COMPUTER TECHNOLOGY

1620 GENERAL PROGRAM LIBRARY Adiabatic **Flame Temperature**, No Dissociation

9.3.011

DISCLAIMER

Although each program has been tested by its contributor, no warranty, express or implied, is made by the contributor or COMMON, as to the accuracy and functioning of the program and related program material, nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the contributor or COMMON, in connection therewith.

Adiabatic Flame Temperature, No Dissociation

By:
H.B.Kerr
Box 21
Tennessee Polytechnic Institute
Cookeville, Tennessee

DECK KEY

Deck 1	Source
Deck 2	Adiabatic Flame Temperature - No Dissociation with S-R

Modifications or revisions to this program, as they occur, will be announced in the appropriate Catalog of Programs for the IBM Data Processing Systems. If such announcement indicates a change to the program decks or tapes, a complete new program, if needed, should be requested from the Program Distribution Center.

A B S T R A C T

ADIABATIC FLAME TEMPERATURE, NO DISSOCIATION (Card)

H. B. Kerr

Direct Inquiries to: H. B. Kerr
Box 21
Tennessee Polytechnic Institute
Cookeville, Tennessee

Purpose/Description: This program was designed to compute the adiabatic flame temperature for the combustion process using a large amount of excess air (such as in the combustion turbine) where the flame temperatures are low enough (below 3000 F) so as to have a negligible amount of dissociation in the products of combustion. The program is designed so that any hydrocarbon having a known enthaply of formatin may be run, with any amount of excess air. The flame temperature is assumed independent of pressure.

Method: N/A

Restrictions/Range: Program is good for any hydrocarbon whose enthaply of formatin is known. Sufficient excess air must be supplied so that chemical dissociation is negligible.

Storage Requirements: 20K

Equipment Specifications: Memory 20K (card 1620), no special features required.

Additional Remarks: Program written in Fortran with format for IBM 1620. Decimal input, format described in write up.

IBM 1620 PROGRAM FOR

ADIABATIC FLAME TEMPERATURE

NO DISSOCIATION

Purpose

This program was designed to compute the adiabatic flame temperature for the combustion process using a large amount of excess air (such as in the combustion turbine) where the flame temperatures are low enough (below 3000 F) so as to have a negligible amount of dissociation in the products of combustion. The program is designed so that any hydrocarbon having a known enthaply of formatin may be run, with any amount of excess air. The flame temperature is assumed independent of pressure.

Description

This program computes an energy balance in the combustion chamber assuming heat losses to be negligible. Equations for the specific heat of the various products of combustion are assumed functions of temperature, independent of pressure . The temperature of the combustion products are assumed. The algebraic sum of the enthalpys of the reactants and the products of combustion are calculated and compared with the required accuracy (input data). If the algebraic sum is not within the required accuracy, the assumed temperature is incremented (or decremented) and the calculations performed repeatedly until the algebraic sum falls within the programmed accuracy. The adiabatic flame temperature, number of necessary trials, and the calculated error is then printed out and the program branches back to the start for new data.

Input Data: (All on one card and in the order and format shown)

(a) For card input (sense switch #1 "Off")

1.	Atoms of Hydrogen per mole of hydrocarbon	F 9.2
2.	Atoms of carbon per mole of hydrogen	F 9.2
3.	Air fraction used, i.e., Fraction of theoretical air (must be greater than 1.0)	F 9.2
4.	Enthalpy of formation of hydrocarbon (BTU per mole)	F 9.0
5.	Initial assumption of temperature (degrees of Rankine)	F 9.2
6.	Initial increment in temperature (in order of 500-1000) Degrees R	F 9.2
7.	Required accuracy of calculations (BTU)	F 9.2

(b) For typewriter input (sense switch #1 "on")
Format same as in card input

Output Data

1. Adiabatic flame temperature (Degrees Rankine)
2. Number of trials used
3. Actual error in first law energy balance (BTU per mole of fuel fired)

Machine Requirements:

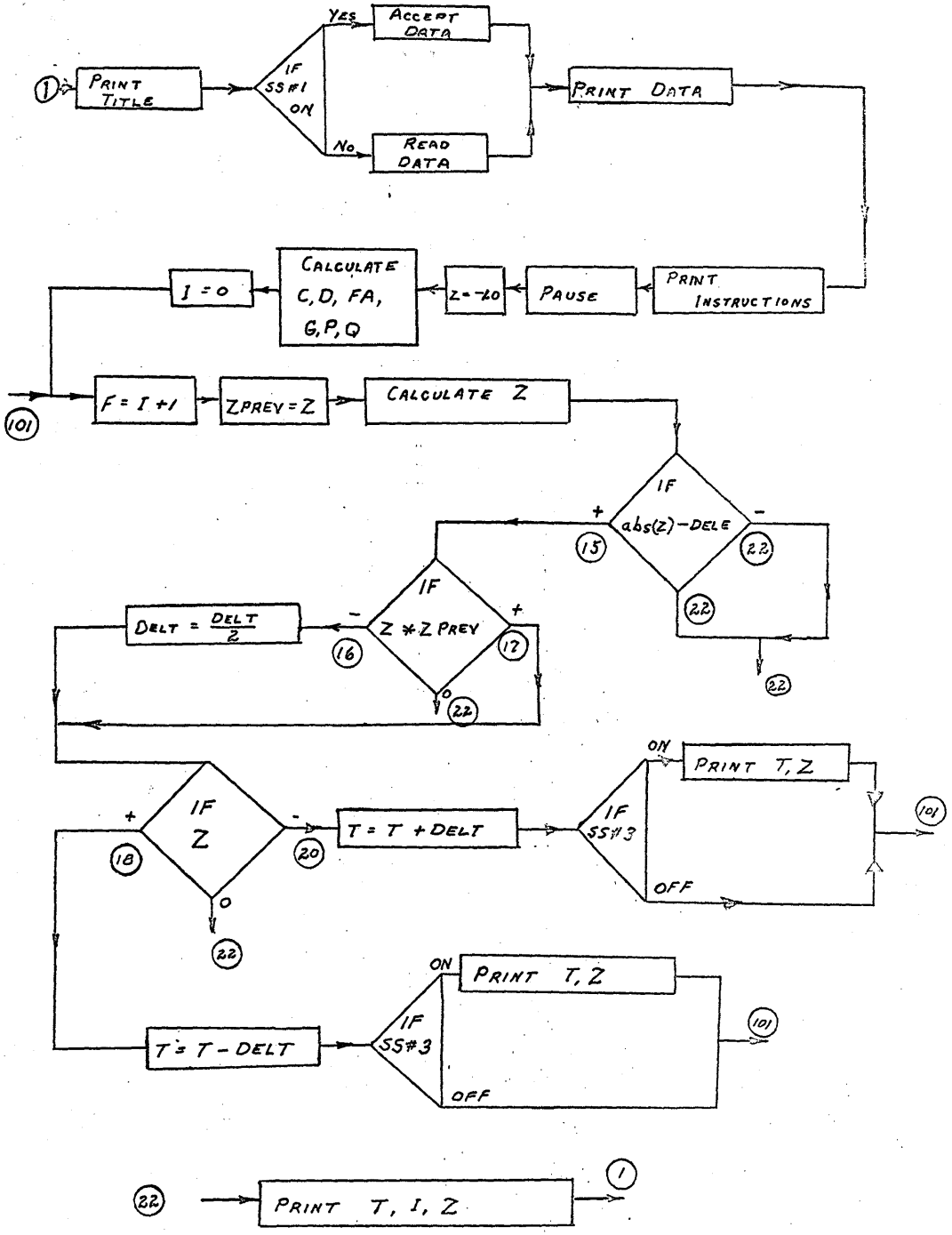
Basic 20K IBM 1620, no special features.

Operating Instructions:

1. Reset
2. Insert
3. Type 160001000000
4. Release
5. Start
6. Allow to run for 2 or 3 seconds and push "instant stop"
7. Reset
8. Set switches as follows:
   a. MAR check - "stop"
   b. I/O check - "stop"
   c. "0" - "Program"
   d. Sense switch #1
      1. For data input from cards - "off"
      2. For data input from typewriter - "on"
   e. Sense switch #2 - not consulted
   f. Sense switch #3
      1. For trial answer printout - "on"
      2. For only final answer printout - "off"
   g. Sense switch #4 - Not consulted.
9. Stack deck (with data cards, if any, behind) in Read Hopper.
10. Push "Load" (1622)
11. When program is loaded, machine will type out "load data"
12. Push "start" (1620). Machine operation will now depend upon setting of sense switch #1.
    (a) Sense switch #1 "off" - Computer will read data card and execute program.
    (b) Sense switch #1 "on" - Computer will type out program heading and stop in automatic mode to allow data to be entered from typewriter. Type in data and hit the R - S key on the typewriter.
13. Machine will type out data and then type out "For Trial Printout, Sw. 3 on, Push Start". Set switch accordingly and push start.
14. Machine will execute program, type out answer and branch back to the start for more data.

Comments

Sense switch #3 consultation is made in the program (instructions printed out during execution) so that the programmer may call for the results of the intermediate trials to be printed out if he so desires. If punched outputs are desired, all that is necessary is that the "Print" statements in the Fortran program be changed to "Punch" and the program re-compiled. The instructions should, of course, be left as is. A listing of the Fortran program is given in the appendix along with sample solutions. The program has been run approximately 40 times. Arrangement has been made so that input may be made from either card or typewriter by proper sense switch setting. It is possible that, on early trials or for some specific combustion conditions, the output Format may be exceeded (shown in sample problem #4, First "Z" output). In this case, an error typeout is made, and the answer given in "E" Format. Input was made on the typewriter on sample problems 1, 2 and 3 with carriage returns made manually by the operator, (Sense switch #1 "on"). On example problem #4, input was made by card (sense switch #1 "Off")


1
PRINT TITLE
IF SS#1 ON
YES
ACCEPT DATA
NO
READ DATA
PRINT DATA
PRINT INSTRUCTIONS
PAUSE
Z=-40
CALCULATE C, D, FA, G, P, Q
I = 0
101
F = I + 1
ZPREV = Z
CALCULATE Z
IF abs(Z) - DELE
+
-
15
22
22
22
IF Z * Z PREV
-
+
0
16
17
22
DELT = DELT / 2
IF Z
+
-
0
18
20
22
T = T + DELT
IF SS#3
ON
OFF
PRINT T, Z
101
T = T - DELT
IF SS#3
ON
OFF
PRINT T, Z
101
22
PRINT T, I, Z
1

APPENDIX

```
C      TYPE ADIABATIC FLAME TEMPERATURE - NO DISSOCIATION
C      BY H. B. KERR, ENGINEERING SCIENCE DEPARTMENT
C      TENNESSEE POLYTECHNIC INSTITUTE
    1 PRINT 30
      IF(SENSE SWITCH 1)998,999
  998 ACCEPT 2,B,ALPHA,A,HO,T,DELT,DELE
      GO TO 1000
   30 FORMAT (20X,36HADIABATIC FLAME TEMP-NO DISSOCIATION//)
  999 READ 2,B,ALPHA,A,HO,T,DELT,DELE
 1000 PRINT 3,B,ALPHA
    2 FORMAT(F9.2,F9.2,F9.2,F9.0,F9.2,F9.2,F9.2)
    3 FORMAT (7HCARBON=F8.2,14H      HYDROGEN=F8.2/)
      PRINT 191,A
  191 FORMAT (13HAIR FRACTION=F7.2/)
      PRINT 4,HO,DELE
    4 FORMAT (22HENTHALPY OF FORMATION=F11.0,16H      MAX. ERROR=F7.0/)
      PRINT 997
  997 FORMAT(39HFOR TRIAL PRINTOUT, SW.3 ON, PUSH START//)
      PAUSE
      Z=-1.
      C=ALPHA/2.
      D=(B+ALPHA/4.)*(A-1.)
      FA=(B+ALPHA/4.)*3.76*A
      G=6.214*B+7.256*C+6.148*D+6.524*FA
      P=5.776*B+1.277*C+1.722*D+.694*FA
      Q=.087*C-1.094*B-.285*D-.001*FA
      I=0
  101 I=I+1
      ZPREV=Z
      Z1=-HO+B*(-1.6929E+5)-(ALPHA*1.0407E+5)/2.+G*(T-537.)
      Z2=(P*((T**2.)-2.8835E+5))/2.E+3
      Z3=(Q*((T**3.)-1.318E+8))/3.E+6
      Z=Z1+Z2+Z3
      ZX=SQRT(Z*Z)
      IF(ZX-DELE)22,22,15
   15 IF(Z*ZPREV)16,22,17
   16 DELT=.5*DELT
   17 IF(Z)20,22,18
   18 T=T-DELT
      IF(SENSE SWITCH 3)104,19
  104 PRINT 105,T,Z
  105 FORMAT (2HT=F10.2,10X,2HZ=F10.2)
   19 CONTINUE
      GO TO 101
   20 T=T+DELT
      IF(SENSE SWITCH 3)104,19
   22 PRINT 55
   55 FORMAT (18HSOLUTION.....//)
      PRINT 56,T,I,Z
   56 FORMAT(7HTEMP = F9.2,5X,9HTRIALS = I3,5X,8HERROR = F10.2//)
```



```
      GO TO 1
      END

RELOCATABLE SUBROUTINES CALLED
SQRT

OBJECT PROGRAM DATA TABLE
00790 STORAGE POSITIONS

PROCESSING COMPLETE
```

(Sample problem No. 1)

```
LOAD DATA
                    ADIABATIC FLAME TEMP-NO DISSOCIATION

2.0000000                                  C2 H2
4.0000000
3.0000000
22493.000
1000.0000
1000.0000
100.00000RS
CARBON=   +2.00      HYDROGEN=   +4.00

AIR FRACTION=  +3.00

ENTHALPY OF FORMATION=    +22493.      MAX. ERROR=  +100.

FOR TRIAL PRINTOUT, SW.3 ON, PUSH START


T=  +2000.00          Z=-421478.47
T=  +3000.00          Z= -73762.14
T=  +2500.00          Z=+306845.72
T=  +2000.00          Z=+112900.08
T=  +2250.00          Z= -73762.14
T=  +2125.00          Z= +18599.82
T=  +2187.50          Z= -27830.80
T=  +2250.00          Z=  -4677.01
T=  +2218.75          Z= +18599.82
T=  +2187.50          Z=  +6946.09
T=  +2203.12          Z=  -4677.01
T=  +2195.31          Z=  +1130.74
T=  +2199.21          Z=  -1774.10
T=  +2203.12          Z=   -321.89
T=  +2201.17          Z=  +1130.71
T=  +2199.21          Z=   +404.32
T=  +2200.19          Z=   -321.89
SOLUTION.....

TEMP =  +2200.19     TRIALS = +18     ERROR =     +41.21
```


(Sample problem No. 2)

```
                    ADIABATIC FLAME TEMP-NO DISSOCIATION

3.0000000
8.0000000
1.5000000
 44676.00
1000.0000
1000.0000
100.00000RS
CARBON=   +3.00      HYDROGEN=   +8.00

AIR FRACTION=  +1.50

ENTHALPY OF FORMATION=    -44676.      MAX. ERROR=  +100.

FOR TRIAL PRINTOUT, SW.3 ON, PUSH START


SOLUTION.....

TEMP =  +3287.10     TRIALS = +18     ERROR =     +18.87
```

(Sample problem No. 3)

```
                    ADIABATIC FLAME TEMP-NO DISSOCIATION


1.0000000
4.0000000
2.0000000
 32200.00
1000.0000
1000.0000
100.00000RS
CARBON=   +1.00      HYDROGEN=   +4.00

AIR FRACTION=  +2.00

ENTHALPY OF FORMATION=    -32200.      MAX. ERROR=  +100.

FOR TRIAL PRINTOUT, SW.3 ON, PUSH START


SOLUTION.....

TEMP =  +2664.06     TRIALS = +10     ERROR =     -81.50
```

(Sample problem No. 4)

ADIABATIC FLAME TEMP-NO DISSOCIATION

```
CARBON=   +8.00      HYDROGEN=  +18.00

AIR FRACTION=  +2.00

ENTHALPY OF FORMATION=   -107530.      MAX. ERROR=  +100.

FOR TRIAL PRINTOUT, SW.3 ON, PUSH START


T=  +2000.00           Z=
ERROR F8 -.17626099E+07
T=  +3000.00           Z=-767920.87
T=  +2500.00           Z=+324727.82
T=  +2750.00           Z=-232388.30
T=  +2625.00           Z= +43653.34
T=  +2687.50           Z= -95019.36
T=  +2750.00           Z= -25843.08
T=  +2718.75           Z= +43653.34
T=  +2687.50           Z=  +8865.60
T=  +2703.12           Z= -25843.08
T=  +2718.75           Z=  -8498.88
T=  +2710.93           Z=  +8865.60
T=  +2703.12           Z=   +180.70
T=  +2707.03           Z=  -8498.88
T=  +2710.93           Z=  -4159.22
T=  +2708.98           Z=   +180.60
T=  +2709.96           Z=  -1989.55
T=  +2710.93           Z=   -904.32
T=  +2710.44           Z=   +180.50
T=  +2710.69           Z=   -361.86
SOLUTION.....

TEMP =  +2710.69     TRIALS = +21     ERROR =     -90.69
```

COMPUTER
TECHNOLOGY