbol	Description	Card Column Numbers	Format
1	PB	Barometric Pressure	1-3	XXX
1	COO	COHb _o (Commander)	5-8	X.XX
1	COO	COHb _o (Driver)	10-13	X.XX
1	COO	COHb _o (Loader)	15-18	X.XX
1	COO	COHb _o (Gunner)	20-23	X.XX
2 thru (n-1)	TI	Exposure Time (min)	1-5	XXX.X
2 thru (n-1)	WE	Work Exposure (Commander)	7	X
2 thru (n-1)	PPM	CO Exposure (Commander)	9-13	XXXXX
2 thru (n-1)	WE	Work Effort (Driver)	15	X
2 thru (n-1)	PPM	CO Exposure (Driver)	17-21	XXXXX
2 thru (n-1)	WE	Work Effort (Loader)	23	X
2 thru (n-1)	PPM	CO Exposure (Loader)	25-29	XXXXX
2 thru (n-1)	WE	Work Effort (Gunner)	31	X
2 thru (n-1)	PPM	CO Exposure (Gunner)	33-37	XXXXX
Last Card ^a	WE	Work Effort (Commander)	7	X

^aNote that the last data card should be punched either with a zero in column 7 or a negative 1 in columns 1 and 2 in accordance with the program logic (see card number 26 of the program listing in the appendix).

REFERENCES

1. Coburn, R.F., Forster, R.E., & Kane, P.G. Considerations for the physiological variables that determine the blood carboxyhemoglobin concentration in man. Journal of Clinical Investigation, 1965, 44, 1899-1910.
2. Department of Defense. Procedure for carbon monoxide detection and control in aircraft. MIL-STD-800, Naval Publications Center, Philadelphia, PA.
3. Steinberg, S., & Nielsen, G.D. A proposal for evaluating human exposure to carbon monoxide contamination in military vehicles. Technical Memorandum 11-77, US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD, March 1977.
4. US Army Test and Evaluation Command. Toxic hazards tests for vehicles and other equipment. TOP 2-2-614, Aberdeen Proving Ground, MD, 17 January 1977.

APPENDIX

PROGRAM LISTING AND SAMPLE PRINTOUT

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Program Listing and Sample Printout

This appendix presents both a listing of Program COHBI, written in the FORTRAN IV language, and a printout of the sample problem given in reference 3 (Appendix B - Table 1).

Listing of Program COHBI - 52 Punched Cards

```

1      PROGRAM COHBI (CARD=1, N=1, TAPE5=INPUT, TAPE6=OUTPUT)
      DIMENSION COHBT(4), COHBT(4), PPM(4), IBWS(4), DL(5),
1      COO(5), HDR(8), DCOHB(4)
      DATA DL/30.0, 35.0, 40.0, 50.0, 60.0/,
5      COO/100.0, 1200.0, 18000.0, 24000.0, 30000.0/
100     K=1, 100) HDR, PPM, COO
110     FORMAT (80A1/F3.0, 4(18,F4.2))
      TIME = 0.0
      RTIME = 0.0
10     290     WRITE (6, 300) HDR, COO
      300     FORMAT (1H1, 'SCENARIO: ', 80A1)
15     1      208, 'BAROMETRIC PRESSURE =', F6.1, ' (MM HG) '//
2      14, 'CUR TIME', T15, 'D-TIME',
3      123, '----- COMMANDER -----',
4      T51, '----- BEAVER -----',
5      T79, '----- FINGER -----',
6      T107, '----- GUNNER -----' /
7      T3, 'HRS', T10, 'MIN', T17, 'MIN',
8      4(' WE CO-PPM = COHB T-COHB' //)
20     WRITE (6, 300) HDR, TIME, COO
      350     FORMAT (1X, F5.2, 1X, F6.1, 1X, 4(19X, F8.2, 1X))
      DO 400 I = 1, 5
400     B(I) = 1.0/DL(I) + (PPM(I)/VA(I))
500     READ (5, 10) T1, IBWS(I), PPM(I), I=1, 4)
25     510     FORMAT (F1.1, 4(1X, 11, 18, F5.0))
      IF (T1.EQ.0.0 OR IBWS(I).EQ.0.0) GO TO 715
      IF (T1.EQ.0.0) GO TO 100
      DO 600 K = 1, 4
30     TERM = EXP(-T1*2398.76*(IBWS(K)))
      COHBT(K) = COO(K)*TERM + 218.0*(1.0-TERM)*(0.007*B(IBWS(K))
1+PPM(K)/1316.0)
600     DCOHB(K) = COHBT(K) + COO(K)
      DO 650 L = 1, 4
650     COO(L) = COHBT(L)
35     TIME = TIME + T1
      RTIME = RTIME/COO(L)
      LINES = LINES + 1
      IF (MOD(LINES, 50) .EQ. 0) WRITE (6, 175) HDR
40     675     FORMAT (1H1, 'SCENARIO: ', 80A1 /
1      14, 'CUR TIME', T15, 'D-TIME',

```

Listing of Program COHB1 (Continued)

```
2      T23,'----- COMMANDER -----',
3      T51,'----- DRIVER -----',
4      T79,'----- LOADER -----',
5      T107,'----- GUNNER -----'/
45     6      T3,'HRS',T10,'MIN',T17,'MIN',
7      4(' WE CO-PPM D-COHB T-COHB'//)
      WRITE (6,700) HTIME,TIME,TI,
      1(IBWS(M),PPM(M),DCOHB(M),COHBT(M),M=1,4)
50     700   FORMAT (1X,F5.2,1X,F6.1,F7.1,4(I4,F8.0,F7.2,F8.2,1X))
      710   GO TO 500
      715   STOP
      720   END
```

SAMPLE PRINTOUT

SCENARIO: (IDENTIFYING HEADING FOR COHB CALCULATION) - VERIFY TM 11-77 EXAMPLE
 BAROMETRIC PRESSURE = 760.0 (MM HG)

CUM TIME HRS	D-TIME MIN	COMMANDER			DRIVER			LOADER			GUNNER							
		WE	CO-PPM	D-COHB	T-COHB	WE	CO-PPM	D-COHB	T-COHB	WE	CO-PPM	D-COHB	T-COHB					
0.00	0.0																	
3.00	180.0	3	20.	1.66	2.66	2	20.	1.69	2.19	1	20.	.99	1.99	5	20.	1.16	3.16	2.00
3.17	190.0	5	20.	.07	2.73	2	20.	.06	2.25	1	20.	.04	2.03	5	20.	.02	3.18	3.18
3.18	191.0	1.0	1500.	2.05	4.78	2	1500.	1.16	3.41	1	1500.	.68	2.71	5	1500.	2.52	5.70	5.70
3.20	192.0	1.0	700.	.93	5.71	2	700.	.53	3.95	1	700.	.31	3.02	5	700.	1.13	6.83	6.83
3.21	192.5	.5	100.	.05	5.76	2	100.	.03	3.98	1	100.	.02	3.04	5	100.	.05	6.88	6.88
3.22	193.0	.5	50.	.01	5.77	2	50.	.01	3.99	1	50.	.01	3.05	5	50.	.01	6.89	6.89
3.38	203.0	10.0	35.	.01	5.78	2	35.	.09	4.08	1	35.	.08	3.13	5	35.	-.10	6.79	6.79
6.38	383.0	180.0	20.	-1.62	4.15	1	20.	-.21	3.87	2	20.	.18	3.31	3	20.	-2.32	4.47	4.47
6.55	393.0	10.0	20.	-.08	4.08	1	20.	-.01	3.86	2	20.	.01	3.32	3	20.	-.07	4.40	4.40
6.57	394.0	1.0	1500.	2.04	6.12	1	1500.	.67	4.53	2	1500.	1.16	4.48	3	1500.	1.57	5.97	5.97
6.58	395.0	1.0	700.	.92	7.04	1	700.	.31	4.84	2	700.	.53	5.00	3	700.	.71	6.68	6.68
6.59	395.5	.5	100.	.04	7.08	1	100.	.02	4.85	2	100.	.03	5.03	3	100.	.03	6.71	6.71
6.60	396.0	.5	50.	.01	7.08	1	50.	.01	4.86	2	50.	.01	5.04	3	50.	.01	6.72	6.72
6.77	406.0	10.0	35.	-.12	6.96	1	35.	.03	4.89	2	35.	.04	5.08	3	35.	-.05	6.67	6.67
9.77	586.0	180.0	20.	-2.44	4.52	3	20.	-1.02	3.87	5	20.	-1.44	3.64	1	20.	-1.22	5.45	5.45
9.93	596.0	10.0	20.	-.11	4.41	3	20.	-.03	3.85	5	20.	-.03	3.62	1	20.	-.05	5.40	5.40
9.95	597.0	1.0	1500.	2.04	6.45	3	1500.	1.57	5.42	5	1500.	2.51	6.13	1	1500.	.67	6.07	6.07
9.97	598.0	1.0	700.	.92	7.37	3	700.	.71	6.13	5	700.	1.13	7.26	1	700.	.30	6.37	6.37
9.98	598.5	.5	100.	.04	7.40	3	100.	.03	6.17	5	100.	.05	7.30	1	100.	.01	6.38	6.38
9.98	599.0	.5	50.	.00	7.41	3	50.	.01	6.17	5	50.	.01	7.31	1	50.	.00	6.38	6.38
10.15	609.0	10.0	35.	-.15	7.26	3	35.	-.02	6.16	5	35.	-.14	7.17	1	35.	-.01	6.38	6.38

This sample printout from program COHBI is related directly to the sample problem given in Appendix B of reference 3. The printout for the "Commander" duplicates the specific problem given as Table 1B (reference 3). The calculated values of COHB (in percent) in the above printout match exactly those given in the reference.

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