APPENDIX E

PREDICTIVE COMPUTER PROGRAM

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PREDICTIVE COMPUTER PROGRAM

This appendix documents the Fortran program logic used to predict ebullated bed phase holdups from operating conditions.

Figures E-1 through E-4 are simplified flow charts of major subroutines whose purpose is not immediately apparent from the coding. Table E-I lists all subroutines and their functions.

The Fortran coding and a list of vector locations appear at the end of this appendix. Because this program shares several subroutines with the program for experimental data analysis, the vector list will not be continuous. Similarly, vectors such as EC, EGG, and ELG may be deleted if desired.

The Peebles and Garber correlation is presented in Table E-II to aid in tracing the logic of Subroutine PEEBLE.

TABLE E-I

PROGRAM SUBROUTINE FUNCTIONS

MAIN Program	Controls iteration sequence.
BHATIA	Calculates phase holdups from velocities.
CHGCD	Overlays vectors after normal cards read in.
DRIFT	Calculates V_{CD}, drift flux.
ELTAM	Calculates X_k.
FLOWS	Converts ft/sec to volume units.
LINEAR	Calculates linear velocities of gas and liquid based on bed volume fractions.
PEEBLE	Calculates bubble diameter from terminal bubble velocity.
READ	Reads data cards.
UTB	Calculates bubble terminal velocity.
WAKE	Calculates ratio of wake to bubble holdup.

TABLE E-II

TERMINAL VELOCITY OF ISOLATED BUBBLES IN LIQUIDS

Region	Terminal Velocity, U_t	Range of Applicability
1	$\frac{2r_e^2(\rho_l - \rho_g)g}{9\mu_l}$	$Re_b < 2$ where Re_b bubble Reynolds number = $\frac{2\rho_l U_t r_e}{\mu_l}$
2	$0.33g^{0.76}\left(\frac{\rho_l}{\mu_l}\right)^{0.32} r_e^{1.28}$	$2 < Re_b < 4.02M^{-0.214}$ where M Morton Number = $\frac{g\mu_l^4}{\rho_l\sigma^3}$
3	$1.35\left(\frac{\sigma}{\rho_l r_e}\right)^{1/2}$	$4.02M^{-0.214} < Re_b < 3.10M^{-1/4}$ or $16.32M^{0.144} < G < 5.75$ where $G = \frac{g\, r_e^4 U_t^4 \rho_l^3}{\sigma^3}$
4	$1.18\left(\frac{g\,\sigma}{\rho_l}\right)^{0.25}$	$3.10\ G < Re_b$ $5.75 < G$

Source of Information: Peebles, F. N., and Garber, H. J., "Studies on the Motion of Gas Bubbles in Liquids," Chemical Engineering Progress, 49, 2 (1953).

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REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

   ISN 0002            COMMON EL(20),EGP(10),EFP(10),ELP(10),EGG(100),EFG(100),ELG(100)
   ISN 0003            COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0004            COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
   ISN 0005            KCOUNT=0
   ISN 0006            KS(44) = 0
                  C         CONSTANTS
   ISN 0007            C(6) = 32.12
   ISN 0008            C(7) = 32.12
                  C         DEFAULT VALUES FOR KK OPTION
   ISN 0009            DO 5 L = 47,50
   ISN 0010          5 KS (L) = -99
   ISN 0011            KS(46) = 0
                  C         WRITE HEADER FOR OUTPUT TABLE
   ISN 0012            WRITE(6,197H)
                  C     READ UNIT DATA
   ISN 0013         10 CALL READ
                  C         SET DEFAULT, MAX NUMBER OF ITERATIONS TO 20
   ISN 0014            IF (KS(43).LE.0)  KS(43) = 20
                  C         IF END OF DATA, QUIT
   ISN 0016            IF( KS(44).NE.0 )   GO TO 9999
                  C         ZERO COUNTER FOR NUMBER OF ITERATIONS
   ISN 0018            KS(42) = 0
                  C
                  C         CONVERT FLOWS TO ENGLISH UNITS
                  C
   ISN 0019            CALL FLOWS
                  C
                  C         INITIAL GUESSES FOR CAT, SLURRY, GAS HOLDUPS
   ISN 0020            E(1) = 0.1
   ISN 0021            E(9) = 0.7
   ISN 0022            E(2) = 0.2
                  C         NOW ITERATE ON UP TO 5 OPTIONS TO CALCULATE KK
                  C         THE RELATIVE SOLIDS HOLDUP IN THE BUBBLE WAKE
   ISN 0023            DO 100 KL = 46,50
   ISN 0024            KS(19) = KS (KL)
   ISN 0025            IF (KS(19).LT.0) GO TO 100
                  C         A VALUE OF LESS THAN ZERO IMPLIES THERE IS NO MORE TO BE DONE
                  C         MAIN LOOP TO CALCULATE HOLDUPS STARTS HERE
   ISN 0027         15 E(21) = E(1)
   ISN 0028            E(22) = E(2)
   ISN 0029            E(23) = E(9)
                  C         SEE IF TOO MANY ITERATIONS
   ISN 0030            KS(42) = KS(42) + 1
   ISN 0031            IF(KS(42).GT.KS(43) )  GO TO 300
                  C
                  C         IF FINES PRESENT, APPORTION SLURRY TO LIQ + FINES
   ISN 0033            E(25) = 100.*V(5)*E(1)/(E(1)*V(5) + E(14)*(100.-V(5)))
   ISN 0034            E(3) = E(9) *(100.-E(25))/100.
   ISN 0035            E(4) = E(9)*E(25)/100.
                  C         DETERMINE LINEAR VELOCITIES BASED ON THESE VOLUME FRACTIONS
   ISN 0036            CALL LINEAR
                  C
                  C         DETERMINE BUBBLE TERMINAL VELOCITY-LEAVE HERE TO ALLOW
```

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                C          POSSIBLE FUTURE CORRELATIONS INVOLVING VOLUME FRACTIONS
                C
ISN 0037                CALL UTH
                C
                C          AND USE BUBBLE TERMINAL VELOCITY IN BHATIA-EPSTEIN MODEL
                C          TO CALCULATE PHASE HOLDUPS
                C
ISN 0038                CALL BHATIA
                C
                C          AND BACK SUBSTITUTE CALCULATED HOLDUPS
ISN 0039                E(2) = Z(18)
ISN 0040                E(9) = Z(19)
ISN 0041                E(3) = E(9)*(100.-E(25))/100.
ISN 0042                E(4) = E(9)*E(25)/100.
ISN 0043                E(1) = 1.-E(2)-E(9)
                C
                C          IS FURTHER ITERATION NECESSARY?
ISN 0044                DEL1 = ABS(E(1)-Z(21))
ISN 0045                DEL2 = ABS(E(2)-Z(22))
ISN 0046                DEL9 = ABS(E(9)-Z(23))
ISN 0047                IF (  (DEL1.GT.0.01). OR . (DEL2.GT.0.01).  OR .(DEL9.GT.0.01))
                       1        GO TO 15
                C          AND DETERMINE BUBBLE DIAMETER FROM BUBBLE TERMINAL VELOCITY
ISN 0049                CALL PEEBLE
                C
                C          DETERMINE DANTON-HARRISON DRIFT FLUX, VCO
                C
ISN 0050                CALL DRIFT
                C
                C          PERCENT HEO EXPANSION FROM CATALYST PROPERTIES AND EC
ISN 0051                E(40) = 100 *(((F(9)/F(10))/E(1))-1.)
                C
ISN 0052          30  CONTINUE
ISN 0053                WRITE (6,1979) (C(I),I=1,3), E(14), V(21), (E(I),I=1,3),E(40),
                       1      F(17),E(5)
ISN 0054           1978 FORMAT (1H ,6HRUN ID,2X,8HCOMMENTS,8X,2HUL,4X,2HUG,
                       1  5X,2HEC,4X,2HEG,4X,2HEL,2X,4H% BE,4X,2HXK,5X,3HUTH//)
ISN 0055           1979 FORMAT (1H ,3A2,3X,9HPREDICTED,2A,2F7.3,3F6.2,F6.0,2F7.3)
ISN 0056            100 CONTINUE
                C          WRITE TRAILER
ISN 0057                WRITE(6,1980)
ISN 0058           1980 FORMAT(1H ,90(1H_))
                C
                C          READ NEW SET OF OPERATING CONDITIONS
ISN 0059            300 GO TO 10
ISN 0060           9999 STOP
ISN 0061                END
```

MAIN / SIZE OF PROGRAM 000640 HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C SF	C	R*4	000BB8	F SFA	C	R*4	000898	F F	C	R*4	000A28	I F		I*4	000194
L SF		I*4	000198	S	C	R*4	NR	V F	C	R*4	000578	Z F	C	R*4	000708
EC	C	R*4	NR	UG	C	R*4	NR	IC	C	I*4	NR	IV	C	I*4	NR
IZ	C	I*4	NR	FL SF		I*4	00019C	RS SF	C	I*4	00106A	TM	C	R*4	NR
EFG	C	R*4	NR	EFP	C	R*4	NR	EGG	C	R*4	NR	EGP	C	R*4	NR
ELG	C	R*4	NR	ELP	C	R*4	NR	UTH SF	XF		000000	ZGR	C	R*4	NR

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REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XT

   ISN 0002            SUBROUTINE RHATIA
   ISN 0003            COMMON EC(20),EGP(10),EFP(10),FLP(10),FGG(100),EFG(100),ELG(100)
   ISN 0004            COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0005            COMMON KS(50),S(20),TM(300),IZ(20),IV(20),IC(20),KCOUNT
                  C
                  C          TEST TO ENSURE THAT THREE PHASES EXIST
                  C
   ISN 0006            IF ( V(2) .LE. 0.00001)  GO TO 9999
   ISN 0008            IF ( E(14) .LE. 0.00001)  GO TO 9999
                  C          ASSIGN MEASURED VALUES TO OLD VARIABLE LOCATIONS
   ISN 0010            F(41) = E(1)
   ISN 0011            E(42) = E(2)
   ISN 0012            E(48) = E(18)
   ISN 0013            E(43) = 1.0-E(2)- E(1)
                  C
                  C      LIMIT TO ITERATIONS, DEFAULT VALUE WILL BE 20
   ISN 0014            KKLIM = KS(30)
   ISN 0015            IF(KKLIM.LE.0) KKLIM=20
                  C
                  6          EQUATION 8  VGL = UTB + 2 UG
   ISN 0017            Z(10)=E(51)+2.*V(2)
                  C          NUMBER OF ITERATIONS COUNTER
   ISN 0018            KK=1
                  C          DETERMINE XA
   ISN 0019           10 CALL ELTAM
                  C
                  C          NOW DETERMINE RATIO OF WAKE VOLUME TO BUBBLE VOLUME
                  C          SEE EL-TENTAMY REFERENCE IN SUBROUTINE ELTAM
   ISN 0020            CALL WAKE
                  C
   ISN 0021            Z(11) = E(56) * EXP( -5.0* E(42))
   ISN 0022            Z(12) = Z(11) * E(42)
                  C
                  C     GAS LINEAR VELOCITY IN BED
   ISN 0023            E(48)=V(2)/E(42)
                  C
                  C         LIQUID HOLDUP  (ELF")  EQUATION 5--  TEST ARGUMENT FIRST       BEFORE
                  C          BEFORE RAISING TO EXPONENT 1/N
   ISN 0024           20 Z(23)=((E(14)-E(48)*Z(12)*(1.-F(17)))/(F(21)*(1.-F(42)-Z(12))))
                  C          TEST TO SEE IF ZERO--IF SO, RETURN
   ISN 0025            IF(Z(23).LE.0)  RETURN
   ISN 0027            Z(13) = Z(23) ** (1./E(52))
                  C
                  C     CALCULATE NEW LINEAR GAS VELOCITY , VG, EQUATION 4
   ISN 0028           30 Z(10)=(E(14)+V(2)+Z(13)*(1.-F(42)-Z(12))*Z(10))/(1.-F(41))
                  C
                  C     AVERAGE GAS VELOCITY FOR NEW GUESS
   ISN 0029            Z(17)=(Z(10)+E(48))/2.
                  C          NEW VALUE OF EG
   ISN 0030            Z(18)=V(2)/Z(17)
                  C
                  C     CALCULATE NEW VALUE OF (EL+EF) FROM EQUATION 2
   ISN 0031            Z(19)=Z(12)*(1.-F(17))+Z(13)*(1.-F(42)-Z(12)*F(17)*Z(12))
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                C
                C     CALCULATE NEW VALUE OF EC FROM EQUATION 3
                C
ISN 0032           40 Z(20)=1.-Z(19)-Z(18)
                C
                C     TEST CONVERGENCE
ISN 0033          125 TEG=ABS(Z(18)-E(42))
ISN 0034              TEL=ABS(Z(19)-E(43) )
ISN 0035              TVG=ABS(Z(16)-E(48))
ISN 0036              IF(TEL.LE.0.01 .AND. TEG.LE.0.1 .AND. TVG.LE.0.01)GO TO 200
ISN 0038              IF(KK.GE.KKLIM)GO TO 200
ISN 0040              KK=KK+1
ISN 0041              E(42)=Z(18)
ISN 0042              E(43)=Z(19)
ISN 0043              E(41)=Z(20)
ISN 0044              GO TO 10
ISN 0045          200 CONTINUE
ISN 0046          250  CONTINUE
ISN 0047              RETURN
                C          ERROR SECTION-  ZERO VELOCITY
ISN 0048         9999 CONTINUE
ISN 0049              WRITE (6,9998)
ISN 0050         9998 FORMAT (1H1, * ZERO VELOCITY FOR RHATIA-EPSTEIN MODEL*)
ISN 0051              STOP
ISN 0052              END
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RHATIA / SIZE OF PROGRAM 000552 HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C	C	R*4	NR	E SFA	C	R*4	000898	F F	C	R*4	000A28	S	C	R*4	NR
V F	C	R*4	000578	Z SFA	C	R*4	000708	EC	C	R*4	NR	GR	C	R*4	NR
IC	C	I*4	NR	IV	C	I*4	NR	IZ	C	I*4	NR	KK SF		I*4	000128
KS F	C	I*4	001068	IM	C	R*4	NR	EFG	C	R*4	NR	EFP	C	R*4	NR
EGG	C	R*4	NR	EGP	C	R*4	NR	ELG	C	R*4	NR	ELP	C	R*4	NR
EXP F	XF	R*4	000000	TEG S		R*4	00012C	TEL S		R*4	000130	TVG S		R*4	000134
ZGR	C	R*4	NR	WAKE SF	XF		000000	ELTAM SF	XF		000000	KKLIM S		I*4	000138
FNAPR#	XF	R*4	000000	RHATIA		R*4	00013C	IBCOM# F	XF	I*4	000000	KCOUNT	C	I*4	NR

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK * * SIZE OF BLOCK 001404 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
EC	R*4	000000 NR	EGP	R*4	000250 NR	EFP	R*4	000078 NR	ELP	R*4	000A40 NR
EGG	R*4	000258 NR	EFG	R*4	000258 NR	ELG	R*4	0003E8 NR	V	R*4	000578
Z	R*4	000708	F	R*4	000498	F	R*4	000A28	C	R*4	000BB8 NR
GR	R*4	000D48 NR	ZGR	R*4	000E08 NR	KS	I*4	001068	S	R*4	001130 NR
IC	R*4	001298 NR	IZ	I*4	001310 NR	IV	I*4	001360 NR	IC	I*4	001388 NR
KCOUNT	I*4	001400 NR									

SOURCE STATEMENT LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR

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REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE ENDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOBAL INTERM IBM FLAG(I) XL

   ISN 0002            SUBROUTINE CHGCU
   ISN 0003            COMMON EC(20),EGP(10),EFP(10),ELP(10),EGG(100),EFG(100),ELG(100)
   ISN 0004            COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0005            COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
                  C
                  C          THIS SUBROUTINE ALLOWS INDIVIDUAL VECTOR VALUES
                  C          TO BE CHANGED AFTER ALL NORMAL INPUT IS READ IN
                  C
   ISN 0006            DIMENSION VARNAM(20)
   ISN 0007            DIMENSION  IMX (20)
   ISN 0008            DATA VARNAM/3H EC,3HEGP,3HEFP,3HELP,3HEGG,
                      1            3HEFG,3HELG,3H  V,3H  Z,3H  E,
                      2            3H  F,3H  C,3H GR,3HZGR,3H KS,
                      3            3H  S,3H TM,3H IZ,3H IV,3H IC/
   ISN 0009            DATA BL/3H   /
   ISN 0010            DATA IMX/20,3*10,10*100,50,20,100,3*20/
   ISN 0011            DATA DASH/1H-/
                  C     BEGIN
                  C        BYPASS       CARDS           WITH FORM 315-08
   ISN 0012          28 READ(5,25,END=400) LC,VBL
   ISN 0013          25 FORMAT(13,A1)
                  C        IS THIS THE LAST CARD?
   ISN 0014            IF(LC.GE.998) GO TO 400
   ISN 0016            IF(VBL.EQ.DASH) GO TO 28
                  C        NOT END CARD, NOT A DASH-IMPLIES THIS IS A CHANGE CARD
   ISN 0018            BACKSPACE 5
   ISN 0019            JNAMES=20
   ISN 0020          50 READ(5,100,END=400) LC,VBL,IS,IF
   ISN 0021         100 FORMAT(13,A3,213)
                  C     LAST CARD?
   ISN 0022            IF(LC.GE.998) GO TO 400
                  C        BYPASS BLANK CARD
   ISN 0024            IF(VBL.EQ.BL) GO TO 50
                  C        TEST FOR PROPER SEQUENCE
   ISN 0026            IF(IS.LE.0)  GO TO 900
   ISN 0028            IF(IF.LE.0)  GO TO 900
   ISN 0030            IF(IS.GT.IF) GO TO 900
                  C
                  C          MAIN LOOP TO IDENTIFY VARIABLE NAME
                  C
   ISN 0032            DO 200 J=1,JNAMES
   ISN 0033            JS=J
   ISN 0034            IF(VBL.EQ.VARNAM(J))  GO TO 225
   ISN 0036         200 CONTINUE
                  C
                  C          GO BEGIN = ERROR
                  C
   ISN 0037            GO TO 925
                  C
                  C          BEGIN=1024 TEST FOR VALID UPPER LIMIT
                  C
   ISN 0044         225 IF(IF.GT.IMX(JS))      GO TO 910
                  C
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                C         READ THE DATA
                C
ISN 0040              GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20),JS
ISN 0041            1 READ(5,280)(EC(I),I=IS,IF)
ISN 0042              GO TO 50
ISN 0043            2 READ(5,280)(EGP(I),I=IS,IF)
ISN 0044              GO TO 50
ISN 0045            3 READ(5,280)(EFP(I),I=IS,IF)
ISN 0046              GO TO 50
ISN 0047            4 READ(5,280)(ELP(I),I=IS,IF)
ISN 0048              GO TO 50
ISN 0049            5 READ(5,280)(EGG(I),I=IS,IF)
ISN 0050              GO TO 50
ISN 0051            6 READ(5,280)(EFG(I),I=IS,IF)
ISN 0052              GO TO 50
ISN 0053            7 READ(5,280)(ELG(I),I=IS,IF)
ISN 0054              GO TO 50
ISN 0055            8 READ(5,280)(  V(I),I=IS,IF)
ISN 0056              GO TO 50
ISN 0057            9 READ(5,280)(  Z(I),I=IS,IF)
ISN 0058              GO TO 50
ISN 0059           10 READ(5,280)(  E(I),I=IS,IF)
ISN 0060              GO TO 50
ISN 0061           11 READ(5,280)(  F(I),I=IS,IF)
ISN 0062              GO TO 50
ISN 0063           12 READ(5,280)(  C(I),I=IS,IF)
ISN 0064              GO TO 50
ISN 0065           13 READ(5,280)( GW(I),I=IS,IF)
ISN 0066              GO TO 50
ISN 0067           14 READ(5,280)(ZGW(I),I=IS,IF)
ISN 0068              GO TO 50
ISN 0069           15 READ(5,390)( KS(I),I=IS,IF)
ISN 0070              GO TO 50
ISN 0071           16 READ(5,280)(  S(I),I=IS,IF)
ISN 0072              GO TO 50
ISN 0073           17 READ(5,280)( TM(I),I=IS,IF)
ISN 0074              GO TO 50
ISN 0075           18 READ(5,380)( IZ(I),I=IS,IF)
ISN 0076              GO TO 50
ISN 0077           19 READ(5,380)( IV(I),I=IS,IF)
ISN 0078              GO TO 50
ISN 0079           20 READ(5,380)( IC(I),I=IS,IF)
ISN 0080              GO TO 50
ISN 0081          280 FORMAT(8F9.0,8X)
ISN 0082          380 FORMAT(8I9,8X)
ISN 0083          400 RETURN
                C
                C         ERROR SECTION
                C
ISN 0084              900 WRITE (6,905)
ISN 0085              905 FORMAT(1H0,28HIMPROPER CHANGE CARD INDICES)
ISN 0086                  GO TO 950
ISN 0087              920 WRITE (6,925)
ISN 0088              925 FORMAT(1H0,21HUNKNOWN VARIABLE NAME)
ISN 0089                  GO TO 950
ISN 0090              930 WRITE (6,935)
ISN 0091              935 FORMAT(1H0,30HFIXED INDEX TOO HIGH FOR ARRAY)
ISN 0092                  GO TO 950
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ISN 0093      950 WRITE(6,955) LC,VBL,TS,IF
ISN 0094      955 FORMAT(1H ,I3,A3,2I3,10X,14H(CARD IGNORED))
ISN 0095          GO TO 50
ISN 0096     9999 RETURN
ISN 0097          END
```

/ CHGCD / SIZE OF PROGRAM 000A4A HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C S	C	R*4	000088	F S	C	R*4	000898	F S	C	R*4	000A28	I F		I*4	000180
J SF		I*4	0001A4	S S	C	R*4	001130	V S	C	R*4	00057A	Z S	C	R*4	000708
BL		R*4	0001A8	EC S	C	R*4	000000	GR S	C	R*4	000D48	IC S	C	I*4	001380
IF SF		I*4	0001AC	IS SF		I*4	000190	IV S	C	I*4	001360	IZ S	C	I*4	001310
JS SF		I*4	000194	KS S	C	I*4	001068	LC SF		I*4	00019A	TM S	C	R*4	001180
EFG S	C	R*4	00025A	EFP S	C	R*4	000078	EGG S	C	R*4	0000C8	EGP S	C	R*4	000050
ELG S	C	R*4	0003E8	ELP S	C	R*4	0000A0	IMX		I*4	0001AC	VBL SF		R*4	00019C
ZGR S	C	R*4	000ED8	DASH		R*4	0001A0	CHGCD		R*4	0001A4	IBCOM# F	XF	I*4	000000
JNAMES SF		I*4	0001A8	KCOUNT	C	I*4	NR	VARNAM		R*4	0001FC				

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK * * SIZE OF BLOCK 001404 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
EC	R*4	000000	EGP	R*4	000050	EFP	R*4	000078	ELP	R*4	0000A0
EGG	R*4	0000C8	EFG	R*4	00025A	ELG	R*4	0003E8	V	R*4	00057A
Z	R*4	000708	E	R*4	000898	F	R*4	000A28	C	R*4	000888
GR	R*4	000D48	ZGR	R*4	000ED8	KS	I*4	001068	S	R*4	001130
TM	R*4	001180	IZ	I*4	001310	IV	I*4	001360	IC	I*4	001380
KCOUNT	I*4	001400 NR									

SOURCE STATEMENT LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
28	12	000300	50	20	00034A	200	36	0003F6	225	38	000412
1	41	000442	2	43	000486	3	45	0004CA	4	47	00050E
5	49	000552	6	51	000596	7	53	0005DA	8	55	00061E
9	57	000662	10	59	0006A6	11	61	0006EA	12	63	00072E
13	65	000772	14	67	0007B6	15	69	0007FA	16	71	00083E
17	73	000882	18	75	0008C6	19	77	00090A	20	79	00094E
400	83	000992	900	86	00099A	920	87	000986	930	90	000902
950	93	0009EE	9999	96	000A2A NR						

COMPILER GENERATED LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
100002	12	000314	100003	15	000336	100004	18	000344	100005	20	00036C
100006	24	00039E	100007	26	0003AC	100008	28	0003B8	100009	30	0003C4
100010	32	000302	100011	33	0003DA	100012	37	00040C	100013	40	00042A

FORMAT STATEMENT LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
25	13	000028	100	21	00002F	280	81	000038	380	82	000041

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REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GUSTMI NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

   ISN 0002            SUBROUTINE DRIFT
   ISN 0003            COMMON EC(20),EGP(10),EFP(10),ELP(10),EGG(100),EFG(100),ELG(100)
   ISN 0004            COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0005            COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
                  C
                  C         CALCULATE TWO OR THREE PHASE DRIFT-FLUX
                  C         UNITS WILL BE IN MM/SEC FOR COMPARISON WITH LIT.
                  C
   ISN 0006          30 E(53)=((V(21)*(1.-E(2)))-(F(14)*E(2)*(1.-E(2))/(E(3)+F(4))))*304.8
   ISN 0007          40  CONTINUE
   ISN 0008            IF(V(21).LE.0.0)E(53)=0.0
   ISN 0010            RETURN
   ISN 0011            END

                                                    /   DRIFT /     SIZE OF PROGRAM 000172 HEXADECIMAL BYTES

  NAME    TAG   TYPE  ADD.      NAME    TAG   TYPE  ADD.      NAME    TAG   TYPE  ADD.      NAME    TAG   TYPE  ADD.
    C       C   R*4     NR        F SF  C   R*4   000898        F     C   R*4     NR        S     C   R*4     NR
    C   F   C   R*4   00057H        Z     C   R*4     NR       EC     C   R*4     NR       GR     C   R*4     NR
    V   F   C   R*4   00057H        Z     C   R*4     NR       EC     C   R*4     NR       GR     C   R*4     NR
   IC       C   I*4     NR       IV     C   I*4     NR       IZ     C   I*4     NR       KS     C   I*4     NR
   TM       C   R*4     NR      EFG     C   R*4     NR      EFP     C   R*4     NR      EGG     C   R*4     NR
  EGP       C   R*4     NR      ELG     C   R*4     NR      ELP     C   R*4     NR      ZGR     C   R*4     NR
DRIFT           R*4   00009C   KCOUNT   C   I*4     NR

                                        *****  COMMON INFORMATION  *****

     NAME OF COMMON BLOCK  *      *   SIZE OF BLOCK     001404 HEXADECIMAL BYTES

VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.
     EC    R*4     000000 NR      EGP    R*4     000050 NR      EFP    R*4     000078 NR      ELP    R*4     0000A0 NR
    EGG    R*4     0000C8 NR      EFG    R*4     000258 NR      ELG    R*4     0003E8 NR        V    R*4     00057A
      Z    R*4     000708 NR        E    R*4     000898         F    R*4     000A28 NR        C    R*4     000BB8 NR
     GR    R*4     000048 NR      ZGR    R*4     000ED8 NR       KS    I*4     001068 NR        S    R*4     001130 NR
     TM    R*4     001180 NR       IZ    I*4     001310 NR       IV    I*4     001360 NR       IC    I*4     0013B0 NR
 KCOUNT    I*4     001400 NR

  SOURCE STATEMENT LABELS

   LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR
      10    6  0000CC           40    7  000136 NR

  COMPILER GENERATED LABELS

   LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR
  000002    9  000146        000003   10  000152

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GUSTMI NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL
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LEVEL 2.3.0 (JUNE 78)                 OS/360  FORTRAN H EXTENDED          DATE 80.094/10.19.46        PAGE   1

REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

  ISN 0002              SUBROUTINE ELTAM
                C
                C            CALCULATES XK FOR FLUIDIZED BEDS BY CORRELATION OF EL-TAMTAMI
                C            REF: INT. J. MULTIPHASE FLOW 4, 19 (1978)
                C
  ISN 0003              COMMON EC(20),EGP(10),EFP(10),ELP(10),EGG(100),EFG(100), ELG(100)
  ISN 0004              COMMON V(100),Z(100),F(100),E(100),C(100),GR(100),ZGR(100)
  ISN 0005              COMMON KS(50), S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
                C
                C
                C
                C            CALCULATE VOL. VELOCITY OF GAS RELATIVE TO TOTAL LIQUID
                C            BASED ON GAMMA RAY SCAN RESULTS
                C
  ISN 0006              Z(25) = V(21)/E(42)   -   E(14)/(1.0 -E(41)-E(42))
                C
  ISN 0007              Z(27) = Z(25)
                C
                C            ACTUAL CORRELATION FOR XK, FORCING IT TO BE >=0
                C            **********
  ISN 0008              Z(26) = (1-0.877*F(21)/Z(27))
  ISN 0009              IF (Z(26). LE. 0.)  Z(26) = 0.
                C
                C            SEE IF COMPUTED OR READ-IN VALUE TO BE USED
  ISN 0011              IF (KS(19). EQ. 3)  GO TO 3500
  ISN 0013              IF (KS(19). EQ.  2) GO TO 1500
  ISN 0015              IF (KS(19). EQ. 0)    GO TO 500
  ISN 0017              F (17) = E(55)
  ISN 0018              RETURN
                C
                C            FOR THIS PATH, ASSIGN EL-TEMTAMY VALUE TO F(17)
  ISN 0019          500 F(17) = Z(26)
                C
                C
                C            NOTE IN ABOVE EXPRESSION THAT VELOCITY USED IS CATALYST
                C            TERMINAL VELOCITY AS USED FOR RICHARDSON/ZAKI EXPRESSION
  ISN 0020         1000 CONTINUE
  ISN 0021              RETURN
                C
  ISN 0022         1500 CONTINUE
                C            HIGHEST LIQUID VELOCITY-USE HIGHEST VALUES ONLY, NOT EXTRAP.
  ISN 0023         2700 Z(28) = TM(75)
  ISN 0024              Z(29) = TM(74)
                C            ACTUAL CORRELATION HERE
                C            FORM:      (1-A)**(-1) = SLOPE * UTR + INTERCEPT
  ISN 0025         3000 F(17) = Z(28) * F(51) + Z(29)
  ISN 0026              F (17) = 1. - (1./F(17))
  ISN 0027              RETURN
                C        THIS SECTION FOR KS (19) = 3
                C        AT LOW VELOCITIES, USE THE EL-TEMTAMY CORRELATION
                C        AT HIGH VELOCITIES, USE THE TM-BASED CORRELATION
  ISN 0028         3500 IF (E(14). GT. E(65) )  GO TO 1500
  ISN 0030              GO TO 500
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ISN 0031      4000 RETURN
ISN 0032           END
```

/ ELTAM / SIZE OF PROGRAM 000246 HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C	C	R*4	NR	F F	C	R*4	000898	F SF	C	R*4	0008A8	S	C	R*4	NR
V F	C	R*4	000578	/ SF	C	R*4	000708	EC	C	R*4	NR	GR	C	R*4	NR
IC	C	I*4	NR	IV	C	I*4	NR	IZ	C	I*4	NR	KS	C	I*4	001068
IH F	C	R*4	001180	EFG	C	R*4	NR	EFP	C	R*4	NR	EGG	C	R*4	NR
EGP	C	R*4	NR	ELG	C	R*4	NR	ELP	C	R*4	NR	ZGR	C	R*4	NR
ELTAM		R*4	000004	KCOUNT	C	I*4	NR								

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK * * SIZE OF BLOCK 001404 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
EC	R*4	000000 NR	EGP	R*4	000050 NR	EFP	R*4	000078 NR	ELP	R*4	0000A0 NR
EGG	R*4	0000C4 NR	EFG	R*4	00025A NR	ELG	R*4	0003E8 NR	V	R*4	00057A
/	R*4	000708	E	R*4	000898	F	R*4	0008A8	C	R*4	000AAA NR
GR	R*4	000048 NR	ZGR	R*4	000ED8 NR	KS	I*4	001068	S	R*4	001130 NR
IH	R*4	001180	IZ	I*4	001310 NR	IV	I*4	001360 NR	IC	I*4	0013A8 NR
KCOUNT	I*4	001400 NR									

SOURCE STATEMENT LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
500	19	0001F0	1000	20	0001FC NR	1500	22	000204	2700	23	000204 NR
3000	25	000224 NR	3500	28	000262	4000	31	000286 NR			

COMPILER GENERATED LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
100001	2	000120	100002	10	00019C	100003	11	0001A8	100004	13	0001BA
100005	14	0001CC	100006	17	0001DC	100007	30	000280			

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*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

*STATISTICS*     SOURCE STATEMENTS =      31,  PROGRAM SIZE =      678,  SUMPROGRAM NAME = ELTAM

*STATISTICS*  ..  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                  3928 BYTES OF CORE NOT USED
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 LEVEL 2.3.1 (JUNE 78)                  OS/360  FORTRAN H EXTENDED          DATE 80.084/10.19.43       PAGE   1

REQUESTED OPTIONS: NOITEM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

   ISN 0002            SUBROUTINE FLOWS
                  C         CONVERTS FEET/SECOND TO OTHER UNITS
   ISN 0003               COMMON EC(20),EGP(10),EFP(10),FLP(10),EGG(100),EFG(100),ELG(100)
   ISN 0004               COMMON V(100),Z(100),E(100),F(100),C(100),GP(100),ZGR(100)
   ISN 0005               COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
                  C
   ISN 0006               IF(F(14).GT.0.0) GO TO 10
                  C         CALCULATE SLURRY DENSITY
   ISN 0008               E(8)=F(1)
   ISN 0009               GO TO 11
   ISN 0010            10 E(8)=(100.*F(1)*F(14))/(V(5)*F(1)+(100.-V(5))*F(14))
                  C    CALCULATE LIQUID  FLOWRATES
   ISN 0011           11 V(19) = E(14)*60.*7.48*(3.1416*C(4)**2/4.)
                  C
                  C
   ISN 0012               E(17)=V(19)/(3.1416*C(4)**2/4.)
                  C
                  C
                  C         CALCULATE GAS FLOW RATES,CFH
   ISN 0013               E(20) = (3.1416*C(4)**2/4.)*V(21)*3600.
   ISN 0014               RETURN
   ISN 0015               END

                                                    /   FLOWS /     SIZE OF PROGRAM 00021A HEXADECIMAL BYTES

  NAME     TAG   TYPE  ADD.       NAME     TAG   TYPE  ADD.       NAME     TAG   TYPE  ADD.       NAME     TAG   TYPE  ADD.
    C  F   C     R*4   000HHH        F  SF   C     R*4   000898        F  F   C     R*4   000A28        S      C     R*4     NR
    V  SF  C     R*4   000578        Z       C     R*4     NR          EC     C     R*4     NR          GR     C     R*4     NR
   IC      C     I*4     NR        IV       C     I*4     NR          IZ     C     I*4     NR          KS     C     I*4     NR
   TM      C     R*4     NR       EFG       C     R*4     NR         EFP     C     R*4     NR         EGG     C     R*4     NR
  EGP      C     R*4     NR       ELG       C     R*4     NR         ELP     C     R*4     NR         ZGR     C     R*4     NR
FLOWS            R*4   0000HC    KCOUNT     C     I*4     NR

                                        *****  COMMON INFORMATION  *****

    NAME OF COMMON BLOCK  *       *  SIZE OF BLOCK    001404 HEXADECIMAL BYTES

VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.
      EC   R*4   000000 NR         EGP   R*4   000050 NR         EFP   R*4   000078 NR         ELP   R*4   0000AA NR
     EGG   R*4   0000C8 NR         EFG   R*4   000258 NR         ELG   R*4   0003E8 NR           V   R*4   000578
       Z   R*4   000708 NR           E   R*4   000898             F   R*4   000A28             C   R*4   000BBB
      GR   R*4   000D4B NR          ZGR   R*4   000ED8 NR          KS   I*4   001068 NR           S   R*4   001130 NR
      TM   R*4   001188 NR          IZ    I*4   001310 NR          IV   I*4   001360 NR          IC   I*4   001380 NR
  KCOUNT   I*4   001400 NR

SOURCE STATEMENT LABELS

 LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR
    10   10  000112            11   11  00016A

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LEVEL 2.3.0 (JUNE 78)                  05/360  FORTRAN H EXTENDED          DATE 80.084/10.19.43       PAGE   1

REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE ENCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

   ISN 0002            SUBROUTINE LINEAR
   ISN 0003            COMMON EC(20),EGP(10),EFP(10),ELP(10),EGG(100),EFG(100),ELG(100)
   ISN 0004            COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0005            COMMON KS(50),S(20),TM(100),I7(20),IV(20),IC(20),KCOUNT
                  C
                  C     CALCULATE LINEAR VELOCITIES FT/SEC
                  C
   ISN 0006            E(15)=E(14)/(F(3)+E(6))
                  C          CALCULATE GAS FLOWS
   ISN 0007            IF(V(21).LE. 0.) GO TO 12
   ISN 0009            E(18) = V(21)/E(2)
   ISN 0010            GO TO 15
   ISN 0011         12 E(18) = 0.
   ISN 0012         15 CONTINUE
   ISN 0013            RETURN
   ISN 0014            END

                                                  /  LINEAR /     SIZE OF PROGRAM 000142 HEXADECIMAL BYTES

      NAME     TAG   TYPE  ADD.      NAME     TAG   TYPE  ADD.      NAME     TAG   TYPE  ADD.      NAME     TAG   TYPE  ADD.
        C        C   R*4     NR        F SF   C   R*4   000898        F      C   R*4     NR        S      C   R*4     NR
        V  F     C   R*4   000578        7    C   R*4     NR       EC      C   R*4     NR       GR      C   R*4     NR
       IC        C   I*4     NR       IV     C   I*4     NR       IZ      C   I*4     NR       KS      C   I*4     NR
       TM        C   R*4     NR      EFG     C   R*4     NR      EFP      C   R*4     NR      EGG      C   R*4     NR
      EGP        C   R*4     NR      ELG     C   R*4     NR      ELP      C   R*4     NR      ZGR      C   R*4     NR
   KCOUNT        C   I*4     NR   LINEAR         I*4   000098

                                        *****  COMMON INFORMATION  *****

      NAME OF COMMON BLOCK  *      *   SIZE OF BLOCK     001404 HEXADECIMAL BYTES

   VAR. NAME  TYPE  REL. ADDR.    VAR. NAME  TYPE  REL. ADDR.    VAR. NAME  TYPE  REL. ADDR.    VAR. NAME  TYPE  REL. ADDR.
         EC   R*4   000000 NR          EGP   R*4   000050 NR          EFP   R*4   000078 NR          ELP   R*4   0000A0 NR
        EGG   R*4   0000C8 NR          EFG   R*4   000258 NR          ELG   R*4   0003E8 NR            V   R*4   000578
          Z   R*4   000708 NR            E   R*4   000898              F   R*4   000A28 NR            C   R*4   000BB8 NR
         GR   R*4   000D48 NR          ZGR   R*4   000ED8 NR           KS   I*4   001068 NR            S   R*4   001130 NR
         TM   R*4   001180 NR           I7   I*4   001310 NR           IV   I*4   001360 NR           IC   I*4   0013B0 NR
     KCOUNT   I*4   001400 NR

  SOURCE STATEMENT LABELS

    LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR
       12   11  000116            15   12  000122

  COMPILER GENERATED LABELS

    LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR          LABEL  ISN   ADDR
   000001    2  0000C0       000002    9  0000F8

*OPTIONS IN EFFECT*NAME(MAIN) OPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
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REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

ISN 0002             SUBROUTINE PEEBLE
              C           THIS SUBROUTINE DETERMINES THE BUBBLE DIAMETER FROM THE
              C           TERMINAL VELOCITY. IT USES THE INVERSE OF THE PEEBLES
              C           AND GARBER CORRELATIONS.
              C
              C           REF: PEEBLES, F.N. AND GARBER, H.J.,
              C                CHEM. ENG. PROGRESS 49 2 (1953)
ISN 0003             COMMON EC(20),EGP(10),EFP(10),ELP(10),EGG(100),EFG(100), ELG(100)
ISN 0004             COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
ISN 0005             COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
              C
              C           TRANSLATE VISCOSITY AND SURFACE TENSION TO ENGLISH UNITS
ISN 0006             F(23) = F(3)* 2.24809E-6/0.0328083
              C
              C           USE LIQUID OR SLURRY VISCOSITY DEPENDING ON PCT. FINES
              C
ISN 0007             IF (V(5). LT. 0.01) GO TO 10
ISN 0009             F(22) = F(5)
ISN 0010             GO TO 15
ISN 0011          10 F(22) = F(2)
ISN 0012          15 F(22) = F(22) * 6.7197E-4
              C
              C        REGION ONE-BUBBLE RADIUS WILL BE OBTAINED IN FEET.
              C
ISN 0013             KS(41) = 1
ISN 0014             F(20) = SQRT((9.*E(51)*F(22))/(2.*(E(8)-F(6))*C(6)))
              C
              C        CALCULATE REYNOLDS NUMBER TO SEE IF REGION IS APPLICABLE
              C
ISN 0015             E(35) = 2.* E(8) *E(51).*F(20)/F(22)
ISN 0016             IF(E(35).LE.2.) GO TO 1000
              C
              C           REGION 2
              C
ISN 0018             KS(41) = 2
ISN 0019             F(20)=(E(51)/(0.33*(C(6)**0.76)*((E(8)/F(22))**0.52)))**(1./1.28)
              C
              C        REYNOLDS NUMBER AND MORTON (WEBER) NUMBER
ISN 0020             E(35) = 2.*E(8)*E(51)*F(20)/F(22)
ISN 0021             E(36) = C(6)*F(22)**4/(E(8)*F(23)**3*C(7)**3)
ISN 0022             IF(E(35).LT.2.)  GO TO 5000
ISN 0024             IF(E(35). LT.(4.02*(F(36)**(-0.214)))    ) GO TO 1000
              C
              C        REGION 3
              C
ISN 0026             KS(41) = 3
ISN 0027             F(20) = (F(23)*C(7)*1.35**2)/(E(8)*E(51)**2)
              C
              C           REYNOLDS NUMBER
              C
ISN 0028             E(35) = 2.*E(8)*E(51) * F(20)/F(22)
              C
              C           W2 NUMBER = ...**2/16 ...
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LEVEL 2.3.0 (JUNE 78)        PEEBLE          05/360  FORTRAN H EXTENDED          DATE 80.044/10.19.44       PAGE   2

                C
 ISN 0029               E(37) = C(6) * F(20)**4 * F(51)**4 * E(8)**3/(F(23)**3 *C(7)**3)
 ISN 0030               F(36) = C(6)*F(22)**4/(F(8)*F(23)**3*C(7)**3)
                C
                C           TEST 1
 ISN 0031               IF((E(35). GT. (4.02*(E(36)**(-0.214)))).  AND  .
                     1    (E(35). LT.  3.10* E(36)**(-0.25)) )   GO TO 1000
                C           TEST 2
                C
 ISN 0033               IF( (E(37). GT. (16.32* E(36)**0.144)  ). AND .
                     1    (F(37). LT. 5.75) )  GO TO 1000
                C
                C           REGION 4
 ISN 0035               KS (41) = 4
 ISN 0036               GO TO 5000
 ISN 0037            1000 F(38) = 2. * F(20)*30.4R
 ISN 0038               RETURN
                C
                C           IF UTH IS TOO HIGH, ENTER A NEGATIVE NUMBER
                C           SINCE THE CORRELATION IS FOR SINGLE BUBBLES
                C           THIS MAY WELL OCCUR IN THE CHURN-TURBULENT REGION
 ISN 0039            5000 CONTINUE
 ISN 0040               E(35) = -99.
 ISN 0041               E(38) = -99.
 ISN 0042               KS(41) = -KS(41)
 ISN 0043               RETURN
 ISN 0044               END
```

/ PEEBLE / SIZE OF PROGRAM 00074C HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C FA	C	R*4	000RR8	F SFA	C	R*4	000898	F SFA	C	R*4	000A28	S	C	R*4	NR
V	C	R*4	000578	Z	C	R*4	NR	EC	C	R*4	NR	GR	C	R*4	NR
IC	C	I*4	NR	IV	C	I*4	NR	IZ	C	I*4	NR	KS SF	C	I*4	001068
TM	C	R*4	NR	EFG	C	R*4	NR	EFP	C	R*4	NR	EGG	C	R*4	NR
EGP	C	R*4	NR	ELG	C	R*4	NR	ELP	C	R*4	NR	ZGR	C	R*4	NR
SQRT F	XF	R*4	000000	FRXPN#	XF	R*4	000000	KCOUNT	C	I*4	NR	PEEBLE		R*4	000148

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK * * SIZE OF BLOCK 001404 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
EC	R*4	000000 NR	EGP	R*4	000050 NR	ELP	R*4	000078 NR	ELP	R*4	0000A0 NR
EGG	R*4	0000C8 NR	EFG	R*4	000258 NR	ELG	R*4	0003E8 NR	V	R*4	000578
Z	R*4	0007U8 NR	E	R*4	000898	F	R*4	000A28	C	R*4	000RR8
GR	R*4	000948 NR	ZGR	R*4	000EDR NR	KS	I*4	001068	S	R*4	001130 NR
TM	R*4	001180 NR	IZ	I*4	001310 NR	IV	I*4	001360 NR	IC	I*4	0013R0 NR
KCOUNT	I*4	001400 NR									

SOURCE STATEMENT LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR

```
 LEVEL 2.3.0 (JUNE 73)                    OS/360  FORTRAN H EXTENDED          DATE 80.084/10.19.42       PAGE   1

REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

   ISN 0002            SUBROUTINE READ
   ISN 0003            COMMON EC(20),EGP(10),EFP(10),ELP(10),EGG(100),EFG(100),ELG(100)
   ISN 0004            COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0005            COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
                  C    START READING DATA
   ISN 0006            IF (KCOUNT.GE.1) GO TO 200
                  C    READ DATA
                  C    READ LIQUID, GAS, CATALYST, AND FINES PROPERTIES
                  C         2 CARDS FOR CATALYST PROPERTIES NOW
   ISN 0008            READ(5,110) C(1),(C(I),I=21,40)
                  C         LIQUID PROPERTIES
   ISN 0009            READ(5,120) F(1),F(2),F(5),F(3)
                  C         GAS PROPERTIES
   ISN 0010            READ(5,130) F(6),F(7)
                  C         CATALYST PROPERTIES
   ISN 0011            READ(5,140)F(8),F(9),F(10),F(11),F(12)
                  C         CATALYST TERMINAL VELOCITY, RICHARDSON/ZAKI INDEX
   ISN 0012            READ(5,140) F(21), E(52)
                  C         FINES PROPERTIES
   ISN 0013            READ(5,150) F(14),F(15)
                  C          READ REACTOR AND MISCELLANEOUS
   ISN 0014            READ(5,140) C(4),V(5),V(7)
                  C         READ COEFFICIENTS FOR CORRELATIONS
   ISN 0015            READ (5,140) (TM(I), I=40,42)
                  C         COEFFICIENTS FOR WAKE VOLUME RATIO
   ISN 0016            READ (5,140) (TM(I),I=43,46)
                  C         VELOCITIES FOR UTH CORRELATION
   ISN 0017            READ (5,140) (TM(I),I=51,54)
                  C         COEFFICIENTS FOR UTB CORRELATION
   ISN 0018            READ (5,140) (TM(I),I= 55,60)
                  C         XK CORRELATION VARIABLES-CROSSOVER VELOCITY + COFFFS
   ISN 0019            READ (5,140) TM(65),TM(74),TM(75)
                  C          READ TEST DATA
                  C
   ISN 0020            KCOUNT = 1
                  C         READ REACTOR FLOWS (FT/SEC)
   ISN 0021          200 CONTINUE
   ISN 0022            READ(5,230,END=9999) (C(I),I=41,50),  E(14),V(21)
                  C
   ISN 0023          300 CONTINUE
                  C
                  C         READ ANY CHANGE CARDS, INCLUDING THE 9999
   ISN 0024          400 CALL CHGCD
   ISN 0025          500 FORMAT(I3)
   ISN 0026          101 FORMAT(2I3)
   ISN 0027          110 FORMAT(5X,A3,12A4,4(5A2),6X)
   ISN 0028          120 FORMAT(10X,5F10.5)
   ISN 0029          130 FORMAT(10X,3F10.5)
   ISN 0030          140 FORMAT(10X,6F10.5)
   ISN 0031          150 FORMAT(10X,3F10.5)
   ISN 0032          160 FORMAT(10X,2F10.5,I10)
   ISN 0033          170 FORMAT(10X,6F10.5)
   ISN 0034          180 FORMAT(8(20X,6F10.5,/))
```

```
ISN 0035     190  FORMAT(20X,I10,F10.5,2I10)
ISN 0036     210  FORMAT(20X,5F10.5)
ISN 0037     220  FORMAT(20X,5F10.5)
ISN 0038     230  FORMAT(10A2,6F10.5)
ISN 0039          RETURN
ISN 0040     9999 KS(44) = 1
ISN 0041          RETURN
ISN 0042          END
```

/ READ / SIZE OF PROGRAM 00045C HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C S	C	R*4	000BB8	E S	C	R*4	00089A	F S	C	R*4	000A28	I F		I*4	000180
S	C	R*4	NR	V S	C	R*4	000578	Z	C	R*4	NR	EC	C	R*4	NR
GR	C	R*4	NR	IC	C	I*4	NR	IV	C	I*4	NR	IZ	C	I*4	NR
KS S	C	I*4	001068	IM S	C	R*4	001180	EFG	C	R*4	NR	EFP	C	R*4	NR
EGG	C	R*4	NR	EGP	C	R*4	NR	ELG	C	R*4	NR	ELP	C	R*4	NR
ZGR	C	R*4	NR	READ		R*4	000184	CHBCD SF	XF		000000	IBCOM# F	XF	I*4	000000
KCOUNT S	C	I*4	001400												

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK * * SIZE OF BLOCK 001404 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
EC	R*4	000000 NR	EGP	R*4	000050 NR	EFP	R*4	000078 NR	ELP	R*4	0000A0 NR
EGG	R*4	0000C8 NR	FFG	R*4	000258 NR	ELG	R*4	0003E8 NR	V	R*4	000578
Z	R*4	000708 NR	E	R*4	00089A	F	R*4	000A28	C	R*4	000BB8
GR	R*4	000D48 NR	ZGR	R*4	000ED8 NR	KS	I*4	001068	S	R*4	001130 NR
TA	R*4	001180	IZ	I*4	001310 NR	IV	I*4	001360 NR	IC	I*4	0013B0 NR
KCOUNT	I*4	001400									

SOURCE STATEMENT LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
200	21	0003DC	300	23	00041C NR	400	24	00041C NR	9999	40	000430

COMPILER GENERATED LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
100001	2	0001B4	100002	5	0001C6	200001	15	000304	100013	22	0003DC
100014	22	0003F0									

FORMAT STATEMENT LABELS

LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR	LABEL	ISN	ADDR
100	25	000026 NR	101	26	00002C NR	110	27	000032	120	28	000043
130	29	00004C	140	30	000055	150	31	00005F	160	32	000067 NR
170	33	000072 NR	180	34	00007A NR	190	35	00008A NR	210	36	000095 NR
220	37	00009E NR	230	38	0000A7						

OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)

OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

```
REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

   ISN 0002            SUBROUTINE UTH
                  C
                  C          CALCULATES BUBBLE TERMINAL VELOCITY FOR
                  C          HHATIA EPSTEIN MODEL
                  C
   ISN 0003            COMMON EC(20),EGP(10),FFP(10),ELP(10),EGG(100),EFG(100),ELG(100)
   ISN 0004            COMMON V(100),Z(100),E(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0005            COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
                  C     USE READ IN VALUE OR CORRELATION ONE?
   ISN 0006            IF (KS(20) .EQ. 1) GO TO 100
                  C
                  C          CALCULATE DELTA V, DIFFERENCE OF GAS AND LIQUID
                  C          SUPERFICIAL VELOCITIES
   ISN 0008            Z(5) = V(21) - E(14)
   ISN 0009            IF (Z(5). GT. TM(52) )  GO TO 40
   ISN 0011            E(51) = TM(55) + TM(56) * Z(5)
   ISN 0012            RETURN
   ISN 0013         40 IF (Z(5).GT. TM(53) )  GO TO 60
   ISN 0015            E(51) = TM(57) + TM(58)* Z(5)
   ISN 0016            RETURN
   ISN 0017         60 E(51) = TM(59) + TM(60)*Z(5)
   ISN 0018            RETURN
   ISN 0019        100 E(51) = E(54)
   ISN 0020            RETURN
   ISN 0021            END
```

/ UTH / SIZE OF PROGRAM 00020A HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C	C	R*4	NR	F SF	C	R*4	000898	F	C	R*4	NR	S	C	R*4	NR
V F	C	R*4	000578	Z SF	C	R*4	00070B	EC	C	R*4	NR	GR	C	R*4	NR
IC	C	I*4	NR	IV	C	I*4	NR	IZ	C	I*4	NR	KS	C	I*4	001068
TM F	C	R*4	001180	EFG	C	R*4	NR	EFP	C	R*4	NR	EGG	C	R*4	NR
EGP	C	R*4	NR	ELG	C	R*4	NR	ELP	C	R*4	NR	UTH		R*4	000084
ZGR	C	R*4	NR	KCOUNT	C	I*4	NR								

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK * * SIZE OF BLOCK 001404 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
EC	R*4	000000 NR	EGP	R*4	000050 NR	EFP	R*4	000078 NR	ELP	R*4	0000A0 NR
EGG	R*4	0000C8 NR	FFG	R*4	000258 NR	ELG	R*4	0003E8 NR	V	R*4	000578
Z	R*4	00070B	E	R*4	000898	F	R*4	000A28 NR	C	R*4	000BBA NR
GR	R*4	000D4B NR	ZGR	R*4	000ED8 NR	KS	I*4	001068	S	R*4	001130 NR
TM	R*4	001180	IZ	I*4	001310 NR	IV	I*4	001360 NR	IC	I*4	0013B0 NR
KCUUNT	I*4	001400 NR									

SOURCE STATEMENT LABELS

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REQUESTED OPTIONS: NOTERM

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EXDECK NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NOALC NOANSF NOTERM IBM FLAG(I) XL

   ISN 0002            SUBROUTINE WAKE
   ISN 0003            COMMON EC(20),EGP(10),EFP(10),FLP(10),FGG(100),EFG(100),ELG(100)
   ISN 0004            COMMON V(100),Z(100),F(100),F(100),C(100),GR(100),ZGR(100)
   ISN 0005            COMMON KS(50),S(20),TM(100),IZ(20),IV(20),IC(20),KCOUNT
                  C
                  C          CALCULATES THE RATIO OF THE WAKE TO THE BUBBLE VOLUME
                  C          CORRELATION USING LETAN-KEMAT APPROACH
                  C          SEE LITERATURE REFERENCE IN SUBROUTINE ELTAM
                  C
                  C
   ISN 0006         100 CONTINUE
                  C          SEE IF IN RANGE OF CORRELATION
   ISN 0007            IF( E(14). LT. TM(40)) GO TO 300
   ISN 0009            IF ( E(14). GT. TM(42)) GO TO 300
                  C          IT'S IN RANGE. SEE IF REGION 1 OR 2
   ISN 0011            IF (E(14). GE. TM(41)) GO TO 250
                  C          LOWER RANGE
   ISN 0013         200 E(56) = EXP(TM(43) + TM(44)*E(14))
   ISN 0014            GO TO 400
   ISN 0015         250 E(56) = EXP(TM(45) + TM(46)*E(14))
   ISN 0016            GO TO 400
   ISN 0017         300 E(56) = -9.87E+65
   ISN 0018         400 CONTINUE
   ISN 0019            IF ( E(57)  .LT. 0.001)  RETURN
                  C          IF A VALUE OF E(57) READ IN. USE IT INSTEAD
   ISN 0021            E(56) = E(57)
   ISN 0022            RETURN
   ISN 0023            END
```

/ WAKE / SIZE OF PROGRAM 00022E HEXADECIMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
C	C	R*4	NR	F SFA	C	R*4	000098	F	C	R*4	NR	S	C	R*4	NR
V	C	R*4	NR	Z	C	R*4	NR	EC	C	R*4	NR	GR	C	R*4	NR
IC	C	I*4	NR	IV	C	I*4	NR	IZ	C	I*4	NR	KS	C	I*4	NR
T4 FA	C	R*4	001180	EFG	C	R*4	NR	EFP	C	R*4	NR	EGG	C	R*4	NR
EGP	C	R*4	NR	ELG	C	R*4	NR	ELP	C	R*4	NR	EXP F	XF	R*4	000000
ZGR	C	R*4	NR	WAKE		R*4	0000B0	KCOUNT	C	I*4	NR				

***** COMMON INFORMATION *****

NAME OF COMMON BLOCK = * SIZE OF BLOCK 001404 HEXADECIMAL BYTES

VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.
EC	R*4	000000 NR	EGP	R*4	000050 NR	EFP	R*4	000078 NR	ELP	R*4	0000A0 NR
EGG	R*4	0000C8 NR	FFG	R*4	000258 NR	ELG	R*4	0003E8 NR	V	R*4	00057A NR
Z	R*4	000708 NR	F	R*4	000898	F	R*4	000A28 NR	C	R*4	000BB8 NR
GR	R*4	000D48 NR	ZGR	R*4	000ED8 NR	KS	I*4	001068 NR	S	R*4	001130 NR
T4	R*4	001180	IZ	I*4	001310 NR	IV	I*4	001360 NR	IC	I*4	0013B0 NR
KCOUNT	I*4	001400 NR									

C VECTOR SYSTEM CONSTANTS

C(1)	Run no.
C(2)	Test no. for base case data.
C(3)	
C(4)	Reactor diameter, ft.
C(6)	g 32.12 ft/sec^2.
C(7)	g_c 32.12 lb_m-ft/sec^2-lb_f.
C(8)	
C(9)	
C(10)	
C(11)	
C(12)	
C(13)	
C(14)	
C(15)	
C(16)	
C(17)	
C(18)	
C(19)	
C(20)	
C(21)-C(25)	Liquid name.
C(26)-C(30)	Gas name.
C(31)-C(40)	Catalyst name.
C(41)-C(50)	Problem ID.

E VECTOR CALCULATED VALUES

E(1)	Catalyst holdup, ϵ_c.
E(2)	Average gas holdup in bed, ϵ_g.
E(3)	Average liquid holdup in bed, ϵ_l.
E(4)	Average fines holdup in bed, ϵ_f.
E(8)	Slurry density, lb/ft^3.
E(9)	Combined ($\epsilon_l + \epsilon_f$).
E(14)	Superficial liquid flow rate, ft/sec.
E(15)	Liquid linear flow in bed, ft/sec.
E(17)	Total liquid flow, gpm/ft^2.
E(18)	Gas linear velocity in bed, ft/sec.
E(20)	Gas volumetric flow, cfh.
E(21)	Old value of E(1).
E(22)	Old value of E(2).
E(23)	Old value of E(9).
E(25)	Vol% fines in liquid.
E(35)	Bubble Reynolds number.
E(36)	Bubble Morton number.
E(37)	Bubble G_2 number.
E(38)	Bubble diameter from U_{tB} (E_{si}).
E(40)	% bed expansion.
E(41)	Old value of E(1) in Bhatia-Epstein model.
E(42)	Old value of E(2) in Bhatia-Epstein model.
E(43)	Old value of [E(3) + E(4)] " " .
E(48)	Gas linear velocity in bed, ft/sec," ".
E(49)	
E(50)	
E(51)	Single bubble terminal velocity, U_{tB}, ft/sec.
E(52)	Richardson-Zaki index, n.
E(53)	Drift flux, V_{CD}, mm/sec.
E(54)	Read-in value of U_{tB}, ft/sec.
E(55)	Read-in value of X_k.
E(56)	K_o for wake holdup.
E(57)	Read-in value of K_o.

F VECTOR PHYSICAL PROPERTIES

F(1)	Liquid density, lb/ft^3.
F(2)	Liquid viscosity, cp.
F(3)	Liquid surface tension, dynes/cm.
F(5)	Slurry viscosity, cp.
F(6)	Gas density, lb/ft^3.
F(7)	Gas viscosity, cp.
F(8)	Soaked catalyst density, lb/ft^3.
F(9)	Bulk density, lb/ft^3.
F(10)	Particle density, lb/ft^3.
F(11)	Catalyst diameter, in.
F(12)	Catalyst length, in.
F(14)	Fines density, lb/ft^3.
F(15)	Average fine size, μ.
F(17)	Ratio of solids in wake to solids in particulate phase, X_k.
F(20)	Bubble radius, ft.
F(21)	Catalyst terminal velocity, ft/sec.
F(22)	Slurry viscosity, lbm/ft-sec.
F(23)	Surface tension, lbf/ft.

KS VECTOR SWITCHES

KS(19)	Option to calculate X_k: 0--Use El-Temtamy correlation. 1--Use read-in value of X_k. 3--Calculate from U_{tB} correlation if $U_1 > U_1^*$; otherwise, use El-Temtamy correlation.
KS(30)	Maximum number of iterations for Bhatia-Epstein routine (default 20).
KS(41)	Region for Peebles/Garber correlation.
KS(42)	Iteration counter for loop in main program.
KS(43)	Maximum limit for KS(42) (default 20).
KS(44)	Read indicator: 0--Normal. 1--End of input deck.
KS(46)	First option for KS(19) to calculate X_k (default 0).
KS(47)-KS(50)	KS(19) option to calculate X_k (default -99).

TM VECTOR CORRELATION VALUES

TM(40)	U_{l_1}	Wake volume correlation.
TM(41)	U_{l_2}	" "
TM(42)	U_{l_3}	" "
TM(43)	a_{12}	" "
TM(44)	b_{12}	" "
TM(45)	a_{23}	" "
TM(46)	b_{23}	" "
TM(51)	Δ_1	Bubble terminal velocity correlation.
TM(52)	Δ_2	" "
TM(53)	Δ_3	" "
TM(54)	A_4	" "
TM(55)	a_{12}	" "
TM(56)	b_{12}	" "
TM(57)	a_{23}	" "
TM(58)	b_{23}	" "
TM(59)	a_{34}	" "
TM(60)	b_{34}	" "
TM(65)	U_l^*	Crossover liquid velocity, ft/sec.
TM(74)	a	X_k correlation.
TM(75)	b	X_k correlation.

V VECTOR OPERATING VARIABLES

V(5)	Fines concentration in liquid, wt%.
V(7)	Initial bed heights.
V(19)	Liquid flow rate, gpm.
V(21)	Gas superficial velocity, ft/sec.

Z VECTOR INTERMEDIATE CALCULATIONS

Z(5)	$U_g - U_l$, ft/sec.
Z(10)	Relative velocity between bubble phase and liquid in particulate phase. (V_{gl}''') ft/sec.
Z(11)	$\epsilon_k''/\epsilon_g''$ two-phase wake/two-phase gas holdup.
Z(12)	Wake holdup (ϵ_k).
Z(13)	Liquid holdup in two-phase particulate phase.
Z(16)	New linear gas V_g velocity in Subroutine BHATIA.
Z(17)	Average linear gas velocity used as new value.
Z(18)	New value of gas holdup in BHATIA (ϵ_g).
Z(19)	New value of liquid holdup in BHATIA (ϵ_l).
Z(20)	New value of ϵ_c.
Z(23)	Value in expression for Z(13).
Z(25)	V_{gl} for El-Temtamy calculation of X_k, ft/sec.
Z(26)	X_k from El-Temtamy calculation.
Z(27)	Identical with Z(25).
Z(28)	Slope for X_k correlation.
Z(29)	Intercept for X_k correlation.

Figure E-1

Main program

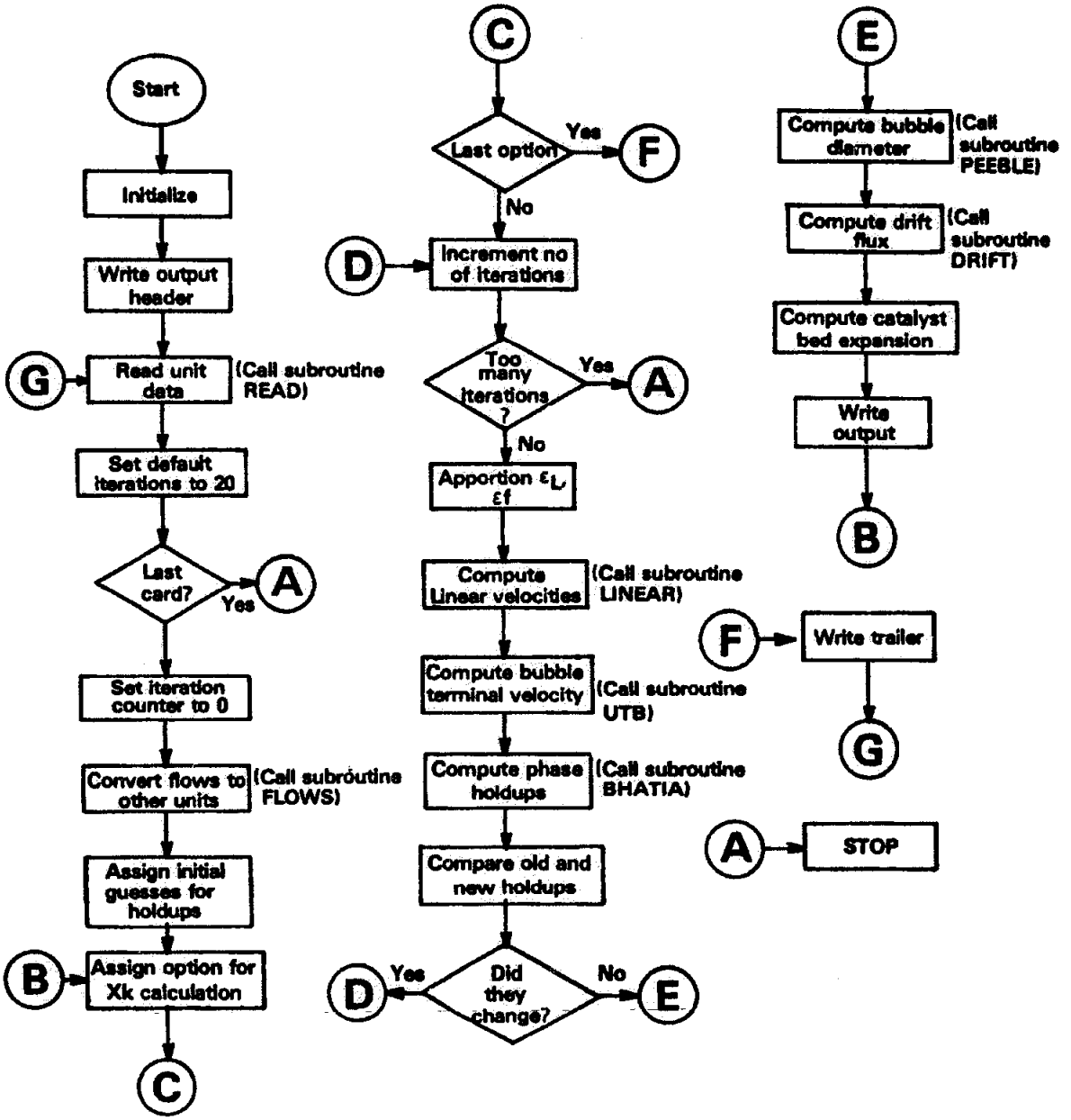


Figure E-2

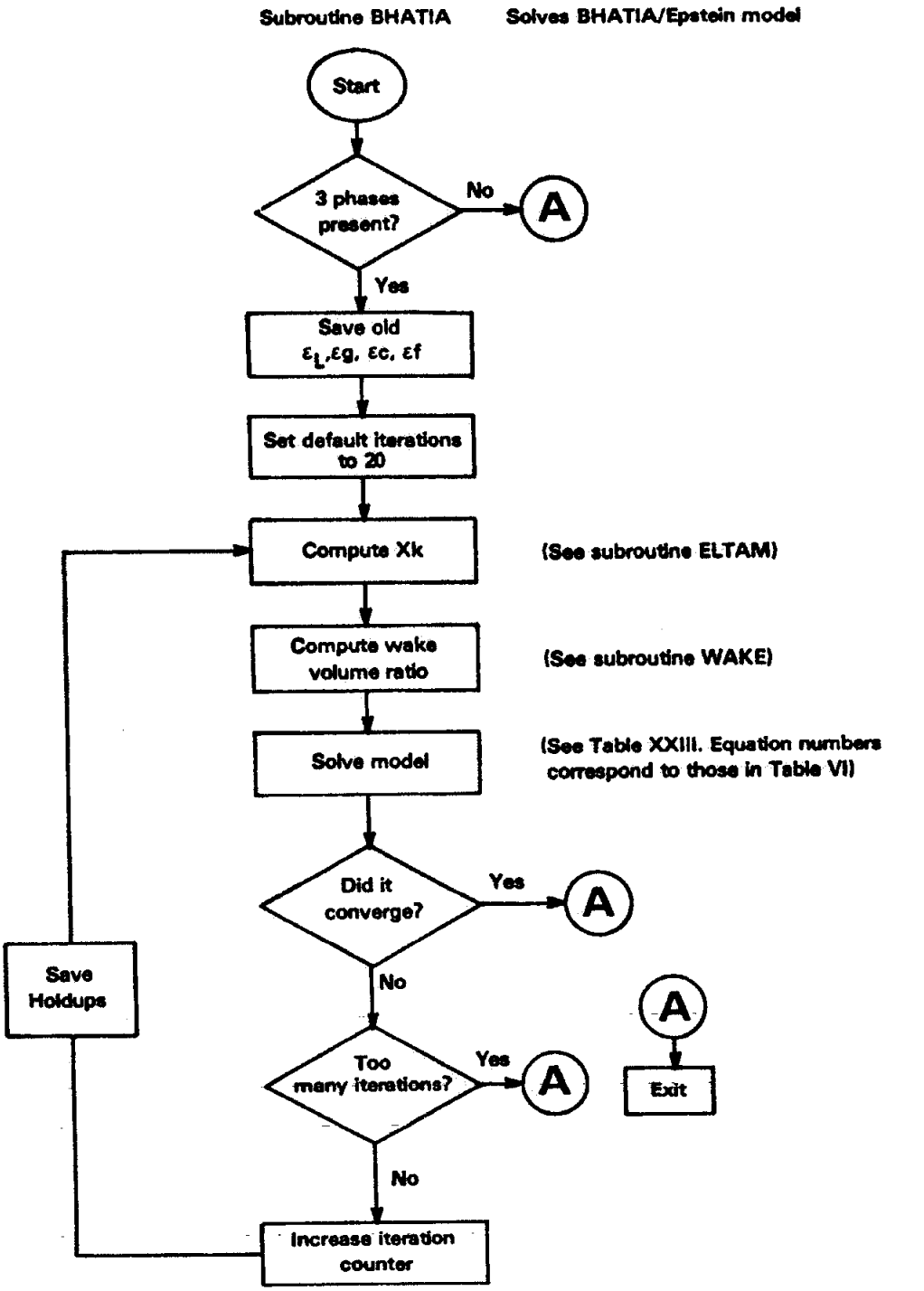

Subroutine BHATIA
Solves BHATIA/Epstein model
Start
3 phases present?
No
A
Yes
Save old ε_L, εg, εc, εf
Set default iterations to 20
Compute Xk
(See subroutine ELTAM)
Compute wake volume ratio
(See subroutine WAKE)
Solve model
(See Table XXIII. Equation numbers correspond to those in Table VI)
Did it converge?
Yes
A
No
Too many iterations?
Yes
A
A
Exit
No
Increase iteration counter
Save Holdups

Figure E-3

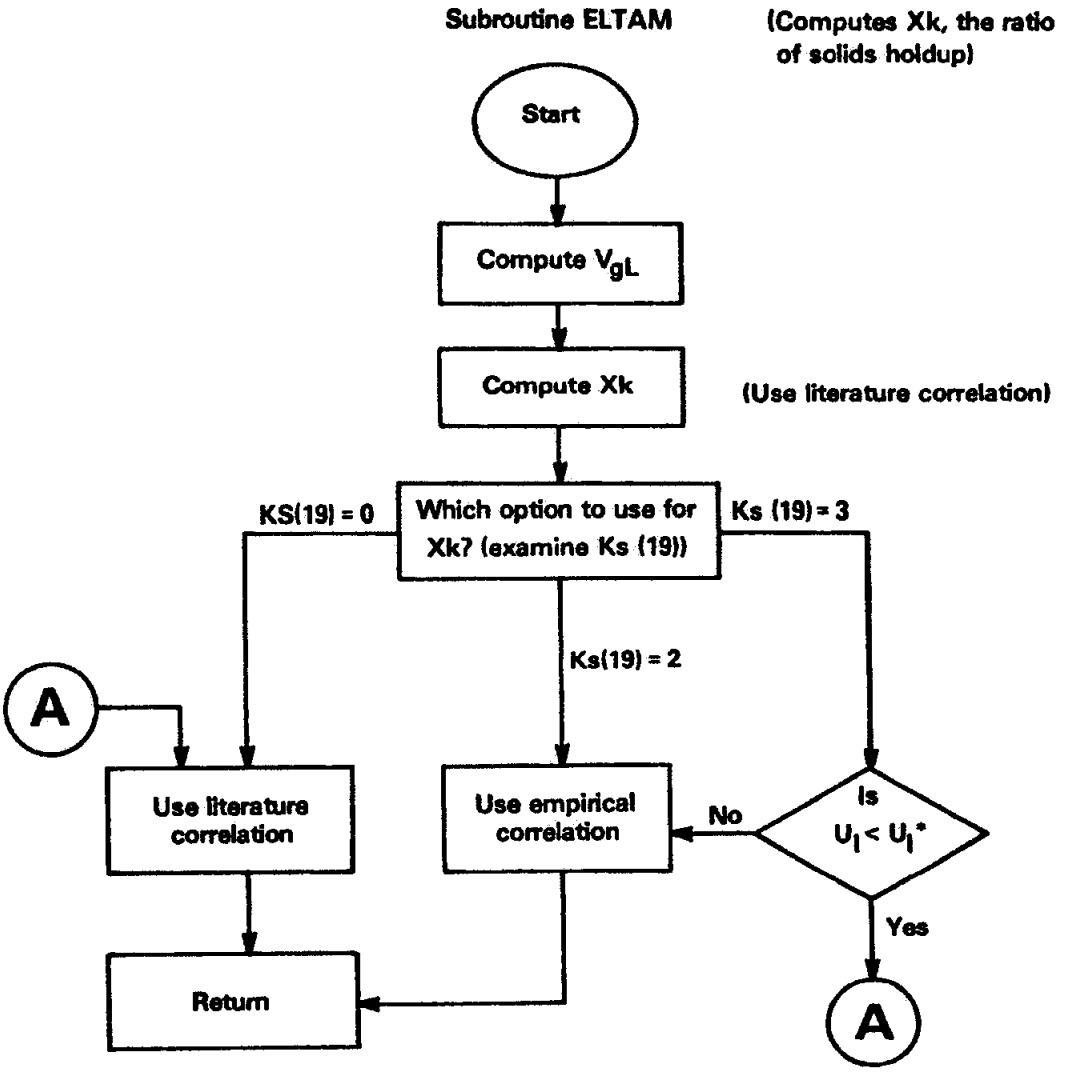
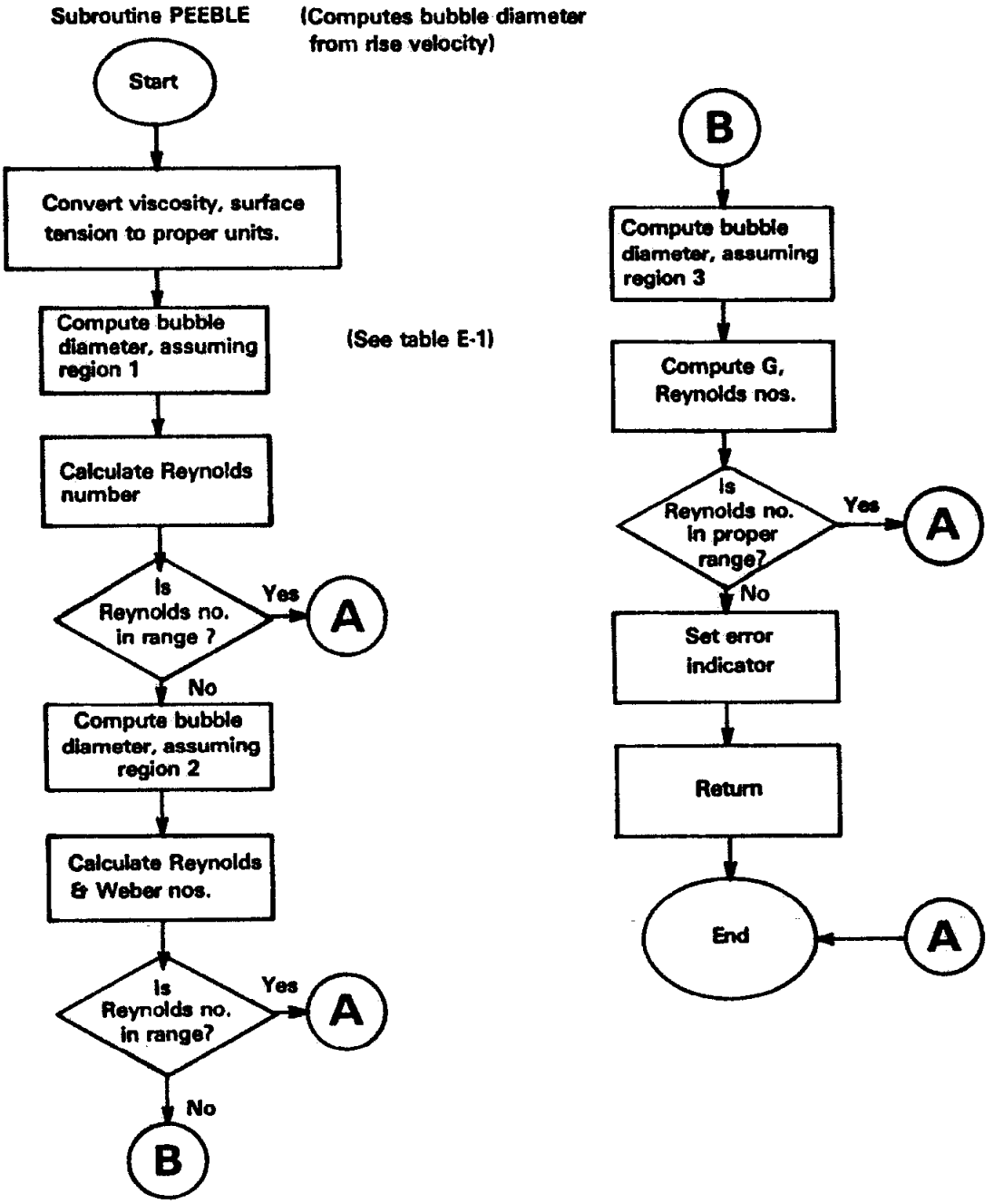

Subroutine ELTAM
(Computes Xk, the ratio of solids holdup)
Start
Compute V_{gL}
Compute Xk
(Use literature correlation)
Which option to use for Xk? (examine Ks (19))
KS(19) = 0
Ks (19) = 3
Ks(19) = 2
A
Use literature correlation
Use empirical correlation
No
Is $U_l < U_l^*$
Yes
Return
A

Figure E-4


Subroutine PEEBLE
(Computes bubble diameter from rise velocity)
Start
Convert viscosity, surface tension to proper units.
Compute bubble diameter, assuming region 1
(See table E-1)
Calculate Reynolds number
Is Reynolds no. in range ?
Yes
A
No
Compute bubble diameter, assuming region 2
Calculate Reynolds & Weber nos.
Is Reynolds no. in range?
Yes
A
No
B
B
Compute bubble diameter, assuming region 3
Compute G, Reynolds nos.
Is Reynolds no. in proper range?
Yes
A
No
Set error indicator
Return
End
A