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Fortran 77 Computer Program for Test Procedure Calculations of Vented Heaters

Robert A. Wise
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U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Building Equipment Division
Washington, D.C. 20234

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Prepared for:
United States Department of Energy
Washington, D.C. 20585
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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

* 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]. Appendix B is different than the DOE publication in that only the pages relating to the testing requirements of vented heaters are included and the columns 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

<table>
<thead>
<tr>
<th>Title #1</th>
<th>Title #2</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>System #</th>
<th>Fuel #</th>
<th>Control #</th>
<th>Option #</th>
<th>Fuel Cost c/Therm.</th>
<th>Elect. Cost c/kWh</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Pilot Btu/min*</th>
<th>Elect. kW *</th>
<th>Jacket Loss, % *</th>
</tr>
</thead>
</table>

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.

<table>
<thead>
<tr>
<th>Stack Area sq. in.</th>
<th>Damper area sq. in.</th>
<th>Angle deg.</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>Barometer &quot;Hg or mb&quot;</th>
<th>Gas Temp. F or C</th>
<th>Gas Conc. % or ppm</th>
<th>Gas Flow cu.ft./min</th>
<th>Trac.Conc. % or ppm</th>
<th>Flue Temp. F or C</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>Barometer &quot;Hg or mb&quot;</th>
<th>Gas Temp. F or C</th>
<th>Gas Conc. % or ppm</th>
<th>Gas Flow cu.ft./min</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>Barometer &quot;Hg or mb&quot;</th>
<th>Gas Temp. F or C</th>
<th>Gas Conc. % or ppm</th>
<th>Gas Flow cu.ft./min</th>
</tr>
</thead>
</table>

Figure 1
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  
Auxillary 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, RTP; 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 necessary. 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

<table>
<thead>
<tr>
<th>Program</th>
<th>Test Pros.</th>
<th>Section</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>QP</td>
<td>( Q_p )</td>
<td>3.5</td>
<td>Btu/min.</td>
</tr>
<tr>
<td>PE</td>
<td>( P_e )</td>
<td>3.1.3</td>
<td>kilowatts</td>
</tr>
<tr>
<td>QJ</td>
<td>( J )</td>
<td>3.2</td>
<td>%</td>
</tr>
<tr>
<td>QIN</td>
<td>( Q_{in} )</td>
<td>3.1.1</td>
<td>Btu/min.</td>
</tr>
<tr>
<td>TRA</td>
<td>( T_{ra} )</td>
<td>3.1.1</td>
<td>Deg. F</td>
</tr>
<tr>
<td>TSS</td>
<td>( T_{ss} )</td>
<td>3.1.1</td>
<td>Deg. F</td>
</tr>
<tr>
<td>TFS</td>
<td>( T_{fs} )</td>
<td>3.1.1</td>
<td>Deg. F</td>
</tr>
<tr>
<td>C02S</td>
<td>( X_{co2s} )</td>
<td>3.1.1</td>
<td>%</td>
</tr>
<tr>
<td>C02F</td>
<td>( X_{co2f} )</td>
<td>3.1.1</td>
<td>%</td>
</tr>
<tr>
<td>QINR</td>
<td>( Q_{red.in} )</td>
<td>4.1.11</td>
<td>Btu/min.</td>
</tr>
<tr>
<td>TRAR</td>
<td>-</td>
<td>-</td>
<td>Deg. F</td>
</tr>
<tr>
<td>TSSR</td>
<td>-</td>
<td>-</td>
<td>Deg. F</td>
</tr>
<tr>
<td>TFSR</td>
<td>-</td>
<td>-</td>
<td>Deg. F</td>
</tr>
<tr>
<td>C02SR</td>
<td>-</td>
<td>-</td>
<td>%</td>
</tr>
<tr>
<td>C02FR</td>
<td>-</td>
<td>-</td>
<td>%</td>
</tr>
<tr>
<td>AD</td>
<td>( A_d )</td>
<td>3.4</td>
<td>sq. in.</td>
</tr>
<tr>
<td>AS</td>
<td>( A_s )</td>
<td>3.4</td>
<td>sq. in.</td>
</tr>
<tr>
<td>AN</td>
<td>( n )</td>
<td>3.4</td>
<td>Degrees</td>
</tr>
<tr>
<td>PB</td>
<td>( P_b )</td>
<td>3.6</td>
<td>in. Hg</td>
</tr>
<tr>
<td>TT</td>
<td>( T_t )</td>
<td>3.6</td>
<td>Deg. F</td>
</tr>
<tr>
<td>CTT</td>
<td>-</td>
<td>-</td>
<td>% or ppm</td>
</tr>
<tr>
<td>VT</td>
<td>( V_t )</td>
<td>3.6</td>
<td>cu.ft./min.</td>
</tr>
<tr>
<td>CT</td>
<td>( C_t )</td>
<td>3.6</td>
<td>% or ppm</td>
</tr>
<tr>
<td>TF</td>
<td>( T_{tf,off} )</td>
<td>3.6</td>
<td>Deg. F</td>
</tr>
<tr>
<td>PBO</td>
<td>( P_b )</td>
<td>4.3.3</td>
<td>in. Hg</td>
</tr>
<tr>
<td>TTO</td>
<td>( T_t )</td>
<td>4.3.3</td>
<td>Deg. F</td>
</tr>
<tr>
<td>CTTO</td>
<td>( C_t )</td>
<td>4.3.3</td>
<td>% or ppm</td>
</tr>
<tr>
<td>VTO</td>
<td>( V_t )</td>
<td>4.3.3</td>
<td>cu.ft./min.</td>
</tr>
<tr>
<td>CTO(I)</td>
<td>( C_t )</td>
<td>4.3.3</td>
<td>% or ppm</td>
</tr>
<tr>
<td>TFO(I)</td>
<td>( T_{t,off} )</td>
<td>4.3.3</td>
<td>Deg. F</td>
</tr>
<tr>
<td>PBOR</td>
<td>-</td>
<td>-</td>
<td>in. Hg</td>
</tr>
<tr>
<td>TTOR</td>
<td>-</td>
<td>-</td>
<td>Deg. F</td>
</tr>
<tr>
<td>CTTOR</td>
<td>-</td>
<td>-</td>
<td>% or ppm</td>
</tr>
<tr>
<td>VTOR</td>
<td>-</td>
<td>-</td>
<td>cu.ft./min.</td>
</tr>
<tr>
<td>CTOR(I)</td>
<td>-</td>
<td>-</td>
<td>% or ppm</td>
</tr>
<tr>
<td>TFOR(I)</td>
<td>-</td>
<td>-</td>
<td>Deg. F</td>
</tr>
</tbody>
</table>

**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 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 Da, 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 "Da" 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 O of the test procedure (Appendix B of this report). The section numbers and changes are as follows:
VENTED HEATER SIMPLIFIED FLOW DIAGRAM, PROGRAM "PROG.VENT"

NOTE: DAMP is yes if ISYS = 5, 6, 7, 8, 11, or 12
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 CO2 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 pseudo 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.
APPENDIX A - PROGRAM "VENT"

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 amended 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.

By: R.A.Wise, F.C.Parsons, 3-1-84

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.,4,1./
300 DATA CDS/3*1.,85,4*1.,4*1.0/
310 DATA TOAI,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, Damper 12=Direct, Power, Damper
560 C
570 C -----IFUL-----
580 C 1=No.1 oil 1=No optional tests
590 C 2=No.2 oil 2=Meas.draft factor
600 C 3=Natural gas 3=Measured off-loss
610 C 4=Manufactured gas 4=Manual w/heat control or thermal damper
620 C
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)
FORMAT(1X,'*********** INPUT SELECTIONS **********')

WRITE(6,522)

FORMAT(1X,'SYSTEM # FUEL CONTROL OPTIONS ',
# 'FUEL-COST ELECT-COST')

WRITE(6,523)ISYS,IPUL,ICRL,IOPT,FC,EC

FORMAT(4(6X,I1),6X,2(3X,F6.2))

READ(5,*)QP,PE,QJ

IF(QP.GT.0.0)WRITE(6,524)QP

FORMAT(1X,'WITH PILOT LIGHT, QP=BTU/Min.=',F5.1)

IF(QP.GT.1.0)WRITE(6,525)

FORMAT(1X,'WITHOUT PILOT LIGHT')

WRITE(6,526)PE

FORMAT(1X,'ELECTRIC POWER, KW=',F4.3)

WRITE(6,527)QJ

IF(QJ.GT.0.0)WRITE(6,527)QJ

FORMAT(1X,'JACKET LOSS, % LOSS=',F5.2,/)  

WRITE(6,528)

FORMAT(1X,'INSTALLED INDOORS',/

WRITE(6,529)

IF(ICRL.EQ.1 OR ICRL.GT.3)G0 TO 1

WRITE(6,*)'LOW FUEL INPUT RATE'

WRITE(6,*')  

READ(5,*)QINR,TRAR,TSSR,TFSR,C02SR,C02FR

IF(TRAR.LT.40.0 AND TSSR.GT.10.0)TSSR=CF(TSSR)

WRITE(6,531)QINR,TRAR,TSSR,TFSR,C02SR,C02FR

IF(IOPT.EQ.3)G0 TO 2

WRITE(6,532)AD,AS,AN

FORMAT(' DAMPER MEASUREMENTS: DAMPER AREA=',F6.2,
# 'STACK AREA=',F6.2,' ANGLE=',F4.1)

WRITE(6,533)

FORMAT(1X,'BARO. TEMP. CONC. VOLM. CONC. TEMP.',
# '/X,' PRES. TRAC. TRAC. TRAC. FLUE FLUE')

READ(5,*)PB,TT,CTT,VT,CT,TF

IF(PB.EQ.0.0)PB=30.0

IF(PB.GT.100.)PB=PB/33.867

IF(TT.EQ.0.0)TT=TRA

WRITE(6,534)PB,TT,CTT,VT,CT,TF

FORMAT(2X,F5.2,3X,F4.1,3(2X,E7.2),2X,F5.1)

GO TO 5

WRITE(6,533)

IF(ICRL.EQ.3)G0 TO 3

WRITE(6,*)'HIGH FIRE OFF-LOSS DATA.'
1260  READ(*,*)PBO,TT0,CT0,VTO
1270  IF(PBO.EQ.0.0)PBO=30.0
1280  IF(PBO.GT.100.0)PBO=PBO/33.867
1290  IF(CT0.EQ.0.0)TT0=TRA
1300  READ(*,*)CT(I),TFO(I),I=1,10
1310  IF(TFO.LT.40.0)THEN
1320       DO 22 I=1,10
1330   TFO(I)=TF(TFO(I))
1340   ENDF
1350  IF(TFO.LT.40.0)TT0=CF(TT0)
1360  WRITE(6,534)PBO,TT0,CT0,VTO,CT(1),TFO(1)
1370  WRITE(6,535)(CT0(I),TFO(I),I=2,10)
1380  353  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(*,*)PBOR,TTOR,CTTOR,VTOR
1430  IF(PBOR.EQ.0.0)PBOR=30.0
1440  IF(PBOR.GT.100.0)PBOR=PBOR/33.867
1450  IF(TT0R.EQ.0.0)TTOR=TRAR
1460  READ(*,*)CTOR(I),TFOR(I),I=1,10
1470  IF(TF0R.LT.40.0)THEN
1480       DO 33 I=1,10
1490   TFOR(I)=CF(TFOR(I))
1500   ENDF
1510  IF(TFOR.LT.40.0)TTOR=CF(TFOR)
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  Calculate steady-state values
1560  C
1570  CALL SSLOSS(IFUL,QJ,TRA,TSS,TFS,C02S,C02F,
1580  # HHV,AFRHQ,QLH,RTFH,QSSH,EFYSSH,SFRH)
1590  PP=QP/QIN
1600  CJ=0.0
1610  C  If outdoor, assign CJ
1620  C
1630   IF(QJ.GT.1.0)CJ=2.8
1640  C  Calculate reduced firing rate values.
1650  C
1660  C
1670  IF(ICRL.EQ.1.OR.ICRL.GT.3)GO TO 10
1680  CALL SSLOSS(IFUL,QJ,TRA,TSS,TFS,C02S,CO2F,
1690  # HHV,AHRQ,QLH,RTFH,QSSH,EFYSSH,SFRH)
1700  CALL WHT(QIN,EFYSSH,QINR,EFYSSH,
1710  # RLOW,TOAHI,TOAHI,TC)
1720  RHIGH=1.0-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,'BALSE POINT TEMP.=',F5.2)
1760  C  Weighted steady-state efficiency calculations.
1770  C
1780  C
1790  10  EFYSSH=EFYSSH
1800  IF(ICRL.EQ.1.OR.ICRL.GT.3)GO TO 20
1810  EFYSSH=EFYSSH
1820  IF(ICRL.EQ.3)EFYSSA=(EFYSSH-EFYSSH)*(TC-TOAHI)/(TC-15.)+EFYSSH
1830  IF=EFYSSH=RLOW*EFYSSH+RHIGH*EFYSSH
1840  C

-A3-
C Optional tracer gas off-loss calculations.

1850 C
1860 C  IF(ICRL.GT.3.)GO TO 60
1870 IF (IOPT .NE. 3) GO TO 30
1880 IF(ICRL .EQ. 3)GO TO 25
1890 CALL LOSOFF(PBO,TTO,CTTO,VTO,CTO,TFO,TON,QIN,TRA,TOAH,  
1900 # QSOFFH, QIOFFH)
1910  IF (ICRL.EQ.1) GO TO 60
1920 CALL LOSOFF(PBOR,TTOR,CTTOR,VTOR,CTOR,TFOR,TON,QINR,TRAR,TOAL,  
1930 # QSOFFM, QIOFFM)
1940 GO TO 60
1950
1960 C Calculate electro-mechanical damper factor.
1970 C
1980 C  IF(ISYS.LT.5.OR.(ISYS.GT.8.AND.ISYS.LT.11))GO TO 40
1990 IF(DO.GT.1.0)DO=1.0
2000 IF(DO.LT.0.0)DO=0.0
2010 WRITE(6,555)AS,AD,AN,DO
2020 IF(ISYS.EQ.1)GO TO 60
2030 IF(ISYS.EQ.8)DS=D0*DF
2040 C ASSIGN TABLE VALUES FOR DF AND DS
2050 C
2060 C  IF(IOPT.NE.2)GO TO 50
2070 IF(ISYS.GT.10)DF=DF*DO
2080 DS=CDS(ISYS)
2090 IF(DS.LT.0.0)DS=DO
2100 IF(ISYS.EQ.8)DS=DO*DF
2110 C OPTIONAL PROCEDURE FOR CALCULATING DP,DS AND DF
2120 C
2130 C  IF(IOPT.NE.2)GO TO 50
2140 IF(ISYS.GT.10)DF=DF*DO
2150 IF(ISYS.GT.10)DS=DF*DS
2160 IF(ISYS.EQ.8)DS=DO
2170 IF(ISYS.EQ.8)DS=DO
2180 IF(ISYS.EQ.8)DS=DO
2190 IF(ISYS.EQ.8)DS=DO
2200 C
2210 ZSS=QIN*(RTFH*AFR+1.0)/HHV
2220 IF(ISYS.GT.10)DF=DF+1.0
2230 IF(ISYS.EQ.8)DS=DO
2240 IF(ISYS.EQ.8)DS=DO
2250 IF(ISYS.EQ.8)DS=DO
2260 IF(ISYS.EQ.8)DS=DO
2270 IF(ISYS.GT.10) DS=1.0
2280 IF(ISYS.GT.10) DS=1.0
2290 IF(ISYS.GT.10) DS=1.0
2300 IF(ISYS.GT.10) DS=1.0
2310 CONTINUE
2320 C Calculate AFUE, no thermal damper or off-loss measure
2330 C and not manual controls.
2340 C
2350 C  IF(DF.GT.1.0)DF=1.0
2360 IF(DS.GT.1.0)DS=1.0
2370 WRITE(6,560)DF,DS
2380 IF(DS.GT.1.0)DS=1.0
2390 IF(DS.GT.1.0)DS=1.0
2400 IF(DS.GT.1.0)DS=1.0
2410 IF(DS.GT.1.0)DS=1.0
2420 IF(DS.GT.1.0)DS=1.0
2430 C

C -A4-
Continue calculations for manual control, thermal damper, or measured off-losses.

Calculate on-cycle losses.

QSON = QSSH
CIONH = 100. * .24 * SFRH * .7 * (1 + RTFH * AFR) / HHV

IF(ICRL.EQ.1) GO TO 70
IF(ICRL.GT.3) THEN

Calculate pseudo cycling loss for manual controls.

EFFYU = EFYSSW - QION
WRITE(6, 570) QION
GO TO 90
END IF

Calculate for two stage or modulating controls.

QSSA = QSSH
IF(ICRL.EQ.3) QSSA = (QSSH - QSSM) * (TC - TOAHI) / (TC - 15.) + QSSM
QSON = RLOW * QSSM + RHIGH * QSSA
CIONM = 100. * .24 * SFRM * .7 * (1 + RTFM * AFR) / HHV
CIONA = CIONH
IF(ICRL.EQ.3) CIONA = (CIONH + CIONM) / 2.

QION = RLOW * CIONM * (70. - TOAL0) + RHIGH * CIONA * (70. - TOAHI)

Calculate off-cycle losses.

For two stage controls.

QS0FF = RLOW * QS0FFM
QIOFF = RLOW * QIOFFM
IF(ICRL.EQ.3) GO TO 80

For step modulating controls.

QS0FF = QS0FF + RHIGH * QS0FFH
QIOFF = QIOFF + RHIGH * QIOFFH
GO TO 80

For single stage controls.

QS0FF = QS0FFH
QIOFF = QIOFFH

Calculate cycling, part-load, efficiency.

EFFYU = 100. - QL - CJ * QJ - TON * (QSON + QS0FF + QION + QIOFF) / (TON + PF * TOFF)
WRITE(6, 580) QSON, QION, QS0FF, QIOFF
FORMAT(3X, 'Ls, on = ', F5.2, 6X, 'Li, on = ', F5.2,
# /3X, 'Ls, off = ', F5.2, 6X, 'Li, off = ', F5.2)

Calculate AFUE.

IF(ICRL.EQ.4) QIN = QIN * 2.0
AFUE = 4400. * EFYSSW * EFFYU * QIN / (4400. * EFYSSW * QIN +
# 2.5 * 4600. * EFFYU * QP)

Calculate electric power.

IF(ICRL.EQ.1 OR ICRL.GT.3) GO TO 1010
PE = PE * 1.3
IF(ICRL.EQ.2) GO TO 1010
FR = QIN / QINR
PE = PE * 1.7
IF(FR.GE.0.7) PE = PE * 1.4
**Subroutine SSLOSS(IFUL,QJ,TRA,TSS,TFS,C02S,C02F,**

**# HHV AFR QL RTF SFR QSSS EFYSS **

**DIMENSION HH(6),AP(6),Q(6),A(6),B(6),C(6),D(6)***

**DATA (HH(J),J=1,6)/19800.,19500.,20120.,18500.,21500.,20890./

**DATA (AP(J),J=1,6)/14.56,14.49,14.45,11.81,15.58,15.36/

**DATA (Q(J),J=1,6)/6.55,6.50,9.55,10.14,7.99,7.79/

**DATA (A(K),K=1,6)/.0679,.06668,.09194,.09646,.0841,.0808/

**DATA (B(K),K=1,6)/14.22,14.34,10.96,10.10,12.60,12.93/

**DATA (C(K),K=1,6)/.0179,.0181,.0175,.0155,.0177,.018/

**DATA (D(K),K=1,6)/.167,.167,.171,.235,.151,.143/

**HHV=HH(IFUL)

**APR=AP(IFUL)

**QL=Q(IFUL)

**RTF=(B(IFUL)/C02F)+A(IFUL)

**SFR=1.0

**IF(QJ.GT.0.0) SFR=0.0

**IF(IFUL.LT.3) SFR=1.4

**IF(C02S.LT.0.1) GO TO 10

3900 C Calculate S/F for Hood or Diverter or measured Barometric damper.

3910 RTS=(B(IFUL)/C02S)+ 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.
(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 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.

(3) 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.

(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.

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.

The estimated operating cost per million Btu output for gas or oil vented home heating equipment with an auxiliary electric system shall be the
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 "Barometric 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 2.1.2 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 flue 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 flue 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 inert 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" (QH) means the rate of energy supplied in fuel to a vented heater operating under steady-state conditions, expressed in Btu 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" (QH) 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" (QH) by the steady-state efficiency divided by 100. For floor furnaces, it is obtained by multiplying (A) the "heat input" (QH) by (B) the steady-state efficiency divided by 100, minus the quantity (2.8) (L) divided by 100, where L is the jacket loss as determined in section 3.2 of this appendix.
1.14 "Higher heating value" (HHV) means the heat produced by 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, Bu's per cubic foot for gaseous fuel, or Bu'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 vented heater" means a fuel-burning home heating appliance such as a furnace or water heater which operates with a draft diverter, a) supplying air for combustion at a pressure exceeding atmospheric pressure, or b) burning a fuel which 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 (2.8°C) 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 (1.7°C) 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 heat 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 to improvement of the diverter 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 32. 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 stack 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.
2.2.2 Gas fueled home heating equipment employing draft diverters or draft hoods with horizontally 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 heather's having a horizontally discharging draft diverter or draft hood, a five (5) foot long test stack of two elbows, and a five (5) foot 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...
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 Electric 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 (15.6°C) 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 instructions 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. In order to prevent modulation of the heater at maximum input, place 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 CO₂ 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 hourly manufacturer’s recommended 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 Designation D1290-72. 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 CO₂ reading, to maintain the maximum Btu rating and an hourly Btu input rating. When using a power burner, the smoke in the flue must be reduced to No. 1 or lower.

2.4.3 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 given in Table 2.3.1794. Use fuel oil conforming to the specifications given in Tables 2.3.1 and 3.0 of ANSI Standard Z111-1972.

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 the ANSI standard 291-1972.

2.5 Circulating air adjustments.

2.5.1 Forced air vented wall furnaces (including circulating air stoves) and floor furnaces. In tests maintain the air flow through the heater as specified by the manufacturer and operated the vented heater with the outlet air temperature between 60°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 Z114.1975.

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 with lines intersecting at right angles in the horizontal plane at points one third and two thirds of the distance between the center of the stack and the wall.

For units which employ a direct vent system, locate at least one thermocouple at the center of each flue line. 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 the 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 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 exists a possibility that the thermocouples could receive direct radiation from the fire, install radiation shields on the fire side of the thermocouples only 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 thermocouples 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 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 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 or gas exit 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 (±2.8°C) of the value T_A measured during the stack test. If conditions are such that during these tests the room temperature exceed 100°F (37.8°C) or fall below 65°F (18.3°C), temperature T_A shall be the arithmetic average temperature of the test area, determined by measurement with four No. 24 AWG bead-type thermocouples with junctions within 6 inches of the wall and conditioned 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 2 inches from the heater or test enclosure and localed 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 opening. The temperature of the air for combustion and the air for draft relief shall not differ more than ±2°F from room temperature as measured above.

2.9.2 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 to be used at both or either 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, 2.2, and 2.3 of this appendix. The draft diverters shall be in the normal open condition. If the flue shall be insulated, (Insulation of the stack is no longer required for the vented heater.) 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 2.4.1.1 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 a 5°C (2.8°F) or the flue gas temperature for vented heaters equipped with draft hoods or direct vent systems; in three successive readings taken 15 minutes apart.

On units employing draft diverters, measure the room temperature T_A as described in section 2.9 of this appendix and measure the steady-state stack gas temperature T_M using the nine thermocouples located in the 5 foot test stack as specified in section 2.6.3.1. Of this appendix. Secure a sample of the stack gases in the plane where T_M is measured or within 3.5 feet downstream of this plane. Determine the concentration by volume of carbon dioxide (X_CO2) present in the dry stack gas. If the location of the sample point 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. At no time during the steady-state test as described in section 2.9 of this appendix and measure the steady-state flue gas temperature of 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 CO2 (X_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 CO2 (X_CO2) present in dry stack gas.

Determine the steady-state heat input rate Q_WM 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 CO2 (X_CO2) 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 a representative sample shall be obtained for the CO2 concentration. For units with heat exchanger outlets, measure the CO2 concentration in a sample from each outlet to obtain the average CO2 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 fuel input rate 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 home heating equipment (including direct vent systems).

Set up and adjust the vented heater as specified in sections 2.1.2, 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 a sample of the flow, 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 Z111.2-1965 [ASTM D 2156-65]
Measure the room temperature \( T_{\text{Amb}} \) as described in section 2.9 of this appendix and measure the steady-state flue gas temperature \( T_{\text{Gas, SS}} \) using nine thermocouples located in the flue pipe as described in section 2.6.2. Select a sample of the flue gas in the plane of temperature measurement and determine the concentration by volume of CO\(_2\)(X\(_{\text{CO2}}\)) present in dry flue gas. Measure and record the steady-state heat input rate \( (Q_a) \).

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

### 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 auxiliary electric power \( (P_a) \) expressed in kilowatts. For vented heaters with modulating controls, the recorded \( P_a \) shall be maximum measured electric power multiplied by the following factor \( (R) \). For two stage controls, the 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.

### Jacket loss measurement

Conduct a jacket loss test for vented floor furnaces. Measure the jacket loss \( (L) \) in accordance with the ANSI standard Z21.48-1976 section 2.12.3.

### 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 2.6.3 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 rates. \( R = 1.3 \) for step modulating controls.

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 the air 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 has been equilibrated in the stack.

Continuous 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 three values as the midpoint of each 10 minute interval before shut down and ten minutes after burner shut down. Meter response time and sampling delay time shall be considered in timing these measurements.

#### 3.5 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 \( (A_d) \), and the angle that the plate makes with a plane perpendicular to the stack \( (\theta) \). The net area of the damper plate means the area of the damper plate minus the area of any holes through the damper plate.

#### 3.6 Optional procedure for determining \( D_p, D_r \) and \( D_s \) for systems of all types of vented heaters

For all types of vented heaters, \( D_p, D_r \) 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 3°F (1.7°C) in the flue gas temperature in three successive readings taken 15 minutes apart. Then shut the unit off with the stack or flue damper controlled by-passed or adjusted so that the stack or flue damper remains open during the result time. The test is considered valid 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 -0.01 to +0.03 inches of water gauge) for the average steady-state draft) during this cool down period.

#### 3.7 Measurement of the flue gas mass flow rate of the cool down test described above at a specific off-cycle flue gas temperature and to obtain its value at the steady-state flue gas temperature

Measure the flue gas mass flow rate \( (M_{\text{Gas}}) \) by measuring the cool down test described above at a specific off-cycle flue gas temperature and to obtain its value at the steady-state flue gas temperature \( (T_{\text{SS}}) \), using the procedure described below.

Within one minute after the unit is shut off to start the cool down test for determining \( D_p \), 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 cool down test, at an accuracy of ±2 percent in the value of the temperature measurement and the measurement of tracer gas concentration coincide. In addition, determine the temperature of the tracer gas entering the flow meter \( (T_f) \) and the barometric pressure \( (P_b) \).

#### 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 \( (D_s) \) 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 \( (P_p) \) expressed as a decimal and defined as:

\[
P_p = \frac{Q_p}{Q_a}
\]

where:

\[
Q_p = \frac{Q_{\text{Tracer}}}{Q_a}
\]

4.1.5 Jacket loss for floor furnaces. Determine the jacket loss \( (L) \) expressed as a percent and measured in accordance with section 2.2 of this appendix. For other vented heaters, \( L = 0.0 \).

4.1.6 Latent heat loss. Based on the fuel, obtain the latent heat loss \( (L) \) 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 \( (R_{\text{Air}}) \), and defined as:

\[
R_{\text{Air}} = A + B \times \frac{X_{\text{CO2}}}{X_{\text{Air}}}
\]

where:

\[
A = \text{as determined from Table 2 of this appendix}
\]

\[
B = \text{as determined from Table 2 of this appendix}
\]

X_{\text{CO2}} = \text{as defined in 3.1 of this appendix}

X_{\text{Air}} = \text{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 draft hood, determine the ratio of combustion and relief air mass flow rate to stoichiometric air mass flow rate \( R_{a} \), and defined as:

\[ R_{a} = \frac{A}{[B/X_{COns}]} \]

where:

- \( A = \) as determined from Table 2 of this appendix
- \( B = \) as determined from Table 2 of this appendix
- \( X_{COns} = \) 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 \( L_{ss.A} \) expressed as a percent and defined as:

\[ L_{ss.A} = \frac{C[R_{a} + D]}{(T_{a} - T_{a})} \]

where:

- \( C = \) as determined from Table 2 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, \( \eta_{ss} \), expressed as a percent and defined as:

\[ \eta_{ss} = 100 - L_{ss.A} - L_{ss.A} \]

where:

- \( L_{ss.A} = \) as defined in 4.1.6 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 \( Q_{red.out} \) as:

\[ Q_{red.out} = \eta_{ss} \times Q_{red.in} \]

where:

- \( \eta_{ss} = \) 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 \( Q_{max.out} \) as:

\[ Q_{max.out} = \eta_{ss} \times Q_{max.in} \]

where:

- \( \eta_{ss} = \) 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, determine the ratio of reduced to maximum heat output rates \( R \), expressed as a decimal and defined as:

\[ R = \frac{Q_{red.out}}{Q_{max.out}} \]

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 \( (X_{m}) \) 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 thermostats, determine the fraction of heating load at the maximum operating mode or noncycling mode \( (X_{m}) \) 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 \( \eta_{ss} \) as defined in section 4.1.10 of this appendix. For vented heaters equipped with two stage thermostats, \( \eta_{ss.wt} \) is defined as:

\[ \eta_{ss.wt} = X_{1} \times \eta_{ss} + X_{2} \times \eta_{ss} \]

where:

- \( X_{1} = \) as defined in 4.1.14 of this appendix
- \( X_{2} = \) as defined in 4.1.15 of this appendix
- \( \eta_{ss} = \) as defined in 4.1.10 of this appendix
- \( \eta_{ss.wt} = \) 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:

\[ AFUE = \eta_{SS.wt} \times 1 - 7.65D_{1} - 0.89D_{1} \times 1 - 2.8 L_{1} + 1.81 \]

where:

- \( D_{1} = \) as defined in 4.1.16 of this appendix
- \( D_{2} = \) as defined in 4.1.2 of this appendix
- \( D_{3} = \) as defined in 4.1.3 of this appendix
- \( D_{4} = \) as defined in 4.1.4 of this appendix
- \( L_{1} = \) 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 venis 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:

\[ S/F = 1.3R_{a}/R_{a} \]
where,

\[ R_T = \text{as defined in 4.1.8 of this appendix with } X_{s,0} \text{ measured at 50°F fuel input rate} \]

\[ R_{F,’’} = \text{as defined in 4.1.7 of this appendix with } X_{s,0} \text{ measured at 20°F fuel input rate} \]

1.2.2 Multiplication factor for infiltration loss during burner on-cycle. Calculate the multiplication factor for infiltration loss during burner on-cycle (K_{on}) defined as:

\[ K_{on} = 100 \left( \frac{S/F}{0.7} \right) \left[ 1 + R_{F,’’}(F/A) \right] / HIV \]

where:

- 100 = converts a decimal fraction into a percent
- 0.7 = specific heat of air
- S/F = stoichiometric air/fuel ratio, determined in accordance with Table 2 of this appendix

\[ S/F = \text{as defined in 4.2.1 of this appendix at 50 percent of rated maximum fuel input} \]

\[ 0.7 = \text{infiltration parameter} \]

\[ R_{F,’’} = \text{as defined in 4.1.7 of this appendix} \]

\[ HIV = \text{average higher heating value of the test fuel determined in accordance with Table 2 of this appendix} \]

4.2.3 On-cycle infiltration heat loss. Calculate the on-cycle infiltration heat loss (L_{on}) expressed as a percent and defined as:

\[ L_{on} = K_{on} \cdot \left( L_{s,s,a,-ave} + F_{s,a} \cdot L_{s,s,a,-max} \right) \]

where:

\[ L_{s,s,a,-ave} = \text{as defined in 4.1.9 of this appendix} \]

\[ L_{s,s,a,-max} = \text{as defined in 4.1.9 of this appendix} \]

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 stock 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,s,a}) expressed as a percent and defined as:

\[ L_{s,s,a} = \text{as defined in 4.1.9 of this appendix} \]

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

\[ L_{on} = X_{,0} \cdot L_{s,s,a,-ave} + X_{,0} \cdot L_{s,s,a,-max} \]

where:

\[ X_{,0} = \text{as defined in 4.1.14 of this appendix} \]

4.3.2 Off-cycle sensible heat loss. For vented heaters equipped with single stage thermostats, calculate the off-cycle sensible heat loss (L_{off}) at the maximum fuel input rate.

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

\[ L_{on} = X_{,0} \cdot L_{s,s,a,-ave} + X_{,0} \cdot L_{s,s,a,-max} \]

where:

\[ X_{,0} = \text{as defined in 4.1.14 of this appendix} \]

4.4.1.2 Annual fuel utilization efficiency. For manually controlled heaters with various input rates, the weighted average steady-state efficiency (\( \eta_{w,ST} \)) is as follows:

\[ \eta_{w,ST} = \text{as defined in 4.2.4 of this appendix} \]

\[ L_{on} = \text{as defined in 4.2.3 of this appendix} \]

4.6 Annual fuel utilization efficiency. For manually controlled vented heaters.

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

\[ AFUE = \frac{4400 \eta_{w,ST} \cdot Q_x \cdot Q_y}{4400 \eta_{s,s,a,-ave} + 2.5 \cdot 4000 \eta_{w,ST} \cdot Q_y} \]

where:

\[ 4400 = \text{average number of heating degree days} \]

\[ \eta_{w,ST} = \text{as defined in 4.2.4 of this appendix} \]

\[ Q_x \cdot Q_y = \text{as defined as } Q_x \text{ at the maximum fuel input rate, as defined in 3.1 of this appendix} \]

\[ \eta_{s,s,a,-ave} = \text{as defined in 3.3 of this appendix} \]

\[ Q_x = \text{as defined in 4.1.14 of this appendix} \]

\[ K_{on,max} = \text{as defined as } K_{on} \text{ in 4.2.2 of this appendix at the maximum heat input rate} \]

\[ 70 = \text{as defined in 4.2.3 of this appendix} \]

\[ T_o = \text{as defined in 4.3.4 of this appendix} \]

\[ K_{on,min} = \text{as defined as } K_{on} \text{ in 4.2.2 of this appendix at the minimum heat input rate} \]

4.1.10 For vented heaters equipped with step-modulating thermostats, calculate L_{on} defined as:

\[ L_{on} = X_{,0} \cdot K_{on,min}(70-T_o) + X_{,0} \cdot K_{on,min}(70-T_o) \]

where:

\[ X_{,0} = \text{as defined in 4.1.14 of this appendix} \]

\[ K_{on,min} = \frac{[K_{on,max} + K_{on,min}]}{2} \]

\[ 70 = \text{as defined in 4.2.3 of this appendix} \]

\[ T_o = \text{as defined in 4.3.4 of this appendix} \]

\[ X_{,0} = \text{as defined in 4.1.15 of this appendix} \]

\[ T_o = \text{as defined in 4.3.4 of this appendix} \]

4.3.3 Off-cycle sensible heat loss. For vented heaters equipped with single stage thermostats, calculate the off-cycle sensible heat loss (L_{off}) at the maximum fuel input rate.

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

\[ L_{on} = X_{,0} \cdot L_{s,s,a,-ave} + X_{,0} \cdot L_{s,s,a,-max} \]

where:

\[ X_{,0} = \text{as defined in 4.1.14 of this appendix} \]

\[ L_{off} = \text{as defined in 4.3.3 of this appendix at the reduced fuel input rate} \]

4.4.1.2 For vented heaters equipped with two stage thermostats, calculate L_{on} defined as:

\[ L_{on} = X_{,0} \cdot L_{s,s,a,-ave} + X_{,0} \cdot L_{s,s,a,-max} \]

where:

\[ X_{,0} = \text{as defined in 4.1.14 of this appendix} \]

\[ L_{off} = \text{as defined in 4.3.3 of this appendix at the reduced fuel input rate} \]

4.4.1.2 For vented heaters equipped with two stage thermostats, calculate L_{on} defined as:

\[ L_{on} = X_{,0} \cdot L_{s,s,a,-ave} + X_{,0} \cdot L_{s,s,a,-max} \]

where:

\[ X_{,0} = \text{as defined in 4.1.14 of this appendix} \]

\[ L_{off} = \text{as defined in 4.3.3 of this appendix at the maximum fuel input rate} \]

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

\[ L_{off} = \text{as defined in 4.3.3 of this appendix at the maximum fuel input rate} \]

4.4.1.2 For vented heaters equipped with two stage thermostats, calculate L_{on} defined as:

\[ L_{on} = X_{,0} \cdot L_{s,s,a,-ave} + X_{,0} \cdot L_{s,s,a,-max} \]

where:

\[ X_{,0} = \text{as defined in 4.1.14 of this appendix} \]

\[ L_{off} = \text{as defined in 4.3.3 of this appendix at the maximum fuel input rate} \]
where:

100 = conversion factor for percent
0.24 = specific heat of air in Btu per pound

\[ Q_{a,un} = \text{fuel input rate, as defined in 3.1 of this appendix in Btu per minute} \]

\[ t_{un} = \text{average burner on time per cycle and is 20 minutes} \]

\[ \Sigma m_{s,off}(T_{s,off} - T_{ra}) = \text{summation of the twenty values of the quantity, } m_{s,off}(T_{s,off} - T_{ra}), \text{measured in accordance with 3.3 of this appendix} \]

\[ m_{s,off} = \text{stack gas mass flow rate pounds per minute} \]

\[ m_{s,off} = \frac{1.325 P_v C_T}{C_T(T_T + 460)} \]

\[ T_{s,off} = \text{stack gas temperature measured in accordance with 3.3 of this appendix} \]

\[ T_{ra} = \text{average room temperature measured in accordance with 3.3 of this appendix} \]

\[ P_v = \text{barometric pressure in inches of mercury} \]

\[ V_T = \text{flow rate of the tracer gas through the stack in cubic feet per minute} \]

\[ C_T = \text{concentration by volume of the active tracer gas in the mixture in percent and is 100 when the tracer gas is a single component} \]

\[ C_T = \text{concentration by volume of the active tracer gas in the diluted stack gas in percent} \]

\[ T_T = \text{temperature of the tracer gas entering the flow meter in degrees Fahrenheit} \]

\[ T_T + 460 = \text{absolute temperature of the tracer gas entering the flow meter in degrees Rankine} \]

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 3 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 \( L_{off} \) at the maximum fuel input rate. For vented heaters equipped with step-modulating thermostats, calculate \( L_{off} \) defined as:

\[ L_{off} = X_s L_{off,red} \]

where:

\[ X_s = \text{as defined in 4.1.14 of this appendix} \]

\[ L_{off,red} = \text{as defined in 4.3.3 of this appendix at the reduced fuel input rate} \]

\[ L_{off,red} = X_s L_{off,red} * X_s L_{off,max} \]

where:

\[ X_s = \text{as defined in 4.1.14 of this appendix} \]

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 \( D_s \), defined as:

\[ D_s = 1.62 \sqrt{1 - A_b \cos \Omega / A_s} \]

where:

\[ A_b = \text{as defined in 3.4 of this appendix} \]

\[ \Omega = \text{as defined in 3.4 of this appendix} \]

\[ A_s = \text{as defined in 3.4 of this appendix} \]

4.5 Additional 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, \( D_s \) 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 \( D_s \) for vented home heating equipment.

Calculate the ratio \( D_s \) of the rate of flue gas mass through the vented heater during the off-period, \( m_{off}(T_{s,ss}) \), to the rate of flue gas mass flow during the on-period, \( m_{ss}(T_{s,ss}) \), and defined as:

\[ D_s = m_{off}(T_{s,ss}) / m_{ss}(T_{s,ss}) \]

For vented heaters in which no draft is maintained during the steady-state or cool down tests, \( m_{off}(T_{s,ss}) \) is defined as:

\[ m_{off}(T_{s,ss}) = m_{off}(T_{s,ind}) \]

where:

\[ T_{s,ss} = \text{as defined in 3.1.1 of this appendix} \]

\[ T_{s,ind} = \text{flue gas temperature during the off-period measured in accordance with 3.5 of this appendix in degrees Fahrenheit} \]

\[ T_{s,ra} = \text{as defined in 2.9 of this appendix} \]
$M_{\text{in}}(T, \text{ in}) = \frac{1.333 P_a V_{\text{r}}(100 - C_0)}{C_1(T + 460)}$

$P_a = \text{barometric pressure measured in inches of mercury}$

$V_{\text{r}} = \text{flow rate of tracer gas through the vented heater measured in cubic feet per minute}$

$C_p = \text{barometric draft regulator}$

$C_p' = \text{concentration by volume of the active tracer gas in the mixture in percent and is 100 when the tracer gas is a single component gas}$

$T_f = \text{the temperature of the tracer gas entering the flow meter in degrees Fahrenheit}$

$(T_f + 460) = \text{absolute temperature of the tracer gas entering the flow meter in degrees Fahrenheit}$

$M_{\text{fn}}(T_f, \text{ in}) = \frac{C_{p}}{R_{p}(A/F - 1)}/60\text{(HHV)}$

$Q_{\text{in}} = \text{as defined in 4.1.7 of this appendix}$

$A/F = \text{as defined in 4.2.2 of this appendix}$

$\text{HHV} = \text{as defined in 4.2.2 of this appendix}$

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_{\text{f}}) defined as:

$D_f = D_r$

For systems numbered 11 or 12: $D_f = D_1 D_0$

where:

$D_0 = \text{as defined in 4.5.1 of this appendix}$

$D_1 = \text{as defined in 4.4 of this appendix}$

4.5.3 Optional procedure for determining off-cycle draft factor for stock gas flow for vented heaters. Calculate the off-cycle draft factor for stack gas flow (D_{\text{f}}) defined as:

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

For systems numbered 3 or 4: $D_f = (D_0 + 0.79)/1.4$

For systems numbered 5 or 6: $D_f = D_0$

For systems numbered 7 or 8 and if $D_0(S/F) < 1.0$: $D_f = D_0$

For systems numbered 7 or 8 and if $D_0(S/F) > 1.0$: $D_f = D_0 D_r - [0.83 - D_r D_0] (D_0(S/F) - 1)/[S/F - 1]$

where:

$D_r = \text{as defined in 4.5.1 of this appendix}$

$D_0 = \text{as defined in 4.4 of this appendix}$
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

This figure is based on 4500 degree-days and 15°F outdoor design temperature.
APPENDIX C

EXAMPLES

Completed Input Form
Input Files
Computer Runs
## Example-Completed Input Form

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

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

### System Information

<table>
<thead>
<tr>
<th>Fuel #</th>
<th>Control #</th>
<th>Option #</th>
<th>Fuel Cost $/Therm.</th>
<th>Electric. Cost $/kW-h</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>64.6</td>
</tr>
</tbody>
</table>

### Pilot Data

<table>
<thead>
<tr>
<th>Btu/min</th>
<th>Electric kW</th>
<th>Jacket Loss, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0</td>
<td>0.100</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**NOTE #1** Enter 50% input rate values if manual control, type #4.

**NOTE #2** *= enter 0.0 if not measured.

### Fuel Input Data

<table>
<thead>
<tr>
<th>Fuel Input Btu/min</th>
<th>Room Amb. Temp. F or C</th>
<th>Stack Temp. F or C *</th>
<th>Flue Temp. F or C *</th>
<th>CO2 Stack % *</th>
<th>CO2 Flue %</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>21.5</td>
<td>143</td>
<td>157.5</td>
<td>5.6</td>
<td>8.5</td>
</tr>
</tbody>
</table>

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 and Damper Data

<table>
<thead>
<tr>
<th>Stack Area Sq. in.</th>
<th>Damper area Sq. in.</th>
<th>Angle deg.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

### Barometer Data

<table>
<thead>
<tr>
<th>Barometer &quot;Hg or mb&quot;</th>
<th>Gas Temp. F or C</th>
<th>Gas Conc. % or ppm</th>
<th>Gas Flow cu.ft./min</th>
<th>Trac. Conc. % or ppm</th>
<th>Flue Temp. F or C</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.1</td>
<td>20.5</td>
<td>508000</td>
<td>0.00078398</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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


<table>
<thead>
<tr>
<th>Meas. Trac. Conc No.</th>
<th>Trac. Conc % or ppm</th>
<th>Flue Temp. F or C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73.1</td>
<td>161.6</td>
</tr>
<tr>
<td>2</td>
<td>73.3</td>
<td>125.8</td>
</tr>
<tr>
<td>3</td>
<td>77.6</td>
<td>100.3</td>
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<tr>
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<td>89.9</td>
</tr>
<tr>
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<td>78.5</td>
<td>76.8</td>
</tr>
<tr>
<td>6</td>
<td>79.3</td>
<td>70.2</td>
</tr>
<tr>
<td>7</td>
<td>80.3</td>
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<td>61.3</td>
</tr>
<tr>
<td>9</td>
<td>104.9</td>
<td>57.9</td>
</tr>
<tr>
<td>10</td>
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</tbody>
</table>

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


<table>
<thead>
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<th>Meas. Trac. Conc No.</th>
<th>Trac. Conc % or ppm</th>
<th>Flue Temp. F or C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.5</td>
<td>508000</td>
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</tbody>
</table>

### Barometer Data

<table>
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<tr>
<th>Barometer &quot;Hg or mb&quot;</th>
<th>Gas Temp. F or C</th>
<th>Gas Conc. % or ppm</th>
<th>Gas Flow cu.ft./min</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.O</td>
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<td>508000</td>
<td>0.0057</td>
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</tbody>
</table>

Enter next lines only if measured high fire off-loss measured.
### Example Computer Data File

**tstdat.vhtst7**

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

<p>| | | | | | | | |</p>
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</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

---

**Temperatures in degrees celsius**

**Barometric pressure in millibars**

**Default barometric pressure**

END OF FILE

>
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

<table>
<thead>
<tr>
<th>INPUT AMB TEMP TEMP CO2 CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU/MIN TEMP STACK FLUE STACK FLUE</td>
</tr>
<tr>
<td>500.0 72.0 379.9 505.4 6.5 10.0</td>
</tr>
</tbody>
</table>

LOW FUEL INPUT RATE

| 400.0 70.7 289.4 315.5 5.5 8.5 |

HIGH FIRE OFF-LOSS DATA.

| BARO. TEMP. CONC. VOLM. CONC. TEMP. |
| PRES. TRAC. TRAC. TRAC. FLUE 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
-C3-
EXAMPLE COMPUTER DATA FILE

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

<p>| INPUT AMB TEMP TEMP CO2 CO2 |</p>
<table>
<thead>
<tr>
<th>BTU/MIN TEMP STACK FLUE STACK FLUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>800.0 72.0 380.0 505.5 6.5 10.0</td>
</tr>
</tbody>
</table>

HIGH FIRE OFF-LOSS DATA.

<p>| BARO. TEMP. CONC. VOLM. CONC. TEMP. |</p>
<table>
<thead>
<tr>
<th>PRES. TRAC. TRAC. TRAC. FLUE FLUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.43 70.0 .51+006 .78-003 .73+002 322.9</td>
</tr>
<tr>
<td>.75+002 258.4</td>
</tr>
<tr>
<td>.78+002 212.5</td>
</tr>
<tr>
<td>.78+002 184.8</td>
</tr>
<tr>
<td>.78+002 170.2</td>
</tr>
<tr>
<td>.80+002 159.3</td>
</tr>
<tr>
<td>.88+002 150.4</td>
</tr>
<tr>
<td>.10+003 142.3</td>
</tr>
<tr>
<td>.10+003 136.2</td>
</tr>
<tr>
<td>.11+003 130.8</td>
</tr>
</tbody>
</table>

Ls,on =10.51 Li,on = .04
Ls,off= 1.30 Li,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

<table>
<thead>
<tr>
<th>INPUT BTU/MIN</th>
<th>AMB TEMP</th>
<th>TEMP TEMP</th>
<th>CO2 CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>800.0</td>
<td>72.0</td>
<td>380.0</td>
<td>505.5</td>
</tr>
</tbody>
</table>

Df=1.00  Ds=1.00

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

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

\[
AFUE = (0.968 \times 79.94) - 1.78 - 1.84 - \left( \frac{129.80}{800} \right) - (3.93 \times 4.5) + 1.81 = 56.6\% 
\]
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

<table>
<thead>
<tr>
<th>INPUT</th>
<th>AMB TEMP</th>
<th>TEMP</th>
<th>CO2</th>
<th>BTU/MIN</th>
<th>TEMP STACK</th>
<th>FLUE STACK</th>
<th>FLUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD</td>
<td>800.0</td>
<td>72.0</td>
<td>380.0</td>
<td>505.5</td>
<td>6.5</td>
<td>10.0</td>
<td></td>
</tr>
</tbody>
</table>

Li, on= .04

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

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

\[ \eta_{w} = \eta_{ss} - L_{i, on} - C_{i} * L_{i} = 79.94 - 0.04 - (2.8 \times 9.5) = 67.3\% \]

\[ \text{AFUE} = \frac{\eta_{w}}{1 + (2.6 \times \frac{\eta_{w} \times Q_{e}}{Q_{m}})} \]

\[ = \frac{67.3}{1 + (2.6 \times \frac{67.3}{79.94 \times 830})} = 65.85 \% \]

Without \[ C_{i} * L_{i} \]
\[ \eta_{w} = 79.90 \% \]
\[ \text{AFUE} = 77.87 \% \]
\[ \$/\text{M} = 8.44 \]

-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, QF=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

Lit,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, QF=BTU/MIN.= 8.0
ELECTRIC POWER, KW=.100
JACKET LOSS, % LOSS= 4.50

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

HIGH FUEL INPUT RATE DATA

<table>
<thead>
<tr>
<th>BTU/MIN</th>
<th>TEMP</th>
<th>STACK FLUE</th>
<th>FLUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>800.0</td>
<td>72.0</td>
<td>380.0</td>
<td>505.5</td>
</tr>
</tbody>
</table>

DAMPER AREA= 28.00 , STACK AREA= 26.80 ANGLE=25.0

BARO. TEMP. CONC. VOLM. CONC. TEMP.

PRES. TRAC. TRAC. TRAC. FLUE FLUE

Df= .37 Ds= .21

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

WEIGHTED STEADY STATE EFFICIENCY= 79.94%
AFUE= 59.15%
COST/MILLION BTU= $ 11.07
**BIBLIOGRAPHIC DATA SHEET (See instructions)**

<table>
<thead>
<tr>
<th>1. PUBLICATION OR REPORT NO.</th>
<th>2. Performing Organ. Report No.</th>
<th>3. Publication Date</th>
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<tbody>
<tr>
<td>NBSIR 84-2918</td>
<td></td>
<td>September 1984</td>
</tr>
</tbody>
</table>

**4. TITLE AND SUBTITLE**

Fortran 77 Computer Program for Test Procedure Calculations of Vented Heaters

**5. AUTHOR(S)**

R. A. Wise, F. C. Parsons

**6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)**

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

**7. Contract/Grant No.**

**8. Type of Report & Period Covered**

**9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)**

Department of Energy
Forrestal Building
1000 Independence Avenue
Washington, DC 20585

**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

**13. AVAILABILITY**

☐ Unlimited

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☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

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