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ABSTRACT

The Fortran 77 computer program described in this report is to
be used to calculate results from tests run on vented heaters.
The Department of Energy recently published a revised test
procedure for such heaters but which contains a simplified
method for testing with a number of testing options that allow
more detailed tests to be run. The new procedure also provides
for the testing of units with manual controls of two types,
modulating controls of two types, and the testing of units
incorporating thermal stack dampers as well as
electro-mechanical dampers. Once input selections have been
made, the program performs the calculations required and prints
out the results.

Key words: computer program; energy; test procedure; vented
heater; furnace.

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INTRODUCTION

Vented heaters are home heating devices that exhaust the products of combustion to the outside and that furnish warmed air to a living space without duct connections to distribute the heated air. They may use electrically driven fans or blowers to circulate the air from the heater to the living space.

In 1978 the Department of Energy (DOE) published in the Federal Register [1]*a Final Rule test procedure to be used to test vented heaters. This procedure was almost identical to the one for furnaces published at the same time. The rule required that the results of specified tests be used to calculate the estimated annual operating cost, the annual fuel utilization efficiency (AFUE), and the estimated regional annual operating cost. The National Bureau of Standards (NBS) published a report [2] that described the rule as it was proposed to DOE with a Fortran computer program to perform the many and complicated calculations needed to determine the required efficiency and cost information. In 1982, NBS published another report [3] describing a proposed modification to the furnace and the vented heater test procedures to test these products when they incorporate modulating type controls. This publication also contained a Fortran computer program, titled FBVH, which is the basis for the revised program in this report.

On March 28, 1984, DOE published a revised final rule test procedure for furnaces, heaters, and vented heaters [4]. The vented heater section provides an entirely new test method for the determination of annual fuel utilization efficiency (AFUE) and the estimated operating cost per million Btu output. It deletes the requirements for determination of annual operating costs.

The new procedure is quite different from the one it replaces in that it allows the omission of time consuming and computationally complicated heat-up and cool-down tests. The tests are replaced with a formula that applies constant multiplying factors to the steady-state efficiency, to the stack and flue draft factors, to the pilot light energy ratio and to the loss in efficiency due to jacket losses for floor furnaces. The coefficients were determined from a multiple regression of test data on a number of units that were tested using the old DOE test procedure [5]. The newly published procedure also provides test methods for evaluating units with two different types of modulating controls (step modulating and two stage) and two types of manual controls: those with just "on"-"off" control and those

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* Numbers in brackets pertain to references listed on page 17.

that can be adjusted for the fuel burning rate as well as "on" and "off." Background information on the test method for modulating controls may be found in Reference [6]. Finally, a test method to be used for units incorporating thermal dampers has been added to the procedure. The thermal damper test uses a new off-loss tracer gas type of test. The tracer gas test is also allowed to be used as an option for the measurement of the off period heat losses of units without thermal dampers. When the off-loss method is selected or required, the simplified AFUE calculation is not used. Instead, a cycling part load efficiency is calculated and used in determining AFUE. For manual type controls a psuedo part-load efficiency is calculated using only the on-time infiltration loss term.

This report describes a Fortran 77 computer program (Appendix A) to be used to calculate the results of tests performed on vented heaters. The program serves two purposes: it provides computerized calculations of a complex test procedure, and it explicitly defines the test method to be used. The program will be directly useful to some manufacturers or laboratories involved in testing, it can be used to check programs already written, or it can serve as the basis for writing similar programs in other computer languages. The explicit definition can be useful to test users in resolving questions that arise regarding the exact meaning of the wording of the published procedure. The steps to be followed and the meanings of the word descriptions are clarified with a computer program that covers all permitted calculation steps and sequences.

PROGRAM INPUT

Appendix B contains the final rule regulation published by DOE
on March 28, 1984 [4]. Apendix B is different than the DOE
publication in that only the pages relating to the testing
requirements of vented heaters are included and the columms on
the pages have been rearranged to make the text and formulas
flow in a sequential and logical order. This publication
specifies the test methods, the data required, and the
calculations necessary to arrive at the AFUE and the dollars
per million Btu output. Appendix A contains a Fortran 77
program which performs these calculations. This report will
not attempt to describe the details of the test but rather
describe how the data are entered into the program and how the
calculations are performed.

The Fortran program is written so that input information is
taken from a previously written data file stored in the
computer. An example of such a file is on page C2 of Appendix
C. In the Univac computer at NBS, the data is in an element of
a file. After a response to the instruction given on line 340
of the program listing in Appendix A is entered, the computer
reads the lines in the file (element) one by one as READ
statements are encountered. Users of the program may want to
modify this input structure to meet the requirements of the
computer being used. Most of the READ statements of the
program use the free field format, READ(6,*) where logical unit
"6" is the terminal or the "@ADD"ed element. Integer or real
numbers may be entered indiscriminately and the number of
decimal places in the numbers is immaterial. Spaces or commas
may be used to separate entered values. Some compilers may not
accept this type read statement so the program may have to be
modified with additional FORMAT lines.

Figure 1 is an input data sheet which may be used to record
test data prior to entering the data into the computer input
file. An example of a data sheet with handwritten test result
measurements is shown on page C1 of Appendix C. The measurement
units or dimensions to be used for each entry are given
directly under the name of the data value to be entered.
Although some of the units are not specified in the test
procedure, the units on the input form have been selected to
conform to the numerical constants and equations of the test
procedure. The option of entering temperatures in fahrenheit
or in celsius has been provided since converting while entering
data is inconvenient. If celsius value is entered as the
ambient temperature, then the conversion is performed on all
temperature measurements entered on that line. In the same
manner, the option of entering barometric pressure in inches of
mercury or in milibars has been provided and if barometric
pressure was not known or recorded, 0.0 may be entered. The
program will then use a default value of 30 inches of mercury.

VENTED HEATER PROGRAM INPUT FORM

Title #1
Title #2

System #	Fuel #	Control #	Option #	Fuel Cost c/Therm.	Elect. Cost c/kWh

Pilot Btu/min*	Elect. kW *	Jacket Loss, % *

NOTE #1. Enter 50% input rate values
if manual control, type #4.
#2. *=enter 0.0 if not measured

Fuel Input Btu/min.	Room Amb. F or C	Stack Temp. F or C *	Flue Temp. F or C *	CO2 Stack % *	CO2 Flue %

Enter next line only if tested at second (reduced) input rate.

Enter next line only if with damper and off-loss not measured.

Stack Area sq. in.	Damper area sq. in.	Angle deg.

Enter next line only if draft measured (Dp), option #2.

Barometer "Hg or mb*	Gas Temp. F or C	Gas Conc. % or ppm	Gas Flow cu.ft./min	Trac.Conc. % or ppm	Flue Temp. F or C

Enter next lines only if measured high fire off-loss measured.

Barometer "Hg or mb*	Gas Temp. F or C	Gas Conc. % or ppm	Gas Flow cu.ft./min

Meas #	Trac.Conc. % or ppm	Flue Temp. F or C
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Enter next lines only if reduced fire off-loss measured.

Barometer "Hg or mb*	Gas Temp. F or C	Gas Conc. % or ppm	Gas Flow cu.ft./min

Meas #	Trac.Conc. % or ppm	Flue Temp. F or C
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Figure 1
-4-

After the input information from the "Input form", Figure 1, is transferred to a data input element in the computer, the computer program VENT, Appendix A, can be run. The data relating to the tests that were run is READ from the stored data file, or element, line by line by the Fortran READ statements at the following line numbers.

Line 380
   Title. This entry may contain up to 80 characters of alphanumeric written material such as a title, test date, manufacturer or model information etc.

Line 380
   Title. The second entered title line may contain additional information not included in line 1, or a blank line may be entered.

Line 470
   Conditions. This line must contain six numeric entries of four integer numbers followed by two real numbers. The integer numbers select the type of unit being evaluated and the type of fuel used from Tables 1 and 2 of the test procedure, the type control incorporated in the unit tested, and the optional test procedures used. For convenience in reading the program, the meanings of the input selection values are included as comments on lines 480 to 650. The two real numbers are the costs of the fuels used. The cost of fuel is made as an input READ rather than as a fixed DATA statement line in the program to remind the user to enter the latest cost values published by DOE in the Federal Register. The costs of #1 oil, manufactured gas, and butane are not included in the DOE published costs. It is suggested that the cents per therm of natural gas be used for manufactured gas, that the cents per gallon of #2 oil be used for #1 oil, and that cents per gallon of propane be used for butane.

Line 730
   Auxiliary data. Three real number entries are entered on this line. Note that the pilot light fuel input rate is in Btu per minute rather than the more customary Btu/hour. The Btu/min. units were selected because the only time a gas fuel input rate dimension is given in the test procedure the units are in Btu /min. This is in section 4.3.3 of the test procedure where the burner fuel input rate is used in calculating off-losses. The program user can change the data input units to Btu/hr. by dividing the entered values of the pilot and the burner fuel input rates by 60.0 as an added statement or adding a "/60." in lines 2210, 3370, and 3380.
   The jacket loss in percent should be entered as 0.0 for units installed indoors. For floor furnaces (heaters) the measured value using ANSI standard Z21.48-1976 for "vented floor furnaces" multiplied by 0.712 should be used.

Line 900
   The remaining lines in the input data file contain
   measured test data values. The only test data entries
   always needed are READ on line 900 of the program (the
   fifth line on the input form, Figure 1.) This line must be
   entered and it must contain six real number test data
   results. However, if the specified tests on the tested
   unit do not require that some of the values be measured,
   i.e., flue temperature on units having draft diverters, a
   value of 0.0 is entered. Note that the fuel input value
   is in Btu/min (see the discussion above regarding the
   pilot light fuel input rate entry.) If the unit tested has
   a manual type control with adjustable fuel input rate, the
   data entered as "Fuel input" would be the 50% fuel input
   rate actually used.

Line 980
   The next line on the input form is the same as the
   previous line except that the test values are those
   measured at the reduced fuel input rate when the unit
   tested has a modulating type control. The line is skipped
   if the control is non-modulating.

Line 1050
   The physical measurements of the stack damper are entered
   if a damper is included in the unit being tested. This
   applies only to electro-mechanical dampers; thermal
   dampers must be tested using the off-loss tracer gas test.
   The data must be entered for all units with dampers unless
   the option of off-loss testing has been taken, in which
   case the line of data is skipped.

Line 1140
   The next line of data is skipped on the Input Form unless
   testing option #2 was selected, "Optional procedure for
   determining "Dp" for vented home heating equipment." If
   the option was taken, data from the tracer gas test of
   section 3.6 in the test procedure is used.

Lines 1260 and 1300, also 1420 and 1460
   The last two groups of input data values on Figure 1 are
   used only if the tracer gas off-loss testing option #3 was
   selected. If the optional procedure (mandatory for units
   with thermal dampers) is used, the test condition input
   values are entered on the first line followed by ten
   measurements of tracer gas concentration and flue gas
   temperature. The first measured pair of values would have
   been taken 30 seconds after the fuel input was turned off
   after steady-state conditions had been attained. The next
   nine pairs of values would have been taken at one minute
   intervals after the first readings.
   Both groups of test data, high-fire and reduced-fire, will
   be entered if the tested unit has a two-stage modulating
   type control. For single-stage

non-modulating controls only the high-fire values are
entered, and for step-modulating type controls only the
reduced fire test data are taken and entered.

As the program is structured, a minimum of five lines of input
data must be entered and a maximum of 28 line entries may be
used. It is possible to have only four test data values or as
many as 39 measured test data values.

PROGRAM DESCRIPTION

The 401 line Fortran 77 program of Appendix A contains 110
comment lines, three subroutines, and one function. The
function, lines 4060 to 4090, converts temperature value units.
Following are the starting lines of the subroutines along with
a description of their use.

  Line 3720
    Subroutine SSLOSS calculates the steady-state test results.
    Air mass-flow rate ratio, RTF; S/F ratio, SFR; sensible
    heat loss, QSSS; and steady state efficiency, EFYSS, are
    calculated. The higher heating value, HHV; air to fuel
    ratio, AFR; and latent heat loss, QL, are assigned table
    values. This subroutine is similar to SENLOS which was
    used in previously published Fortran programs.

  Line 3460
    Subroutine WGHT provides the values needed for modulating
    furnace evaluation. The balance point temperature is
    calculated. The average outside air temperatures, when in
    the high and reduced firing rate modes, and the ratio of
    time during the heating season that the unit is in its low
    firing rate mode are selected from the values listed in
    Table 3 of the test procedure. WGHT is similar to the
    subroutine WEIGHT used in the program FBVH [3] except that
    16 values of "Heat output ratio" from Table 3 are used as
    look-up table values.

  Line 3270
    Subroutine LOSOFF is used when the optional test procedure
    for measuring off-losses is used. The subroutine
    calculates latent and sensible heat losses during the off
    period when the unit is cycling. LOSOFF is similar to the
    subroutine OFFLOS of program FBVH except that only 10
    rather than 20 measurements are used. Also, the barometric
    pressure, Pb, required by the test procedure is
    incorporated into the equations.

Input to the program was covered in the previous section but
Table 1 on the following page of this report should be helpful
in comparing the input variable names in the test procedure
with the names used in the program. The number of the section
of the test procedure, Appendix B, where the variable name
first appears is also listed along with the units that apply to
the variable. The units are not necessarily in the section
where the name first appears. The subscripts and number-type
to alpha letter convention of Fortran make the renaming
neccessary. Figure 2 shows a flow chart of the inputs to the
program. The chart is self explanatory and clearly illustrates

TABLE 1

INPUT VARIABLES FOR
VENTED HEATER TEST PROCEDURE

Program	Test Pros.	Section	Units
QP	Q_p	3.5	Btu/min.
PE	P_e	3.1.3	kilowatts
QJ	L_j	3.2	%
QIN	Q_{in}	3.1.1	Btu/min.
TRA	T_{ra}	3.1.1	Deg. F
TSS	$T_{s,ss}$	3.1.1	Deg. F
TFS	$T_{f,ss}$	3.1.1	Deg. F
CO2S	X_{co2s}	3.1.1	%
CO2F	X_{co2f}	3.1.1	%
QINR	$Q_{red.in}$	4.1.11	Btu/min.
TRAR	—	—	Deg. F
TSSR	—	—	Deg. F
TFSR	—	—	Deg. F
CO2SR	—	—	%
CO2FR	—	—	%
AD	A_d	3.4	sq. in.
AS	A_s	3.4	sq. in.
AN	Ω	3.4	Degrees
PB	P_b	3.6	in. Hg
TT	T_t	3.6	Deg. F
CTT	—	—	% or ppm
VT	V_t	3.6	cu.ft./min.
CT	C_t	3.6	% or ppm
TF	$T_{f,off}$	3.6	Deg. F
PBO	P_b	4.3.3	in. Hg
TTO	T_t	4.3.3	Deg. F
CTTO	C_t	4.3.3	% or ppm
VTO	V_t	4.3.3	cu.ft./min.
CTO(I)	C_t	4.3.3	% or ppm
TFO(I)	$T_{s,off}$	4.3.3	Deg. F
PBOR	—	—	in. Hg
TTOR	—	—	Deg. F
CTTOR	—	—	% or ppm
VTOR	—	—	cu.ft./min.
CTOR(I)	—	—	% or ppm
TFOR(I)	—	—	Deg. F

NOTE:
- Means that the variable name is the same as
another variable name in the test procedure.

VENTED HEATER PROGRAM, "PROG.VENT"
INPUT VARIABLE FLOW CHART
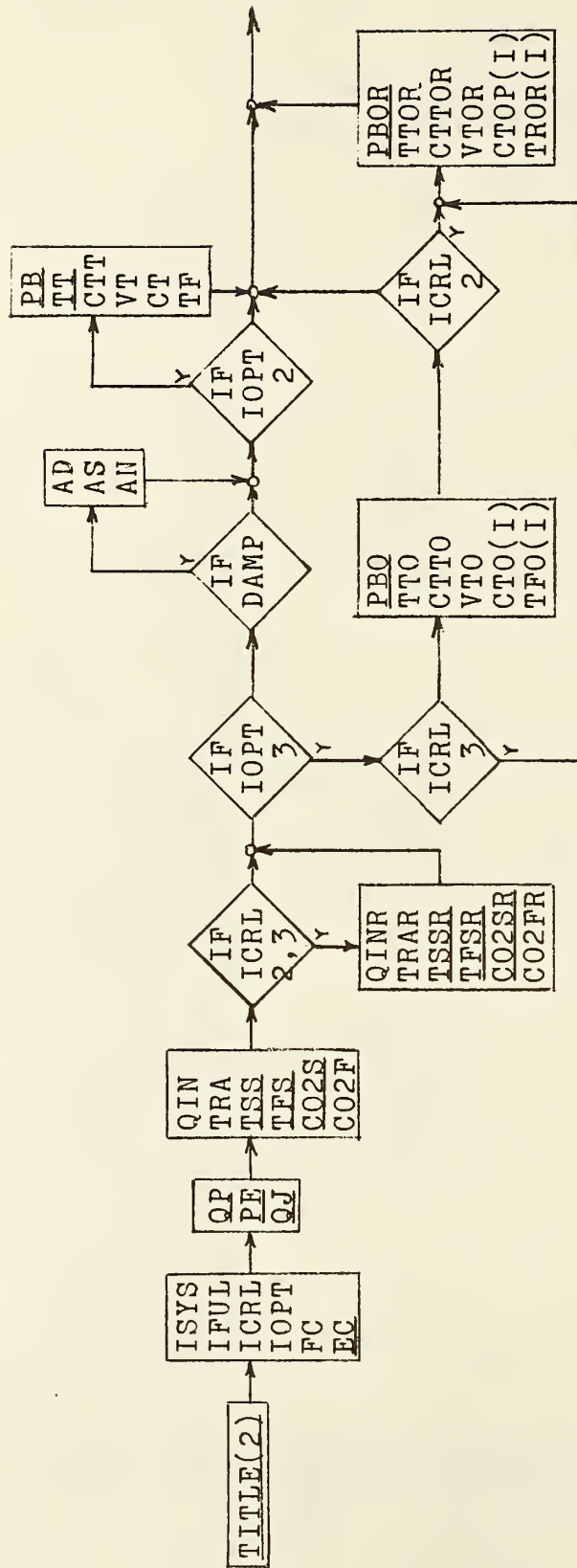
NOTE : DAMP = ISYS 5,6,7,8,11, or 12
       If thermal damper, IOPT must = 3
       Underlined variables sometimes entered as 0.0
       I = Measurements one to ten

Figure 2

the various inputs required for the different control types and options selected. The input section of the program, lines 380 to 1560 covers all of the inputs, the various options, the conversions of temperatures and barometric pressure, and the printout of the input titles, program selections, and test data. No checks have been incorporated to assure that the data entered fall within acceptable or normal ranges and no check for incorrectly entered data has been made.

After the the data have been read, lines 1560 to line 3050 calculate the results needed to obtain the values required by the test procedure, section 430.22, pages 12156-7 (AFUE and estimated operating cost per million Btu output.) The calculation portion of the program can be seen in the simplified flow chart of Figure 3. The chart shows only the subroutine calls and a few intermediate variables and omits most calculations and many intermediate values. The flow chart and the comments in the program itself should be sufficient to explain the steps taken and the conditional evaluations that are made to perform the needed actions. Only two checks have been included in the program. The one at lines 2010, 2020 is made to assure that "Do" is not negative or greater than one. If greater, "Do" is made equal to one and if less than 0.0 it is changed to 0.0. The formula in Section 4.4 used to calculate "Do" is not a rigorous mathematical evaluation so it can generate values that have no physical significance. At lines 2370, 2380, another check is made to make sure that the draft factors, Df and Ds, are not assigned values greater than one. Again, if greater than one, it is made equal to 1.0.

The calculated value,"Do", is printed out along with the input measurements of the damper, and "Df" and "Ds" are printed out when the simplified AFUE calculation is used. When modulating type controls are tested, the heat fractions and balance point temperature are printed. When the tracer gas test for off-losses is used, the "on" and "off" infiltration and sensible heat losses are printed as output. The main output of the program is the steady state efficiency and the two results required by the test procedure, AFUE and cost per million Btu.

DEVIATIONS FROM TEST PROCEDURE

The Fortran program of this report was written to conform as closely as possible to the published test procedure. In several instances there are differences due to typographical errors or inadvertent omissions of needed changes that were not included in the procedure as published. The program was written with as many errors corrected as possible. The deviations are in sections of Appendix 0 of the test procedure (Appendix B of this report). The section numbers and changes are as follows:
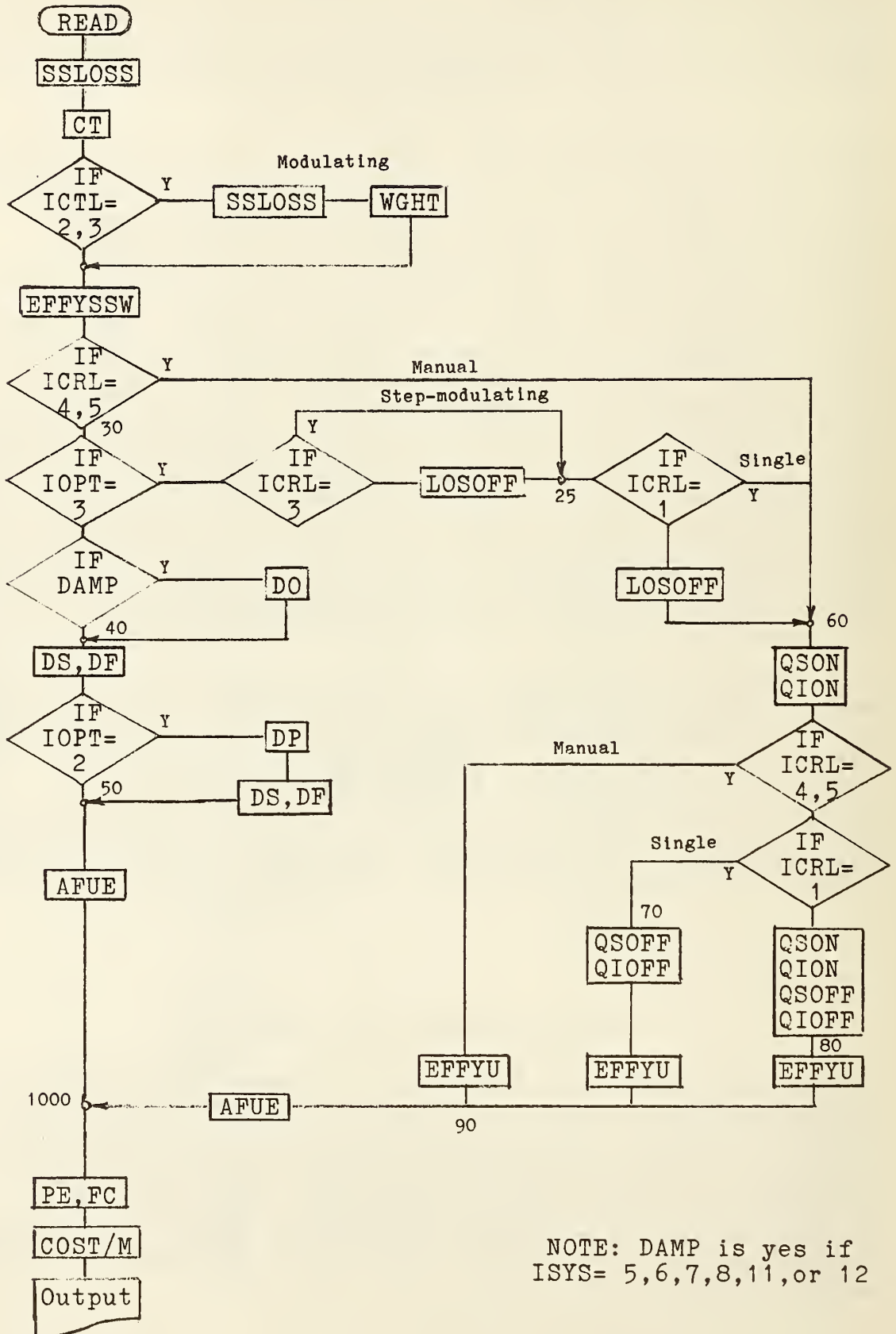
FIGURE 3

4.1.3 - The off-cycle stack draft factors, Ds, from Table 1 of the test procedure are not given for systems 9 through 12. For these types, Ds is taken as 1.0, is assigned at line 300 and 2100, and used in line 2410. It would appear that, for direct vent systems, Ds should equal 0.0. However, 1.0 was used for Ds in the data used in a multiple regression to determine the coefficients of the simplified test method AFUE formula. Because of this, a Ds of 1.0 is used in the program.

4.1.11 and 4.1.12 - The heat output rate calculation should include division by 100.0 to change percent to a decimal value. Since these values are used to determine the ratio "R", the omission is not important in the program calculations but the changes were made in lines 3570 and 3590.

4.1.17 - The simplified test method calculation of AFUE on line 2410 uses 3.93 as the coefficient for the jacket loss, Lj, because this value is a multiple regression coefficient. A change in one coefficient would require a change in the others. The change from 3.93 to 2.8 in the test procedure was made to reduce the adjustment factor for lower outdoor air temperature and cycling conditions. Measured jacket loss may be multiplied by 0.7 prior to entering the data and running the program to make the test procedure allowed reduction. However, the correlation between results obtained using the simplified vs. the standard test methods is not known.

4.2.1 - The ratio of S/F is not given in a table or calculated for units using outside air for combustion or for oil fueled units. This S/F calculation and the Section 4.2.2 calculation of "Ki,on" are used for all types of units in later Section 4.3. The program has been written to use 0.0 for S/F for outside installations. The 0.0 causes "Li,on" to be calculated as zero for floor furnaces. The subroutine SSLOSS has been written so that for oil fueled units, a ratio of Rt,s to Rt,f is used without the 1.3 multiplication factor if a CO_2 measurement was made in the stack (above the barometric damper). If not measured, a S/F of 1.4 is assigned. The assignments or calculation is made in the subroutine SSLOSS on lines 3870, 3880, and 3930.

4.2.5 - The psuedo part-load efficiency calculation for manually controlled units omits jacket losses of floor or outside installations. Although none are known to exist, such designs are possible so the program has been modified at line 2550 to subtract Cj * Lj to calculate this efficiency, EFFYU. In the attached examples, Appendix C, the second example showed a AFUE of 12% lower than if Cj=2.8 and Lj=4.5 were omitted.

4.3.2 - The values of X1 and X2 are reversed in the test procedure, section 4.1.2. The correct values are used in lines 2630 and 2670 in the program.

4.3.3, 4.3.5 and 4.3.6 – The values of 20 minutes for ton and toff are given in the test procedure. The correct 10 minute value is used in the program on the several lines on which these values appear. Also, the number of measured values of tracer gas concentration and flue gas temperature is ten instead of twenty as listed in the procedure.

4.3.6 – The typographic error in section 4.3.6 that used "Ls,off" a second time instead of "Li,off" was corrected on line 2850 of the program.

4.3.7 – The weighted steady-state efficiency was used on line 2920 instead of just steady-state efficiency for the calculation of AFUE as was done in section 4.3.7

4.5.1 The value 100.0 was replaced with the variable CTT on line 2170 so that diluted tracer gas may be used for the "Dp" test as it was permitted in the offloss test on line 3330 of subroutine LOSOFF. The variable was defined in section 4.5.1 but not used in the equation.

CONCLUSIONS

The Fortran program described in this report was tested with
many simulated runs with as many combinations of heater types,
control types, test options etc. as practical. A few of these
tests are included in Appendix C for illustrative purposes.
Each run is preceded by a printout of the data entry file used.
The examples are not actual tests but were made up to cover
extreme conditions. The Fortran 77 computer program of this
report should prove useful to the vented heater manufacturing
industry, testing laboratories, and those persons who must
understand the test procedure and its calculations.

```
100 C ***** HTRS*PROG.VENT *****
110 C  Program to use the DOE test procedure for Vented Heaters on units
120 C   having single, two-stage, step-modulating or manual controls.
130 C   The manual type may have adjustable fuel rate or only on-off
140 C   control.A test method for thermal dampers is also included.
150 C  This program is based on the previously published program
160 C   titled FBVH but is modified to include the changed
170 C   procedures of the ammended final rule.
180 C  Input to the program starts with two lines of identification.
190 C  The input data to the program requires three additional lines
200 C   but other lines may be added to provide data for reduced
210 C   firing rate, damper measurements, and optional power burner
220 C   draft factor data or off-loss test data.
230 C
240 C   By:  R.A.Wise, F.C.Parsons,  3-1-84
250 C
260        DIMENSION TITLE(20,2),CTO(10),TFO(10),CTOR(10),TFOR(10),
270      # CDF(12),CDS(12)
280        DATA PI/3.141592654/
290        DATA CDF/1.,.4,1.,.4,1.,.4,1.,.4,1.,.4,1.,.4/
300        DATA CDS/3*1.,.85,4*-1.,4*1.0/
310        DATA TOAHI,TON,TOFF/45.,10.,10./
320 C
330        WRITE(6,500)
340 500    FORMAT(//20X,'VENTED HEATER TEST REPORT')
350        WRITE(6,501)
360 501    FORMAT(/2X,'Input data, type-"@ADD FILENAME.ELEMENTNAME"')
370 C
380 C  Read two lines of title and test set-up information.
390 C
400        READ (5,502) TITLE
410 502    FORMAT (20A4)
420        WRITE (6,503) ((TITLE(I,J),I=1,20),J=1,2)
430 503    FORMAT (/2(5X,20A4/))
440 C
450 C  Read test conditions
460 C
470        READ (5,*) ISYS,IFUL,ICRL,IOPT,FC,EC
480 C
490 C  ----ISYS----
500 C 1=Hood/diverter, Atmos.            7=Barometric, Atmos., Damper
510 C 2=Hood/diverter, Power             8=Barometric, Power , Damper
520 C 3=Barometric, Atmos.              9=Direct, Atmos.
530 C 4=Barometric, Power              10=Direct, Power
540 C 5=Hood/Diverter, Atmos., Damp.   11=Direct, Atmos., Damper
550 C 6=Hood/Diverter, Power , Damp.   12=Direct, Power , Damper
560 C  ----IFUL----          ----ICRL----                 ----IOPT----
570 C 1=No.1 oil          1=Single stage             1=No optional tests
580 C 2=No.2 oil          2=Two stage                2=Meas.draft factor
590 C 3=Natural gas       3=Step Modulating          3=Measured off-loss
600 C 4=Manufactured gas  4=Manual w/heat control       or thermal damper
610 C 5=Propane           5=Manual, on-off
620 C 6=Butane
630 C ----FC=Fuel cost: Cents/Therm for 3 or 4,Cents/Gallon for others.
640 C ----EC=Electric cost, Cents/kWh
650 C
660        WRITE(6,521)
```

```
670 521    FORMAT(/1X,'*********** INPUT SELECTIONS ***********')
680        WRITE(6,522)
690 522    FORMAT(/1X,'SYSTEM #  FUEL   CONTROL   OPTIONS   ',
700      #  'FUEL-COST  ELECT-COST')
710        WRITE(6,523)ISYS,IFUL,ICRL,IOPT,FC,EC
720 523    FORMAT(4(6X,I1),6X,2(3X,F6.2))
730        READ(5,*)QP,PE,QJ
740        IF(QP.GT.0.0)WRITE(6,524)QP
750 524    FORMAT(1X,'WITH PILOT LIGHT, QP=BTU/MIN.=',F5.1)
760        IF(QP.LT.1.0)WRITE(6,525)
770 525    FORMAT(1X,'WITHOUT PILOT LIGHT')
780        WRITE(6,526)PE
790 526    FORMAT(1X,'ELECTRIC POWER,  KW=',F4.3)
800        IF(QJ.GT.0.0)WRITE(6,527)QJ
810 527    FORMAT(1X,'JACKET LOSS, % LOSS=',F5.2,/)
820        IF(QJ.LT.1.0)WRITE(6,528)
830 528    FORMAT(1X,'INSTALLED INDOORS',/)
840        WRITE(6,*)'*********** INPUT DATA *****************'
850        IF(ICRL.NE.4)WRITE(6,*)'HIGH FUEL INPUT RATE DATA'
860        IF(ICRL.EQ.4)WRITE(6,*)' 50% FUEL INPUT RATE'
870        WRITE(6,530)
880 530    FORMAT(5X,'INPUT     AMB   TEMP    TEMP    CO2    CO2',
890      #      /4X,'BTU/MIN   TEMP  STACK    FLUE   STACK    FLUE')
900        READ(5,*)QIN,TRA,TSS,TFS,CO2S,CO2F
910        IF(TRA.LT.40.0.AND.TSS.GT.10.0)TSS=CF(TSS)
920        IF(TRA.LT.40.0.AND.TFS.GT.10.0)TFS=CF(TFS)
930        IF(TRA.LT.40.0)TRA=CF(TRA)
940        WRITE(6,531)QIN,TRA,TSS,TFS,CO2S,CO2F
950 531    FORMAT(4X,6F7.1)
960        IF(ICRL.EQ.1.OR.ICRL.GT.3)GO TO 1
970        WRITE(6,*)'LOW FUEL INPUT RATE'
980        READ(5,*)QINR,TRAR,TSSR,TFSR,CO2SR,CO2FR
990        IF(TRAR.LT.40.0.AND.TSSR.GT.10.0)TSSR=CF(TSSR)
1000       IF(TRAR.LT.40.0.AND.TFSR.GT.10.0)TFSR=CF(TFSR)
1010       IF(TRAR.LT.40.0)TRAR=CF(TRAR)
1020       WRITE(6,531)QINR,TRAR,TSSR,TFSR,CO2SR,CO2FR
1030 1     IF(IOPT.EQ.3)GO TO 2
1040       IF(ISYS.LT.5.OR.(ISYS.GT.8.AND.ISYS.LT.11))GO TO 4
1050       READ(5,*)AD,AS,AN
1060       WRITE(6,532)AD,AS,AN
1070 532   FORMAT(' DAMPER MEASUREMENTS: DAMPER AREA=',F6.2,
1080     #  '  ,STACK AREA=',F6.2,'   ANGLE=',F4.1)
1090 4     IF(IOPT.NE.2)GO TO 5
1100       WRITE(6,*)' OPTIONAL Dp PROCEDURE TEST DATA'
1110       WRITE(6,533)
1120 533   FORMAT(1X,' BARO.   TEMP.   CONC.   VOLM.   CONC.   TEMP.',
1130     #      /1X,' PRES.   TRAC.   TRAC.   TRAC.   FLUE   FLUE')
1140       READ(5,*)PB,TT,CTT,VT,CT,TF
1150       IF(PB.EQ.0.0)PB=30.0
1160       IF(PB.GT.100.)PB=PB/33.867
1170       IF(TT.EQ.0.0)TT=TRA
1180       IF(TT.LT.40.0)TF=CF(TF)
1190       IF(TT.LT.40.0)TT=CF(TT)
1200       WRITE(6,534)PB,TT,CTT,VT,CT,TF
1210 534   FORMAT(2X,F5.2,3X,F4.1,3(2X,E7.2),2X,F5.1)
1220       GO TO 5
1230 2     IF(ICRL.EQ.3)GO TO 3
1240       WRITE(6,*)'HIGH FIRE OFF-LOSS DATA.'
1250       WRITE(6,533)
```

```
1260          READ(5,*)PBO,TTO,CTTO,VTO
1270          IF(PBO.EQ.0.0)PBO=30.0
1280          IF(PBO.GT.100.)PBO=PBO/33.867
1290          IF(TTO.EQ.0.0)TTO=TRA
1300          READ(5,*)(CTO(I),TFO(I),I=1,10)
1310          IF(TTO.LT.40.0) THEN
1320          DO 22 I=1,10
1330 22       TFO(I)=CF(TFO(I))
1340          ENDIF
1350          IF(TTO.LT.40.0)TTO=CF(TTO)
1360          WRITE(6,534)PBO,TTO,CTTO,VTO,CTO(1),TFO(1)
1370          WRITE(6,535)(CTO(I),TFO(I),I=2,10)
1380 535      FORMAT(34X,E7.2,2X,F5.1)
1390 3        IF(ICRL.EQ.1.OR.ICRL.GT.3)GO TO 5
1400          WRITE(6,*)'LOW FIRE OFF-LOSS DATA.'
1410          IF(ICRL.EQ.3)WRITE(6,533)
1420          READ(5,*)PBOR,TTOR,CTTOR,VTOR
1430          IF(PBOR.EQ.0.0)PBOR=30.0
1440          IF(PBOR.GT.100.)PBOR=PBOR/33.867
1450          IF(TTOR.EQ.0.0)TTOR=TRAR
1460          READ(5,*)(CTOR(I),TFOR(I),I=1,10)
1470          IF(TTOR.LT.40.0)THEN
1480          DO 33 I=1,10
1490 33       TFOR(I)=CF(TFOR(I))
1500          ENDIF
1510          IF(TTOR.LT.40.0)TTOR=CF(TTOR)
1520          WRITE(6,534)PBOR,TTOR,CTTOR,VTOR,CTOR(1),TFOR(1)
1530          WRITE(6,535)(CTOR(I),TFOR(I),I=2,10)
1540 5        CONTINUE
1550 C
1560 C    Calculate steady-state values
1570 C
1580          CALL SSLOSS (IFUL,QJ,TRA,TSS,TFS,CO2S,CO2F,
1590        # HHV,AFRH,QLH,RTFH,QSSH,EFYSSH,SFRH)
1600          PF=QP/QIN
1610          CJ=0.0
1620 C If outdoor, assign CJ
1630          IF (QJ.GT.1.0) CJ=2.8
1640 C
1650 C    Calculate reduced firing rate values.
1660 C
1670          IF (ICRL.EQ.1.OR.ICRL.GT.3) GO TO 10
1680          CALL SSLOSS (IFUL,QJ,TRAR,TSSR,TFSR,CO2SR,CO2FR,
1690        # HHV,AFR,QL,RTFM,QSSM,EFYSSM,SFRM)
1700          CALL WGHT(QIN,EFYSSH,QINR,EFYSSM,
1710        # RLOW,TOALO,TOAHI,TC)
1720          RHIGH= 1. - RLOW
1730          WRITE(6,540)RLOW,RHIGH,TC
1740 540      FORMAT(/3X,'LOW HEAT FRACTION=',F5.3,3X,'HIGH HEAT FRACTION=',
1750        # F5.3,/3X,'BALANCE POINT TEMP.=',F5.2)
1760 C
1770 C    Weighted steady-state efficiency calculations.
1780 C
1790 10       EFYSSW=EFYSSH
1800          IF(ICRL .EQ. 1 .OR. ICRL .GT. 3)GO TO 20
1810          EFYSSA=EFYSSH
1820          IF(ICRL.EQ.3)EFYSSA=(EFYSSH-EFYSSM)*(TC-TOAHI)/(TC-15.)+EFYSSM
1830          EFYSSW=RLOW*EFYSSM+RHIGH*EFYSSA
1840 C
```

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1850 C     Optional tracer gas off-loss calculations.
1860 C
1870 20      IF(ICRL.GT.3.)GO TO 60
1880         IF (IOPT .NE. 3) GO TO 30
1890         IF(ICRL .EQ. 3)GO TO 25
1900         CALL LOSOFF(PBO,TTO,CTTO,VTO,CTO,TFO,TON,QIN,TRA,TOAHI,
1910       # QSOFFH,QIOFFH)
1920         IF (ICRL.EQ.1) GO TO 60
1930 25      CALL LOSOFF(PBOR,TTOR,CTTOR,VTOR,CTOR,TFOR,TON,QINR,TRAR,TOALO,
1940       # QSOFFM,QIOFFM)
1950         GO TO 60
1960 C
1970 C   Calculate electro-mechanical damper factor.
1980 C
1990 30      IF(ISYS.LT.5.OR.(ISYS.GT.8.AND.ISYS.LT.11))GO TO 40
2000         DO=1.62*(1.-AD*COS(PI*AN/180.)/AS)
2010         IF(DO.GT.1.0)DO=1.0
2020         IF(DO.LT.0.0)DO=0.0
2030         WRITE(6,555) AS,AD,AN,DO
2040 555     FORMAT(/2X,'As=',F5.2,3X,'Ad=',F5.2,3X,'An=',F4.1,3X,'Do=',F4.2)
2050 C
2060 C       ASSIGN TABLE VALUES FOR DF AND DS
2070 C
2080 40      DF=CDF(ISYS)
2090         IF(ISYS .GT. 10)DF=DF*DO
2100         DS=CDS(ISYS)
2110         IF(DS .LT. 0.)DS=DO
2120         IF(ISYS .EQ.8)DS=DO*DF
2130 C
2140 C       OPTIONAL PROCEDURE FOR CALCULATING DP,DS AND DF
2150 C
2160         IF(IOPT.NE.2)GO TO 50
2170         ZOFF=1.325*PB*VT*(CTT-CT)/(CT*(TT+460.))
2180         ZFSS=ZOFF
2190         IF(IFUL.GT.2)ZFSS=ZOFF*((TFS-TRA)/(TF-TRA))**.56
2200       # *((TF+460.)/(TFS+460.))**1.19
2210         ZSS=QIN*(RTFH*AFR+1.)/HHV
2220         DP=ZFSS/ZSS
2230         DF=DP
2240         IF(ISYS .GT. 10)DF=DP*DO
2250         IF(ISYS .GT. 8)GO TO 50
2260         IF(ISYS .LT. 3)DS=1.
2270         IF(ISYS .EQ. 3 .OR. ISYS .EQ. 4)DS=(DP+.79)/1.4
2280         IF(ISYS .EQ. 5 .OR. ISYS .EQ. 6)DS=DO
2290         IF(ISYS .GT. 6 .AND. (DO*SFRH .LT. 1.))DS=DP*DO
2300         IF(ISYS .GT. 6 .AND. (DO*SFRH .GE. 1.))DS=DP*DO+(.85-DP*DO)*
2310       # (DO*SFRH-1.)/(SFRH-1.)
2320 50      CONTINUE
2330 C
2340 C   Calculate AFUE, no thermal damper or off-loss measure
2350 C     and not manual controls.
2360 C
2370         IF(DF.GT.1.0)DF=1.0
2380         IF(DS.GT.1.0)DS=1.0
2390         WRITE(6,560)DF,DS
2400 560     FORMAT(/2X,'Df=',F4.2,3X,'Ds=',F4.2)
2410         AFUE=.968*EFYSSW-1.78*DF-1.89*DS-129.*PF-3.93*QJ+1.81
2420         GO TO 1000
2430 C
```

```
2440 C   Continue calculations for manual control, thermal
2450 C      damper, or measured off-losses.
2460 C
2470 C   Calculate on-cycle losses.
2480 C
2490 60      QSON=QSSH
2500         CIONH=100.*.24*SFRH*.7*(1.+RTFH*AFR)/HHV
2510         QION=CIONH*(70.-45.)
2520         IF(ICRL.EQ.1)GO TO 70
2530         IF(ICRL.GT.3) THEN
2540 C   Calculate psudo cycling loss for manual controls.
2550         EFFYU=EFYSSW-QION
2560         WRITE(6,570) QION
2570 570     FORMAT(/2X,'Li,on=',F5.2)
2580         GO TO 90
2590         ENDIF
2600 C   Calculate for two stage or modulating controls.
2610         QSSA=QSSH
2620         IF(ICRL.EQ.3)QSSA=(QSSH-QSSM)*(TC-TOAHI)/(TC-15.)+QSSM
2630         QSON=RLOW*QSSM+RHIGH*QSSA
2640         CIONM=100.*.24*SFRM*.7*(1.+RTFM*AFR)/HHV
2650         CIONA=CIONH
2660         IF(ICRL.EQ.3)CIONA=(CIONH+CIONM)/2.
2670         QION=RLOW*CIONM*(70.-TOALO)+RHIGH*CIONA*(70.-TOAHI)
2680 C
2690 C   Calculate off-cycle losses.
2700 C
2710 C   For two stage controls.
2720         QSOFF=RLOW*QSOFFM
2730         QIOFF=RLOW*QIOFFM
2740         IF(ICRL .EQ. 3)GO TO 80
2750 C   For step modulating controls.
2760         QSOFF=QSOFF+RHIGH*QSOFFH
2770         QIOFF=QIOFF+RHIGH*QIOFFH
2780         GO TO 80
2790 C   For single stage controls.
2800 70      QSOFF=QSOFFH
2810         QIOFF=QIOFFH
2820 C
2830 C   Calculate cycling, part-load, efficiency.
2840 C
2850 80      EFFYU=100.-QL-CJ*QJ-TON*(QSON+QSOFF+QION+QIOFF)/(TON+PF*TOFF)
2860         WRITE(6,580)QSON,QION,QSOFF,QIOFF
2870 580     FORMAT(3X,'Ls,on =',F5.2,6X,'Li,on =',F5.2,
2880       #        /3X,'Ls,off=',F5.2,6X,'Li,off=',F5.2)
2890 C
2900 C     Calculate AFUE.
2910 90      IF(ICRL.EQ.4) QIN=QIN*2.0
2920         AFUE=4400.*EFYSSW*EFFYU*QIN/(4400.*EFYSSW*QIN+
2930       # 2.5*4600.*EFFYU*QP)
2940 C
2950 C   Calculate electric power.
2960 C
2970 1000    IF(ICRL.EQ.1.OR.ICRL.GT.3)GO TO 1010
2980         PE=PE*1.3
2990         IF(ICRL.EQ.2)GO TO 1010
3000         FR=QIN/QINR
3010         PE=PE*1.7
3020         IF(FR.GE.0.7)PE=PE*1.4
```

```
3620          N=1
3630          DO 10 I=1,16
3640       10 IF(RATIO .GE. CHECK(I) .AND. RATIO .LT. CHECK(I+1)) N=I
3650          RLOW=RLO(N)
3660          TOALO=TOAL(N)
3670          TOAHI=TOAH(N)
3680          RETURN
3690          END
3700 C
3710 C *** CALCULATION  OF HHV AFR QL RTF SFR QSSS EFYSS ***
3720          SUBROUTINE SSLOSS(IFUL,QJ,TRA,TSS,TFS,CO2S,CO2F,
3730        # HHV,AFR,QL,RTF,QSSS,EFYSS,SFR)
3740          DIMENSION HH(6),AF(6),Q(6),A(6),B(6),C(6),D(6)
3750          DATA (HH(J),J=1,6)/19800.,19500.,20120.,18500.,21500.,20890./
3760          DATA (AF(J),J=1,6)/14.56,14.49,14.45,11.81,15.58,15.36/
3770          DATA (Q(J),J=1,6)/6.55,6.50,9.55,10.14,7.99,7.79/
3780          DATA (A(K),K=1,6)/.0679,.06668,.09194,.09646,.0841,.0808/
3790          DATA (B(K),K=1,6)/14.22,14.34,10.96,10.10,12.60,12.93/
3800          DATA (C(K),K=1,6)/.0179,.0181,.0175,.0155,.0177,.018/
3810          DATA (D(K),K=1,6)/.167,.167,.171,.235,.151,.143/
3820          HHV=HH(IFUL)
3830          AFR=AF(IFUL)
3840          QL=Q(IFUL)
3850          RTF=(B(IFUL)/CO2F)+A(IFUL)
3860          SFR=1.0
3870          IF(QJ.GT.0.0) SFR=0.0
3880          IF(IFUL.LT.3) SFR=1.4
3890          IF(CO2S.LT.0.1) GO TO 10
3900 C  Calculate S/F for Hood or Diverter or measured Barometric damper.
3910          RTS=(B(IFUL)/CO2S)+ A(IFUL)
3920          SFR = 1.3*(RTS/RTF)
3930          IF(IFUL.LT.3) SFR = RTS/RTF
3940       10 CONTINUE
3950          IF(TSS.LT.1.0) THEN
3960 C  Calculate steady-state efficiency for units w/o diverters.
3970          QSSS=C(IFUL)*(RTF+D(IFUL))*(TFS-TRA)
3980          ELSE
3990 C  Calculate steady-state efficiency for units with diverters.
4000          QSSS=C(IFUL)*(RTS+D(IFUL))*(TSS-TRA)
4010          ENDIF
4020          EFYSS=100.-QL-QSSS
4030          RETURN
4040          END
4050 C
4060 C *** Convert deg. C to deg. F ***
4070          FUNCTION CF(T)
4080          CF=T*1.8 + 32.0
4090          RETURN
4100          END
```

APPENDIX B

DOE TEST PROCEDURE

FEDERAL REGISTER

MARCH 28 , 1984

Sections pertaining to vented heaters-
Pages 12156, 12157, and 12169 to 12178
Text and equations have been rearranged to
be in continuous columns.

PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS

Provisions of 10 CFR Part 430, § 430.2, § 430.22, Appendix G, Appendix N, and Appendix O are amended as follows:

(o) *Vented home heating equipment.*

(1) The annual fuel utilization efficiency for vented home heating equipment, expressed in percent, which is the ratio of the annual fuel output of useful energy delivered to the heated space to the annual fuel energy input to the vented heater, shall be determined either according to section 4.1.17 of Appendix O of this subpart for vented heaters without either manual controls or thermal stack dampers; according to section 4.2.6 of Appendix O of this subpart for vented heaters equipped with manual controls; or according to section 4.3.7 of Appendix O of this subpart for vented heaters equipped with thermal stack dampers.

(2) The estimated operating cost per million Btu output for vented heaters without an auxiliary electric system shall be the product of: (i) One hundred; (ii) the quotient of one million Btu output divided by the annual fuel utilization efficiency as determined in paragraph (o) (1) and (iii) the representative unit cost in dollars per Btu for natural gas, propane, or oil, as appropriate, as provided pursuant to section 323(b)(2) of the Act, the resulting product shall be rounded to the nearest 0.01 dollar per million Btu output.

(3) The estimated operating cost per million Btu output for gas or oil vented home heating equipment with an auxiliary electric system shall be the product of: (A) The quotient of one million Btu divided by the sum of: (1) The product of the maximum fuel input in Btu's per hour as determined in 3.1.1 or 3.1.2 of Appendix O of this subpart times the annual fuel utilization efficiency in percent as determined in 4.1.17, 4.2.6, or 4.3.7 of this appendix as appropriate divided by 100, plus (2) the product of the maximum electric power in watts as determined in 3.1.3 of Appendix O of this subpart times the quantity 3.412; and (B) of the sum of: (1) the product of the maximum fuel input in Btu's per hour as determined in 3.1.1 of this appendix times the representative unit cost in dollars per Btu for natural gas, propane, or oil, as appropriate, as provided pursuant to section 323(b)(2) of the Act; plus (2) the product of the maximum auxiliary electric power in kilowatts as determined in 3.1.3 of Appendix O of this subpart times the representative unit cost in dollars per kilowatt-hour as provided pursuant to section 323(b)(2) of the Act, the resulting quantity shall be rounded off to the nearest 0.01 dollar per million Btu output.

(4) Other useful measures of energy consumption for vented home heating equipment shall be those measures of energy consumption which the Secretary determines are likely to assist consumers in making purchasing decisions and which are derived from the application of Appendix O of this subpart.

5. Appendix O to Subpart B of Part 430 is revised to read as follows:

Appendix O to Subpart B of Part 430–
Uniform Test Method for Measuring the Energy Consumption of Vented Home Heating Equipment

1.0 *Definitions.*

1.1 "Air shutter" means an adjustable device for varying the size of the primary air inlet(s) to the combustion chamber power burner.

1.2 "Air tube" means a tube which carries combustion air from the burner fan to the burner nozzle for combustion.

1.3 "Barometic draft regulator or barometric damper" means a mechanical device designed to maintain a constant draft in a vented heater.

1.4 "Draft hood" means an external device which performs the same function as an integral draft diverter, as defined in section 1.17 of this appendix.

1.5 "Electro-mechanical stack damper" means a type of stack damper which is operated by electrical and/or mechanical means.

1.6 "Excess air" means air which passes through the combustion chamber and the vented heater flues in excess of that which is theoretically required for complete combustion.

1.7 "Flue" means a conduit between the flue outlet of a vented heater and the integral draft diverter, draft hood, barometric damper or vent terminal through which the flue gases pass prior to the point of draft relief.

1.8 "Flue damper" means a device installed between the furnace and the integral draft diverter, draft hood, barometric draft regulator, or vent terminal which is not equipped with a draft control device, designed to open the venting system when the appliance is in operation and to close the venting system when the appliance is in a standby condition.

1.9 "Flue gases" means reaction products resulting from the combustion of a fuel with the oxygen of the air, including the inerts and any excess air.

1.10 "Flue losses" means the sum of sensible and latent heat losses above room temperature of the flue gases leaving a vented heater.

1.11 "Flue outlet" means the opening provided in a vented heater for the exhaust of the flue gases from the combustion chamber.

1.12 "Heat input" (Q_{in}) means the rate of energy supplied in a fuel to a vented heater operating under steady-state conditions, expressed in Btu's per hour. It includes any input energy to the pilot light and is obtained by multiplying the measured rate of fuel consumption by the measured higher heating value of the fuel.

1.13 "Heating capacity" (Q_{out}) means the rate of useful heat output from a vented heater, operating under steady-state conditions, expressed in Btu's per hour. For room and wall heaters, it is obtained by multiplying the "heat input" (Q_{in}) by the steady-state effiency (η_{ss}) divided by 100. For floor furnaces, it is obtained by multiplying (A) the "heat input" (Q_{in}) by (B) the steady-state efficiency divided by 100, minus the quantity (2.8) (L_j) divided by 100,

where L_j is the jacket loss as determined in section 3.2 of this appendix.

1.14 "Higher heating value" (HHV) means the heat produced per unit of fuel when complete combustion takes place at constant pressure and the products of combustion are cooled to the initial temperature of the fuel and air and when the water vapor formed during combustion is condensed. The higher heating value is usually expressed in Btu's per pound, Btu's per cubic foot for gaseous fuel, or Btu's per gallon for liquid fuel.

1.15 "Induced draft" means a method of drawing air into the combustion chamber by mechanical means.

1.16 "Infiltration parameter" means that portion of unconditioned outside air drawn into the heated space as a consequence of loss of conditioned air through the exhaust system of a vented heater.

1.17 "Integral draft diverter" means a device which is an integral part of a vented heater, designed to: (1) Provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft diverter, (2) prevent a back draft from entering the vented heater, and (3) neutralize the stack action of the chimney or gas vent upon the operation of the vented heater.

1.18 "Manually controlled vented heaters" means either gas or oil fueled vented heaters equipped without thermostats.

1.19 "Modulating control" means either a step-modulating or two-stage control.

1.20 "Power burner" means a vented heater burner which supplies air for combustion at a pressure exceeding atmospheric pressure, or a burner which depends on the draft induced by a fan incorporated in the furnace for proper operation.

1.21 "Reduced heat input rate" means the factory adjusted lowest reduced heat input rate for vented home heating equipment equipped with either two stage thermostats or step-modulating thermostats.

1.22 "Single stage thermostat" means a thermostat that cycles a burner at the maximum heat input rate and off.

1.23 "Stack" means the portion of the exhaust system downstream of the integral draft diverter, draft hood or barometric draft regulator.

1.24 "Stack damper" means a device installed downstream of the integral draft diverter, draft hood, or barometric draft regulator, designed to open the venting system when the appliance is in operation and to close off the venting system when the appliance is in the standby condition.

1.25 "Stack gases" means the flue gases combined with dilution air that enters at the integral draft diverter, draft hood or barometric draft regulator.

1.26 "Steady-state conditions for vented home heating equipment" means equilibrium conditions as indicated by temperature variations of not more than 5° F (2.8C) in the flue gas temperature for units equipped with draft hoods, barometric draft regulators or direct vent systems, in three successive readings taken 15 minutes apart or not more than 3° F (1.7C) in the stack gas temperature for units equipped with integral draft diverters in three successive readings taken 15 minutes apart.

1.27 "Step-modulating control" means a control that either cycles off and on at the low input if the heating load is light, or gradually, increases the heat input to meet any higher heating load that cannot be met with the low firing rate.

1.28 "Thermal stack damper" means a type of stack damper which is dependent for operation exclusively upon the direct conversion of thermal energy of the stack gases into movement of the damper plate.

1.29 "Two stage control" means a control that either cycles a burner at the reduced heat input rate and off or cycles a burner at the maximum heat input rate and off.

1.30 "Vaporizing-type oil burner" means a device with an oil vaporizing bowl or other receptacle designed to operate by vaporizing liquid fuel oil by the heat of combustion and mixing the vaporized fuel with air.

1.31 "Vent/air intake terminal" means a device which is located on the outside of a building and is connected to a vented heater by a system of conduits. It is composed of an air intake terminal through which the air for combustion is taken from the outside atmosphere and a vent terminal from which flue gases are discharged.

1.32 "Vent limiter" means a device which limits the flow of air from the atmospheric diaphragm chamber of a gas pressure regulator to the atmosphere. A vent limiter may be a limiting orifice or other limiting device.

1.33 "Vent pipe" means the passages and conduits in a direct vent system through which gases pass from the combustion chamber to the outdoor air.

2.0 *Testing conditions.*

2.1 *Installation of test unit.*

2.1.1 *Vented wall furnaces (including direct vent systems).* Install gas fueled vented wall furnaces for test as specified in sections 2.1.3 and 2.1.4 of ANSI Z21.49–1975. Install gas fueled wall furnaces with direct vent systems for test as described in sections 2.1.3 and 2.1.4 of ANSI Z21.44–1973. Install oil fueled vented wall furnaces as specified in UL–730–1974, section 33. Install oil fueled vented wall furnaces with direct vent systems as specified in UL–730–1974, section 34.

2.1.2 *Vented floor furnaces.* Install vented floor furnaces for test as specified in sections 35.1 through 35.5 of UL–729–1976.

2.1.3 *Vented room heaters.* Install in accordance with manufacturer's instructions.

2.2 *Flue and stock requirements.*

2.2.1 *Gas fueled vented home heating equipment employing integral draft diverters and draft hoods (excluding direct vent systems).* Attach to, and vertically above the outlet of gas fueled vented home heating equipment employing draft diverters or draft hoods with vertically discharging outlets, a five (5) foot long test stack having a cross sectional area the same size as the draft diverter outlet.

Attach to the outlet of vented heaters having a horizontally discharging draft diverter or draft hood outlet a 90 degree elbow, and a five (5) foot long vertical test stack. A horizontal section of pipe may be used on the floor furnace between the diverter and the elbow if necessary to clear

any framing used in the installation. Use the minimum length of pipe possible for this section. Use stack, elbow, and horizontal section with same cross sectional area as the diverter outlet.

2.2.2 *Oil fueled vented home heating equipment (excluding direct vent systems).* Use flue connections for oil fueled vented floor furnaces as specified in section 35 of UL 729–1976. sections 34.10 through 34.18 of UL 730–1974 for oil fueled vented wall furnaces and sections 36.2 and 36.3 of UL 896–1973 for oil fueled vented room heaters.

2.2.3 *Direct vent systems.* Have the exhaust/air intake system supplied by the manufacturer in place during all tests. Test units intended for installation with a variety of vent pipe lengths with the minimum length recommended by the manufacturer. Do not connect a heater employing a direct vent system to a chimney or induced draft source. Vent the gas solely on the provision for venting incorporated in the heater and the vent/air intake system supplied with it.

2.3 *Fuel supply.*

2.3.1 *Natural gas.* For a vented heater utilizing natural gas, maintain the gas supply to the unit under test at a normal inlet test pressure immediately ahead of all controls at 7 to 10 inches water column. Maintain the regulator outlet pressure at normal test pressure approximately at that recommended by the manufacturer. Use natural gas having a specific gravity of approximately 0.65 and a higher heating value within ± 5 percent of 1,025 Btu's per standard cubic foot. Determine the actual higher heating value in Btu's per standard cubic foot for the natural gas to be used in the test with an error no greater than one percent.

2.3.2 *Propane gas.* For a vented heater utilizing propane gas, maintain the gas supply to the unit under test at a normal inlet pressure of 11 to 13 inches water column and a specific gravity of approximately 1.53. Maintain the regulator outlet pressure, on units so equipped, approximately at that recommended by the manufacturer. Use propane having a specific gravity of approximately 1.53 and a higher heating value within ± 5 percent of 2,500 Btu's per standard cubic foot. Determine the actual higher heating value in Btu's per standard cubic foot for the propane to be used in the test with an error no greater than one percent.

2.3.3 *Other test gas.* Use other test gases with characteristics as described in section 2.2. table VII, of ANSI Standard Z21.11.1–1974. Use gases with a measured higher heating value within ± 5 percent of the values specified in the above ANSI standard. Determine the actual higher heating value of the gas used in the test with an error no greater than one percent.

2.3.4 *Oil supply.* For a vented heater utilizing fuel oil, use No. 1, fuel oil (kerosene) for vaporizing-type burners and either No. 1 or No. 2 fuel oil, as specified by the manufacturer, for mechanical atomizing type burners. Use No. 1 fuel oil with a viscosity meeting the specifications as specified in UL-730–1974, section 36.9. Use test fuel conforming to the specifications given in tables 2 and 3 of ANSI Standard Z91.1–1972

for No. 1 and No. 2 fuel oil. Measure the higher heating value of the test fuel with an error no greater than one percent.

2.3.5 *Electrical supply.* For auxiliary electric components of a vented heater, maintain the electrical supply to the test unit within one percent of the nameplate voltage for the entire test cycle. If a voltage range is used for nameplate voltage. maintain the electrical supply within one percent of the mid-point of the nameplate voltage range.

2.4 *Burner adjustments.*

2.4.1 *Gas burner adjustments.* Adjust the burners of gas fueled vented heaters to their maximum Btu ratings at the test pressure specified in section 2.3 of this appendix. Correct the burner volumetric flow rate to 60° F (15.6C) and 30 inches of mercury barometric pressure. set the fuel flow rate to obtain a heat rate of within ±2 percent of the hourly Btu rating specified by the manufacturer as measured after 15 minutes of operation starting with all parts of the vented heater at room temperature. Set the primary air shutters in accordance with the manufacturer's recommendations to give a good flame at this adjustment. Do not allow the deposit of carbon during any test specified herein.

If a vent limiting means is provided on a gas pressure regulator. have it in place during all tests.

For gas fueled heaters with modulating controls adjust the controls to operate the heater at the maximum fuel input rate. Set the thermostat control to the maximum setting. Start the heater by turning the safety control valve to the "on" position. In order to prevent modulation of the burner at maximum input. place the thermostat sensing element in a temperature control bath which is held at a temperature below the maximum set point temperature of the control.

For gas fueled heaters with modulating controls adjust the controls to operate the heater at the reduced fuel input rate. Set the thermostat control to the minimum setting. Start the heater by turning the safety control valve to the "on" position. If ambient test room temperature is above the lowest control set point temperature. initiate burner operation by placing the thermostat sensing element in a temperature control bath that is held at a temperature below the minimum set point temperature of the control.

2.4.2 *Oil burner adjustments.* Adjust the burners of oil fueled vented heaters to give the CO_2 reading recommended by the manufacturer and an hourly Btu input. during the steady-state performance test described below. which is within ±2 percent of the heater manufacturer's specified normal hourly Btu input rating. On units employing a power burner do not allow smoke in the flue to exceed a No. 1 smoke during the steady-state performance test as measured by the procedure in ANSI Standard Z11.182–1965 (R1971) (ASTM D 2156–65 (1970)). If, on units employing a power burner. the smoke in the flue exceeds a No. 1 smoke during the steady-state test. readjust the burner to give a lower smoke reading. and. if necessary a lower CO_2 reading. and start all tests over. Maintain the average draft over the fire and in the flue during the steady-state performance test at that recommended by the manufacturer

within ±0.005 inches of water gauge. Do not make additional adjustments to the burner during the required series of performance tests. The instruments and measuring apparatus for this test are described in section 6.3 of ANSI standard Z91.1–1972.

2.5 *Circulating air adjustments.*

2.5.1 *Forced air vented wall furnaces (including direct vent systems).* During tests maintain the air flow through the heater as specified by the manufacturer and operate the vented heater with the outlet air temperature between 80° F and 130° F above room temperature. If adjustable air discharge registers are provided, adjust them so as to provide the maximum possible air restriction. Measure air discharge temperature as specified in section 2.14 of ANSI Z21.49–1975.

2.5.2 *Fan type vented room heaters and floor furnaces.* During tests on fan type furnaces and heaters, adjust the air flow through the heater as specified by the manufacturer. If adjustable air discharge registers are provided, adjust them to provide the maximum possible air restriction.

2.6 *Location of temperature measuring instrumentation.*

2.6.1 *Gas fueled vented home heating equipment (including direct vent systems).* For units employing an integral draft diverter. install nine thermocouples, wired in parallel, in a horizontal plane in the five foot test stack located one foot from the test stack inlet. Equalize the length of all thermocouple leads before paralleling. Locate one thermocouple in the center of the stack. Locate eight thermocouples along imaginary lines intersecting at right angles in this horizontal plane at points one third and two thirds of the distance between the center of the stack and the stack wall.

For units which employ a direct vent system, locate at least one thermocouple at the center of each flue way exiting the heat exchanger. Provide radiation shields if the thermocouples are exposed to burner radiation.

For units which employ a draft hood or units which employ a direct vent system which does not significantly preheat the incoming combustion air. install nine thermocouples. wired in parallel. in a horizontal plane located within 12 inches (304.8 mm) of the heater outlet and upstream of the draft hood on units so equipped. Locate one thermocouple in the center of the pipe and eight thermocouples along imaginary lines intersecting at right angles in this horizontal plane at points one third and two thirds of the distance between the center of the pipe and the pipe wall.

For units which employ direct vent systems that significantly preheat the incoming combustion air. install nine thermocouples. wired in parallel. in a plane parallel to and located within 6 inches (152.4 mm) of the vent/air intake terminal. Equalize the length of all thermocouple leads before paralleling. Locate one thermocouple in the center of the vent pipe and eight thermocouples along imaginary lines intersecting at right angles in this plane at points one third and two thirds of the distance between the center of the flue pipe and the pipe wall.

Use bead-type thermocouples having wire size not greater than No. 24 American Wire Gauge (AWG). If there is a possibility that the thermocouples could receive direct radiation from the fire, install radiation shields on the fire side of the thermocouples only and position the shields so that they do not touch the thermocouple junctions.

Install thermocouples for measuring conditioned warm air temperature as described in ANSI Z21.49–1975, section 2.14. Establish the temperature of the inlet air by means of single No. 24 AWG bead-type thermocouple, suitably shielded from direct radiation and located in the center of the plane of each inlet air opening.

2.6.2 *Oil fueled vented home heating equipment (including direct vent systems).* Install nine thermocouples, wired in parallel and having equal length leads, in a plane perpendicular to the axis of the flue pipe. Locate this plane at the position shown in Figure 34.4 of UL 730–1974, or Figures 35.1 and 35.2 of UL 729–1976 for a single thermocouple, except that on direct vent systems which significantly preheat the incoming combustion air, it shall be located within 6 inches (152.5 mm) of the outlet of the vent/air intake terminal. Locate one thermocouple in the center of the flue pipe and eight thermocouples along imaginary lines intersecting at right angles in this plane at points one third and two thirds of the distance between the center of the pipe and pipe wall.

Use bead-type thermocouples having a wire size not greater than No. 24 AWG. If there is a possibility that the thermocouples could receive direct radiation from the fire, install radiation shields on the fire side of the thermocouples only and position the shields so that they do not touch the thermocouple junctions.

Install thermocouples for measuring the conditioned warm air temperature as described in sections 35.12 through 35.17 of UL 730–1974. Establish the temperature of the inlet air by means of a single No. 24 AWG bead-type thermocouple, suitably shielded from direct radiation and located in the center of the plane of each inlet air opening.

2.7 *Combustion measurement instrumentation.* Analyze the samples of stack and flue gases for vented heaters to determine the concentration by volume of carbon dioxide present in the dry gas with instrumentation which will result in a reading having an accuracy of ±0.1 percentage points.

2.8 *Energy flow instrumentation.* Install one or more instruments, which measure the rate of gas flow or fuel oil supplied to the vented heater, and if appropriate, the electrical energy with an error no greater than one percent.

2.9 *Room ambient temperature.* During the time period required to perform all the testing and measurement procedures specified in section 3.0 of this appendix, maintain the room temperature within ±5° F (±2.8C) of the value T_{RA} measured during the steady-state performance test. At no time during these tests shall the room temperature exceed 100° F (37.8C) or fall below 65° F (18.3C).

Temperature (T_{RA}) shall be the arithmetic average temperature of the test area.

determined by measurement with four No. 24 AWG bead-type thermocouples with junctions shielded against radiation, located approximately at 90-degree positions on a circle circumscribing the heater or heater enclosure under test, in a horizontal plane approximately at the vertical midpoint of the appliance or test enclosure, and with the junctions approximately 24 inches from sides of the heater or test enclosure and located so as not to be affected by other than room air. Locate a thermocouple at each elevation of draft relief inlet opening and combustion air inlet opening at a distance of approximately 24 inches from the inlet openings. The temperature of the air for combustion and the air for draft relief shall not differ more than ±5° F from room temperature as measured above.

2.10 *Equipment used to measure mass flow rate in flue and stack.* The tracer gas chosen for this task should have a density which is less than or approximately equal to the density of air. Use a gas unreactive with the environment to be encountered. Using instrumentation of either the batch or continuous type, measure the concentration of tracer gas with an error no greater than 2 percent of the value of the concentration measured.

3.0 *Testing and measurements.*

3.1 *Steady-state testing.*

3.1.1 *Gas fueled vented home heating equipment (including direct vent systems).* Set up the vented heater as specified in sections 2.1, 2.2, and 2.3 of this appendix. The draft diverter shall be in the normal open condition and the stack shall not be insulated. (Insulation of the stack is no longer required for the vented heater test.) Begin the steady-state performance test by operating the burner and the circulating air blower, on units so equipped, with the adjustments specified by sections 2.4.1 and 2.5 of this appendix, until steady-state conditions are attained as indicated by a temperature variation of not more than 3° F (1.7 C) in the stack gas temperature for vented heaters equipped with draft diverters or 5° F (2.8 C) in the flue gas temperature for vented heaters equipped with either draft hoods or direct vent systems; in three successive readings taken 15 minutes apart.

On units employing draft diverters, measure the room temperature (T_{RA}) as described in section 2.9 of this appendix and measure the steady-state stack gas temperature ($T_{S.SS}$) using the nine thermocouples located in the 5 foot test stack as specified in section 2.6.1 of this appendix. Secure a sample of the stack gases in the plane where $T_{S.SS}$ is measured or within 3.5 feet downstream of this plane. Determine the concentration by volume of carbon dioxide (X_{CO2S}) present in the dry stack gas. If the location of the gas sampling differs from the temperature measurement plane, there shall be no air leaks through the stack between these two locations.

On units employing draft hoods or direct vent systems, measure the room temperature (T_{RA}) as described in section 2.9 of this appendix and measure the steady-state flue gas temperature ($T_{F.SS}$), using the nine thermocouples located in the flue pipe as described in section 2.6.1 of this appendix.

Secure a sample of the flue gas in the plane of temperature measurement and determine the concentration by volume of CO_2 ($X_{F.CO2}$) present in dry flue gas. In addition, for units employing draft hoods, secure a sample of the stack gas in a horizontal plane in the five foot test stack located one foot from the test stack inlet; and determine the concentration by volume of CO_2 (X_{CO2S}) present in dry stack gas.

Determine the steady-state heat input rate (Q_{in}) including pilot gas by multiplying the measured higher heating value of the test gas by the steady-state gas input rate corrected to standard conditions of 60° F and 30 inches of mercury. Use measured values of gas temperature and pressure at the meter and the barometric pressure to correct the metered gas flow rate to standard conditions.

After the above test measurements have been completed on units employing draft diverters, secure a sample of the flue gases at the exit of the heat exchanger(s) and determine the concentration of CO_2 (X_{CO2F}) present. In obtaining this sample of flue gas, move the sampling probe around or use a sample probe with multiple sampling ports in order to assure that an average value is obtained for the CO_2 concentration. For units with multiple heat exchanger outlets, measure the CO_2 concentration in a sample from each outlet to obtain the average CO_2 concentration for the unit. A manifold (parallel connected sampling tubes) may be used to obtain this sample.

For heaters with single stage thermostat control (wall mounted electric thermostats), determine the steady-state efficiency at the maximum fuel input rate as specified in section 2.4 of this appendix.

For gas fueled vented heaters equipped with either two stage thermostats or step-modulating thermostats, determine the steady-state efficiency at the maximum fuel input rate, as specified in section 2.4.1 of this appendix, and at the reduced fuel input rate, as specified in section 2.4.1 of this appendix.

For manually controlled gas fueled vented heaters, with various input rates determine the steady-state efficiency at a fuel input rate that is within ±5 percent of 50 percent of the maximum fuel input rate. If the heater is designed to use a control that precludes operation at other than maximum output (single firing rate) determine the steady state efficiency at the maximum input rate only.

3.1.2 *Oil fueled vented home heating equipment (including direct vent systems).* Set up and adjust the vented heater as specified in sections 2.1, 2.2, and 2.3.4 of this appendix. Begin the steady-state performance test by operating the burner and the circulating air blower, on units so equipped, with the adjustments specified by sections 2.4.2 and 2.5 of this appendix until steady-state conditions are attained as indicated by a temperature variation of not more than 5° F (2.8 C) in the flue gas temperature in three successive readings taken 15 minutes apart.

Do not allow smoke in the flue, for units equipped with power burners, to exceed a No. 1 smoke during the steady-state performance test as measured by the procedure described in ANSI standard Z11.182–1965 (R1971) (ASTM D 2156–65

(1970)). Maintain the average draft over the fire and in the breeching during the steady-state performance test at that recommended by the manufacturer ±0.005 inches of water gauge.

Measure the room temperature (T_{RA}) as described in section 2.9 of this appendix and measure the steady-state flue gas temperature ($T_{F,SS}$) using nine thermocouples located in the flue pipe as described in section 2.6.2 of this appendix. Secure a sample of the flue gas in the plane of temperature measurement and determine the concentration by volume of CO_2(X_{CO_2F}) present in dry flue gas. Measure and record the steady-state heat input rate (Q_{in}).

For manually controlled oil fueled vented heaters, determine the steady-state efficiency at a fuel input rate that is within ±5 percent of 50 percent of the maximum fuel input rate.

3.1.3 *Auxiliary Electric Power Measurement.* Allow the auxiliary electrical system of a gas or oil vented heater to operate for at least five minutes before recording the maximum auxiliary electric power measurement from the wattmeter. Record the maximum electric power (P_E) expressed in kilowatts. For vented heaters with modulating controls, the recorded (P_E) shall be maximum measured electric power multiplied by the following factor (R). For two stage controls, R=1.3. For step modulating controls, R=1.4 when the ratio of minimum-to-maximum fuel input is greater than or equal to 0.7, R=1.7 when the ratio of minimum-to-maximum fuel input is less than 0.7 and greater than or equal to 0.5, and R=2.2 when the ratio of minimum-to-maximum fuel input is less than 0.5.

3.2 *Jacket loss measurement.* Conduct a jacket loss test for vented floor furnaces. Measure the jacket loss (L_j) in accordance with the ANSI standard Z21.48–1976 section 2.12.

3.3 *Measurement of the off-cycle losses for vented heaters equipped with thermal stack dampers.* Install the thermal stack damper according to the manufacturer's instructions. Unless specified otherwise, the thermal stack damper should be at the draft diverter exit collar. Attach a five foot length of bare stack to the outlet of the damper. Install thermocouples as specified in section 2.6.1 of this appendix.

For vented heaters equipped with single stage thermostats, measure the off-cycle losses at the maximum fuel input rate. For vented heaters equipped with two stage thermostats, measure the off-cycle losses at the maximum fuel input rate and at the reduced fuel input rate. For vented heaters equipped with step-modulating thermostats, measure the off-cycle losses at the reduced fuel input rate.

Let the vented heater heat up to a steady-state condition. Feed a tracer gas at a constant metered rate into the stack directly above and within one foot above the stack damper. Record tracer gas flow rate and temperature. Measure the tracer gas concentration in the stack at several locations in a horizontal plane through a cross section of the stack at a point sufficiently above the stack damper to ensure that the tracer gas is well mixed in the stack.

Continuously measure the tracer gas concentration and temperature during a 10 minute cool down period. Shut the burner off and immediately begin measuring tracer gas concentration in the stack, stack temperature, room temperature, and barometric pressure. Record these values as the midpoint of each one-minute interval between burner shutdown and ten minutes after burner shut down. Meter response time and sampling delay time shall be considered in timing these measurements.

3.4 *Measurement of the effectiveness of electro-mechanical stack dampers.* For vented heaters equipped with electro-mechanical stack dampers, measure the cross sectional area of the stack (A_s), the net area of the damper plate (A_o), and the angle that the damper plate makes when closed with a plane perpendicular to the axis of the stack (Ω). The net area of the damper plate means the area of the damper plate minus the area of any holes through the damper plate.

3.5 *Pilot light measurement.* Measure the energy input rate to the pilot light (Q_p) with an error no greater than 3 percent for vented heaters so equipped.

3.6 *Optional procedure for determining D_p, D_F, and D_s for systems for all types of vented heaters.* For all types of vented heaters, D_p, D_F, and D_s can be measured by the following optional cool down test.

Conduct a cool down test by letting the unit heat up until steady-state conditions are reached, as indicated by temperature variation of not more than 5°F (2.8°C) in the flue gas temperature in three successive readings taken 15 minutes apart, and then shutting the unit off with the stack or flue damper controls by-passed or adjusted so that the stack or flue damper remains open during the resulting cool down period. If a draft was maintained on oil fueled units in the flue pipe during the steady-state performance test described in section 3.1 of this appendix, maintain the same draft (within a range of −.001 to +.005 inches of water gauge of the average steady-state draft) during this cool down period.

Measure the flue gas mass flow rate ($m_{F,OFF}$) during the cool down test described above at a specific off-period flue gas temperature and corrected to obtain its value at the steady-state flue gas temperature ($T_{F,SS}$), using the procedure described below.

Within one minute after the unit is shut off to start the cool down test for determining D_F, begin feeding a tracer gas into the combustion chamber at a constant flow rate of V_T, and at a point which will allow for the best possible mixing with the air flowing through the chamber. (On units equipped with an oil fired power burner, the best location for injecting this tracer gas appears to be through a hole drilled in the air tube.) Periodically measure the value of V_T with an instantaneously reading flow meter having an accuracy of ±3 percent of the quantity measured. Maintain V_T at less than 1 percent of the air flow rate through the furnace. If a combustible tracer gas is used, there should be a delay period between the time the burner gas is shut off and the time the tracer gas is first injected to prevent ignition of the tracer gas.

Between 5 and 6 minutes after the unit is shut off to start the cool down test, measure at the exit of the heat exchanger the average flue gas temperature, $T^*_{F,OR}$. At the same instant the flue gas temperature is measured, also measure the percent volumetric concentration of tracer gas in the flue gas in the same plane where $T^*_{F,OR}$ is determined. Obtain the concentration of tracer gas using an instrument which will result in an accuracy of ±2 percent in the value of C_T measured. If use of a continuous reading type instrument results in a delay time between drawing of a sample and its analysis, this delay should be taken into account so that the temperature measurement and the measurement of tracer gas concentration coincide. In addition, determine the temperature of the tracer gas entering the flow meter (T_T) and the barometric pressure (P_B).

The rate of the flue gas mass flow through the vented heater and the factors D_P, D_F, and D_S are calculated by the equations in sections 4.5.1 through 4.5.3 of this appendix.

4.0 *Calculations.*

4.1 *Annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped without manual controls and without thermal stack dampers.* The following procedure determines the annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped without manual controls and without thermal stack dampers.

4.1.1 *System number.* Obtain the system number from Table 1 of this appendix.

4.1.2 *Off-cycle flue gas draft factor.* Based on the system number, determine the off-cycle flue gas draft factor (D_F) from Table 1 of this appendix.

4.1.3 *Off-cycle stack gas draft factor.* Based on the system number, determine the off-cycle stack gas draft factor (D_s) from Table 1 of this appendix.

4.1.4 *Pilot fraction.* Calculate the pilot fraction (P_F) expressed as a decimal and defined as:

$$P_F = Q_P/Q_{in}$$

where:

Q_P=as defined in 3.5 of this appendix
Q_{in}=as defined in 3.1 of this appendix at the maximum fuel input rate

4.1.5 *Jacket loss for floor furnaces.* Determine the jacket loss (L_j) expressed as a percent and measured in accordance with section 3.2 of this appendix. For other vented heaters L_j=0.0.

4.1.6 *Latent heat loss.* Based on the fuel, obtain the latent heat loss ($L_{L,A}$) from Table 2 of this appendix.

4.1.7 *Ratio of combustion air mass flow rate to stoichiometric air mass flow rate.* Determine the ratio of combustion air mass flow rate to stoichiometric air mass flow rate ($R_{T,F}$), and defined as:

$$R_{T,F} = A + B/X_{CO_2F}$$

where:

A=as determined from Table 2 of this appendix
B=as determined from Table 2 of this appendix
X_{CO_2F}=as defined in 3.1 of this appendix

4.1.8 *Ratio of combustion and relief air mass flow rate to stoichiometric air mass flow rate.* For vented heaters equipped with

either an integral draft diverter or a drafthood, determine the ratio of combustion and relief air mass flow rate to stoichiometric air mass flow rate ($R_{T,S}$), and defined as:

$$R_{T,S} = A + [B/X_{CO,S}]$$

where:

A = as determined from Table 2 of this appendix
B = as determined from Table 2 of this appendix
$X_{CO,S}$ = as defined in 3.1 of this appendix

4.1.9 *Sensible heat loss at steady-state operation.* For vented heaters equipped with either an integral draft diverter or a draft hood, determine the sensible heat loss at steady-state operation ($L_{S,SS,A}$) expressed as a percent and defined as:

where:

$L_{S,SS,A} = C(R_{T,S} + D)(T_{S,SS} - T_{RA})$
C = as determined from Table 2 of this appendix
$R_{T,S}$ = as defined in 4.1.8 of this appendix
D = as determined from Table 2 of this appendix
$T_{S,SS}$ = as defined in 3.1 of this appendix
T_{RA} = as defined in 2.9 of this appendix

For vented heaters equipped without an integral draft diverter, determine ($L_{S,SS,A}$) expressed as a percent and defined as:

$$L_{S,SS,A} = C(R_{T,F} + D)(T_{F,SS} - T_{RA})$$

where:

C = as determined from Table 2 of this appendix
$R_{T,F}$ = as defined in 4.1.7 of this appendix
D = as determined from Table 2 of this appendix
$T_{F,SS}$ = as defined in 3.1 of this appendix
T_{RA} = as defined in 2.9 of this appendix

4.1.10 *Steady-state efficiency.* For vented heaters equipped with single stage thermostats, calculate the steady-state efficiency (excluding jacket loss, η_{SS}, expressed in percent and defined as:

$$\eta_{SS} = 100 - L_{J,A} - L_{S,SS,A}$$

where:

$L_{J,A}$ = as defined in 4.1.6 of this appendix
$L_{S,SS,A}$ = as defined in 4.1.9 of this appendix

For vented heaters equipped with either two stage thermostats or with step-modulating thermostats, calculate the steady-state efficiency at the reduced fuel input rate, $\eta_{SS,L}$ expressed in percent and defined as:

$$\eta_{SS,L} = 100 - L_{J,A} - L_{S,SS,A}$$

where:

$L_{J,A}$ = as defined in 4.1.6 of this appendix
$L_{S,SS,A}$ = as defined in 4.1.9 of this appendix in which $L_{S,SS,A}$ is determined at the reduced fuel input rate

For vented heaters equipped with two stage thermostats, calculate the steady-state efficiency at the maximum fuel input rate, $\eta_{SS,H}$ expressed in percent and defined as:

$$\eta_{SS,H} = 100 - L_{J,A} - L_{S,SS,A}$$

where:

$L_{J,A}$ = as defined in 4.1.6 of this appendix
$L_{S,SS,A}$ = as defined in 4.1.9 of this appendix in which $L_{S,SS,A}$ is measured at the maximum fuel input rate

For vented heaters equipped with step-modulating thermostats calculate the

weighted-average steady-state efficiency in the modulating mode, $\eta_{SS,MOD}$, expressed in percent and defined as:

$$\eta_{SS,MOD} = [\eta_{SS,H} - \eta_{SS,L}]\left[\frac{T_C - T_{OA}}{T_C - 15}\right] + \eta_{SS,L}$$

where:

$\eta_{SS,H}$ = as defined in 4.1.10 of this appendix
$\eta_{SS,L}$ = as defined in 4.1.10 of this appendix
T_{OA} = average outdoor temperature for vented heaters with step-modulating thermostats operating in the modulating mode and is obtained from Table 3 or Figure 1 of this appendix
T_C = balance point temperature which represents a temperature used to apportion the annual heating load between the reduced input cycling mode and either the modulating mode or maximum input cycling mode and is obtained either from Table 3 of this appendix or calculated by the following equation:

$$T_C = 65 - [(65 - 15)R]$$

where:

65 = average outdoor temperature at which a vented heater starts operating
15 = national average outdoor design temperature for vented heaters
R = ratio of reduced to maximum heat output rates, as defined in 4.1.13 of this appendix

4.1.11 *Reduced heat output rate.* For vented heaters equipped with either two stage thermostats or step-modulating thermostats, calculate the reduced heat output rate ($Q_{red,out}$) defined as:

$$Q_{red,out} = \eta_{SS,L}Q_{red,in}$$

where:

$\eta_{SS,L}$ = as defined in 4.1.10 of this appendix
$Q_{red,in}$ = the reduced fuel input rate

4.1.12 *Maximum heat output rate.* For vented heaters equipped with either two stage thermostats or step-modulating thermostats, calculate the maximum heat output rate ($Q_{max,out}$) defined as:

$$Q_{max,out} = \eta_{SS,H}Q_{max,in}$$

where:

$\eta_{SS,H}$ = as defined in 4.1.10 of this appendix
$Q_{max,in}$ = the maximum fuel input rate

4.1.13 *Ratio of reduced to maximum heat output rates.* For vented heaters equipped with either two stage thermostats or step-modulating thermostats, calculate the ratio of reduced to maximum heat output rates (R) expressed as a decimal and defined as:

$$R = Q_{red,out}/Q_{max,out}$$

where:

$Q_{red,out}$ = as defined in 4.1.11 of this appendix
$Q_{max,out}$ = as defined in 4.1.12 of this appendix

4.1.14 *Fraction of heating load at reduced operating mode.* For vented heaters equipped with either two stage thermostats or step-modulating thermostats, determine the fraction of heating load at the reduced operating mode (X_1) expressed as a decimal

and listed in Table 3 of this appendix or obtained from Figure 2 of this appendix.

4.1.15 *Fraction of heating load at maximum operating mode or noncycling mode.* For vented heaters equipped with either two stage thermostats or step-modulating therostats, determine the fraction of heating load at the maximum operating mode or noncycling mode (X_2) expressed as a decimal and listed in Table 3 of this appendix or obtained from Figure 2 of this appendix.

4.1.16 *Weighted-average steady-state efficiency.* For vented heaters equipped with single stage thermostats, the weighted-average steady-state efficiency ($\eta_{SS,WT}$) is equal to η_{SS}, as defined in section 4.1.10 of this appendix. For vented heaters equipped with two stage thermostats, $\eta_{SS,WT}$ is defined as:

$$\eta_{SS,WT} = X_1\eta_{SS,L} + X_2\eta_{SS,H}$$

where:

X_1 = as defined in 4.1.14 of this appendix
$\eta_{SS,L}$ = as defined in 4.1.10 of this appendix
X_2 = as defined in 4.1.15 of this appendix
$\eta_{SS,H}$ = as defined in 4.1.10 of this appendix

For vented heaters equipped with step-modulating thermostats, $\eta_{SS,WT}$ is defined as:

$$\eta_{SS,WT} = X_1\eta_{SS,L} + X_2\eta_{SS,MOD}$$

where:

X_1 = as defined in 4.1.14 of this appendix
$\eta_{SS,L}$ = as defined in 4.1.10 of this appendix
X_2 = as defined in 4.1.15 of this appendix
$\eta_{SS,MOD}$ = as defined in 4.1.10 of this appendix

4.1.17 *Annual fuel utilization efficiency.* Calculate the annual fuel utilization efficiency (AFUE) expressed as percent and defined as:

$$AFUE = [0.968\eta_{SS,WT}] - 1.76D_F - 1.89D_S - 129P_F - 2.8 L_J + 1.81$$

where:

$\eta_{SS,WT}$ = as defined in 4.1.16 of this appendix
D_F = as defined in 4.1.2 of this appendix
D_S = as defined in 4.1.3 of this appendix
P_F = as defined in 4.1.4 of this appendix
L_J = as defined in 4.1.5 of this appendix

4.2 *Annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped with manual controls.* The following procedure determines the annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped with manual controls.

4.2.1 *Average ratio of stack gas mass flow rate to flue gas mass flow rate at steady-state operation.* For vented heaters equipped with either direct vents or direct exhaust or are outdoor units, the average ratio of stack gas mass flow rate to flue gas mass flow rate at steady-state operation (S/F) shall be equal to unity. (S/F=1.) For all other types of vented heaters, calculate (S/F) defined as:

$$S/F = 1.3R_{T,S}/R_{T,F}$$

where,

$R_{T,F}$ = as defined in 4.1.8 of this appendix with X_{co} measured at 50% fuel input rate

$R_{T,F}$ = as defined in 4.1.7 of this appendix with $X_{co,F}$ measured at 50% fuel input rate

4.2.2 *Multiplication factor for infiltration loss during burner on-cycle.* Calculate the multiplication factor for infiltration loss during burner on-cycle ($K_{I,ON}$) defined as:

$$K_{I,ON} = 100(0.24) (S/F) (0.7) [1 + R_{T,F}(A/F)]/ HHV_A$$

where:

100 = converts a decimal fraction into a percent

0.24 = specific heat of air

A/F = stoichiometric air/fuel ratio, determined in accordance with Table 2 of this appendix

S/F = as defined in 4.2.1 of this appendix at 50 percent of rated maximum fuel input

0.7 = infiltration parameter

$R_{T,F}$ = as defined in 4.1.7 of this appendix

HHV_A = average higher heating value of the test fuel, determined in accordance with Table 2 of this appendix

4.2.3 *On-cycle infiltration heat loss.* Calculate the on-cycle infiltration heat loss ($I_{I,ON}$) expressed as a percent and defined as:

$$L_{I,ON} = K_{I,ON} (70-45)$$

where:

$K_{I,ON}$ = as defined in 4.2.2 of this appendix

70 = average indoor temperature

45 = average outdoor temperature

4.2.4 *Weighted-Average Steady-State Efficiency.* For manually controlled heaters with various input rates the weighted average steady-state efficiency ($\eta_{SS \cdot WT}$), is at 50 percent of the maximum fuel input rate as measured in either section 3.1.1 to this appendix for manually controlled gas vented heaters or section 3.1.2 to this appendix for manually controlled oil vented heaters. For manually controlled heater with one single firing rate the weighted average steady-state efficiency is the steady state efficiency measured at the single firing rate.

4.2.5 *Part-load fuel utilization efficiency.* Calculate the part-load fuel utilization efficiency (η_u) expressed as a percent and defined as:

$$\eta_u = \eta_{SS \cdot WT} - L_{I,ON}$$

where:

$\eta_{SS \cdot WT}$ = as defined in 4.2.4 of this appendix

$L_{I,ON}$ = as defined in 4.2.3 of this appendix

4.2.6 *Annual fuel utilization efficiency.* For manually controlled vented heaters. Calculate the annual fuel utilization efficiency (AFUE) expressed as a percent and defined as:

$$AFUE = \frac{4400 \eta_{SS} \eta_u Q_{in-max}}{4400 \eta_{SS} Q_{in-max} + 2.5(4600) \eta_u Q_P}$$

where:

4400 = average number of heating degree days

η_{SS} = as defined as $\eta_{SS \cdot WT}$ in 4.2.4 of this appendix

η_u = as defined in 4.2.5 of this appendix

Q_{in-max} = as defined as Q_{in} at the maximum fuel input rate, as defined in 3.1 of this appendix

4600 = average number of non-heating season hours per year

Q_P = as defined in 3.5 of this appendix

4.3 *Annual fuel utilization efficiency by the tracer gas method.* The annual fuel utilization efficiency shall be determined by the following tracer gas method for all vented heaters equipped with thermal stack dampers. All other types of vented heaters can elect to use the following tracer gas method, as an optional procedure.

4.3.1 *On-cycle sensible heat loss.* For vented heaters equipped with single stage thermostats, calculate the on-cycle sensible heat loss ($L_{S,ON}$) expressed as a percent and defined as:

$$L_{S,ON} = L_{S,SS,A}$$

where:

$L_{S,SS,A}$ = as defined in 4.1.9 of this appendix

For vented heaters equipped with two stage thermostats, calculate $L_{S,ON}$ defined as:

$$L_{S,ON} = X_1 L_{S,SS,A \cdot red} + X_2 L_{S,SS,A \cdot max}$$

where:

X_1 = as defined in 4.1.14 of this appendix

$L_{S,SS,A \cdot red}$ = as defined as $L_{S,SS,A}$ in 4.1.9 of this appendix at the reduced fuel input rate

X_2 = as defined in 4.1.15 of this appendix

$L_{S,SS,A \cdot max}$ = as defined as $L_{S,SS,A}$ in 4.1.9 of this appendix at the maximum fuel input rate

For vented heaters with step-modulating thermostats, calculate $L_{S,ON}$ defined as:

$$L_{S,ON} = X_1 L_{S,SS,A \cdot red} + X_2 L_{S,SS,A \cdot avg}$$

where:

X_1 = as defined in 4.1.14 of this appendix

$L_{S,SS,A \cdot red}$ = as defined in 4.3.1 of this appendix

X_2 = as defined in 4.1.15 of this appendix

$L_{S,SS,A \cdot avg}$ = average sensible heat loss for step-modulating vented heaters operating in the modulating mode

$$L_{S,SS,A-avg} = \left[[L_{S,SS,A-max} - L_{S,SS,A-red}] \left[\frac{T_C - T_{OA \cdot}}{TC - 15} \right] + L_{S,SS,A-red} \right]$$

where:

$L_{S,SS,A \cdot avg}$ = as defined in 4.3.1 of this appendix

T_C = as defined in 4.1.10 of this appendix

$T_{OA \cdot}$ = as defined in 4.1.10 of this appendix

15 = as defined in 4.1.10 of this appendix

4.3.2 *On-cycle infiltration heat loss.* For vented heaters equipped with single stage thermostats, calculate the on-cycle infiltration heat loss ($L_{I,ON}$) expressed as a percent and defined as:

$$L_{I,ON} = K_{I,ON}(70-45)$$

where:

$K_{I,ON}$ = as defined in 4.2.2 of this appendix

70 = as defined in 4.2.3 of this appendix

45 = as defined in 4.2.3 of this appendix

For vented heaters equipped with two stage thermostats, calculate $L_{I,ON}$ defined as:

$$L_{I,ON} = X_1 K_{I,ON \cdot max}(70 - T_{OA \cdot}) + X_2 K_{I,ON \cdot red}(70 - T_{OA})$$

where:

X_1 = as defined in 4.1.14 of this appendix

$K_{I,ON \cdot max}$ = as defined as $K_{I,ON}$ in 4.2.2 of this appendix at the maximum heat input rate

70 = as defined in 4.2.3 of this appendix

$T_{OA \cdot}$ = as defined in 4.3.4 of this appendix

$K_{I,ON \cdot red}$ = as defined as $K_{I,ON}$ in 4.2.2 of this appendix at the minimum heat input rate

T_{OA} = as defined in 4.3.4 of this appendix

X_2 = as defined in 4.1.15 of this appendix

For vented heaters equipped with step-modulating thermostats, calculate $L_{I,ON}$ defined as:

$$L_{I,ON} = X_1 K_{I,ON \cdot avg}(70 - T_{OA \cdot}) + X_2 K_{I,ON \cdot red}(70 - T_{OA})$$

where:

X_1 = as defined in 4.1.14 of this appendix

$$K_{I,ON \cdot avg} = \frac{[K_{I,ON \cdot max} + K_{I,ON \cdot red}]}{2}$$

70 = as defined in 4.2.3 of this appendix

$T_{OA \cdot}$ = as defined in 4.3.4 of this appendix

X_2 = as defined in 4.1.15 of this appendix

T_{OA} = as defined in 4.3.4 of this appendix

4.3.3 *Off-cycle sensible heat loss.* For vented heaters equipped with single stage thermostats, calculate the off-cycle sensible heat loss ($L_{S,OFF}$) at the maximum fuel input rate. For vented heaters equipped with step-modulating thermostats, calculate $L_{S,OFF}$ defined as:

$$L_{S,OFF} = X_1 L_{S,OFF \cdot red}$$

where:

X_1 = as defined in 4.1.14 of this appendix

$L_{S,OFF \cdot red}$ = as defined as $L_{S,OFF}$ in 4.3.3 of this appendix at the reduced fuel input rate

For vented heaters equipped with two stage thermostats, calculate $L_{S,OFF}$ defined as:

$$L_{S,OFF} = X_1 L_{S,OFF \cdot red} + X_2 L_{S,OFF \cdot max}$$

where:

X_1 = as defined in 4.1.14 of this appendix

$L_{S,OFF \cdot red}$ = as defined as $L_{S,OFF}$ in 4.3.3 of this appendix at the reduced fuel input rate

X_2 = as defined in 4.1.15 of this appendix

$L_{S,OFF \cdot max}$ = as defined as $L_{S,OFF}$ in 4.3.3 of this appendix at the maximum fuel input rate

Calculate the off-cycle sensible heat loss ($L_{S,OFF}$) expressed as a percent and defined as:

$$L_{S.OFF}=\frac{100(0.24)}{Q_{in}t_{on}}\sum m_{S.OFF}(T_{S.OFF}-T_{RA})$$

where:

100 = conversion factor for percent

0.24 = specific heat of air in Btu per pound — °F

Q_{in} = fuel input rate, as defined in 3.1 of this appendix in Btu per minute (as appropriate for the firing rate)

t_{on} = average burner on-time per cycle and is 20 minutes

$\sum m_{S.OFF}(T_{S.OFF}-T_{RA})$ = summation of the twenty values of the quantity, $m_{S.OFF}(T_{S.OFF}-T_{RA})$, measured in accordance with 3.3 of this appendix

$m_{S.OFF}$ = stack gas mass flow rate pounds per minute

$$m_{S.OFF}=\frac{1.325P_BV_T(C_{T\cdot}-C_T)}{C_T(T_T+460)}$$

$T_{S.OFF}$ = stack gas temperature measured in accordance with 3.3 of this appendix

T_{RA} = average room temperature measured in accordance with 3.3 of this appendix

P_B = barometric pressure in inches of mercury

V_T = flow rate of the tracer gas through the stack in cubic feet per minute

$C_{T\cdot}$ = concentration by volume of the active tracer gas in the mixture in percent and is 100 when the tracer gas is a single component gas

C_T = concentration by volume of the active tracer gas in the diluted stack gas in percent

T_T = temperature of the tracer gas entering the flow meter in degrees Fahrenheit

(T_T+460) = absolute temperature of the tracer gas entering the flow meter in degrees Rankine

4.3.4 *Average outdoor temperature.* For vented heaters equipped with single stage thermostats, the average outdoor temperature (T_{OA}) is 45°F. For vented heaters equipped with either two stage thermostats or step-modulating thermostats, T_{OA} during the reduced operating mode is obtained from Table 3 or Figure 1 of this appendix. For vented heaters equipped with two stage thermostats, T_{OA}^* during the maximum operating mode is obtained from Table 3 or Figure 1 of this appendix.

4.3.5 *Off-cycle infiltration heat loss.* For vented heaters equipped with single stage thermostats, calculate the off-cycle infiltration heat loss $(L_{I.OFF})$ at the maximum fuel input rate. For vented heaters equipped with step-modulating thermostats, calculate $L_{I.OFF}$ defined as:

$$L_{I.OFF}=X_1L_{I.OFF.red}$$

where:

X_1 = as defined in 4.1.14 of this appendix

$L_{I.OFF.red}$ = as defined in $L_{I.OFF}$ in 4.3.3 of this appendix at the reduced fuel input rate

For vented heaters equipped with two stage thermostats, calculate $L_{I.OFF}$ defined as:

$$L_{I.OFF}=X_1L_{I.OFF.red}+X_2L_{I.OFF.max}$$

where:

X_1 = as defined in 4.1.14 of this appendix

$L_{I.OFF.red}$ = as defined as $L_{I.OFF}$ in 4.3.3 of this appendix at the reduced fuel input rate

X_2 = as defined in 4.1.15 of this appendix

$L_{I.OFF.max}$ = as defined as $L_{I.OFF}$ in 4.3.3 of this appendix at the maximum fuel input rate

Calculate the off-cycle infiltration heat loss $(L_{I.OFF})$ expressed as a percent and defined as:

$$L_{I.OFF}=\frac{100(0.24)(1.3)(0.7)(70-T_{OA})}{Q_{in}t_{on}}\sum m_{S.OFF}$$

where:

100 = conversion factor for percent

0.24 = specific heat of air in Btu per pound — °F

1.3 = dimensionless factor for converting laboratory measured stack flow to typical field conditions

0.7 = infiltration parameter

70 = assumed average indoor air temperature. °F

T_{OA} = average outdoor temperature as defined in 4.3.4 of this appendix

Q_{in} = fuel input rate, as defined in 3.1 of this appendix in Btu per minute (as appropriate for the firing rate)

t_{on} = average burner on-time per cycle and is 20 minutes

$\sum m_{S.OFF}$ = summation of the twenty values of the quantity, $m_{S.OFF}$, measured in accordance with 3.3 of this appendix

$m_{S.OFF}$ = as defined in 4.3.3 of this appendix

4.3.6 *Part-load fuel utilization efficiency.* Calculate the part-load fuel utilization efficiency (η_u) expressed as a percent and defined as:

$$\eta_u=100-L_{I.A}-C_JL_J-\left[\frac{t_{on}}{t_{on}+P_Ft_{OFF}}\right]$$

$$+[L_{S.ON}+L_{S.OFF}+L_{I.ON}+L_{I.OFF}]$$

where:

C_J = 2.8, adjustment factor

L_J = jacket loss as defined in 4.1.5

$L_{I.A}$ = as defined in 4.1.6 of this appendix

t_{on} = as defined in 4.3.3 of this appendix

$L_{S.ON}$ = as defined in 4.3.1 of this appendix

$L_{S.OFF}$ = as defined in 4.3.3 of this appendix

$L_{I.ON}$ = as defined in 4.3.2 of this appendix

$L_{I.OFF}$ = as defined in 4.1.4 of this appendix

P_F = as defined in 4.1.4 of this appendix

t_{OFF} = average burner off-time per cycle and is 20 minutes

4.3.7 *Annual fuel utilization efficiency.* Calculate the annual fuel utilization efficiency (AFUE) expressed as a percent and defined as:

$$AFUE=\frac{4400\eta_{SS-WT}\eta_uQ_{in-max}}{4400\eta_{SS}Q_{in-max}+2.5(4600)\eta_uQ_p}$$

where:

4400 = as defined in 4.2.6

η_{SS-WT} = as defined in 4.1.16 of this appendix

η_u = as defined in 4.3.6 of this appendix

Q_{in-max} = as defined in 4.2.6 of this appendix

4600 = as defined in 4.2.6 of this appendix

Q_p = as defined in 3.5 of this appendix

4.4 *Stack damper effectiveness for vented heaters equipped with electro-mechanical stack dampers.* Determine the stack damper effectiveness for vented heaters equipped with electro-mechanical stack dampers (D_o), defined as:

$$D_o=1.62[1-A_D\cos\Omega/A_s]$$

where:

A_D = as defined in 3.4 of this appendix

Ω = as defined in 3.4 of this appendix

A_s = as defined in 3.4 of this appendix

4.5 *Addition requirements for vented home heating equipment using indoor air for combustion and draft control.* For vented home heating equipment using indoor air for combustion and draft control, D_F, as described in section 4.1.2 of this appendix, and D_s, as described in section 4.1.3 of this appendix, shall be determined from Table 1 of this appendix.

4.5.1 *Optional procedure for determining D_p for vented home heating equipment.* Calculate the ratio (D_p) of the rate of flue gas mass through the vented heater during the off-period, $M_{F.OFF}(T_{F.SS})$, to the rate of flue gas mass flow during the on-period, $M_{F.SS}(T_{F.SS})$, and defined as:

$$D_P=M_{F.OFF}(T_{F.SS})/M_{F.SS}(T_{F.SS})$$

For vented heaters in which no draft is maintained during the steady-state or cool down tests, $M_{F.OFF}(T_{F.SS})$ is defined as:

$$M_{F.OFF}(T_{F.SS})=$$

$$M_{F.OFF}(T^*_{F.OFF})\left[\frac{T_{F.SS}-T_{RA}}{T^*_{F.OFF}-T_{RA}}\right]^{0.56}\left[\frac{T^*_{F.OFF}+460}{T_{F.SS}+460}\right]^{1.19}$$

For oil fueled vented heaters in which an imposed draft is maintained, as described in section 3.6 of this appendix, $M_{F.OFF}(T_{F.SS})$ is defined as:

$$M_{F.OFF}(T_{F.SS})=M_{F.OFF}(T^*_{F.OFF})$$

where:

$T_{F.SS}$ = as defined in 3.1.1 of this appendix

$T^*_{F.OFF}$ = flue gas temperature during the off-period measured in accordance with 3.6 of this appendix in degrees Fahrenheit

T_{RA} = as defined in 2.9 of this appendix

$$M_{F,OH}(T_{F,OH}) = \frac{1.325 P_B V_T (100 - C_T)}{C_T(T_T + 460)}$$

p_B = barometric pressure measured in accordance with 3.6 of this appendix in inches of mercury

V_T = flow rate of tracer gas through the vented heater measured in accordance with 3.6 of this appendix in cubic feet per minute

C_T = concentration by volume of tracer gas present in the flue gas sample measured in accordance with 3.6 of this appendix in percent

C_T^* = concentration by volume of the active tracer gas in the mixture in percent and is 100 when the tracer gas is a single component gas

T_T = the temperature of the tracer gas entering the flow meter measured in accordance with 3.6 of this appendix in degrees Fahrenheit

$(T_T + 460)$ = absolute temperature of the tracer gas entering the flow meter in degrees Rankine

$M_{F,SS}(T_{F,SS}) = C_n[R_T(A/F)+1]/[60HHV_A]$

Q_a = as defined in 3.1 of this appendix

R_T = as defined in 4.1.7 of this appendix

A/F = as defined in 4.2.2 of this appendix

HHV_A = as defined in 4.2.2 of this appendix

4.5.2 *Optional procedure for determining off-cycle draft factor for flue gas flow for vented heaters.* For systems numbered 1 thru 10, calculate the off-cycle draft factor for flue gas flow (D_F) defined as:

$D_F = D_P$

For systems numbered 11 or 12: $D_F = D_P D_O$

where:

D_P = as defined in 4.5.1 of this appendix

D_O = as defined in 4.4 of this appendix

4.5.3 *Optional procedure for determining off-cycle draft factor for stack gas flow for vented heaters.* Calculate the off-cycle draft factor for stack gas flow (D_S) defined as:

For systems numbered 1 or 2: $D_S = 1.0$

For systems numbered 3 or 4: $D_S = (D_P + 0.79)/1.4$

For systems numbered 5 or 6: $D_S = D_O$

For systems numbered 7 or 8 and if $D_O(S/F) < 1$: $D_S = D_O D_P$

For systems numbered 7 or 8 and if $D_O(S/F) > 1$:

$D_S = D_O D_P + [0.85 - D_O D_P][D_O(S/F) - 1]/[S/F - 1]$

where:

D_P = as defined in 4.5.1 of this appendix

D_O = as defined in 4.4 of this appendix

TABLE 1.—OFF-CYCLE DRAFT FACTORS FOR FLUE GAS FLOW (D_F) AND FOR STACK GAS FLOW (D_S) FOR VENTED HOME HEATING EQUIPMENT EQUIPPED WITHOUT THERMAL STACK DAMPERS

System number	(D_1)	(D_2)	Burner type	Venting system type [1]
1	1.0	1.0	Atmospheric.	Draft hood or diverter.
2	0.4	1.0	Power.	Draft hood or diverter.
3	1.0	1.0	Atmospheric.	Barometric draft regulator.
4	0.4	0.85	Power.	Barometric draft regulator.
5	1.0	D_o	Atmospheric.	Draft hood or diverter with damper.
6	0.4	D_o	Power.	Draft hood or diverter with damper.
7	1.0	D_o	Atmospheric.	Barometric draft regulator with damper.
8	0.4	$D_o D_o$	Power.	Barometric draft regulator with damper.
9	1.0		Atmospheric.	Direct vent.
10	0.4		Power.	Direct vent.
11	D_o		Atmospheric.	Direct vent with damper.
12	0.4 D_o		Power.	Direct vent with damper.

[1] Venting systems listed with dampers means electro-mechanical dampers only.

TABLE 3.—FRACTION OF HEATING LOAD AT REDUCED OPERATING MODE (X1) AND AT MAXIMUM OPERATING MODE (X2), AVERAGE OUTDOOR TEMPERATURES (TOA AND TOA*), AND BALANCE POINT TEMPERATURE (TC) FOR VENTED HEATERS EQUIPPED WITH EITHER TWO-STAGE THERMOSTATS OR STEP-MODULATING THERMOSTATS

Heat output ratio [*]	X1	X2	TOA	TOA*	TC
0.20 to 0.24	.12	.88	57	40	53
0.25 to 0.29	.16	.84	56	39	51
0.30 to 0.34	.20	.80	54	38	49
0.35 to 0.39	.30	.70	53	36	46
0.40 to 0.44	.36	.64	52	35	44
0.45 to 0.49	.43	.57	51	34	42
0.50 to 0.54	.52	.48	50	32	39
0.55 to 0.59	.60	.40	49	30	37
0.60 to 0.64	.70	.30	48	29	34
0.65 to 0.69	.76	.24	47	27	32
0.70 to 0.74	.84	.16	46	25	23
0.75 to 0.79	.88	.12	46	22	27
0.80 to 0.84	.94	.06	45	20	23
0.85 to 0.89	.96	.04	45	18	21
0.90 to 0.94	.98	.02	44	16	19
0.95 to 0.99	.99	.01	44	13	17

[*] The heat output ratio means the ratio of minimum to maximum heat output rates as defined in 4.1.13.

TABLE 2.—VALUES OF HIGHER HEATING VALUE (HHV$_A$), STOICHIOMETRIC AIR/FUEL (A/F), LATENT HEAT LOSS (L$_{LA}$) AND FUEL-SPECIFIED PARAMETERS (A, B, C, AND D) FOR TYPICAL FUELS

Fuels	HHV$_A$ (Btu/lb)	A/F	L$_{LA}$	A	B	C	D
No. 1 oil	19,800	14.56	6.55	0.0679	14.22	0.0179	0.167
No. 2 oil	19,500	14.49	6.50	0.0667	14.34	0.0181	0.167
Natural gas	20,120	14.45	9.55	0.0919	10.36	0.0175	0.171
Manufactured gas	18,500	11.61	10.14	0.0965	10.10	0.0155	0.235
Propane	21,500	15.58	7.99	0.0841	12.60	0.0177	0.151
Butane	20,000	15.36	7.79	0.0808	12.90	0.0180	0.143

FIGURE 1

Average Outdoor Air Temperature vs. Balance Point Temperature for
Modulating Vented Heaters
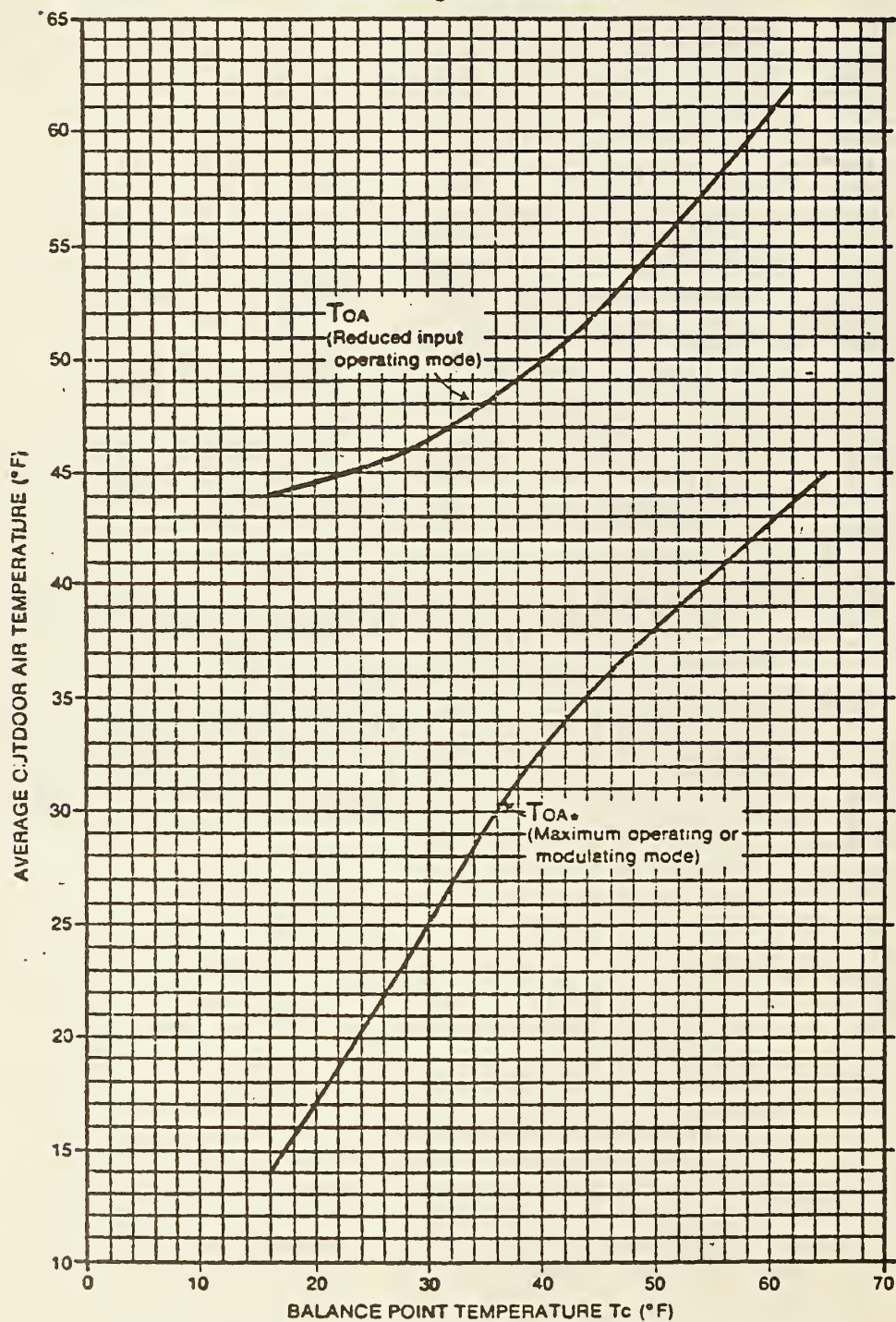
This figure is based on 4500 degree-days and 15°F outdoor design temperature.

FIGURE 2

Fraction of Total Annual Heating Load Applicable to Reduced Operating
Mode (X_1) and to Maximum Operating Mode or Modulating Mode (X_2) vs.
Balance Point Temperature for Modulating Vented Heaters
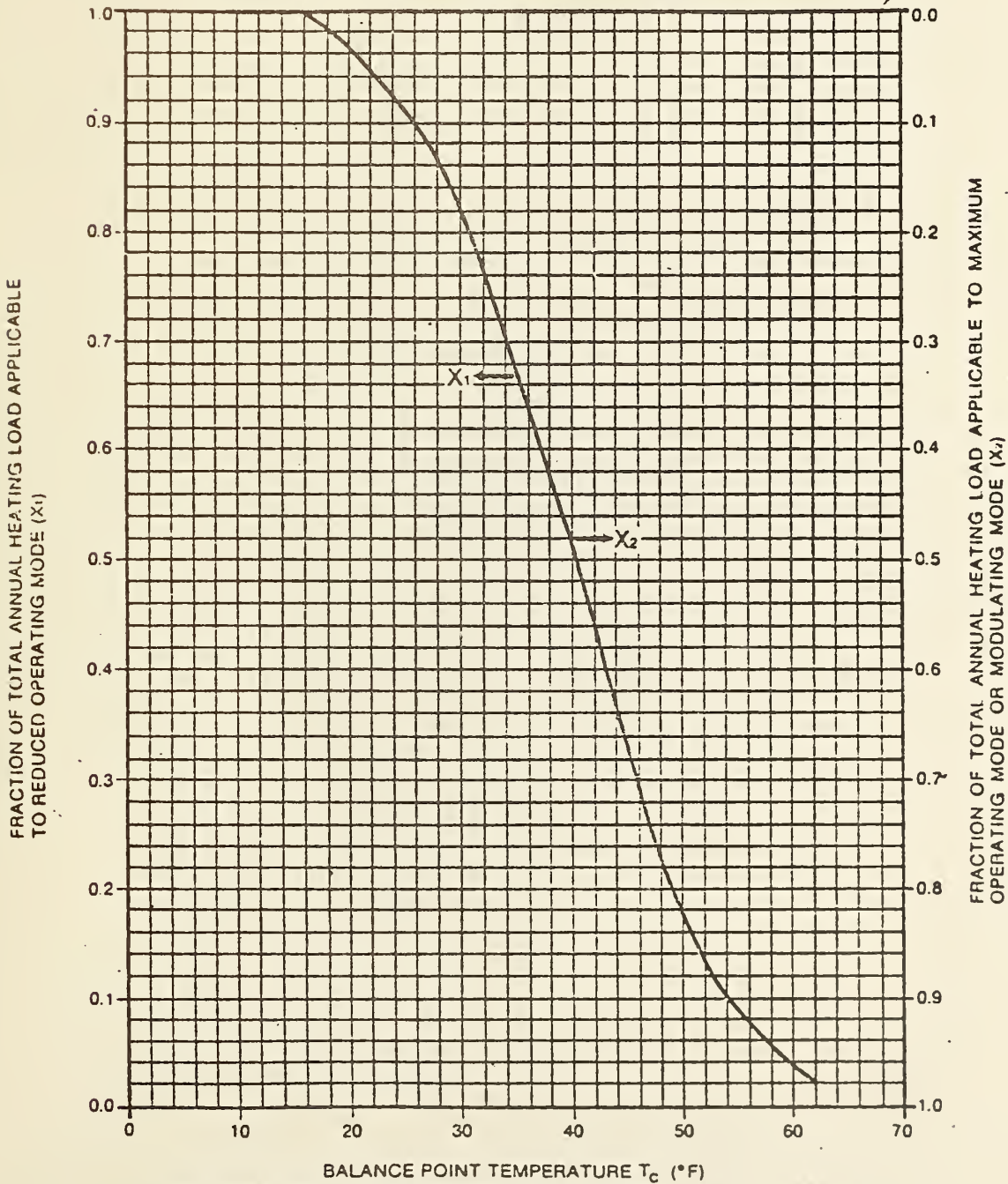
BALANCE POINT TEMPERATURE T_C (°F)
This figure is based on 4500 degree-days and 15°F outdoor design temperature.

APPENDIX C

<u>EXAMPLES</u>

Completed Input Form
Input Files
Computer Runs

Title #1 Assumed data to test program VENT, also check conversions.

Title #2 Two-stage modulating, with damper, measured off-loss.

System #	Fuel #	Control #	Option #	Fuel Cost c/Therm.	Elect. Cost c/kWh
5	3	2	3	64.6	7.63

Pilot Btu/min*	Elect. kW *	Jacket Loss, % *
8.0	0.100	4.5

NOTE #1. Enter 50% input rate values
if manual control, type #4.
#2. *=enter 0.0 if not measured

Fuel Input Btu/min.	Room Amb. F or C	Stack Temp. F or C *	Flue Temp. F or C *	CO2 Stack % *	CO2 Flue %
800	22.22	193.3	263.	6.5	10.0

Enter next line only if tested at second (reduced) input rate.

| 400 | 21.5 | 143 | 157.5 | 5.5 | 8.5 |

Enter next line only if with damper and off-loss not measured.

Stack Area sq. in.	Damper area sq. in.	Angle deg.
—	—	—

Enter next line only if draft measured (Dp), option #2.

Barometer "Hg or mb*	Gas Temp. F or C	Gas Conc. % or ppm	Gas Flow cu.ft./min	Trac.Conc. % or ppm	Flue Temp. F or C
—	—	—	—	—	—

Enter next lines only if measured high fire off-loss measured.

Barometer "Hg or mb*	Gas Temp. F or C	Gas Conc. % or ppm	Gas Flow cu.ft./min
1001	20.5	508 000	.00078398

Meas #	Trac.Conc. % or ppm	Flue Temp. F or C
1	73.1	161.6
2	75.3	125.8
3	77.6	100.3
4	77.6	84.9
5	78.5	76.8
6	79.8	70.7
7	88.3	65.8
8	100.0	61.3
9	104.5	57.9
10	106.8	54.9

Enter next lines only if reduced fire off-loss measured.

Barometer "Hg or mb*	Gas Temp. F or C	Gas Conc. % or ppm	Gas Flow cu.ft./min
0.0	20.5	508 000	.00057

Meas #	Trac.Conc. % or ppm	Flue Temp. F or C
1	120.5	95.2
2	131.1	69.8
3	147.0	55.2
4	160.2	45.1
5	167.8	42.1
6	176.9	40.0
7	184.1	39.0
8	188.9	36.9
9	203.5	35.3
10	213.3	34.6

tstdat.vhtst7

```
1 Assumed data to test program VENT, also check conversions.
2 Two-stage modulating, with damper, measured off-loss.
3 5 3 2 3 64.6 7.63
4 8 .1 4.5
5 800 22.22 193.3 263 6.5 10.0
6 400 21.5 143 157.5 5.5 8.5        ◄──Temperatures in degrees  celsuis
7 1001 20.5 508000 .00078398        ◄──────Barometric pressure in  millibars
8 73.1 161.6
9 75.3 125.8
10 77.6 100.3
11 77.6 84.9
12 78.5 76.8
13 79.8 70.7
14 88.3 65.8
15 100.0 61.3
16 104.5 57.9
17 106.8 54.9
18 0 20.5 508000 .00057             ◄──────────Default barometric pressure
19 120.5 95.2
20 131.1 69.8
21 147.0 55.2
22 160.2 45.1
23 167.8 42.1
24 176.9 40.0
25 184.1 39.0
26 188.9 36.9
27 203.5 35.3
28 213.3 34.6
END OF FILE
->
```

xqt

Input data, type-"@ADD FILENAME.ELEMENTNAME"
>@add tstdat.vhtst7

VENTED HEATER TEST REPORT

Assumed data to test program VENT, also check conversions.
Two-stage modulating, with damper, measured off-loss.

*********** INPUT SELECTIONS ***********

SYSTEM #	FUEL	CONTROL	OPTIONS	FUEL-COST	ELECT-COST
5	3	2	3	64.60	7.63

WITH PILOT LIGHT, QP=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

*********** INPUT DATA ***************
HIGH FUEL INPUT RATE DATA

INPUT BTU/MIN	AMB TEMP	TEMP STACK	TEMP FLUE	CO2 STACK	CO2 FLUE
800.0	72.0	379.9	505.4	6.5	10.0

LOW FUEL INPUT RATE

400.0	70.7	289.4	315.5	5.5	8.5

HIGH FIRE OFF-LOSS DATA.

BARO. PRES.	TEMP. TRAC.	CONC. TRAC.	VOLM. TRAC.	CONC. FLUE	TEMP. FLUE
30.46	68.9	.51+006	.78-003	.73+002	322.9
				.75+002	258.4
				.78+002	212.5
				.78+002	184.8
				.78+002	170.2
				.80+002	159.3
				.88+002	150.4
				.10+003	142.3
				.10+003	136.2
				.11+003	130.8

LOW FIRE OFF-LOSS DATA.

30.00	68.9	.51+006	.57-003	.12+003	203.4
				.13+003	157.6
				.15+003	131.4
				.16+003	113.2
				.17+003	107.8
				.18+003	104.0
				.18+003	102.2
				.19+003	98.4
				.20+003	95.5
				.21+003	94.3

LOW HEAT FRACTION= .520   HIGH HEAT FRACTION= .480
BALANCE POINT TEMP.=39.42
Ls,on = 9.53   Li,on = .90
Ls,off= .86   Li,off= .25
*************** TEST RESULTS ******************

WEIGHTED STEADY STATE EFFICIENCY= 80.92%
AFUE= 65.03%
COST/MILLION BTU= $ 10.11

Temperatures in degrees Fahrenheit

```
tstdat.vhtst6


1 Assumed data to test program VENT
2 Single stage, with damper, measured off-loss.
3 5 3 1 3 64.7 7.63
4 8 .1 4.5
5 800,72,380,505.5,6.5,10.0
6 1000. 70.0 508000. 0.00078398
7 73.1 322.9
8 75.3 258.4
9 77.6  212.5
10 77.6 184.8
11 78.5 170.2
12 79.8 159.3
13 88.3 150.4
14 100.0 142.3
15 104.5 136.2
16 106.8 130.8
END OF FILE
->
```

```
Input data, type-"@ADD FILENAME.ELEMENTNAME"
>@add tstdat.vhtst6
```

VENTED HEATER TEST REPORT

Assumed data to test program VENT
Single stage, with damper, measured off-loss.

*********** INPUT SELECTIONS ***********

SYSTEM #	FUEL	CONTROL	OPTIONS	FUEL-COST	ELECT-COST
5	3	1	3	64.70	7.63

WITH PILOT LIGHT, QP=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

*********** INPUT DATA ****************

HIGH FUEL INPUT RATE DATA

INPUT BTU/MIN	AMB TEMP	TEMP STACK	TEMP FLUE	CO_2 STACK	CO_2 FLUE
800.0	72.0	380.0	505.5	6.5	10.0

HIGH FIRE OFF-LOSS DATA.

BARO. PRES.	TEMP. TRAC.	CONC. TRAC.	VOLM. TRAC.	CONC. FLUE	TEMP. FLUE
30.43	70.0	.51+006	.78-003	.73+002	322.9
				.75+002	258.4
				.78+002	212.5
				.78+002	184.8
				.78+002	170.2
				.80+002	159.3
				.88+002	150.4
				.10+003	142.3
				.10+003	136.2
				.11+003	130.8

L_s,on =10.51 L_i,on = .04
L_s,off= 1.30 L_i,off= .24

*************** TEST RESULTS ********************

WEIGHTED STEADY STATE EFFICIENCY= 79.94%
                        AFUE= 73.62%
            COST/MILLION BTU= $ 8.92

->

VENTED HEATER TEST REPORT

Assumed data to test program VENT
Single stage, minimum testing.

*********** INPUT SELECTIONS ************

SYSTEM #   FUEL   CONTROL   OPTIONS   FUEL-COST   ELECT-COST
   1   3   1   1   64.70   7.63
WITH PILOT LIGHT, QP=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

*********** INPUT DATA *****************
HIGH FUEL INPUT RATE DATA

| INPUT | AMB | TEMP | TEMP | CO2 | CO2 |
BTU/MIN	TEMP	STACK	FLUE	STACK	FLUE
800.0	72.0	380.0	505.5	6.5	10.0

 Df=1.00   Ds=1.00
*************** TEST RESULTS *******************

WEIGHTED STEADY STATE EFFICIENCY= 79.94%
                          AFUE= 56.55%
              COST/MILLION BTU= $ 11.58

$$AFUE = (.968*79.94)-1.78-1.84-(\frac{129.*80.}{800.})-(3.93*4.5)+1.81 = 56.6\%$$

VENTED HEATER TEST REPORT

Assumed data to test program VENT
Manual-on off, minimum testing.

*********** INPUT SELECTIONS ***********

SYSTEM #   FUEL   CONTROL   OPTIONS   FUEL-COST   ELECT-COST
    1   3   5   1   64.70   7.63
WITH PILOT LIGHT, QP=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

*********** INPUT DATA *****************
HIGH FUEL INPUT RATE DATA
    INPUT   AMB   TEMP   TEMP   CO2   CO2
   BTU/MIN   TEMP   STACK   FLUE   STACK   FLUE
   800.0   72.0   380.0   505.5   6.5   10.0

 Li,on= .04
*************** TEST RESULTS ********************

           WEIGHTED STEADY STATE EFFICIENCY= 79.94%
                                     AFUE= 65.85%
                     COST/MILLION BTU= $ 9.96

$$\eta_v = \eta_{ss} - L_{i,on} - C_j * L_j = 79.94 - .04 - (2.8 * 4.5) = 67.3\%$$

$$AFUE = \frac{\eta_v}{1 + \left(2.61 * \frac{\eta_v}{\eta_s} * \frac{Q_p}{Q_{in}}\right)}$$

$$= \frac{67.3}{1 + \left(2.61 * \frac{67.3}{79.94} * \frac{8}{800}\right)} = 65.85\%$$

<u>Without</u> $C_J * L_J$ $\eta_v = 79.90\%$
                        $AFUE = 77.87\%$
                        $\$/M = 8.44$

-C7-

VENTED HEATER TEST REPORT

Assumed data to test program VENT
Manual-adjustable fuel rate, minimum testing.

*********** INPUT SELECTIONS ***********

SYSTEM # FUEL CONTROL OPTIONS   FUEL-COST ELECT-COST
    1   3   4   1   64.70   7.63
WITH PILOT LIGHT, QP=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

*********** INPUT DATA ****************
 50% FUEL INPUT RATE
    INPUT   AMB   TEMP   TEMP   CO2   CO2
   BTU/MIN TEMP STACK   FLUE   STACK FLUE
    400.0   72.0 290.0 315.5   6.5   10.0

 Li,on= .04
*************** TEST RESULTS ********************

     WEIGHTED STEADY STATE EFFICIENCY= 83.01%
                             AFUE= 68.85%
              COST/MILLION BTU= $ 9.53

VENTED HEATER TEST REPORT

Assumed data to test program VENT
Single stage, minimum testing, with damper.

*********** INPUT SELECTIONS ***********

SYSTEM #   FUEL   CONTROL   OPTIONS   FUEL-COST   ELECT-COST
    5   3   1   1   64.70   7.63
WITH PILOT LIGHT, QP=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

*********** INPUT DATA *****************
HIGH FUEL INPUT RATE DATA
   INPUT   AMB   TEMP   TEMP   CO2   CO2   ·
  BTU/MIN   TEMP   STACK   FLUE   STACK   FLUE
   800.0   72.0   380.0   505.5   6.5   10.0

DAMPER DATA: DAMPER AREA= 28.00 ,STACK AREA= 26.80   ANGLE=25.0
    Do= .21

 Df=1.00   Ds= .21
************** TEST RESULTS ******************

        WEIGHTED STEADY STATE EFFICIENCY= 79.94%
                            AFUE= 58.04%
                COST/MILLION BTU= $ 11.28

VENTED HEATER TEST REPORT

Assumed data to test program VENT
Single stage, with damper, measured draft factor.

*********** INPUT SELECTIONS ***********

SYSTEM #	FUEL	CONTROL	OPTIONS	FUEL-COST	ELECT-COST
5	3	1	2	64.70	7.63

WITH PILOT LIGHT, QP=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

*********** INPUT DATA ******************
HIGH FUEL INPUT RATE DATA

INPUT	AMB	TEMP	TEMP	CO2	CO2
BTU/MIN	TEMP	STACK	FLUE	STACK	FLUE
800.0	72.0	380.0	505.5	6.5	10.0

DAMPER DATA: DAMPER AREA= 28.00 ,STACK AREA= 26.80   ANGLE=25.0
OPTIONAL Dp PROCEDURE TEST DATA

BARO.	TEMP.	CONC.	VOLM.	CONC.	TEMP.
PRES.	TRAC.	TRAC.	TRAC.	FLUE	FLUE
29.90	70.0	.51+006	.50-001	.12+006	212.0

$Do= .21$

$Df= .37$ $Ds= .21$
*************** TEST RESULTS ********************

WEIGHTED STEADY STATE EFFICIENCY= 79.94%
AFUE= 59.15%
COST/MILLION BTU= $ 11.07

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5. AUTHOR(S)

R. A. Wise, F. C. Parsons

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

The Fortran 77 computer program described in this report is to be used to calculate results from tests run on vented heaters. The Department of Energy recently published a revised test procedure for such heaters but which contains a simplified method for testing with a number of testing options that allow more detailed tests to be run. The new procedure also provides for the testing of units with manual controls of two types, modulating controls of two types, and the testing of units incorporating thermal stack dampers as well as electro-mechanical dampers. Once input selections have been made, the program performs the calculations required and prints out the results.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Computer program; energy; test procedure; vented heaters; furnace

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