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RADIO SHACK TRS-80 POCKET COMPUTER SOLUTIONS TO COMPOSITE MATER--ETC(U)
AUG 81 W J PARK F33615-79-C-5125

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RADIO SHACK TRS-80 POCKET COMPUTER SOLUTIONS
TO COMPOSITE MATERIALS FORMULAS

WON J. PARK

UNIVERSAL ENERGY SYSTEMS, INC.
DAYTON, OHIO 45432

AUGUST 1981

FINAL REPORT FOR PERIOD JANUARY 1981-MAY 1981

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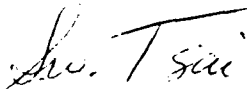
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This technical report has been reviewed and is approved for publication.



S. W. TSAI, Project Engineer & Chief
Mechanics and Surface Interactions Branch
Nonmetallic Materials Division

FOR THE COMMANDER



F. D. CHERRY, Chief
Nonmetallic Materials Division

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BASIC Programming Composite Materials Properties of Undirectional and Laminated Composite In-Plane and Flexural Stiffness and Strength			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)			
This volume contains the description and instructions of the use of Radio Shack TRS-80 Pocket Computer for the key calculations of the stiffness and strength of symmetric laminated composites. The magnetic cassette tapes contain the required programming in the language of BASIC. With the aid of tape recorder for loading the program into TRS-80, instant calculation can be made for practical use. The formulas and equation numbers used in the programming have been derived in a book entitled, <u>Introduction to Composite</u>			

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20. ABSTRACT

Materials, coauthored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, CT, July 1980.

FOREWORD

This report was prepared in the Mechanics and Surface Interactions Branch (AFWAL/MLBM), Nonmetallic Materials Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. The work was performed under Contract F33615-79-C-5125, Project UES 117.

The time period covered by this report was from January to May 1981. Dr. Won J. Park was a senior scientist from Universal Energy Systems, Inc. and Professor of Mathematics and Statistics at Wright State University.

The equations and table numbers which appear in the flow charts are the same as in Introduction to Composite Materials, co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, CT, in July 1980.

Those who want to receive the programmed magnetic cassette tape should contact Dr. Stephen W. Tsai, AFWAL/MLBM, Wright-Patterson AFB, Ohio 45433, Tel: 513-255-3068.

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TABLE OF CONTENTS

<u>SECTION</u>		<u>PAGE</u>
I.	USER GENERAL INSTRUCTIONS	1
II.	CONTENTS OF PROGRAMS	3
III.	PROGRAM 1. STIFFNESS	4
	1. User Instructions for Program 1	5
	a. Loading Program 1	5
	b. Operation for Program 1	6
IV.	PROGRAM 2. STRENGTH	12
	1. User Instructions for Program 2	13
	a. Loading Program 2	13
	b. Operation of Program 2	13
V.	CONCLUSION	20

SECTION I

USER GENERAL INSTRUCTIONS

(1) The program language for TRS-80 Pocket Computer is BASIC and the elementary part of BASIC program instructions are given in the Radio Shack instruction manual - Catalog Number 26-3501, which usually comes with TRS-80 Pocket Computer.

(2) It is noted that the instructions for loading and recording of the program using the magnetic cassette tape can be found in page 74-76 and page 90-94 in the instruction manual.

(3) Two programs, Program 1 and Program 2, are recorded in our magnetic cassette tape with the following characteristics.

Name*	File Name	Tape Counter reading †
Program 1	"PGM-1"	0-47
Program 2	"PGM-2"	50-88

* See the Table of Contents

† Tape counter reading in the tape recorder.

(4) Composite Material Constants listed in (a) and (b) below are inputted in the programs. For a different material constants it is needed to change the input directly on the programs.

(a) Program Step 20 in Program 1.

$$\begin{aligned} **A &= 181E9 \leftrightarrow E_x \\ S &= 10.3E9 \leftrightarrow E_y \\ D &= 280E-3 \leftrightarrow \nu_x \\ F &= 7.17E9 \leftrightarrow E_s \\ H &= .125E-3 \leftrightarrow h_o \end{aligned}$$

**This material constants are for the composite material T300/5208.

(b) Program Step 300 in Program 2.

$$Q = 1.5E9 \leftrightarrow X$$

$$W = 1.5E9 \leftrightarrow X'$$

$$E = 40E6 \leftrightarrow Y$$

$$R = 246E6 \leftrightarrow Y'$$

$$T = 68E6 \leftrightarrow S$$

(5) Once the computation of program 1 was completed and when the loading of program 2 is executed in TRS-80 pocket computer, the data stored in the fixed memories (A - Z memory) will be erased and the data stored only in the flexible memories (A(.) memory) will be remaining in the computer.

SECTION II

CONTENTS OF PROGRAMS

Each of Program 1 and Program 2 can be divided into 3 sub-programs, named "A", "B" and "C". These sub-programs perform a specific composite material computation as follows:

(a) Program 1

"A": Properties of Unidirectional Composites

"B": In-Plane Stiffness of Symmetric Laminates

"C": Flexural Rigidity of Symmetric Sandwich Plates

(b) Program 2

"A": Properties of Unidirectional Composite

"B": In-Plane Strength of Symmetric Laminates

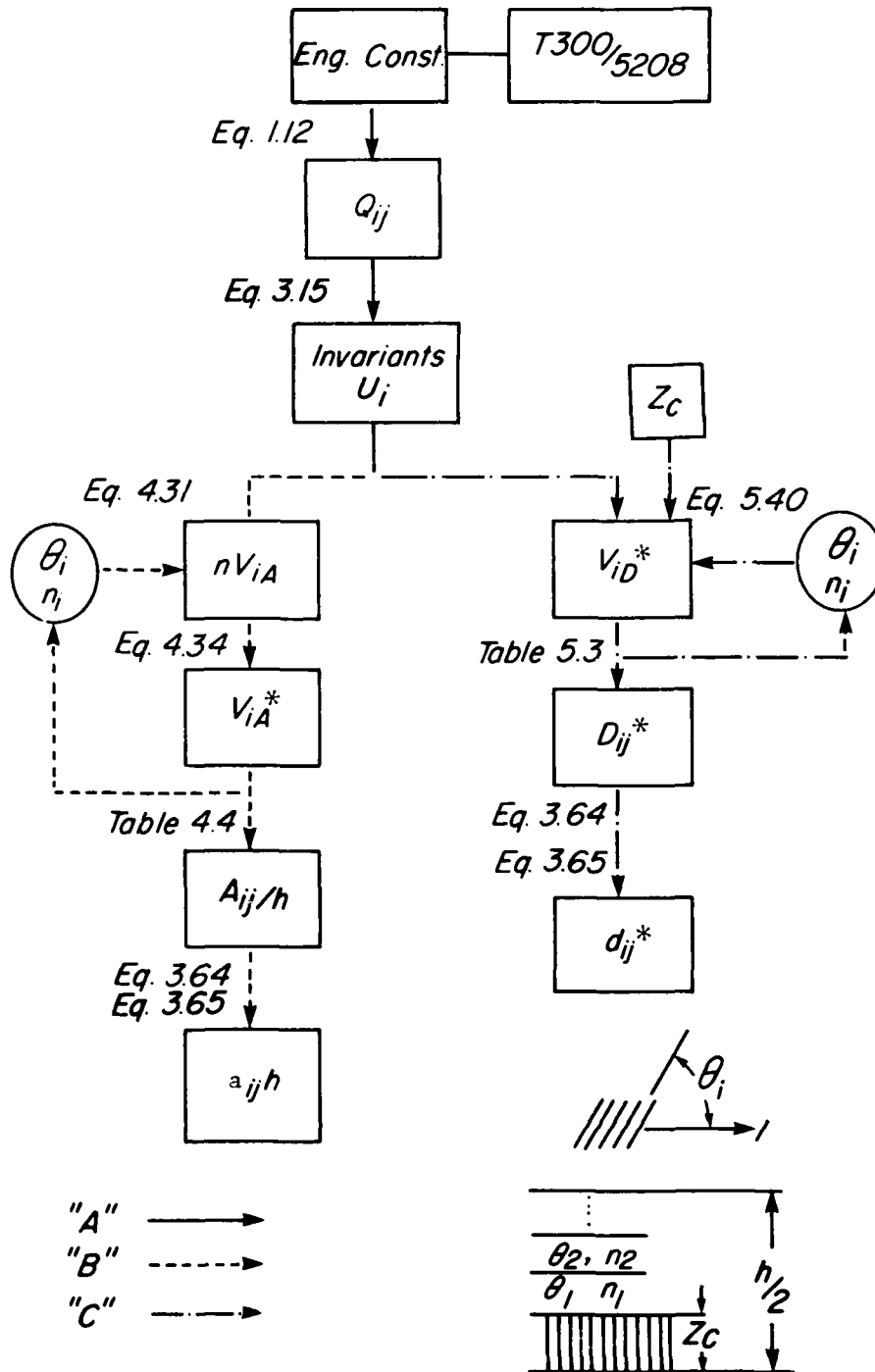
"C": Flexural Strength of Symmetric Sandwich Plates

It is also noted that the sub-program "A" can be utilized by pressing the keys SHFT A , "B" by SHFT B and "C" by SHFT C (see the operations in page 6 and page 13).

SECTION III

PROGRAM 1. STIFFNESS

PROGRAM 1



1. User Instructions for Program 1

a. Loading Program 1.

(a) Connect the cassette interface to the tape recorder and attach TRS-80 computer to the cassette interface. The type counter of the tape recorder should be set at zero.

(b) Turn on TRS-80 (press **ON**) and set DEG and PRO modes.

(c) Press play key **PLAY** of the tape recorder.



(d)

Operation (press)	Display
C L O A D SHFT W P G M - 1 SHFT W	CLOAD "PGM-1"
ENTER	

Note that during the execution of loading, the mode changes from "PRO" to "RUN" and back to "PRO" when the execution is completed.

(e) When the loading of Program 1 is completed, the tape recorder stops automatically, but it is needed to press Stop/Eject key, **STOP/EJECT**, in the tape recorder.



b. Operation of Program 1.

(a) Press $\downarrow$ or $\uparrow$ several times to check that the program is loaded.

(b) Press **MODE** twice to change the mode from PRO to DEF.

(c) Perform the following operations - Sample problems.

Display	Operation	Remarks
	SHFT A	*Beep 1
	SHFT B	
ANGLE =	0 ENTER	$[0_4^0 / 90_4^0]_s$
PLY NO. =	4 ENTER	
ANGLE =	9 0 ENTER	
PLY NO. =	4 ENTER	See **
ANGLE =	R ENTER	R indicates no more angle input. Beep 2
	SHFT C	
CORE PLY NO. =	0 ENTER	0_4^0 90_4^0
ANGLE =	9 0 ENTER	
PLY NO.	4 ENTER	
ANGLE =	0 ENTER	
PLY NO. =	4 ENTER	See **
ANGLE =	R ENTER	Beep 3

*Beep sounds indicate the completion of computations.

** should continue to input the angle and ply no. if there is additional ply layers.

Program 1. Memory Storage
Key-Board Memories

Key	A	B	C	Key	A	B	C	Key	A	B	C
Q		V_{1A}^*	V_{1D}^*	A	$E_X, \bar{U}_6$			Z		A_{11}/h	$12D_{11}/h^3$
W		V_{2A}^*	V_{2D}^*	S	$E_Y, \bar{U}_5$			X		A_{22}/h	$12D_{22}/h^3$
E		V_{3A}^*	V_{3D}^*	D	$v_X, \bar{U}_2$			C		A_{12}/h	$12D_{12}/h^3$
R		*	*	F	$E_S, \bar{U}_3$			V		A_{66}/h	$12D_{66}/h^3$
T		V_{4A}^*	V_{4D}^*	G		A_{26}/h	$12D_{26}/h^3$	B		A_{16}/h	$12D_{16}/h^3$
Y		$\det(A_{ij})$	$\det(D_{ij})$	H	h_0			N		n_i	n_i
U		*	*	J				M	m		
I			*	K			h^*				
O		θ_i	θ_i	L			Core ply no.				
P		sum of n_i	sum of n_i								

A(·) - Memories

A(·)	A	B	C	A(·)	A	B	C	A(·)	A	B	C
27	Q_{xx}			36		*	*	45			d_{11}^*
28	Q_{yy}			37		*	*	46			d_{22}^*
29	Q_{xy}			38		*	*	47			d_{12}^*
30	Q_{ss}			39		a_{11}^h		48			d_{66}^*
31		V_{1A}^*		40		a_{22}^h		49			d_{16}^*
32		V_{3A}^*		41		a_{12}^h		50			d_{26}^*
33		*	*	42		a_{66}^h		51			h^*
34		*	*	43		a_{16}^h		52			
35		*	*	44		a_{26}^h		53			

*denotes control variable

$$\bar{U}_6 = \frac{1}{2}(\bar{U}_1 + \bar{U}_4), \bar{U}_5 = \frac{1}{2}(\bar{U}_1 - \bar{U}_4)$$

Program 1. Computation Problem
After "B"

$[0_4^0 / 90_4^0]_s$

Key-Board Memories

Key		Key		Key	
Q	0	A	4.94877866E10	Z	9.607864876E10
W	1	S	2.688043108E10	X	9.607864876E10
E	0	D	8.573249004E10	C	289692440
R		F	1.971043108E10	V	7170000000
T	0	G	0	B	0
Y		H	.000125	N	
U		J		M	1.00448143
I		K			
O		L			
P					

A(•)-Memories

A(•)		A(•)		A(•)	
27	1.818111383E11	36		45	
28	1.034615873E10	37		46	
29	2896924444	38		47	
30	7170000000	39	1.041761056E-11	48	
31	0	40	1.041761056E-11	49	
32	0	41	-3.141075674E-13	50	
33		42	1.39470014E-10	51	
34		43	0	52	
35		44	0	53	

Program 1. Computation Problem
After "C"

0_4^0
90_4^0

Key-Board Memories

Key		Key		Key	
Q	.75	A	4.94877866E10	Z	1.603780163E11
W	1	S	2.688043108E10	X	3.177928123E10
E	0	D	8.573249004E10	C	2896924440
R		F	1.971043108E10	V	7170000000
T	0	G	0	B	0
Y		H	.000125	N	
U		J		M	
I		K	6.66666666E-10		
O		L	0		
P					

A(•)-Memories

A(•)		A(•)		A(•)	
27	1.818111388E11	36		45	6.245552406E-12
28	1.034615873E10	37		46	3.15894148E-11
29	2896924444	38		47	-5.693298497E-13
30	7170000000	39	1.041761056E-11	48	1.394700139E-10
31	0	40	1.041761056E-11	49	0
32	0	41	-3.41075694E-13	50	0
33		42	1.39470014E-10	51	
34		43	0	52	
35		44	0	53	

```

1      "PGM-1"
10     "A":CLEAR
20     A=181E9, S=10.3E9, D=280E-3, F=7.17E9, H=.125E-3
30     M=1/(1-D*D*S/A)
40     A(27)=M*A, A(28)=M*S, A(29)=M*D*S, A(30)=F
50     A=1/8*(2A(27)+2A(28)+4A(29)), S=1/8*(A(27)+A(28)-2A(29)+4A(30))
60     D=1/2*(A(27)-A(28)), F=1/8*(A(27)+A(28)-2A(29)-4A(30)) : BEEP 1
70     END
80     "B"
85     PAUSE "IN-PLANE STFFNSS"
90     P=0, Q=0, W=0, E=0, T=0, R=500, U=1
110    INPUT "ANGLE="; Q (here Q is the capital letter Q
                           and not the number zero)
120    IF Q<=180 GOTO 140
130    IF Q>180 GOTO 180
140    INPUT "PLY NO.="; N
150    P=P+N
160    Q=Q+N*COS(20), W=W+N*COS(40), E=E+N*SIN(20), T=T+N*SIN(40)
170    GOTO 110
180    Q=Q/P, W=W/P, E=E/P, T=T/P
190    A(31)=Q, A(32)=E
200    GOTO 500
210    A(39)=A(33), A(40)=A(34), A(41)=A(35), A(42)=A(36), A(43)=A(37),
        A(44)=A(38)
220    BEEP 2
230    END
240    "C"
245    PAUSE "FLEX. RIGIDITY"
250    Q=0, W=0, E=0, T=0, R=500, U=2, P=0
260    INPUT "CORE PLY NO.="; L
270    P=L
280    INPUT "ANGLE="; Q
290    IF Q<=180 GOTO 310
300    IF Q>180 GOTO 360
310    INPUT "PLY NO.="; N

```

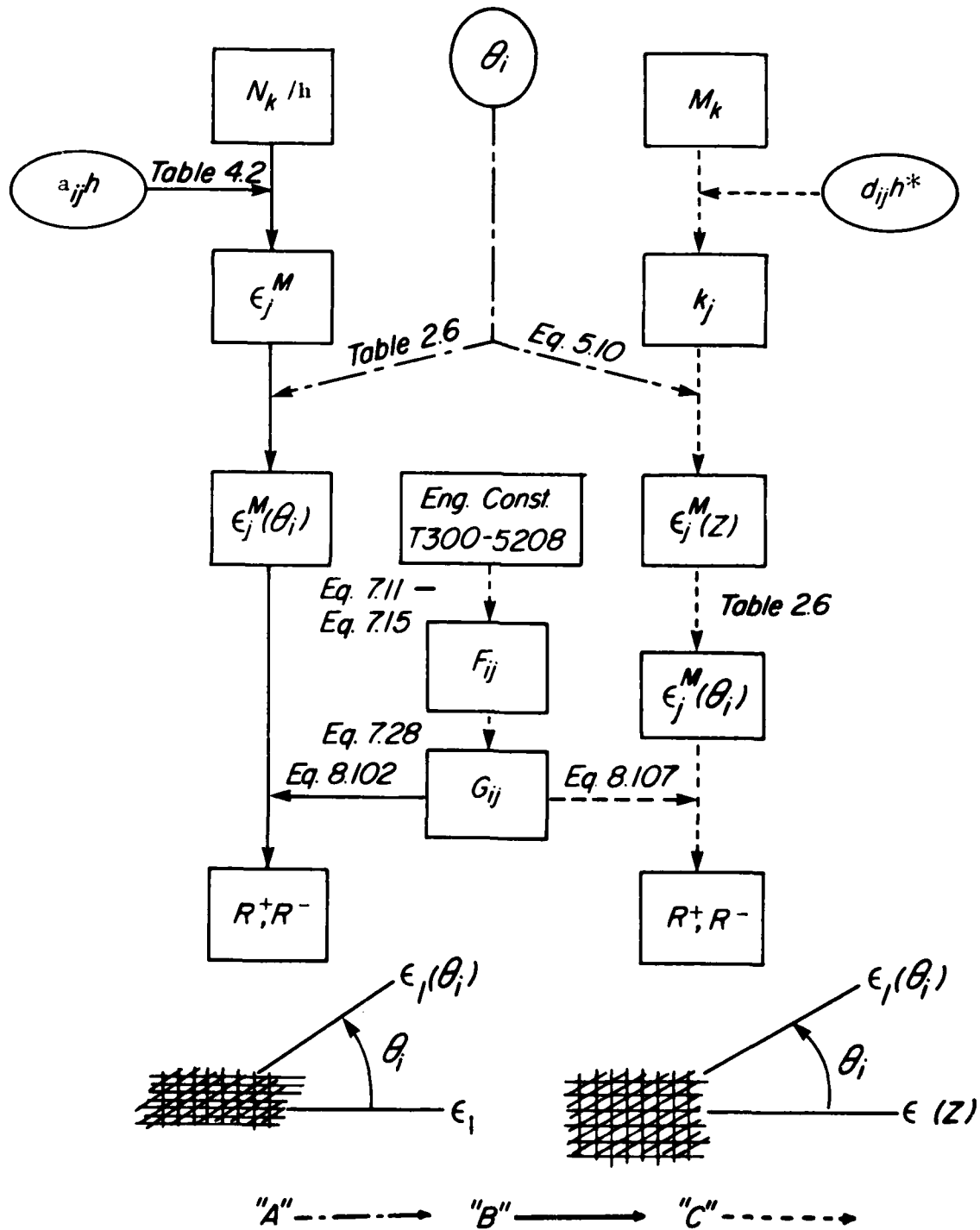
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320     P=P+N
330     Q=Q+(P^3-(P-N)^3)*COS(2Q), W=W+(P^3-(P-N)^3)*COS(4Q)
340     E=E+(P^3-(P-N)^3)*SIN(2Q), T=T+(P^3-(P-N)^3)*SIN(4Q)
350     GOTO 280
360     I=P^3-L^3
370     Q=Q/I, W=W/I, E=E/I, T=T/I
380     GOTO 500
385     K=3/12*I*H^3
390     A(45)=A(33), A(46)=A(34), A(47)=A(35), A(48)=A(36), A(49)=A(37),
        A(50)=A(38)
400     A(51)=K : BEEP 3
410     END
500     Z=A+S-Q*D+W*F, X=A+S-Q*D+W*F, C=A-S-W*F, V=S-W*F,
        B=E*D/2+T*F, G=E*D/2-T*F
510     Y=Z*X*V+2C*G*B-X*B*B-V*C*C-Z*G*G
520     A(33)=(X*V-G*G)/Y, A(34)=(Z*V-B*B)/Y, A(35)=(B*G-C*V)/Y
530     A(36)=(Z*X-C*C)/Y, A(37)=(C*G-X*B)/Y, A(38)=(C*B-Z*G)/Y
540     IF U=1 GOTO 210
550     IF U=2 GOTO 385

```

SECTION IV
PROGRAM 2. STRENGTH

PROGRAM 2



1. User Instructions for Program 2

a. Loading Program 2.

Procedure (a), (b), (c) and (e) are same as in Program 1.

(d)

Operation (press)	Display
C L O A D SHFT W P G M - 2 SHFT W	CLOAD "PGM-2"
ENTER	

b. Operation of Program 2.

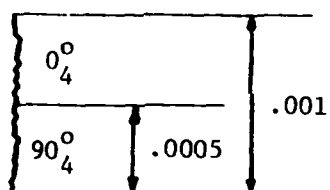
Steps (a) and (b) are same as in Program 1

(c) Perform the following operations - Sample problems.

Display	Operation	Remarks
	SHFT A	
ANGLE =	0 ENTER	Beep 1
	SHFT B	
N1-M/H =	1 ENTER	
N2-M/H =	0 ENTER	
N6-M/H =	0 ENTER	Beep 2
R+ = 6.81882008E8		
	ENTER	
R- = 1.10770531E09		

Display	Operation	Remarks
	SHFT C	
M1 =	1 ENTER	
M2 =	0 ENTER	
M6 =	0 ENTER	
Z =	0 0 0 1 ENTER	Beep 2
R+ = 7.91979781E02		
	ENTER	
R- = 1.13704881E03		
	SHFT A	
ANGLE =	9 0 ENTER	Beep 1
	SHFT B	
N1-M/H	1 ENTER	
N2-M/H	0 ENTER	
N6-M/H	0 ENTER	
R+ = 3.73395515E08		
	ENTER	
R- = 2.26881887E09		
	SHFT C	

Display	Operation	Remarks
M1 =	1 ENTER	
M2 =	0 ENTER	
M6 =	0 ENTER	
Z =	. 5 Exp - 3 ENTER	
R+ = 8.35694320E02		
	ENTER	
R- = 4.80924818E03		



Program 2. Memory Storage

Key-Board Memories

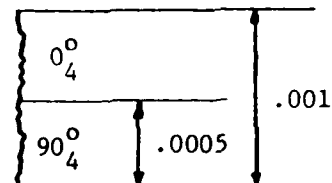
Key	A	B	C	Key	A	B	C	Key	A	B	C
Q		X a	X	A		G_{xx}	G_{xx}	Z		ϵ_1^M	k_1
W		X' b	X'	S		G_{yy}	G_{yy}	X		ϵ_2^M	k_2
E		Y	Y	D		G_{xy}	G_{xy}	C		ϵ_3^M	k_3
R		Y'	Y'	F		G_{ss}	G_{ss}	V		P, R+	P, R+
T		S	S	G		G_x	G_x	B		q, R-	q, R-
Y		F_{xx}	F_{xx}, z	H		G_y	G_y	N		*	*
U		F_{yy}	F_{yy}	J		N_1^M/h	M_1	M	θ_i		
I		F_x	F_x	K		N_2^M/h	M_2				
O		F_y	F_y	L		N_6^M/h	M_6				
P		$F_{xy}^* = -\frac{1}{2}$	F_{xy}^*								

A(•)-Memories

A(•)	A	B	C	A(•)	A	B	C	A(•)	A	B	C
27				36				45			d_{11}^*
28				37				46			d_{22}^*
29				38				47			d_{12}^*
30				39		a_{11}^*		48			d_{66}^*
31				40		a_{22}^*		49			d_{16}^*
32				41		a_{12}^*		50			d_{26}^*
33		$\epsilon_1^M(\theta_i)$	$\epsilon_1^M(\theta_i)$	42		a_{66}^*		51			h^*
34		$\epsilon_2^M(\theta_i)$	$\epsilon_2^M(\theta_i)$	43		a_{16}^*		52			
35		$\epsilon_6^M(\theta_i)$	$\epsilon_6^M(\theta_i)$	44		a_{26}^*		53			

Program 2. Computation Problem
"A", "B" and "C"

Key-Board Memories



Key		Key		Key	
Q		A	12004.38352	Z	
W		S	10680.65201	X	
E		D	-3 069.103205	C	
R		F	11117.84169	V	
T		G	60.64699548	B	
Y		H	216.5964124	N	
U		J		M	0 or 90
I		K			
O		L			
P					

A(•)-Memories

A(•)		A(•)		A(•)	
27		36		45	6.245552406E-12
28		37		46	3.151894148E-11
29		38		47	-5.693298497E-13
30		39	1.041761056E-11	48	1.394700139E-10
31		40	1.041761056E-11	49	
32		41	-3.141075674E-13	50	
33		42	1.39470014E-10	51	
34		43		52	
35		44		53	

```

1      "PGM-2"
10     "A"
20     PAUSE "INPUT ANGLE"
30     INPUT "ANGLE="; M
40     BEEP 1
50     END
60     "B"
70     PAUSE "IN-PLANE STRENGTH"
80     INPUT "N1-M/H="; J
81     INPUT "N2-M/H="; K
82     INPUT "N6-M/H="; L
85     N=1
90     Z=A(39)*J + A(41)*K + A(43)*L
95     X=A(41)*J + A(40)*K + A(44)*L
100    C=A(43)*J + A(44)*K + A(42)*L
110    V=(Z+X)/2, B=(Z-X)/2
120    A(33)=V+B*COS(-2M) + C/2*SIN(-2M)
130    A(34)=V-B*COS(-2M) - C/2*SIN(-2M)
140    A(35)=-2B*SIN(-2M) + C*COS(-2M)
150    IF N=1 GOTO 290
160    IF N=2 GOTO 280
170    END
190    "C"
200    PAUSE "FLEX. STRENGTH"
201    INPUT "M1="; J
202    INPUT "M2="; K
203    INPUT "M6="; L
210    INPUT "Z="; Y
220    N=2
230    Z=A(45)*J + A(47)*K + A(49)*L
240    X=A(47)*J + A(46)*K + A(50)*L
250    C=A(49)*J + A(50)*K + A(48)*L
260    Z=Z/A(51), X=X/A(51), C=C/A(51)
270    GOTO 110

```

```

280      A(33)=A(33)*Y, A(34)=A(34)*Y, A(35)=A(35)*Y
290      P=-1/2
300      Q=1.5E9, W=1.5E9, E=40E6, R=246E6, T=68E6
310      Y=1/Q/W, U=1/E/R, I=1/Q-1/W, O=1/E-1/R
320      P=P*√(Y*U)
330      A=Y*A(27)^2 + 2P*A(27)*A(29) + U*A(29)^2
340      S=Y*A(29)^2 + 2P*A(29)*A(28) + U*A(28)^2
350      D=Y*A(27)*A(29) + P*(A(27)*A(28)+A(29)^2) + U*A(29)*A(28)
360      F=(A(30)/T)^2, G=I*A(27) + O*A(29), H=I*A(29) + O*A(28)
370      Q=A*A(33)*A(33) + 2D*A(33)*A(34) + S*A(34)*A(34) + F*A(35)*A(35)
380      W=G*A(33) + H*A(34)
390      V=-W/2/Q + √(W*W/4/Q/Q + 1/Q)
400      B=W/2/Q + √(W*W/4/Q/Q + 1/Q) : BEEP 2
405      USING "###. #####^"
410      PRINT "R+="; V
415      USING "###. #####^"
420      PRINT "R-="; B
430      END

```

SECTION V

CONCLUSIONS

The description and instruction of the use of Radio Shack TRS-80 pocket computer for the key calculations of the stiffness and strength of symmetric laminated composites are presented in this paper. With the computer packages that were programmed, instant calculations can be made for practical use.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-757-002/79

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RADIO SHACK TRS-80 POCKET COMPUTER SOLUTIONS TO
COMPOSITE MATERIALS FORMULAS(U) UNIVERSAL ENERGY
SYSTEMS INC DAYTON OH W J PARK AUG 81 AFWAL-TR-81-4074
F33615-79-C-5125

2/2

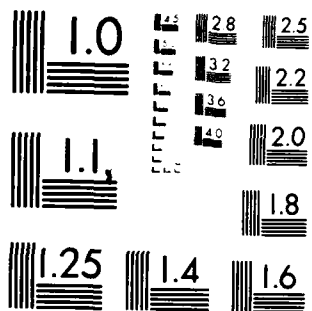
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SUPPLEMENTARY

INFORMATION



DEPARTMENT OF THE AIR FORCE
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

Aug 83

REPLY TO
ATTN OF: MLBM (W. J. Park, 513-255-6685)

SUBJECT: Correction of an Error in AFWAL-TR-81-4074

TO:

1. We are trying to contact anyone who might have received our technical report, AFWAL-TR-81-4074, "Radio Shack TRS-80 Pocket Computer Solutions to Composite Materials Formulas", because we have found a typo error in the report.

2. Please make the following correction in the program:

Page 11, Line 8 from the top,

385 $K = \frac{8}{12} * I * H$ 3, i.e. $\frac{3}{12}$ should be $\frac{8}{12}$ in

the program step 385.

W. J. Park

WON J. PARK
Visiting Scientist
Mechanics and Surface Interactions Branch

