# Ventilation Of Fallout Shelters
# By Induced Draft

Prepared For

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## ABSTRACT

Occupants of family-type fallout shelters require fresh ventilation air at the minimum survival rate of 3 cfm per person. Because cost limitations exclude the use of auxiliary power plants (diesel or gasoline engines) to operate ventilating fans or blowers, an inexpensive, simple, and effective method of supplying fresh air to home shelters is needed. It is demonstrated that a minimum air rate can be obtained in home shelters by inducing draft in the exhaust stack by means of a flame from a kerosene burner which can simultaneously provide illumination.

The ventilation test procedure included inducing air to flow through the shelter, determining the actual cubic feet per minute of air flowing, measuring air temperatures at inlet, room, and stack, measuring the pressure drop or restriction to air flow at the shelter inlet, and finding the effects of various stack sizes and configurations upon air flow rates. Data were also taken to determine the effect of various stack sizes and configurations on the fuel consumption of the heating devices.

Although not originally intended to be a large part of the research work, a considerable amount of time was spent in finding a sensitive and reliable means of measuring low velocity air flows. This work led to the conclusion (incidental as far as shelter ventilation is concerned) that bead-type thermistors are not reliable air measuring devices when used in a temperature-compensating Wheatstone-bridge circuit.

Ventilation of family-type shelters by the induced draft method is effective and reliable if the following conditions are observed:

1. Wind velocities around the stack outlet are kept to a minimum or a good ventilator stack cap is used.
2. Filters are not used at the shelter inlet (air taken from body of house).
3. The intake area of shelter is much larger than the cross-sectional area of the stack.

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# FOREWORD

The experimental information contained in this report was obtained under Contract No. OCD-PS-64-211 by the Montana State University department of Mechanical Engineering, Dr. H. F. Mullikin, head, and was completed on June 30, 1965. The study was under direction of Prof. C. F. Whitehill. Project leader was O. A. Kubal. N. A. Quintero and M. P. Wambach assisted in the investigation.

The main objective of this contract is to study the ventilation of a family-type fallout shelter, made on the premise that there will be no commercial electricity or natural gas available to provide heat, light, or ventilation. Therefore these items must be obtained by other means.

This study determines the feasibility of ventilating a family fallout shelter using a flame in a chimney. Stack configuration and size studies, fuel and burner studies, and the effects of inlet air restriction on the air flow were investigated. From the data obtained, a ventilation system for a family-type shelter can be designed. Heat and light are incidental to the ventilation method.

## THEORY

### Stack Configurations

To determine the effects of various stack configurations on air flow, 6 and 8 in. diameter stacks were used having vertical heights of 5, 10, 15, and 20, feet. Two elbows spaced by a two foot horizontal length of pipe at the bottom of the stack were also used on various tests. See Figure 1 page 3. The elbows and horizontal run permit about 2 ft 9 in. between the centerline of the original vertical stack and the centerline of the second elbow. It is anticipated that about 2½ ft of horizontal length is all that will be required in the majority of shelter situations to provide adequate shielding from fallout radiations.

In a prototype basement shelter, the elbows and horizontal length would permit running the stack out of the shelter near the ceiling, through the concrete wall into surrounding earth or adjacent basement space, and then vertically.

It should be mentioned that all tests conducted for purposes of this investigation utilized circular cross-sectioned "Metal-Bestos" stack. "Metal-Bestos" stack has about a quarter inch air space between an aluminum inside liner and a glavanized sheet metal outside. Thus, it is a type of self-insulated stack. When a stack diameter is mentioned, it always refers to the inside diameter of the aluminum liner.

The vertical portions of the stack can be partially enclosed in stud spaces or run upward through a hallway and can exhaust directly to the atmosphere or to a ventilated attic. If the stack exhausts directly to the atmosphere, a ventilator stack cap should be used, not only to utilize

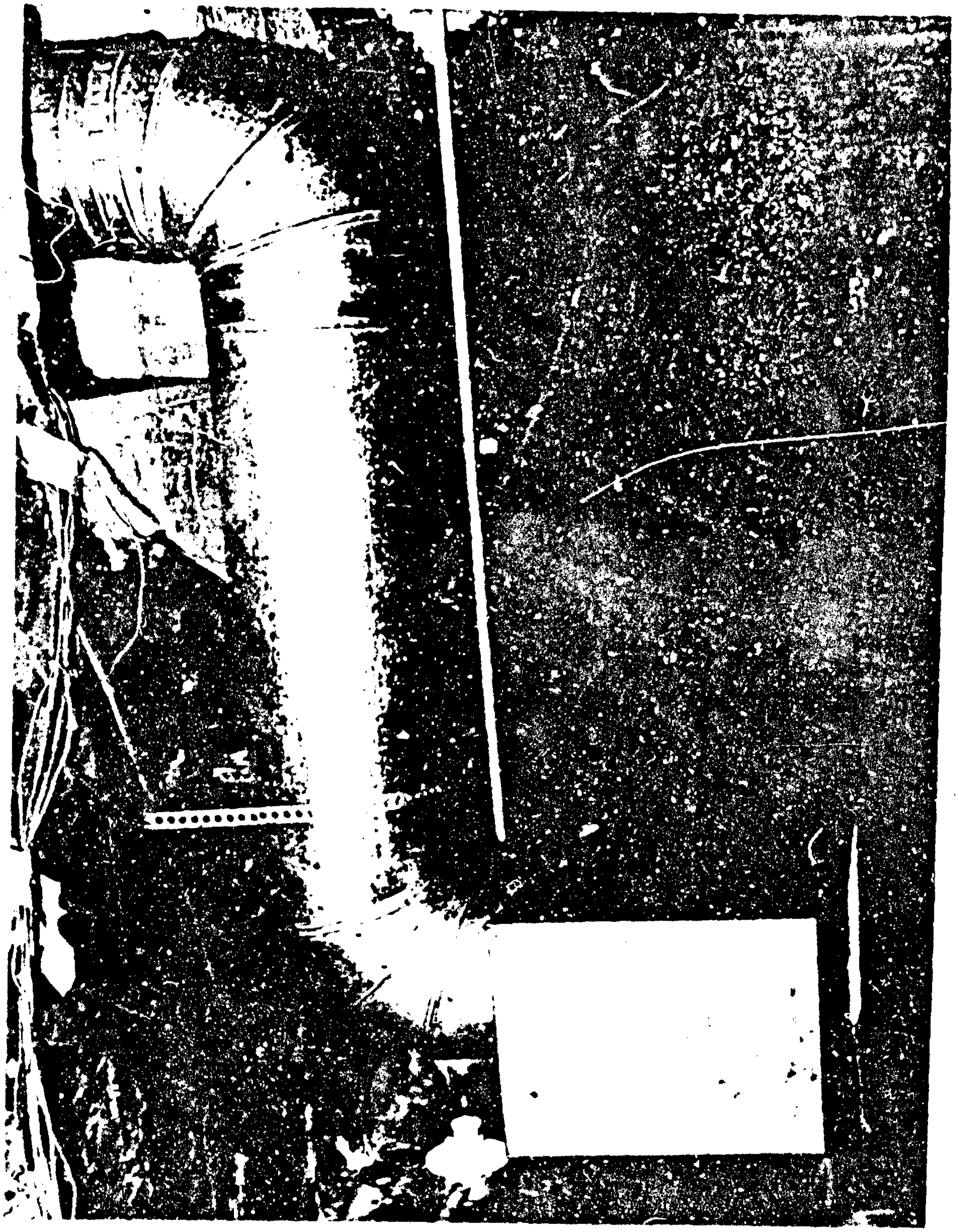


Figure 1. Elbowed Stack Configuration and Entrance Hood

the "suction" forces of prevailing winds to aid ventilation, but also to keep fallout radiation particles and other debris from entering the shelter. If the stack exhausts to an attic containing louvers or other vent openings, a ventilator cap is not needed at the stack outlet because the roof will keep out fallout particles, rain, etc., and will limit wind effects. Intake air can be drawn from the main part of the house. Outside air will enter the house in the normal infiltration method. B. H. Jennings in Heating and Air Conditioning indicates that for the average residence the probable air change rate is about 1-1/2 air changes per hour by natrual infiltration. If the average residence is considered to have a floor area of 1200 sq ft and an 8 ft high ceiling (9600 cu ft of space), this means that normal air infiltration is about 240 cfm. This is more than enough intake air for most basement shelters. Used as the intake air "plemum", the house itself would act as the principal filter for keeping fallout particles from entering the shelter intake. Little additional filtering, if any, would be needed at the intake. Thus a minimum restriction to air flow at the shelter inlet may be obtained.

## Inlet Restrictions

The effects of various inlet restrictions were studied in two general ways-with closed door and open door tests. A closed door test is one in which the door to the shelter is closed and sealed. All air coming into the shelter passes through 8 in. intake ducts. See Figure 2 page 5. In this type of test, the flow rate may or may not be greatly reduced by the restriction offered by the intake duct, depending upon the stack length, diameter, and temperature (or the amount of air trying to flow). This type of test is also designated as closed door in order to distinguish it from an "open door" test which, as the term implies, is

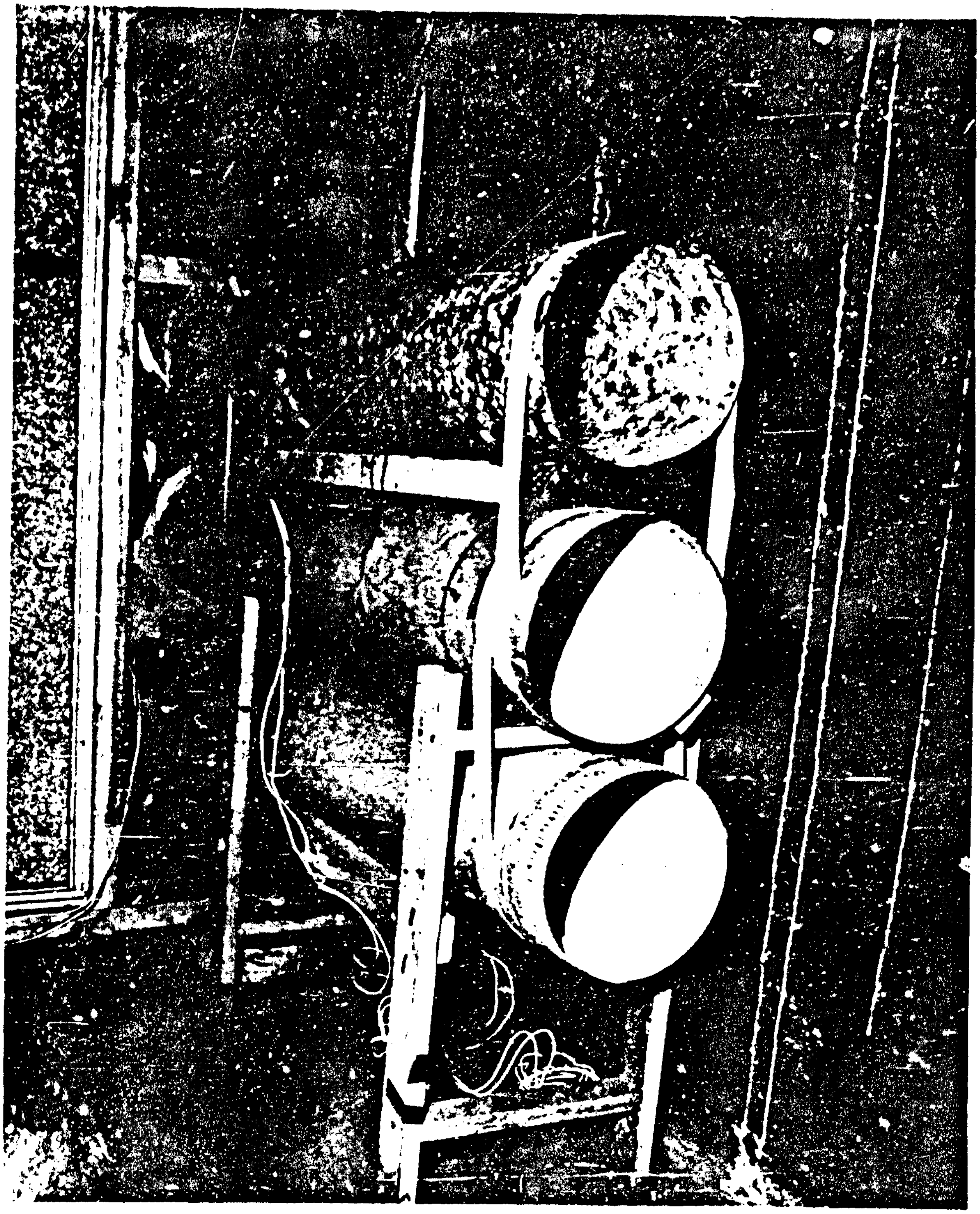


Figure 2. Shelter Air Intake Ducts

conducted with the shelter door open. In this case there is no measurable pressure drop at the intake and thus flow rate is not limited by any intake restriction. The limiting factor for flow is the stack itslef. Thus air flow for an open door test is sometimes called "unrestricted flow" and that for a closed door test is called "restricted flow". In both cases, the restriction or absence of restriction refers to intake conditions only.

## Fuel and Burners

To obtain the required ventilation air through the test shelter, a safe, inexpensive, and easily operated combustion unit is needed to generate heat in the stack bottom. Liquefied petroleum gases such as propane and butane were excluded because of their high specific gravities. Being heavier than air, these fuels would collect in the shelter if leaks developed and would be inherently dangerous from an explosion and fire standpoint. They also present a problem of storage because pressurized containers must be used. Again, this would be dangerous if punctures or leaks developed.

Natural gas would be an ideal fuel to use in the shelter, but it, like electricity, cannot be assumed to be available through normal commercial channels during shelter occupancy.

Gasoline would be unsafe in a shelter situation because of its high volatility and flammability. It would require special and perhaps expensive combustion equipment. When held in storage over relatively long periods of time, gasoline sometimes has a temdency to form gums. Their presence in the fuel could lead to combustion equipment plugging.

At a first consideration it appears that coal, being inexpensive and relatively easy to burn, would be a good fuel. However, coal presents problems from the standpoint of storage space and ash removal. Coal burning devices would be complicated and require more draft than those for oil or gas because of the resistance of the fuel bed. For these reasons coal was deemed undesirable as a test fuel.

It was decided that kerosene (No. 1 diesel oil) would best serve the purpose. This fuel burns with a relatively clean flame, burners need not be complex or expensive, and storage in cans or other ordinary containers is relatively safe. It is also suitable as an illuminant when burned in a wick lamp or wick-type burner.

Flow Equation

To predict air flow through the shelter for stacks and conditions in addition to those tested, an equation which can be applied to various inlet and outlet configurations and conditions is herein developed and discussed.

The following equates the positive buoyant force of a column of hot gases with the force of friction required to establish and maintain flow.

$$(1) \qquad \frac{H}{62.4}\ (\rho\,\mathrm{rm} - \rho\,\mathrm{ch}) = (h_v) + (h_L) = K\left(\frac{V^2}{2g}\right) + f\,\frac{L}{D}\left(\frac{V^2}{2g}\right)$$

where H is vertical stack height, ft; and 62.4 is the density of water at 70° F in lb/cu ft, included so that both sides of the equation are expressed in the common "feet of fluid flowing" units. In the case of air, it is more convenient to deal with the velocity head ($h_v$) and the friction loss head ($h_L$) in "inches of water" units rather than "feet of air" units. The transformation can be made by again using the fundamental buoyancy relation,

$$(2) \qquad h_a \rho_a = \frac{h}{12} \rho_w$$

where $h_a$ = feet of air; $\rho_a$ = density of air in lb/cu ft; h = inches of water (gage); and $\rho_w$ = density of water at 70° F in lb/cu ft. Thus, it is seen that,

$$(3) \qquad h_a = \frac{h}{12} \left(\frac{62.4}{\rho_a}\right) = 5.2 \frac{h}{\rho_a}$$

For the velocity head term, $h_v$, in inches of water,

$$(4) \qquad K \frac{V^2}{2g} = 5.2 \frac{h_v}{\rho_a} \qquad \text{or} \qquad h_v = K \frac{V^2 \rho_a}{5.2\,(2g)}$$

With stack air velocity, V, as feet per minute,

$$(5) \qquad h_v = K \frac{V^2 \rho_a}{(5.2)(2)(32.2)(3600)} = K \frac{V^2 \rho_a}{1,202,000} = K \left(\frac{V}{1096}\right)^2 \rho_a$$

By substituting equation (5) into equation (1), we obtain the driving force relationship expressed in inches of water. Hence,

$$(6) \qquad \frac{H}{62.4}(12)(\rho_{rm} - \rho_{ch}) = \frac{H}{5.2}(\rho_{rm} - \rho_{ch}) = K \left(\frac{V}{1096}\right)^2 \rho_a + f \frac{L}{D} \left(\frac{V}{1096}\right)^2 \rho_a$$

Equation (6) applies to shelter air flow in general if terms with the appropriate subscripts are used. Thus,

$$(7) \qquad \frac{H}{5.2}(\rho_{rm} - \rho_{ch}) = K_1\left(\frac{V_1}{1096}\right)^2\rho_{in} + f_1\frac{L_1}{D_1}\left(\frac{V_1}{1096}\right)^2\rho_{in} + K_2\left(\frac{V_2}{1096}\right)^2\rho_{ch} + f_2\left(\frac{V_2}{1096}\right)^2\rho_{ch}$$

Where: $H$ = vertical height of stack, ft

$\rho$ = air density, lb/cu ft

$K$ = duct or stack entrance loss coefficient

$V$ = air velocity, ft/min

$L$ = duct or stack equivalent length, ft

$D$ = duct or stack diameter, ft

$f$ = duct or stack friction factor

rm = conditions of space surrounding the stack, usually ambient air conditions

1, in = conditions at shelter intake

2, ch = conditions at stack or shelter exhaust

For the purpose of using equation (7) to predict shelter ventilation rates that can be compared to test results, the constants and coefficients had to be evaluated for conditions that existed during experimentation. All closed door test were made with the air passing into the shelter through an 8 in. diameter duct. This allows the D and L terms of equation (7) to be fixed at 0.667 ft and 3.834 ft, respectively. Values for both of the entrance loss coefficients, $K_1$ and $K_2$, are assumed for the poorest entrance conditions, i.e., $K_1 = K_2 = 1$. This assumption is based on several facts and conditions. The intake duct is a re-entrant type of pipe entrance for which the nominal value of loss coefficient is 0.8. In the end of the duct, however, is an aluminum-foil tubular grid which offers not only additional entrance loss, but also additional friction loss. Entrance to the stack, for all test conditions, is made through the rectangular hood described on page 43. It represents a hood condition similar to that described by W. C. L. Hemeon in Plant & Process Ventilation. He states that for a hood with low face velocity and relatively low stack temperatures, the entry coefficient is 0.9. This coefficient is further increased in the test case because the heat generating equipment extends into the hood a short distance and thus disturbs the flow. For these reasons it is believed that the assumption of $K_1 = K_2 = 1$ is very reasonable.

In considering the friction factors for the intake duct and the stack, it is believed that the standard tabulated values of f, given as a function of Reynolds number and pipe relative roughness, are not entirely applicable. Both the intake duct and the stack contain obstructions not normally found in pipes or duct. The intake duct houses the tubular grid near the entrance, a special thermocouple anemometer, a propeller anemometer, and a thermocouple probe. The stack contains pressure taps, thermocouple probes, and, in the case of the 6 in. diameter stack, a layer of soot on the wall surfaces. The friction factors were thus obtained experimentally from a test performed with a 6 in. diameter 15 ft long straight stack. A flow was induced in the system and the room entrance pressure drop, the flow at inlet conditions, and the necessary temperatures were measured. The friction factor at inlet, $f_1$, was then calculated by equating the measured $\Delta P_{rm}$ to the first two terms on the right-hand side of the equations (7) and solving for $f_1$. The value arrived at in this manner is $f_1 = 0.415$. When this is compared to tabulated friction values it appears to be extremely high. But when the resistance offered by all of the equipement in the duct is considered, this value of $f_1$ seems reasonable. With $f_1$ thus established, equation (7) was solved for the remaining unknown quanity, $f_2$. The value of $f_2$ determined in this manner is 0.064. Another assumption made at this point was that the friction factors would remain constant for all diameters and lengths of stack considered. It is shown in a latter section of this report that this assumption is conservative.

The constants and coefficients thus determined can be inserted into equation (7) to yield a somewhat refined flow equation. Performing the substitutions we obtain.

$$(8)\qquad \frac{H}{5.2}(\rho_{rm}-\rho_{ch}) = 1\left(\frac{V_1}{1096}\right)^2\rho_{in} + \frac{(0.415)(3.834)}{0.667}\left(\frac{V_1}{1096}\right)^2\rho_{in} + 1\left(\frac{V_2}{1096}\right)^2\rho_{ch} + 0.064\,\frac{L_2}{D_2}\left(\frac{V_2}{1096}\right)^2\rho_{ch}$$

which, when simplified, yields,

$$(9)\qquad \frac{H}{5.2}(\rho_{rm}-\rho_{ch}) = 3.385\left(\frac{V_1}{1096}\right)^2\rho_{in} + \left(\frac{V_2}{1096}\right)^2\rho_{ch}\left[1 + 0.064\,\frac{L_2}{D_2}\right]$$

Inspection of this last equation shows the variables to be: barometric pressure; and ambient, stack, and inlet temperatures (all from density considerations, i.e., $\rho = P_B\,(0.491)(144)/R(T+460)$); intake and stack air velocities; stack diameter $D_2$; stack vertical height H; and stack equivalent length $L_2$.

The equivalent stack length ($L_2$) warrants further discussion. For a stack without elbows or bends, $H = L_2$. Additionally the stack may contain two 90° elbows and a 2 ft section of horizontal pipe. In a manner similar to that for finding the friction factors, an equivalent pipe length for one 6 in. 90° elbow was calculated to be 4.2 ft. The total equivalent length of both elbows and the horizontal run is thus 10.4 ft. Reference to the 1963 ASHRAE Guide and Data Book indicates that the equivalent length of such an elbow is 8 ft. This latter value, however, is based on a relatively long duct system containing "full" flow, i.e. forced circulation. When used in this sense, it is not extremely critical. In the test stack the equivalent length has a considerable influence on flow as shown by the equation. The use of the lower value of 4.2 ft per elbow is justified because of the vary short duct arrangement and because "full" flow around the elbow is never realized.

The final assumption for use with equation (9) is that the equivalent length for all diameter elbows is constant at 4.2 ft per elbow. This is again a conservative estimate.

A digital computer program of equation (9) was written in order to predict flows for many different conditions of stack diameters, stack lengths, temperatures, pressure, etc. Values from the computer program are termed "theoretical" values. It should be mentioned that for open-door test predictions, the first term on the right-hand side of equation (9) vanishes. This means that there is essentially no restriction to flow at the shelter inlet.

All tests were conducted at approximately 5000 ft altitude (Bozeman, Montana) and thus the experimental results are in terms of actual conditions, i.e., barometric pressure ($P_B$ = 25 in. Hg) and temperatures at 5000 ft. The computer equation was also solved using standard or sea level conditions

($P_B$ = 29.92 in. Hg and $T_{ambient}$ = 70° F) to determine the effect of altitude on flow.

## DESCRIPTION OF SHELTER

The shelter used for conducting ventilation test is located on the Montana State University campus in Bozeman, Montana. The shelter was adapted from an underground blind tunnel located beneath the floor of the Mechanical Engineering Department's power Laboratory. The original tunnel structure was rectangular in shape with internal dimensions of 37 ft by 6 ft. The ceiling is flat and approximately 6 ft high. Adjacent to the east end of the room is a 6 by 7 ft open entryway. Modifications were made to the original tunnel to the extent of adding a partition and a door at a distance of 7 ft from the east end. Thus the space used as a test shelter was 30 ft by 6 ft dimensions. The walls, floor, and ceiling or the shelter are all 8 in. thick concrete.

The partition, with 2 x 4 framing consists of 6 mil polyethylene sheet fastened to the frame with duct tape. Caulking compound and duct tape were used to close all cracks between the partition framing and concrete. A 2½ ft by 6 ft particle-board door was installed in the center of the partition and sealed with weather stripping.

An 8 in. diameter 3.8 ft long sheet metal duct was installed in the polyethylene partition about 2 ft from the floor and sealed with tape. This duct was used as the air intake to the shelter. To assure streamline flow in the intake, 1 in. diameter aluminum foil tubes, 12 in. long, were nested in the upstream end of the 8 in. duct.

At the west end of the shelter a 1 ft 9 in. square section of concrete was removed from the ceiling through which the outlet stacks were installed. Figure 3 on page 15 is a line sketch of the shelter test facility showing intake duct and stack locations. See also Figure 4 on page 16 for picture

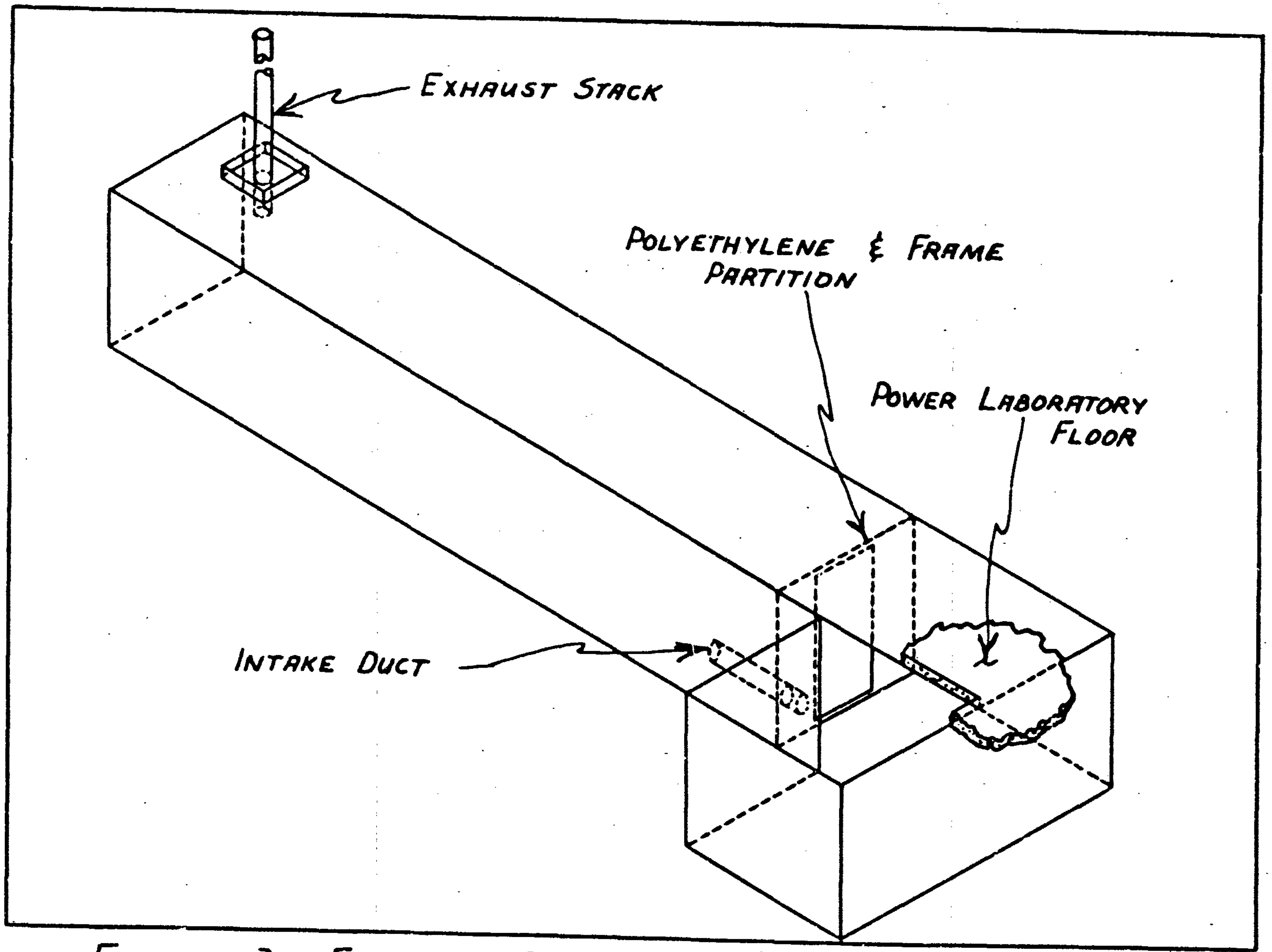


FIGURE 3. FALLOUT SHELTER TEST FACILITY

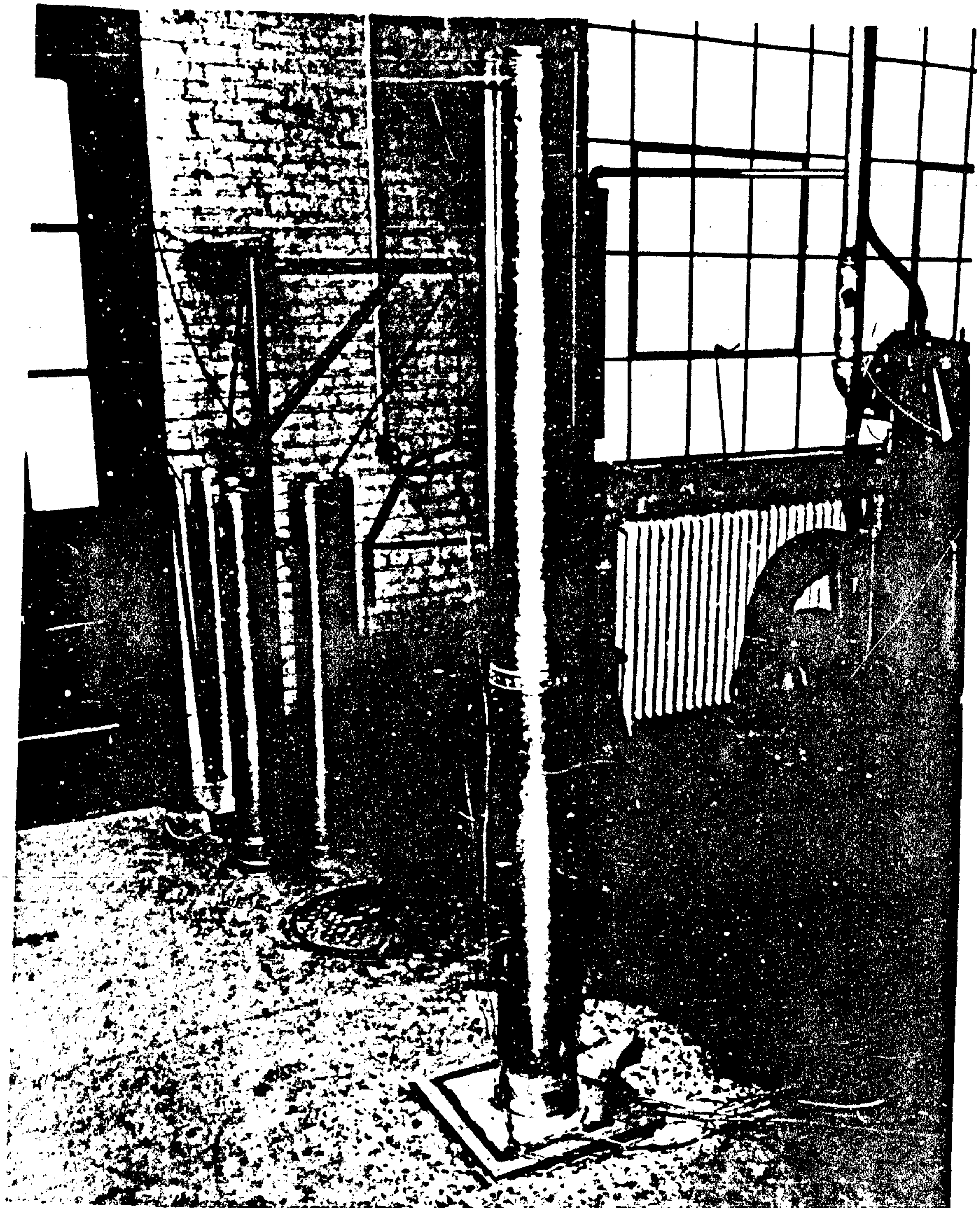


Figure 4. Stack Extending from Shelter

of stack extending from shelter.

Minimums established by the Civil Defense other than the 3 cfm ventilation rate include 60 to 65 cu ft of space per person and 10 sq ft of floor space per person. The test shelter, with a floor area of 180 sq ft and a 6 ft ceiling, provides 60 cu ft of space for each of 18 people. Based on the minimum air rate, at least 54 cfm of outside air is required.

With a rated capacity of 18 people, the test shelter is in the category of family-type shelters. It also represents an ideal family basement shelter in other ways. The stack is completely contained within the power laboratory which has a ceiling approximately 30 ft high. Intake air is drawn at the floor level of and exhausted near the ceiling of the laboratory. Skylight windows in the laboratory ceiling may be opened to permit the hot stack gases to escape into the atmosphere.

## INSTRUMENTATION AND CALIBRATION

### Air Flow Measurements

For use with ventilation tests a reliable and sensitive method for measuring low velocity air flows was needed. Because the pressure available to cause air flow is very small, the method of measuring the air that flows into the shelter has to be such that their is little or no pressure drop. This eliminates an orifice which, by its nature, requires a pressure drop.

Personnel from Electronics Research, Montana State University, were consulted concerning the possibility of measuring air flow in a duct using a thermistor probe. Since this group had previously conducted apparently successful research on thermistors, they agreed to design and build the necessary circuitry and thermistor probe.

The thermistor circuit used was a temperature-compensating Wheatstone-bridge circuit using transistors to maintain constant current. Several bead-type thermistors were tried in this circuit without success. Much time was spent trying to develop a reliable anemometer from the thermistors but the problem of temperature compensation was not completely solved. Details of the thermistor anemometry, including calibration procedures, can be found in Appendix A.

Another unsuccessful attempt to measure air flow was made using a hot-wire anemometer. The instrument was neither sensitive enough nor accurate enough at low air velocities.

In search of an instrument or method to measure air flow through the shelter, a special thermocouple device consisting of two thermocouples wired in series set one behind the other in the air flow stream was constructed. Between the thermocouples is a common resistor giving off a constant quantity of heat. The thermocouples sense the increase in air temperature caused by heating the resistor and produce a voltage output which depends on air velocity. A sketch of the simple anemometer is shown in Figure 5a on page 20. Figure 5b shows in part the thermocouple and resistor wiring diagrams. Assumptions concerning the design paramenters of the meter are:

1. Flow rate range expected to be measured in one 8 in. intake duct is 10 to 150 cfm at actual conditions (70° F and 25 in. Hg).
2. Anemometer will be installed in one of the 1 in. aluminum foil tubes and placed in the center of the intake duct.
3. Accuracy in measurement of air temperature difference at the highest anticipated flow is limited to 1° F using iron-constantan thermocouples.
4. A minimum input of 40 volts d.c. is available as supply voltage.
5. The specific heat of air throughout the expected flow range is constant at 0.24 Btu/lb °F.

Calculations for the required size of resistor are given below. The reader is referred to any standard text on thermodynamics or heat transfer if a more complete explanation of the basic equations is desired.

The weight of air per minute flowing through the 8 in. intake duct ($w_8$) is given by the perfect gas law as:

$$w_8 = \frac{P_B\ (\text{in. Hg}) \times V\ (\text{ft}^3/\text{min}) \times 0.491\ (\text{psi/in. Hg}) \times 144\ (\text{in}^2/\text{ft}^2)}{R(\text{ft-lb/lb}\ ^\circ\text{F abs}) \times T_a\ (^\circ\text{F abs})}$$

$$= \frac{25(0.491)(144)V}{53.3(530)} = 0.0625\ V$$

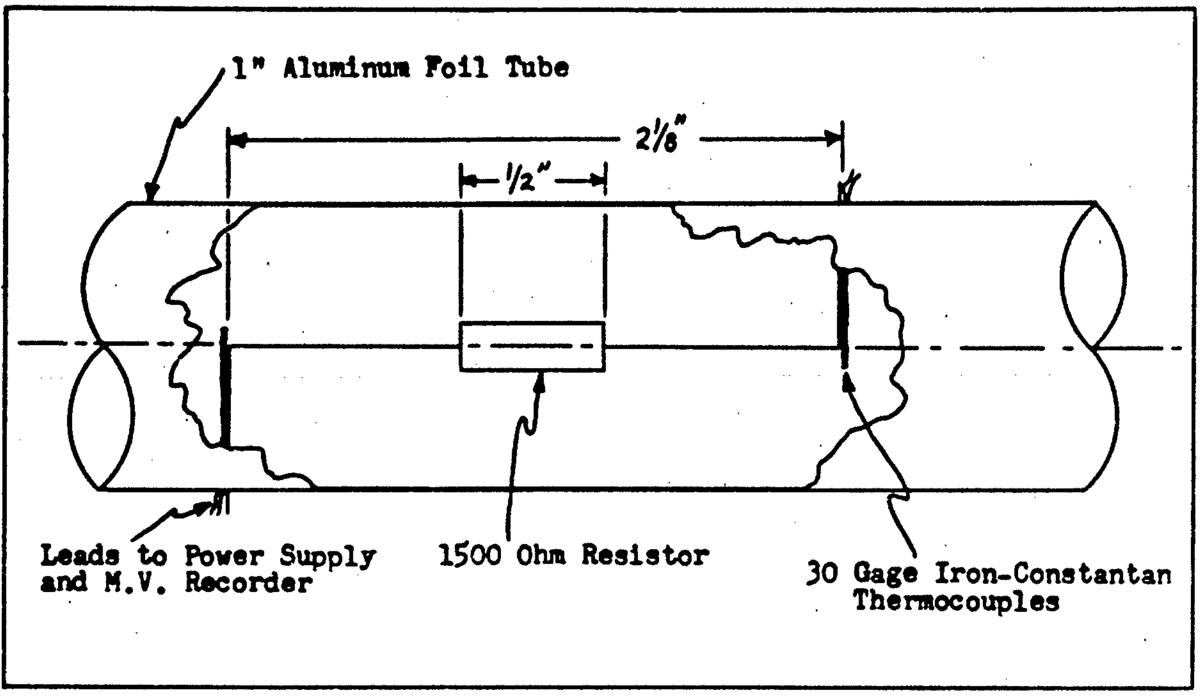


Figure 5a. Special Thermocouple Anemometer

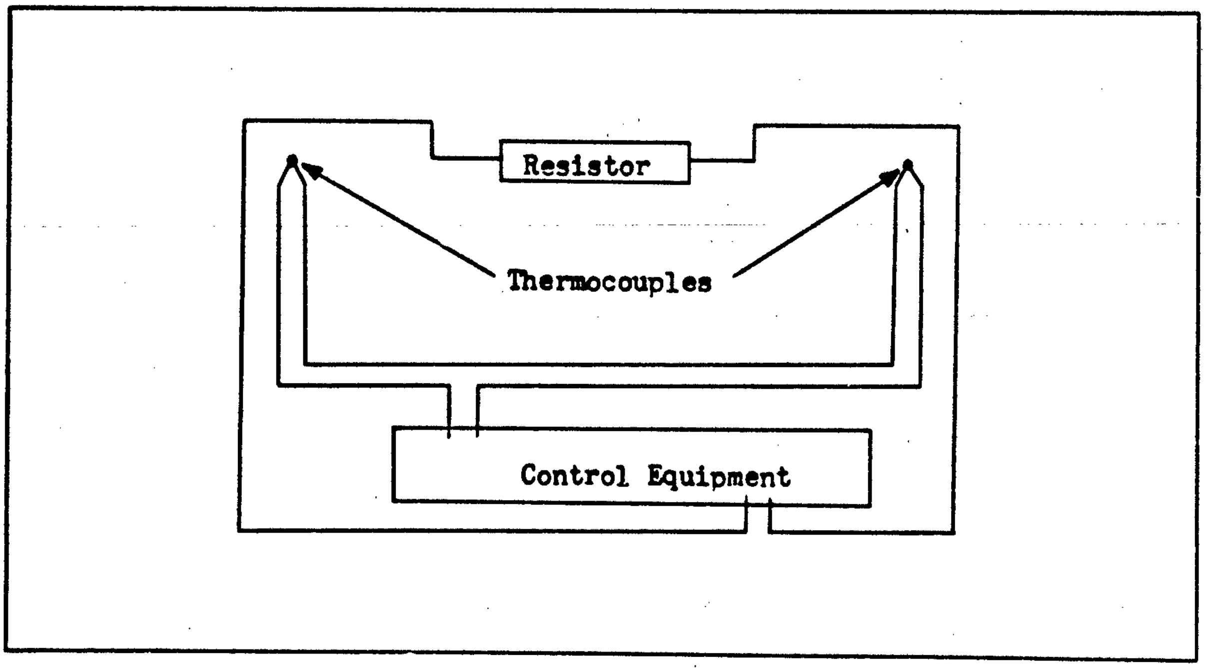


Figure 5b. Resistor & Thermocouple Wiring Diagram

At the lowest flow (V) of 10 cfm,

$$(w_8)_\ell = 0.625 \times 10 = 0.625 \text{ lb/min}$$

At the highest flow of 150 cfm,

$$(w_8)_h = 0.0625 \times 150 = 9.37 \text{ lb/min}$$

Area of the 1 in. foil tube,

$$A_1 = \pi d_1^2/4 = 0.785 \text{ in}^2$$

Area of the 8 in. duct,

$$A_8 = \pi d_8^2/4 = 50.2 \text{ in}^2$$

The weight flow of air in the 1 in. tube is given by multiplying the weight flow in the 8 in duct by the area ratio. Hence,

$$(w_1)_\ell = (w_8)_\ell \times A_1/A_8 = 0.625 \times 0.785/50.2 = 0.00977 \text{ lb/min}$$

and $(w_1)_h = (w_8)_h \times A_1/A_8 = 9.37 \times 0.785/50.2 = 0.1465$ lb/min

Heat from the resistor (Q, Btu/min) supplied to the air is given by the specific heat equation for constant pressure, $Q = wc_p \Delta T$. At the highest flow with a temperature difference ($\Delta T$) of 1° F,

$$Q_h = (w_1)_h c_p \Delta T = 0.1465 \times 0.24 \times 1$$

$$= 0.0351 \text{ Btu/min}$$

If heat from the resistor is held constant at $Q_h$, then $\Delta T$ for any flow is given by,

$$\Delta T = Q_h/w\, c_p = 0.0351/0.24\, w = 0.1452/w.$$

Thus the maximum $\Delta T$, at the lowest weight flow $(w_1)_\ell$ , should be:

$$\Delta T_{max} = 0.1452/0.00977 = 14.87^\circ \text{ F}$$

In order to hold constant the heat from the resistor at $Q_h$, the power (P) supplied to the resistor should be:

$$P = 0.351(\text{Btu/min}) \times 778(\text{ft-lb/Btu})$$

$$\times 1/33.000(\text{ft-lb/min hp}) \times 746 \text{ (watts/hp)} = 0.517 \text{ watts.}$$

Because $P = I^2R = vI$, the current (I) required to maintain the above power (assuming v is constant at 40 volts) is:

$$I = P/v = 0.617/40 = 0.0154 \text{ amps.}$$

The maximum resistance for the anemometer is:

$$R_{max} = v/I = 40/0.0154 = 2595 \text{ ohms.}$$

The thermocouple anemometer was constructed according to the original ideas and assumptions except that the resistor used was one rated at 1 watt and 1500 ohms. This resistor, rather than one of 2595 ohms was decided upon because of availability and its small physical size.

The one-inch foil tube with the meter installed in its center was placed in the center of the tubular grid at the end of the 8 in. intake duct. Appropriate leads were connected to the resistor and thermocouples. A vacuum tube voltmeter was used to read the generated voltage from the thermocouples. A preliminary test run was conducted with about 38 volts input to resistor. This voltage was used instead of 40 volts to keep the power near but less than one watt. The output of the instrument appeared stable over the entire range of flow from 10 to 150 cfm, but the change in output voltage over this flow range was limited to about 0.25 millivolts. To extend the output range scale at the vacuum tube voltmeter (VTVM), a 180 K ohm resistor and a small adjustable resistor were added to the circuit. To obtain a permanent record of output, a 0-10 millivolt recorder was indirectly connected to the 0-1 volt output scale of the VTVM through a voltage divider (two arbitrarily chosen resistances) whose purpose was to again extend the scale range. Arrangement of the equipment is shown in Figure 6 on page 23. The 20.1 K ohm resistor in series with the voltmeter permits close control of input voltage to the anemometer resistor.

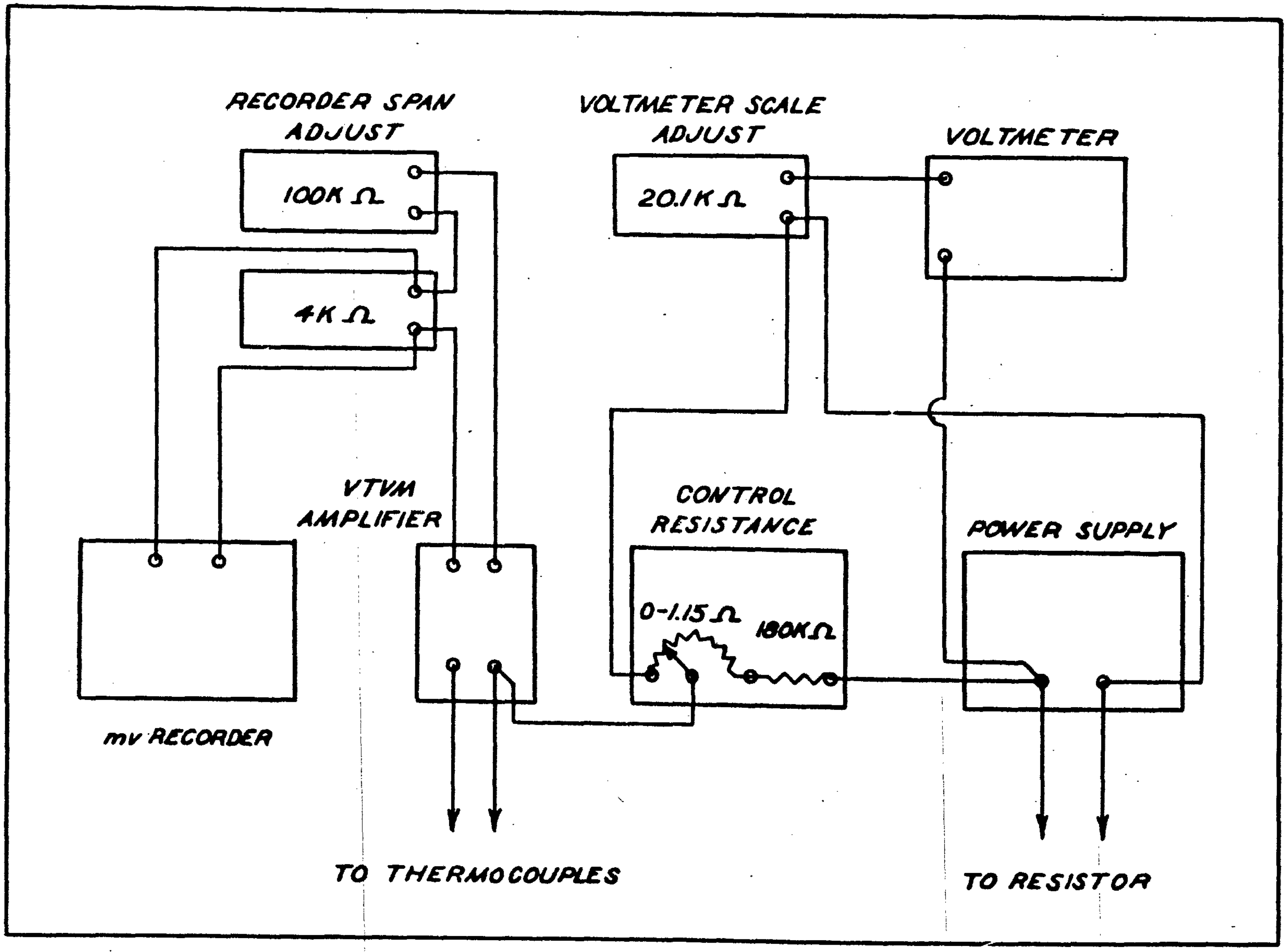


FIGURE 6. CONTROL EQUIPMENT FOR THERMOCOUPLE ANEMOMETER

The 0-1.15 ohm adjustable resistor is used to adjust the recorder scale to zero when the anemometer is in still air. This circuit, with divider resistances chosen by trial and error, allows nearly a 9 millivolt output range at the recorder over the 150 cfm flow range.

Calibration of the thermocouple anemometer indicates that the instrument provides a fairly reliable method of measuring air flows above about 40 acfm. See Figure 7 for the calibration curve. Between flows of 40 and 20 cfm, the millivolt output does not change enough to sufficiently describe a particular point on the circular portion of the curve.

Although the use of the thermocouple anemometer is somewhat limited at low air flows, it was one of the two methods finally used in the shelter ventilation tests. It is believed that flow measurements taken with this device above 40 acfm can be trusted.

The second method of air flow measurement finally adopted employs an all-mechanical propeller anemometer, sometimes referred to in this report as the "windmill". The instrument consists of an eight-bladed fan, each blade being about 1-3/16 inches long. Motion of the fan shaft is transmitted to a set of indicating dials through a network of tiny gears. Figure 8 in page 26 shows the windmill, its position at the outlet end of the intake duct, and the clamping arrangement for its support.

A stop watch is used with the windmill when a reading is taken because the dials indicate lineal feet of air rather than air velocity. Windmill operation is somewhat maladroit because the dials must be correctly read and the readings recorded each time the watch is started and stopped. Also there is no permanent record from which to later recheck a velocity reading. Despite these drawbacks, the propeller anemometer provides a

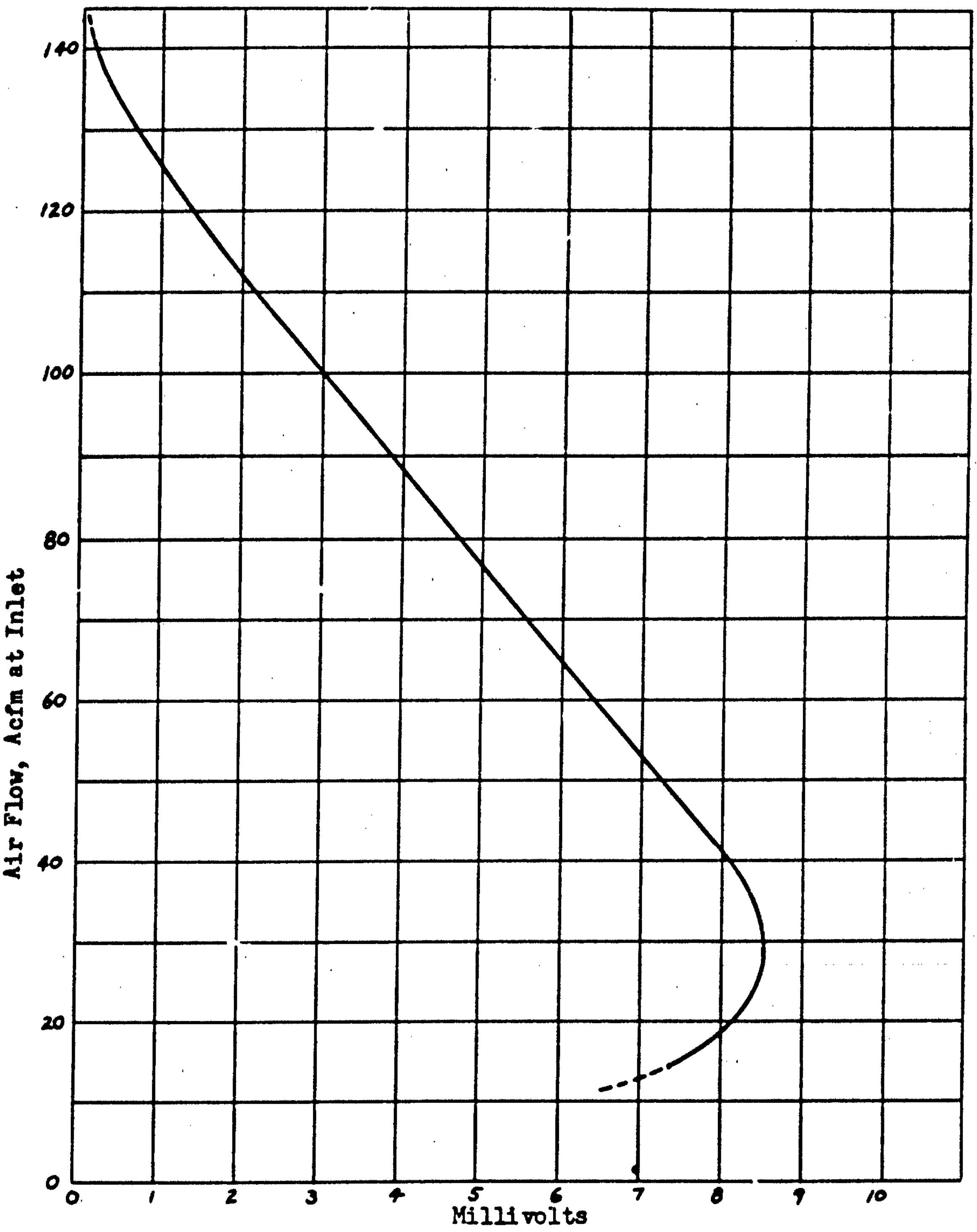


Figure 7. Calibration Curve for Thermocouple Anemometer

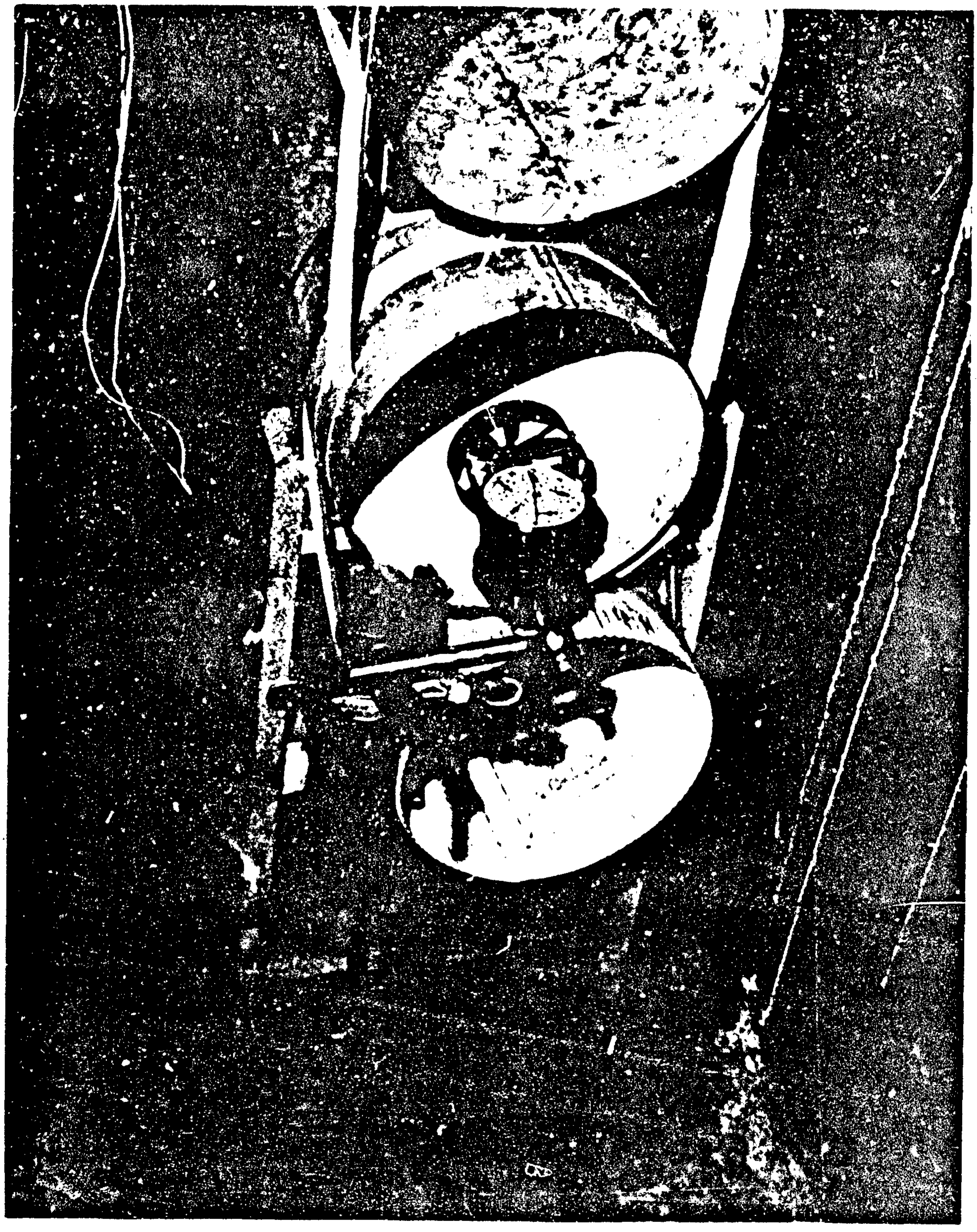


Figure 8. Propeller-Type Anemometer

reasonably accurate and reliable means for measuring air flow.

During calibration of the anemometers, a laminar flow element, manufactured by the Meriam Instrument Company, was used with an accompanying centrifugal blower as the air flow standars. This laminar flow device, applicable to air flows from 0 to 200 standard cfm (at 29.92 in. Hg and 70° F), consists of parallel, capillary-size tubes through which the air flows. The pressure drop across the tubes has a straight-line relationship with the mass air flow. A calibration curve of this relationship, showing pressure drop across the tubes (in. of water) versus standard air flow (lb per min) is supplied with the element.

To calibrate the windmill and the thermocouple anemometers the laminar flow element was connected to a small 4 in. connection on stack roof jack shown in Figure 4 on page 16. This 4 in. connection was used only for pulling air from shelter during calibration. Except for this connection and the air intake duct, the test room was supposedly air tight, but because of imperfections in the construction of the shelter it is conceivable that air leaks existed in the system. Since the total amount of air coming into the shelter (including leakage air) went out through the 4 in. connection, thus into the laminar flow element, the readings obtained from the laminar flow element included the total amount of air drawn into the room. Therefore any leakage air is accounted for in the calibration curve.

Tests covering the entire expected flow range were conducted at air intake temperature intervals of two degrees from 62° F to 90° F. Humidity of the intake air was varied during several of the runs by spraying steam into the stairwell entrance of the shelter. Calibration of

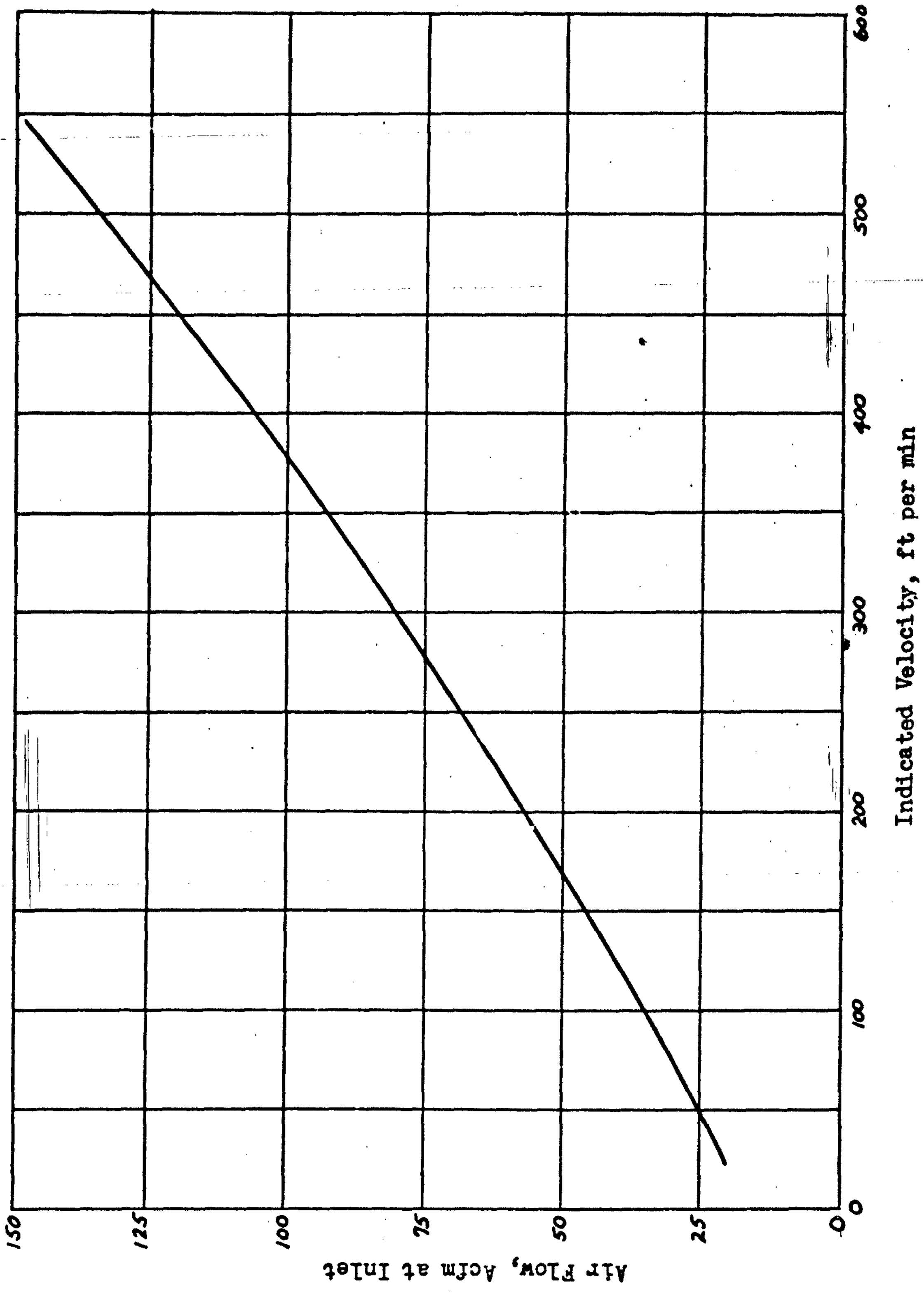


Figure 9. Calibration Curve for Propeller Anemometer

neither instrument is affected by changes in intake air temperature or humidity.

The calibration curve for the propeller anemometer, showing apparent or instrument air velocity (calculated from instrument and stop watch readings) versus actual cfm, is nearly a linear relationship. A representation of this curve is shown in Figure 9. (Below an instrument air velocity of 18 ft per min the anemometer vanes do not rotate.) All calibration points, a total of 87, for all temperatures and humidities lie within +3.5 and -3.3 percent of the points dictated by the calibration curve drawn.

Test points for the calbration curve described earlier for the thermocouple anemometer are all within +4.9 and -7.6 percent (these being the two most erratic points) of the values read from the curve drawn.

Although the windmill and the thermocouple anemometer do not extend to extremely low flows, they do permit reliable air flow measurement from 19 to 143 acfm. Both methods are independent of ambient air temperature and humidity changes, and either method provides results within good engineering accuracy. Because the thermocouple anemometer is the least accurate and the least comprehensive of the two instruments, it is used only to confirm the readings obtained by the propeller anemometer. The two instruments are used simultaneously when testing.

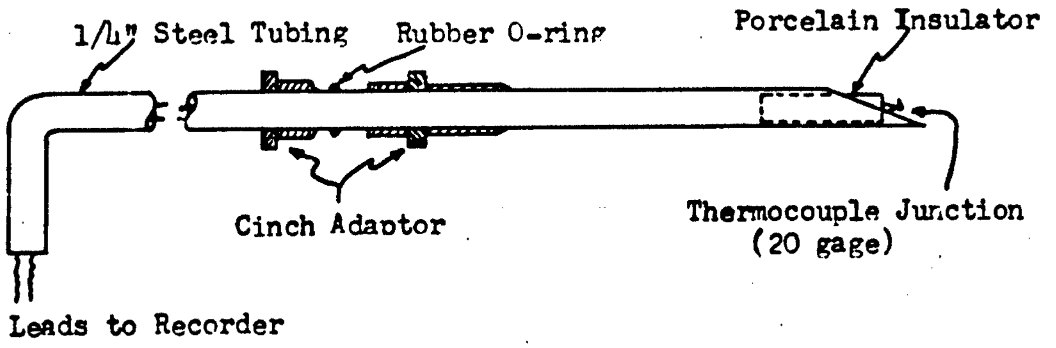
## Temperature Measurements

To properly evaluate the effect of the flame in the chimney, stack as well as room and ambient temperatures must be determined. The first attempt to measure temperature in a straight 6 in. diameter, 15 ft long stack involved placing copper-constantan thermocouples every few feet. The thermocouple wires, with original insulation only, were inserted through small holes in the stack wall. The thermocouple junctions were located at about the center of the gas stream. This arrangement proved to be inadequate because representative temperatures along the stack could not be obtained. Wide variations in temperatures at different locations along the stack were caused by thermocouples "seeing" the flame at the stack bottom and because of temperature and gas velocity profiles across the stack cross section.

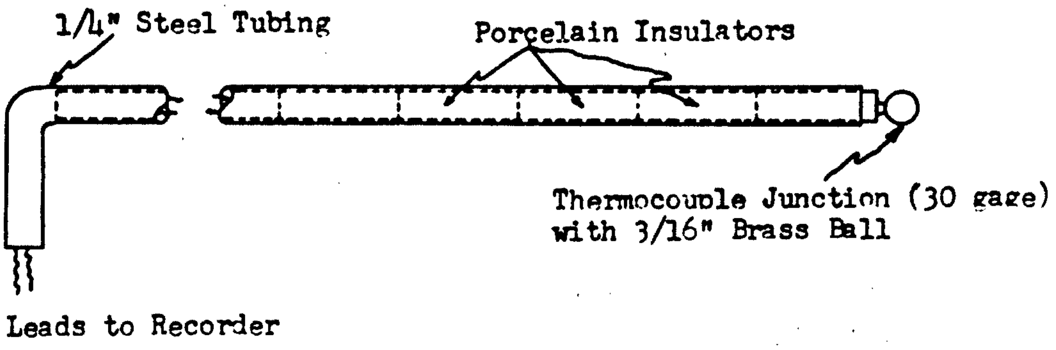
To improve the accuracy of temperature readings and to provide a means of taking a traverse across the stack, movable thermocouple probes were built. The first probes built, shown in Figure 10a on page 31, consist of 20 gage iron-constantan thermocouple wires inside steel tubes about 11 in. long. The tubes pass through brass cinch adapter tubing fittings soldered into the stack wall. The angled end of the probes permits the thermocouple to be exposed to the gases, yet provides shielding against direct radiation from flame.

A temperature traverse was taken with these probes at an average stack temperature of about 500° F. Some very unusual results were obtained, especially with the probe nearest the combustion chamber. A temperature difference as high as 175° F occurred between two points, each point being about 1/2 inch from the stack wall but on opposite sides. The higher of the two temperatures was at the "far wall" point, i.e., with the probe extending all the way across the stack. Similar temperature differences were found at all points along the stack length.

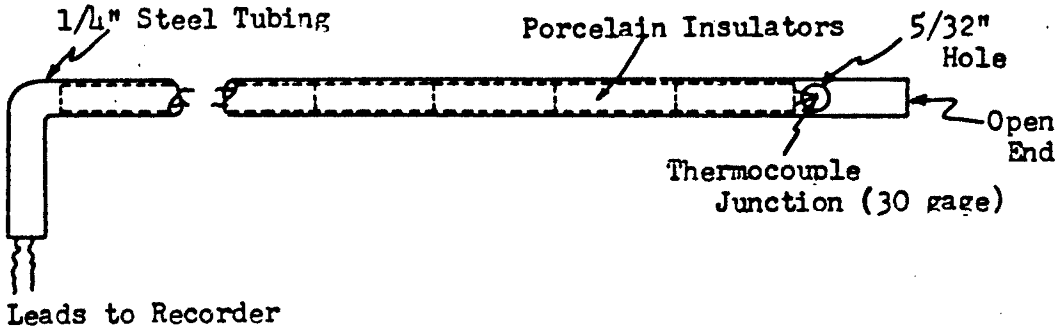
It appeared that heat was being rapidly conducted away from the couple junction by the steel tubing and the large 20 gage wires. The highest conduction rate was when the probe was fully extended, i.e., when the thermocouple junction was at the "near wall" point. The higher rate is due to the cool air surrounding the outside of the stack.



(a) Original Shielded Probe Design



(b) Brass Ball Probe Design



(c) Final Shielded Probe Design

Figure 10. Thermocouple Probe Designs

To reduce heat conduction to a minimum, the probe design was changed. The tubes were cut off "square" on the end, the 20 gage thermocouple wires replaced by smaller 30 gage wire, and porcelain insulators placed inside the tubes around the wires over nearly the full length of the tube. As a type of heat sink for the thermocouples, brass balls about 3/16 inch in diameter were fused onto the couple junctions. This probe design is shown in Figure 10b on page 31.

Temperature traverses with this type probe gave good results at stack heights of 5 ft and above. Temperature readings at the near and far points all agree within eight percent of each other for these heights. This arrangement permits the determination of representative stack temperatures at points 5 ft or more from the flame.

The brass ball temperature probe is not satisfactory for points close to the flame. The probe at the bottom of the stack was eliminated because it received heat directly from flame and thus gave a reading more representative of combustion chamber temperature rather than stack gas temperature. This reading was of no value in determining the mean or average stack temperature.

It was decided that the first temperature along the stack would be read at a point 2-1/2 ft from the bottom. A third type of probe was used for this point. See Figure 10c on page 31. This probe, similar to the ones discussed above, uses a 30 gage junction with no additional heat sink. The thermocouple is in the center of a 5/32 inch hole drilled through the tube at about one-half inch from its end. The probe, used with the small hole in the tube perpendicular to gas flow, reduces radiation and turbulence effects and gives fairly reliable and stable temperature readings.

In order to obtain the average temperature at any stack cross section, plots of temperature versus distance across stack were made. From these plots it was determined that the average cross-sectional temperature for all stack heights is given when the probe thermocouples are at 2 in. from the near wall. (This location applies only for a 6 in. diameter stack.) In an article entitled "Measurement of Mean Temperature in a Duct", appearing in the September, 1961 issue of Instruments and Control Systems, it is stated that when only one temperature sensor is used at a particular stack cross section, it should be placed at 0.58 times the radius away from the center. This is in relatively close agreement with the results obtained through temperature traverse readings. This same procedure for locating temperature probes was used each time the stack diameter was changed.

The final locations decided upon for thermocouple probes along the stack length include the shielded probe at 2-1/2 ft and brass ball probes at 5 ft and every 5 ft interval thereafter. Thus for a stack 15 ft high, four stack temperatures were read and recorded.

The mean stack temperature for a particular test was determined by plotting a curve of temperature versus stack height (a linear relationship) and then selecting the temperature at the mid-height of the stack. Thus for a 15 ft stack, the mean stack temperature (Tm or Tch) is taken from the curve at the 7-1/2 ft point. It is estimated that this method of determining the mean stack temperature is accurate to within 4 percent. Other temperatures determined and recorded during testing included those of the shelter space, the room above the shelter, and intake air temperature. These three temperatures were taken by using copper-constantan thermocouples. Stack temperatures were read from a 0-1000° F recorder and the remainder from a 0-100° F recorder. Both recorders, Honeywell models using type J couples, were periodically calibrated by inserting one thermocouple in 32° F ice water and adjusting the indicators as required.

## Pressure Measurements

At the outset of the project, the need to measure the pressure drop at the inlet to the shelter in relation to air flow was anticipated. This relationship was needed in order to determine the permissible restriction for shelters in terms of filters and still obtain the required ventilation air.

A type "C" micromanometer, made by E. Vernon Hill & Co., Chicago, was cleaned and filled with a special gage fluid having a specific gravity of 0.797. Although the fluid is not water, the manometer reads in inches of water, the smallest dial division being 0.001 in. of water. The micromanometer is shown in Figure 11 on page 35.

The instrument was located inside the shelter near the stack. The main reason for locating it near the stack is because a pitot tube, used to measure exhaust gas velocity, was installed in the stack and it appeared desirable to have its connection hose as short as possible. Also a pressure probe was installed at the bottom of the stack for measurement of stack entrance pressure drop. To measure the entrance or room pressure drop ($\Delta P_{rm}$), one tube from the manometer extended through the ceiling to measure ambient pressure and the other tube was open to measure the shelter pressure. All pressure tubes from the pitot tube, the room pressure drop arrangement, and the stack bottom converge at a manifold consisting of glass tees and short pieces of Tygon tubing. Only two hoses run from the manifold to the micromanometer. With the use of screw clamps in the appropriate places, measurement of any desired pressure drop is relatively simple.

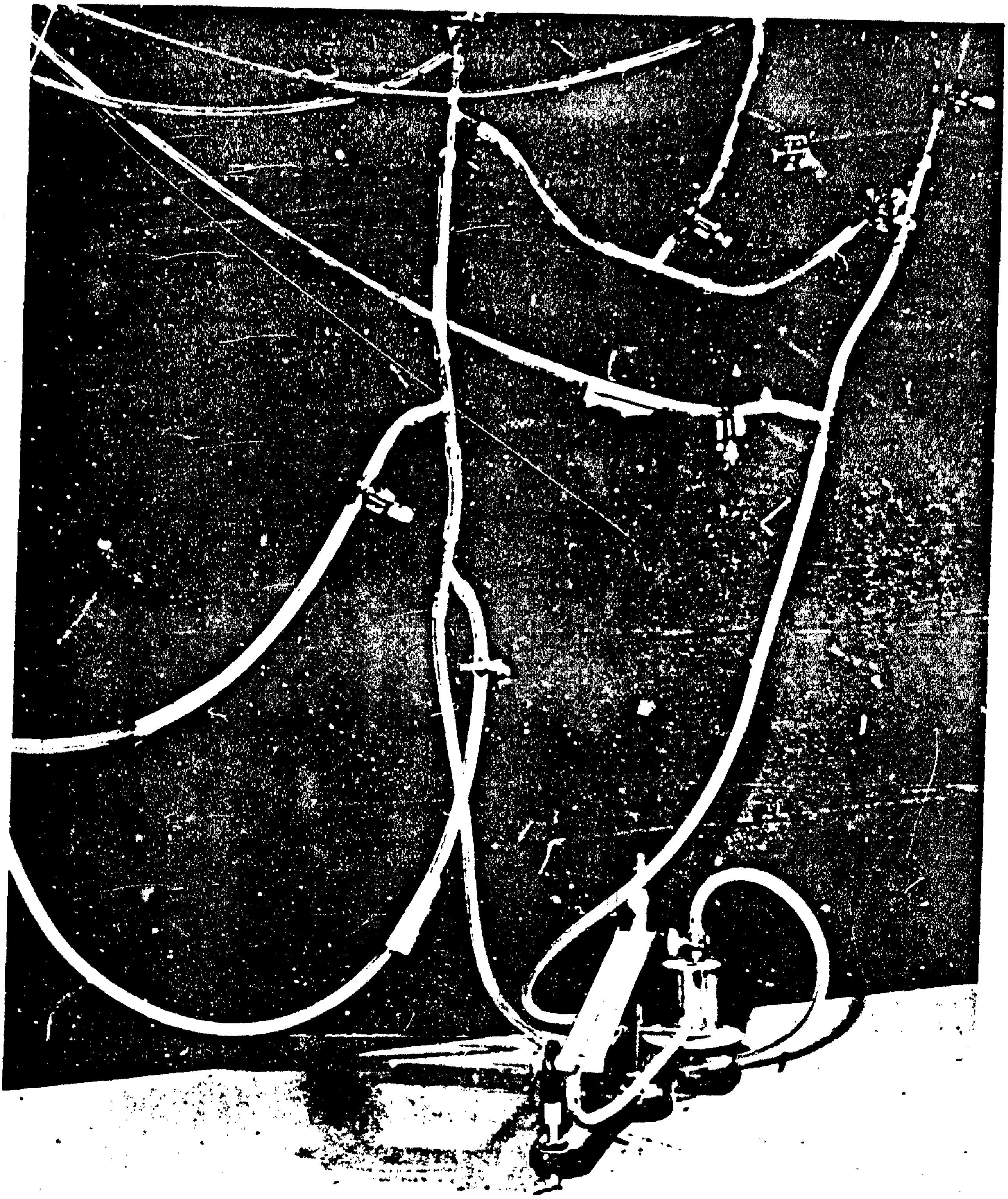


Figure 11. Pressure Measuring Device (micromanometer)

An equation for air flow through the shelter was developed in an earlier section. Indicated in this equation, written in terms of inches of water, are two terms, the sum of which accounts for the total pressure drop $\Delta P_{rm}$ at the shelter entrance. The individual terms account for the friction loss and the velocity head loss in the intake duct. Theoretical values of $\Delta P_{rm}$, taken from a computer program of the flow equations, are plotted in Figure 12 on page 37 along with experimental $\Delta P_{rm}$ values as measured with the micromanometer. Pressures are plotted versus temperature difference, i.e., mean stack temperature ($T_{ch}$) minus ambient temperature around stack ($T_{rm}$). Although this graph is for only two different stack configurations, it is representative and shows the relative accuracy and reliability of the micromanometer readings.

The pressure probe at the bottom of the stack consists of a straight piece of 3/16 in. steel tubing, closed at one end, with 3/64 in. diameter holes drilled completely through and spaced about every half inch along the tube length. The small holes are perpendicular to the air flow. Used in conjuction with the micromanometer, the pressure probe permits measurement of the difference in pressure between the shelter space and the bottom of the stack, i.e., the stack entrance loss.

Because the air was not forced to pass through the intake duct during open door tests, neither the propeller anemometer nor the thermocouple anemometer could be used to measure the air flow. Instead, a pitot tube, installed in the stack at mid-height, was used to measure the air flow. To do this the tube was calibrated during the previous closed door test. Further explanation of calibration follows.

The difference between the static and the stagnation pressures (ps - po) in the stack is measured using the micromanometer. The apparent

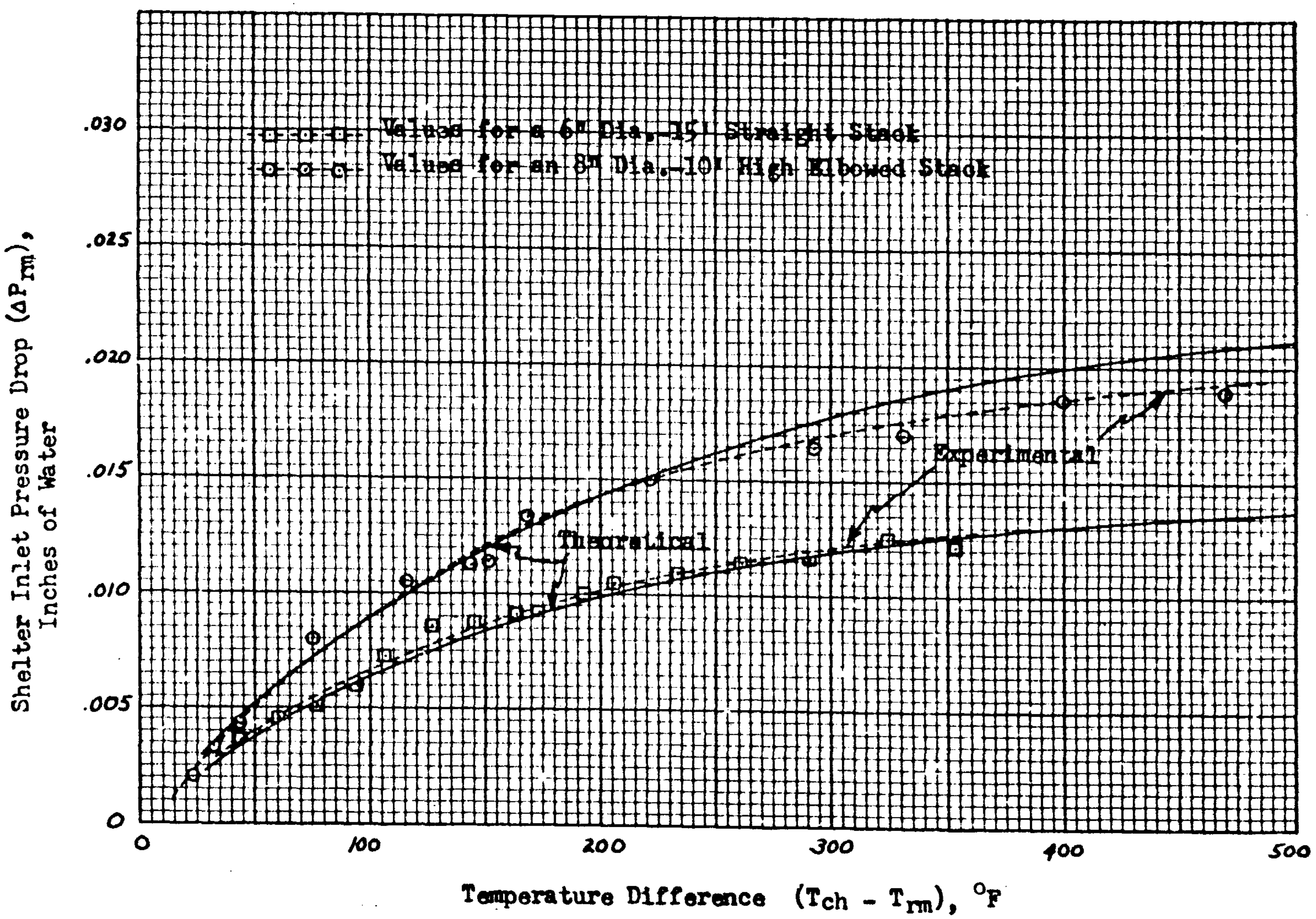


Figure 12. Comparison of Micromanometer Pressure Readings with Theoretical Values

stack air velocity is then calculated using the basic pitot tube equation.

$$(10) \qquad V_o = \sqrt{2g(p_s - p_o)/\gamma} \qquad \text{(ft per sec)}$$

in which $\gamma$ is the air density. Equation (10) can be simplified by letting $\Delta p = (p_s - p_o)$; $V_{sp} = V_o$ = stack velocity as determined from the pitot tube readings; and solving for the air density from the perfect gas law. Clearly,

$$(11) \qquad \gamma = \frac{w}{V} = \frac{P_B}{R(T_{ch} + 460)} = \frac{P_B(0.491)(144)}{(53.3)(T_{ch} + 460)} = \frac{1.327\ P_B}{(T_{ch} + 460)}$$

and by substituting these and the conversion factor, 1 in. $H_2O$ = 5.203 psf, into equation (10), we obtain,

$$(12) \qquad V_{sp} = \sqrt{2g\Delta p/\gamma} = \sqrt{2(32.2)(\Delta p)(5.203)(T_{ch} + 460)/1.327\ P_B}$$

or

$$V_{sp} = \sqrt{252.2(\Delta p)(T_{ch} + 460)/P_B}$$

where $V_{sp}$ = stack gas velocity as determined from the pitot tube readings, ft per sec

$\Delta p$ = pitot tube pressure reading, in. of $H_2O$

$T_{ch}$ = mean stack or chimney temperature, °F

$P_B$ = barometric pressure, in. of Hg

To find the actual cfm of air flowing in the stack, we can write,

$$\frac{(P_i)(ACFM)_i}{(P_s)(ACFM)_s} \qquad \frac{w_iR_i(T_i + 460)}{w_sR_s(T_{ch} + 460)}$$

and because the weight of air flowing per minute and the gas constants are the same at inlet and stack conditions, we may write, if we assume that the barometric pressures are the same,

$$(13) \qquad (ACFM)_s = (ACFM)_i \frac{(T_{ch} + 460)}{(T_i + 460)}$$

where $T_{ch}$ = mean stack temperature, °F

$T_i$ = inlet air temperature, °F

$(ACFM)_i$ = actual air flow at inlet, cu ft per min

$(ACFM)_s$ = actual air flow in stack, cu ft per min

The terms on the right side of equation (13) are determined from the closed door test. The air flow in the stack is also given by multiplying the cross sectional stack area ($A_s$) by the true stack velocity ($V_{st}$). Hence,

$$(14) \qquad ACFM_s = A_s V_{st}$$

or

$$V_{st} = ACFM_s/A_s$$

where $A_s$ is in sq ft. $V_{st}$ is then compared with $V_{sp}$ and a constant or correction factor ($C_1$) determined from the relationship,

$$(15) \qquad V_{st} = C_1 V_{sp}$$

Equation (10) is normally used only for incompressible fluids. It can be used for air with little error if the pitot tube is calibrated for each change in stack configuration over a wide range in air velocities.

## Heat Generating Equipment

Because it is assumed that no electricity will be available in the shelter, which precludes the use of electrically driven fans for supplying ventilation air, consideration was not given to combustion equipment requiring electricity for operation or control.

A first thought was that a small pot burner using fuel oil would be ideal, but a test proved differently. Maximum flow obtainable in a 6 in. diameter 15 ft straight stack with the pot burner was about 30 acfm at a stack temperature of nearly 400° F and a heat output of about 36,000 Btuh. The reason for such a low flow is that most of the pressure drop generated was used to induce proper combustion in the pot burner which uses a barometric damper. Little pressure drop was left to induce air to flow through the shelter. It was concluded that a pot burner which requires a large pressure drop for combustion will not suffice as proper heat generating equipment for shelters.

The next attempt to induce a draft by a flame in the chimney was to utilize a small fuel-oil space heater of the wick-type. Because of the configuration of the hood and to conserve space, it was necessary to remove the tank and wick assembly from the space heater body. (In this report the tank and wick assembly are referred to as the space heater.) When using the tank and wick assembly by itself, it was found that it failed to burn correctly due to improper draft. Therefore a small chimney was built out of sheet metal and placed around the flame. See Figure 14 on page 41. With this burner the full benefit of combustion is realized in generating a pressure differential which causes air to flow through the shelter. The range of air flow obtainable with the wick-type space heater in the 6 in. ft high stack is about 35 to 60 acfm. Maximum mean stack temperature is around 160° F.

As another heat source, a single kerosene lamp of the type common a few years back was tried. About 25 acfm of air can be drawn through the

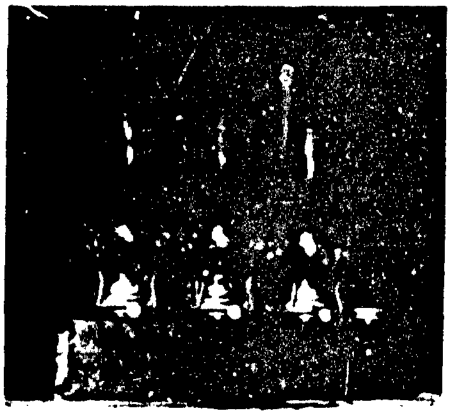


Figure 13. "Three-Holer" Kerosene Lamp

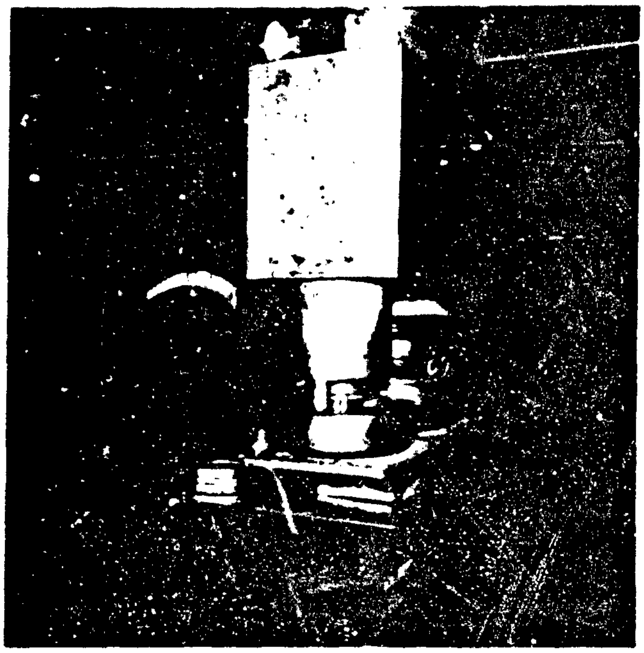


Figure 14. Dual Space-Heater Equipment

shelter when the lamp is operated at "full" flame. A "three-holer" l burner was developed whereby the wicks and glass chimneys of three di kerosene lamps were put on one fuel tank. The rectangular fuel tank nearly one gallon of kerosene. The "three-holer" burner is shown in F 13 on page 41. With this arrangement it is possible to burn one, two, three lamps at a time to obtain increased heat output and air flow. T draft generated by burning the three lamps simultaneously is nearly eq alent to that produced by the small wick-type space heater.

In an endeavor to produce air flows greater than 60 acfm, a secon wick-type space heater was obtained. A portable stand, consisting of a piece of 1/2 in. plywood with two 2 x 4 legs, supports the two burners. Two 2 in. holes were cut in the plywood to supply primary combustion ai to the burners which set flat on the plywood. With this "dual-burner" arrangement at the bottom of a 6 in. 15 ft high straight stack, a maxim flow of 80 acfm is obtained at a mean stack temperature of about 230° F. The dual-space-heater unit is shown in Figure 14 on page 41 as it appea during operation. In the same figure are shown the bottom of the intake hood and a scale balance which is used to determine the weight of fuel burned.

As explained earlier, it cannot be assumed that natural gas will be available during shelter occupancy. However, for the purpose of testing two natural gas burners were utilized in order to reach temperatures and flows considerably above those obtainable by the other methods. Mean stack temperatures of nearly 650° F can be obtained by using the natural gas burners.

## Hood Configurations

At the beginning of ventilation tests, a 6 in. diameter vertical stack was used. The stack entrance loss was measured at a flow of 50 acfm using a wick-type kerosene burner as the heat generator with no entrance hood at the stack. In order to minimize the stack entrance loss, the most economical and practical hood type had to be determined. Tests were conducted, all at air flows of 50 acfm, with various hood configurations. The first hood, conical in shape, was made from heavy aluminum foil. The top diameter of the hood was 6 in., bottom diameter was 24 in., and height was 16 in. Stack entrance loss was measured and recorded at a flow of 50 acfm.

The second hood, also of a conical shape and made from aluminum foil, was 5.5 in. high with top and bottom diameters of 6 and 12 in., respectively. Again the entrance pressure drop at 50 acfm flow was measured.

The third and final hood tested was made of galvanized sheet metal in a rectangular shape of dimensions: height, 13 in.; width, 10 in; and length, 17 in. The pressure drop was measured as before. Stack entrance losses for the four conditions previously described were compared. Results showed that all readings were within 3.5 percent of each other, a negligible difference. From these results it was concluded that air flow by the induced draft method is nearly independent of hood shape and size. Consequently, all further ventilation tests were conducted using the rectangular hood. A rectangular hood is easier to build than a conical one, is cheaper, and better accommodates the various types of combustion equipment discussed in the last section. The rectangular hood is shown in Figures 1 and 14 on pages 3 and 41.

Several tests were conducted with a one-inch layer of fiberglass insulation on the stack intake hood and stack within the shelter to determine the amount of heat added to the shelter in the absence of insulation. A prototype shelter in which the horizontal portion of the stack runs through a concrete wall into adjacent earth or space may or may not be similar to the test insulated condition depending upon conductive qualities of the surroundings. However comparisons could only be made on the basis of what was available. Results shown later clearly indicated the value of insulation.

## PROCEDURE

The original model for conducting tests of ventilation air flow caused by a flame in a chimney was set up with the intent of having a simple installation in order to reduce the variables to a minimum. To accomplish this, the stack was installed vertically out of the shelter --no bends or elbows--to minimize friction and velocity loss effects. Intake air was brought into the shelter through a straight length of 8 in. galvanized sheet metal duct--no bends, no elbows, or filters. Because the stack was completely within the surrounding building, the effects of wind, for testing purposes, were eliminated. This is the simplest set up, though perhaps not the most desirable from the standpoint of fallout radiation elimination, that can be achieved in any home shelter. The stack is vertical, there are no variables induced by wind, and inlet air is not restricted by conditions other than the intake duct itself.

A group of tests were conducted using various lengths of 6 in. diameter straight stack. "Straight stack" means one that is completely vertical and contains no elbows, bends, or horizontal lengths. Pressure, temperature, fuel rate, and air flow-rate data were recorded for the heating methods of kerosene lamps and wick-type space heaters. Similar data, excluding the fuel rate, were taken for the natural gas heating method.

The above data were collected in what is termed a "closed door" test. Open door tests for 6 in. diameter stacks followed the close door tests. For an open door test, then, the pitot tube $\Delta p$ and the mean stack temperature ($T_{ch}$) are read, the apparent stack velocity is calculated from equation (12), correction factor $C_1$ is applied, and the actual flow at inlet conditions is found from equations (13) and (14).

After tests had been completed with 6 in. diameter straight stacks, two 90° four-piece elbows and a 2 ft long horizontal length of single-walled duct were added to the stack bottom. See Figure 1 on page 3.

Both open door and closed door tests were run with this "elbowed" stack arrangement. This condition is often referred to as an "equivalent length" stack. The equivalent length applies to the elbows and is discussed in detail in a later section.

To find the shelter heat-addition difference, tests were conducted with and without insulation at constant mean stack temperatures. Fuel rates for the insulated and the uninsulated stacks were determined by weighing the amount of fuel used over a period of time. From this data the heat saved by insulation can be calculated.

Fuel rate data was also taken for several stack configurations (various lengths and diameters) to determine the relationship between fuel consumption and temperature difference.

Similar tests, with the exclusion of insulation tests, were also conducted with 8 in. diameter stacks ranging in vertical heights from 5 ft to 15 ft. It was deemed unnecessary to conduct insulation tests for the 8 in. stacks because a percentage value, determined in the 6 in. tests, can be applied to the other diameters if fuel saving figures are desired.

To determine the effect on air flow from the use of ventilator caps, tests with 8 in. stacks were made using two types of caps at the stack outlet--a two-directional Artis cap and an all-directional Belmont cap. (Directional refers to wind conditions.)

## RESULTS AND CONCLUSIONS

Much of the data collected from experiments and from the computer programs are presented in this section in the form of graphs. The first eight figures of air flow versus temperature difference compare experimental results with theoretical results in order to indicate the relative accuracy of the flow equation with its associated assumptions. The remaining figures supply information on inlet pressure drop, fuel rates, and the effect of altitude and ventilator caps on flow. A group of curves for designing a ventilation system are also included.

Figures 15 and 16 show $\Delta T$, i.e., mean chimney temperature ($T_{ch}$) minus ambient temperature around stack ($T_{rm}$), versus rate of air flow for 6 in. diameter stacks. The friction factors, $f_1$ and $f_2$ in equation (7), were determined from the experimental curve for the straight stack closed door test, Figure 15. Theoretical values are within 2-1/2 percent or less of the experimental values at all points.

The 25 ft equivalent length experimental curve in Figure 16 was used to determine the equivalent length of the two 90° elbows. Experimental values are again about 2-1/2 percent from theoretical ones. The theoretical values for the other curves in this figure, as well as for all other curves of all diameters, were determined with fixed values of friction factors and equivalent elbow length. These fixed values are $f_1 = 0.415$, $f_2 = 0.064$, and equivalent length = 4.2 ft/elbow. It should be mentioned that an equivalent length stack of, say 40 ft, means one with a vertical height of 30 ft. That is, (30 ft vertical) + (2 ells) $\left(4.2 \frac{\text{eq. ft}}{\text{ell}}\right)$ + (2 ft horizontal) = 40.4 total equivalent stack length. The total

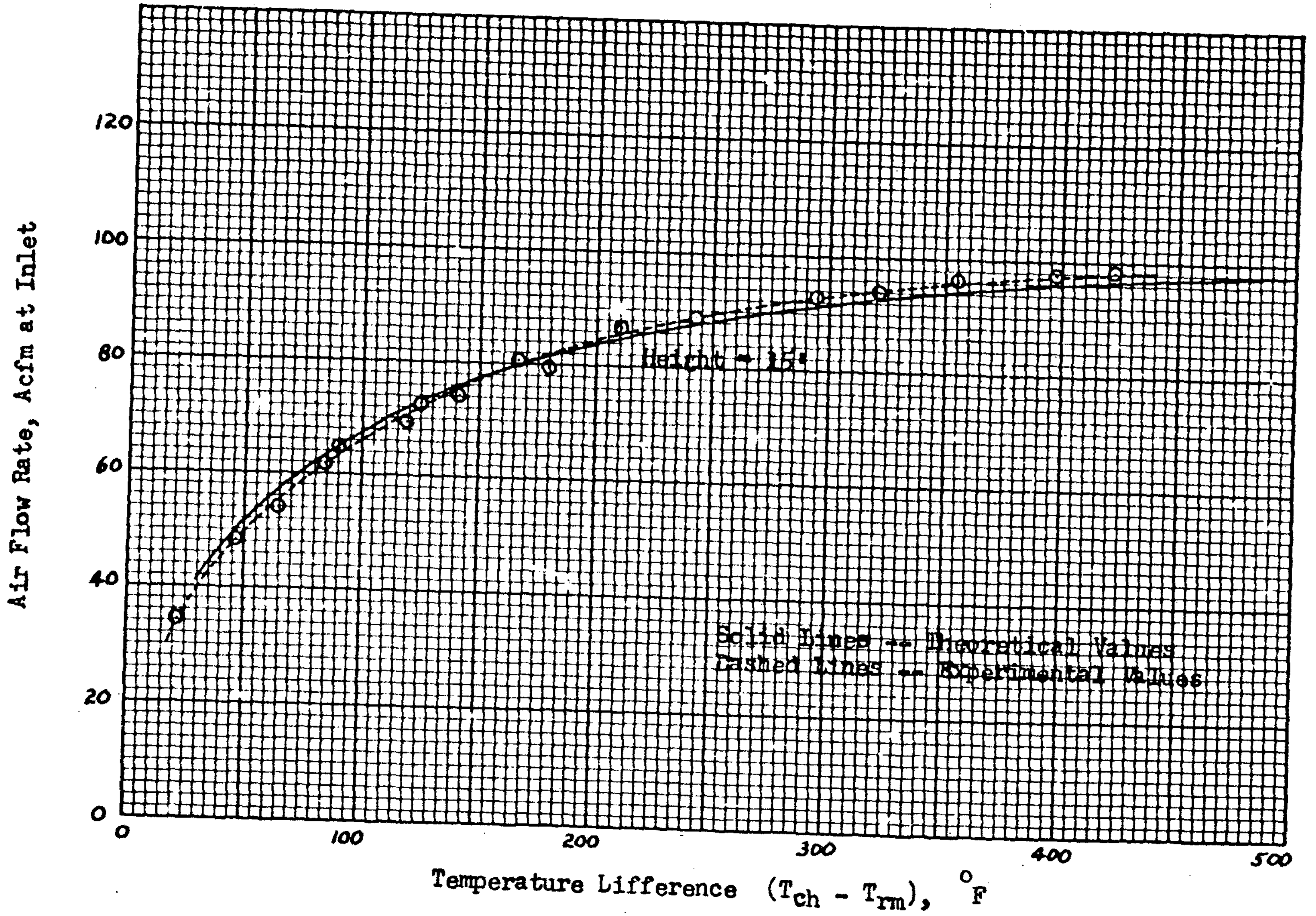


Figure 15. Air Flow vs. Temperature Difference for 6" Diameter Stack. Closed Door Test — Straight Stack

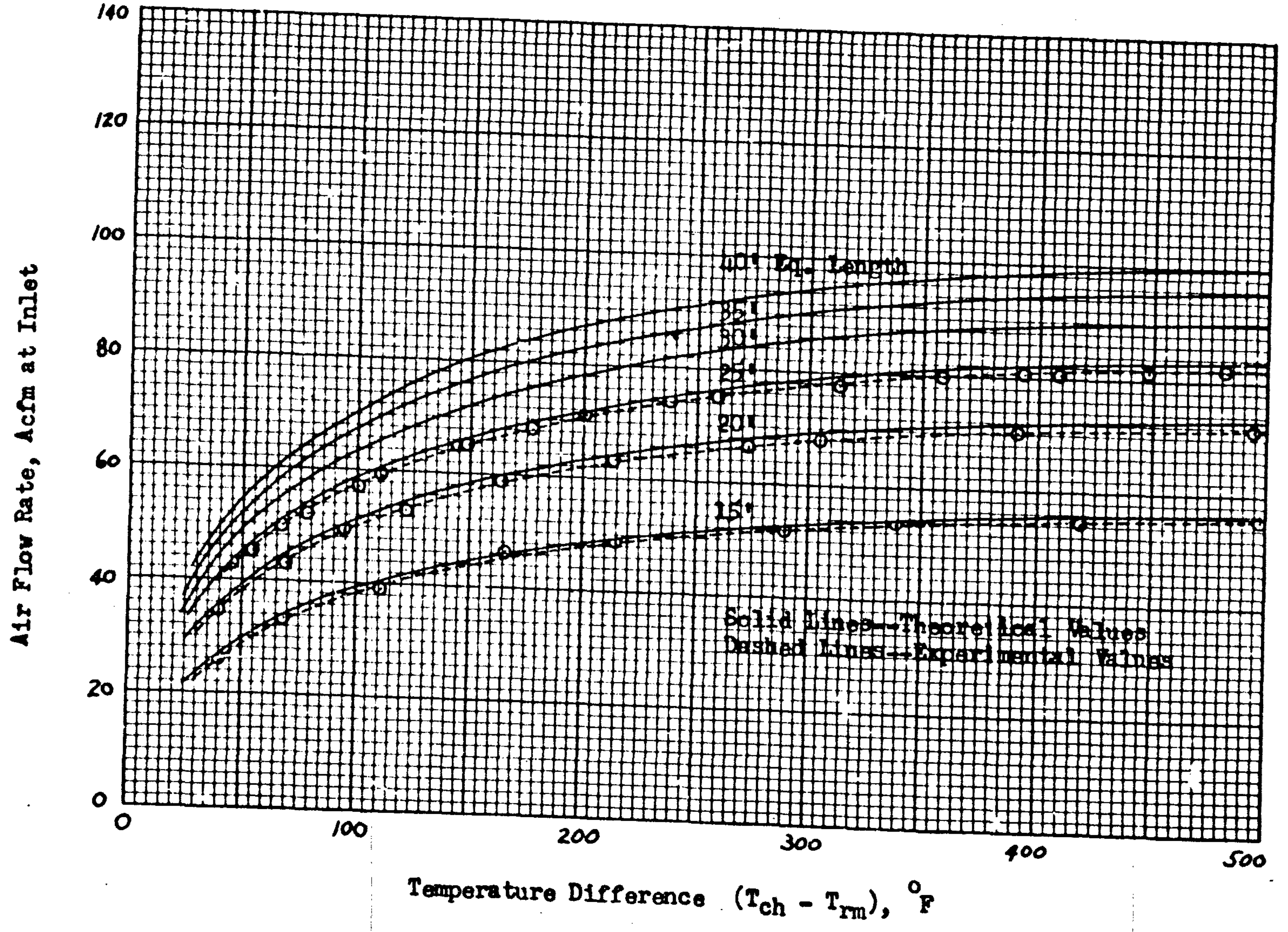


Figure 16. Air Flow vs. Temperature Difference for 6" Diameter Stack
Closed Door Tests — Elbowed Stack

equivalent length is rounded off to the nearest whole number when presented in the graphs.

The open door comparison for the 6 in. stacks are shown in Figures 17 and 18. Experimental values are again in close agreement with theoretical values. This indicates that the choice of $f_2$ and of elbow equivalents is appropriate, at least for the 6 in. diameter stack of 15 ft. length since the intake terms in equation (7) become zero with an open door. The resulting theoretical values are therefore not influenced by the inlet friction factor.

Air flow-temperature relations for 8 in. diameter stacks with closed door are shown in Figures 19 and 20. Because experimental values are somewhat higher than the theoretical ones, it appears that in equations (7) one or more of the factors, perhaps the entrance coefficients, friction factors, or elbow equivalents, are not constant as assumed. It is believed that the principal factor contributing to the higher experimental values is the stack friction factor, $f_2$. Original determination of $f_2$ was for a 6 in. stack which had been in place for nearly five months. Over this period of time a heavy layer of soot collected on the stack walls to which inherently offers more restriction to flow than clean walls. The 8 in. stack, however, had no soot on the walls when tested. The aluminum liner was shiny, smooth, and clean and consequently offered less restriction to flow than a sooted stack. The assumption of a constant friction factor is thus conservative. As a result, theoretical curves include a margin of safety for predicting air flow.

Results of open door tests on 8 in. stacks appear in Figures 21 and 22. Agreement between experimental and theoretical values in again within

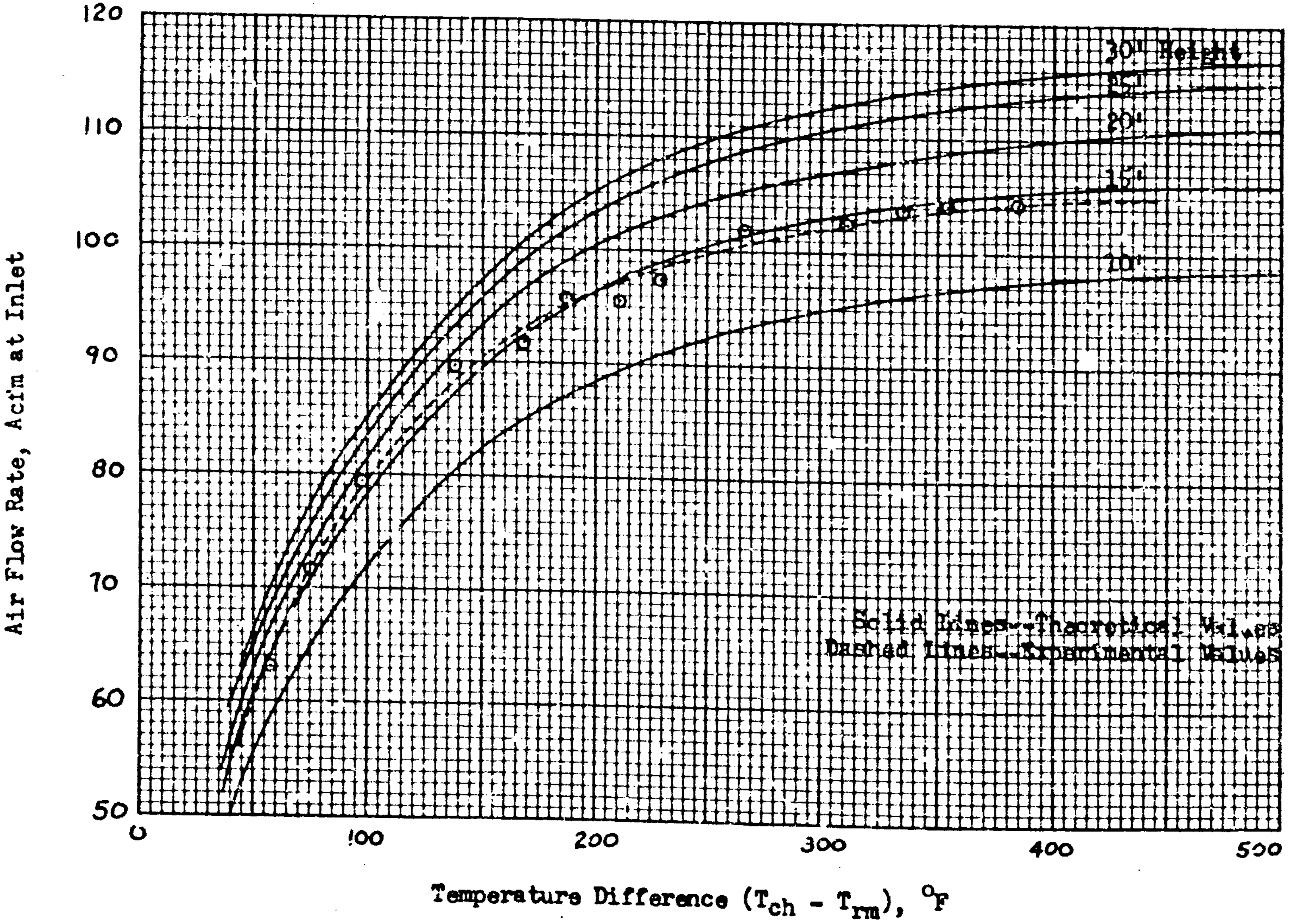


Figure 17. Air Flow vs. Temperature Difference for 6" Diameter Stack
Open Door Tests -- Straight Stack

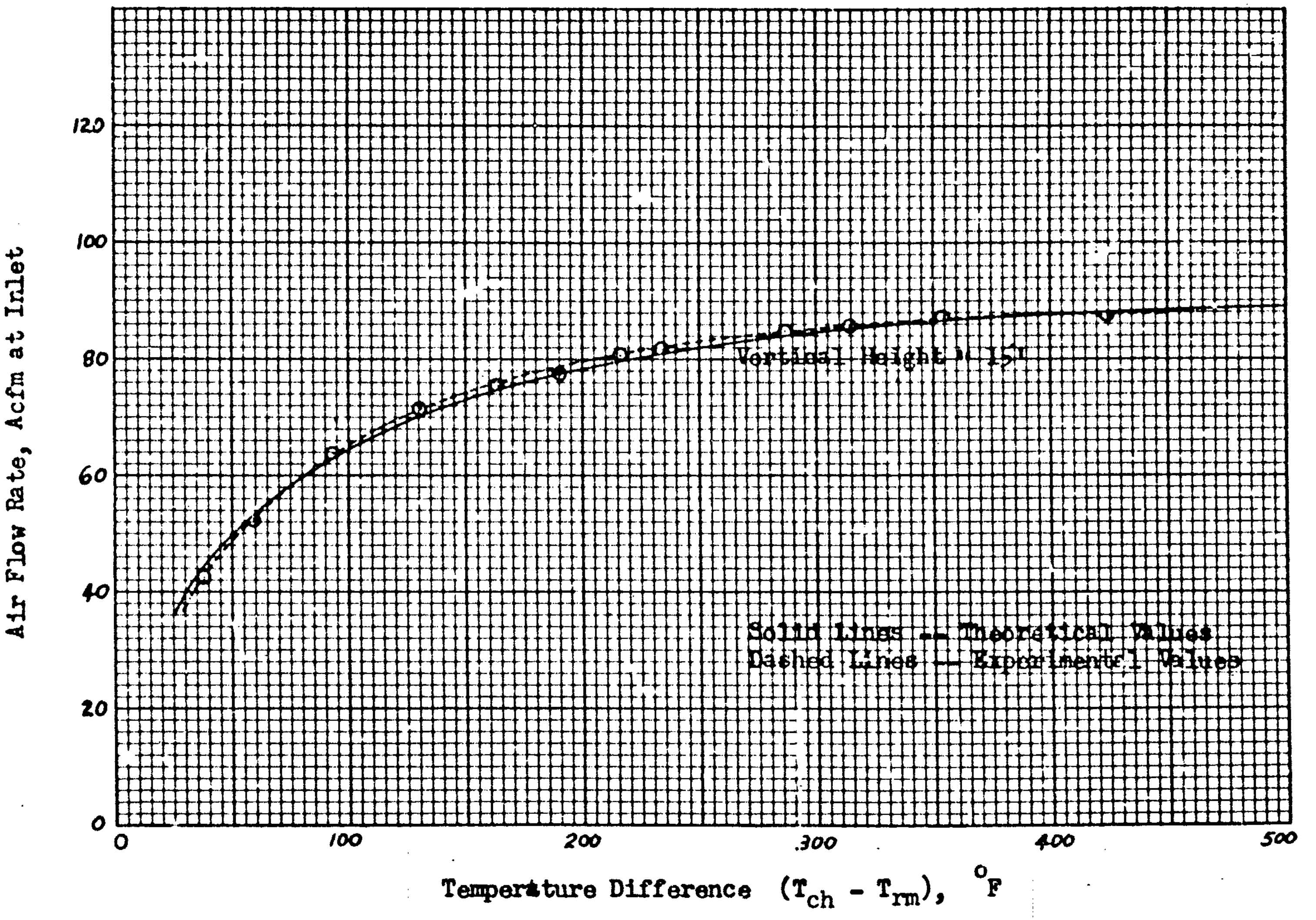


Figure 18. Air Flow vs. Temperature Difference for 6" Diameter Stack.
Open Door Test -- Elbowed Stack

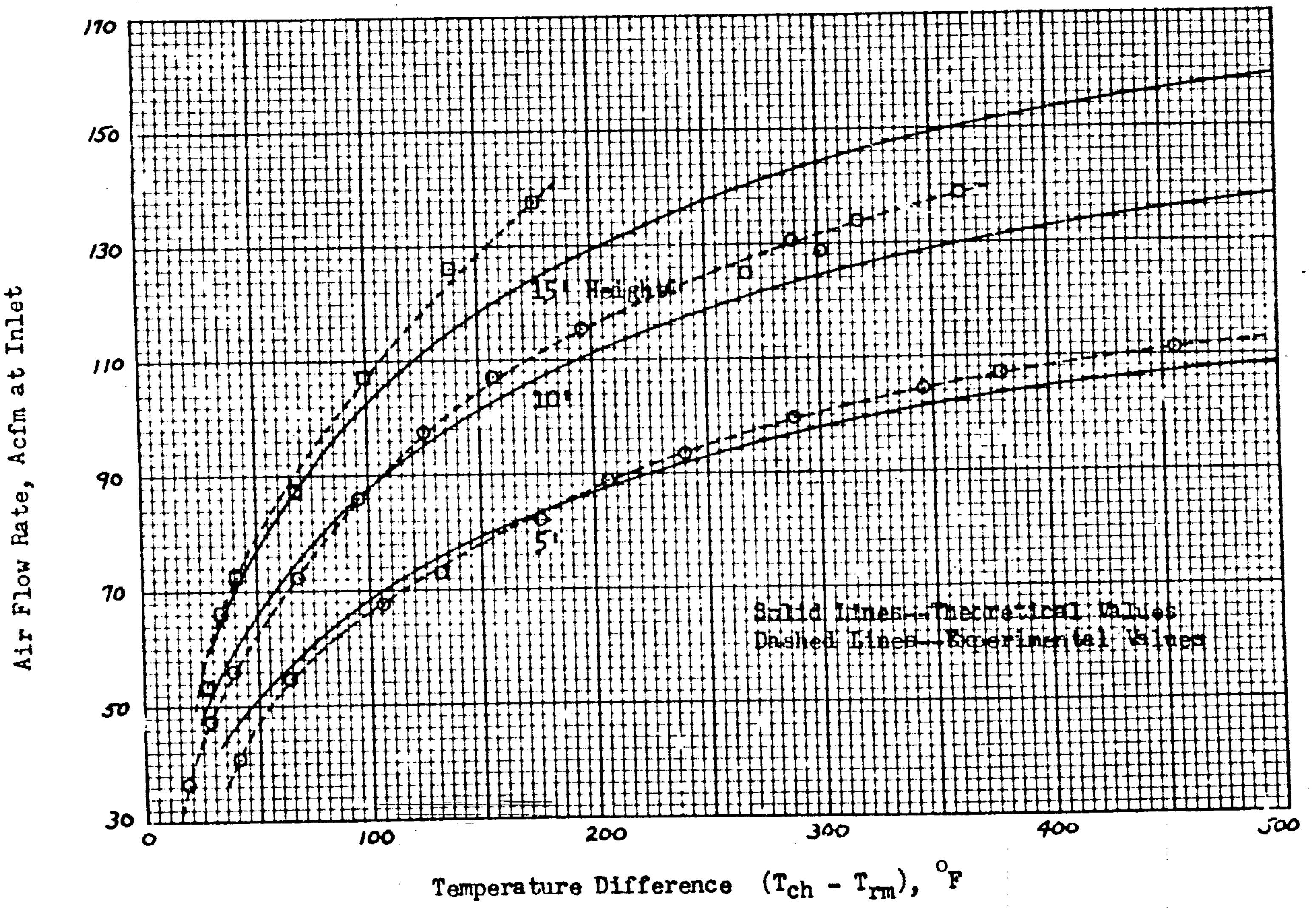


Figure 19. Air Flow vs. Temperature Difference for 8" Diameter Stack
Closed Door Tests -- Straight Stack

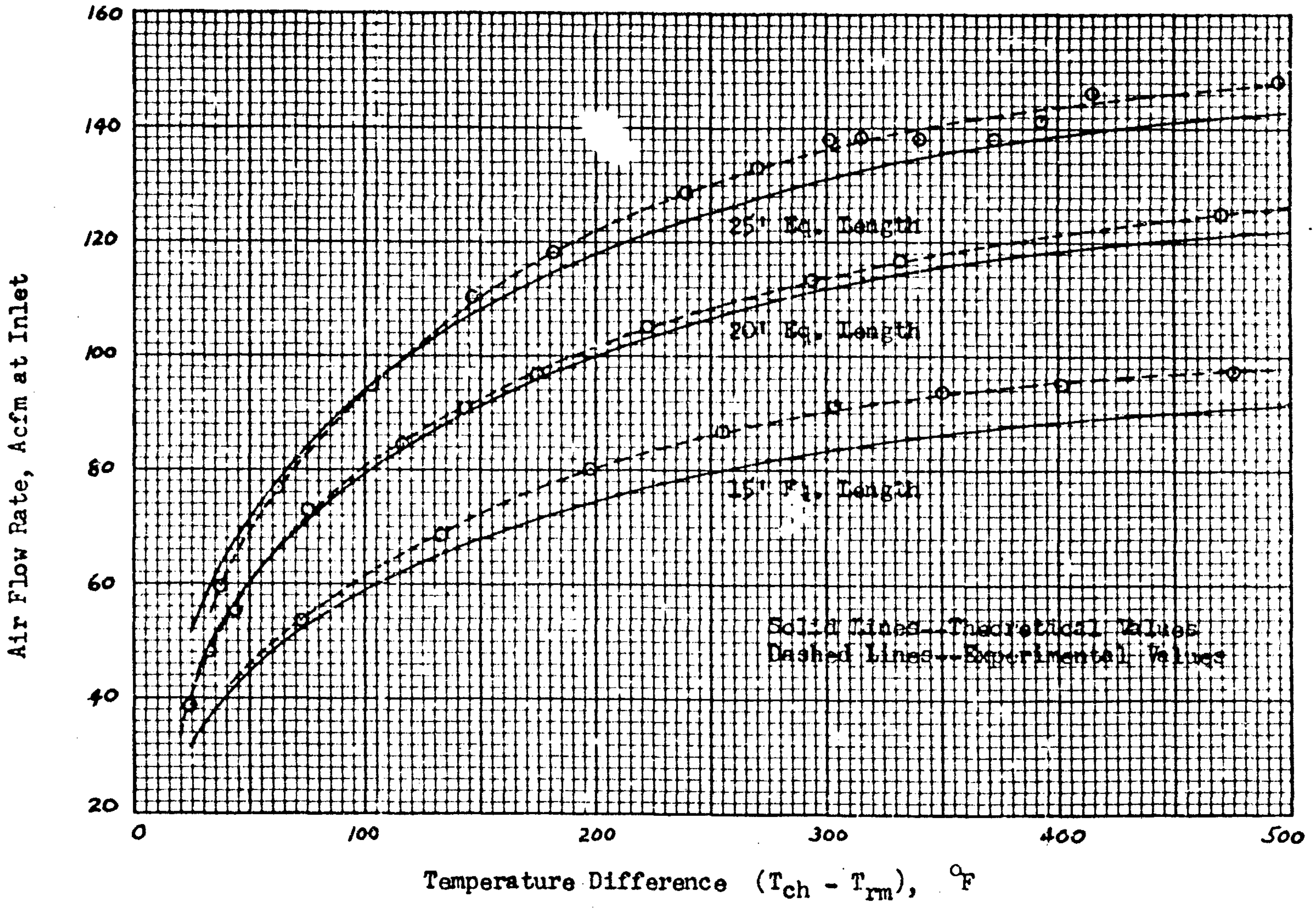


Figure 20. Air Flow vs. Temperature Difference for 8" Diameter Stack
Closed Door Tests -- Elbowed Stack

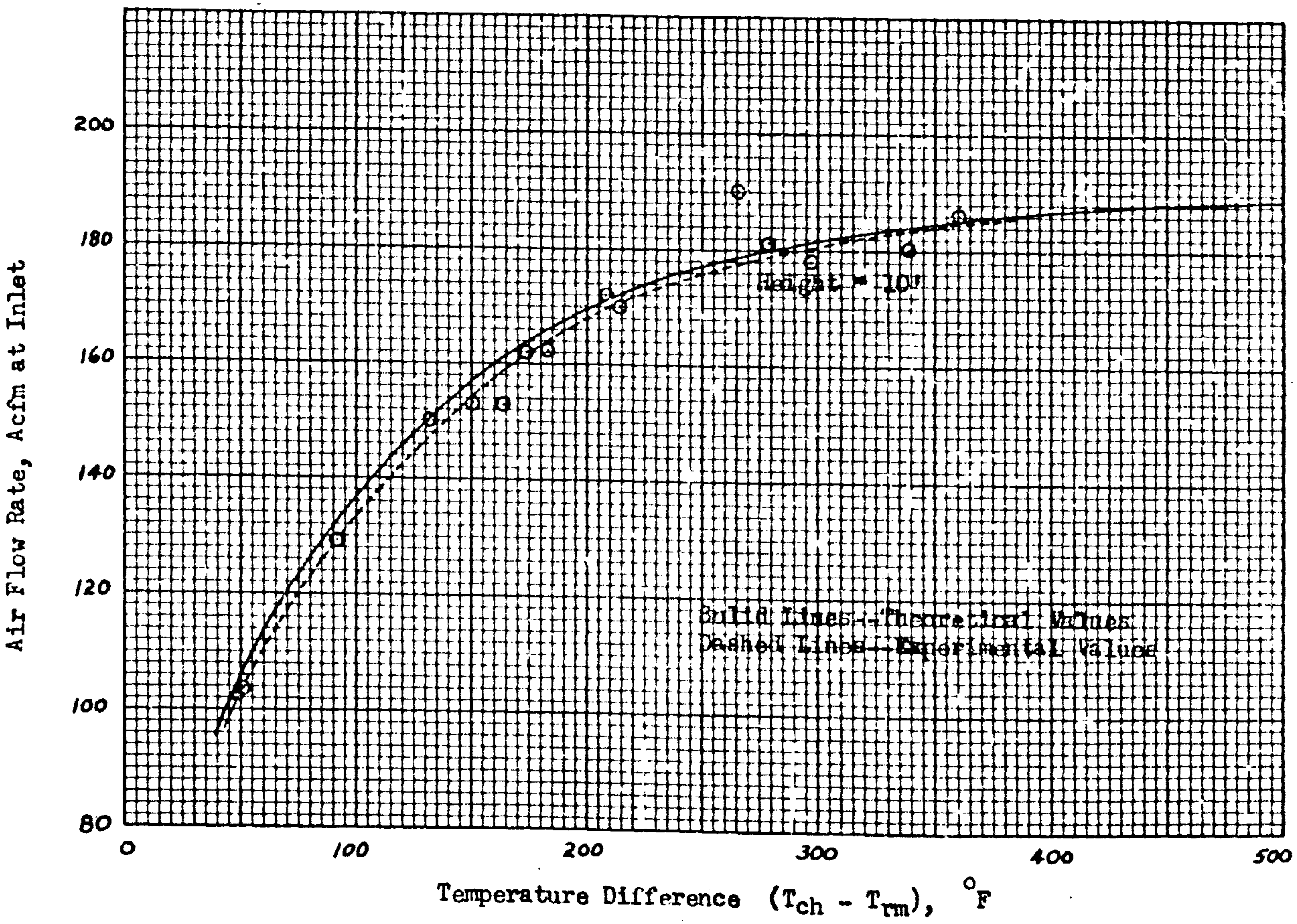


Figure 21. Air Flow vs. Temperature Difference for 8" Diameter Stack.
Open Door Test -- Straight Stack

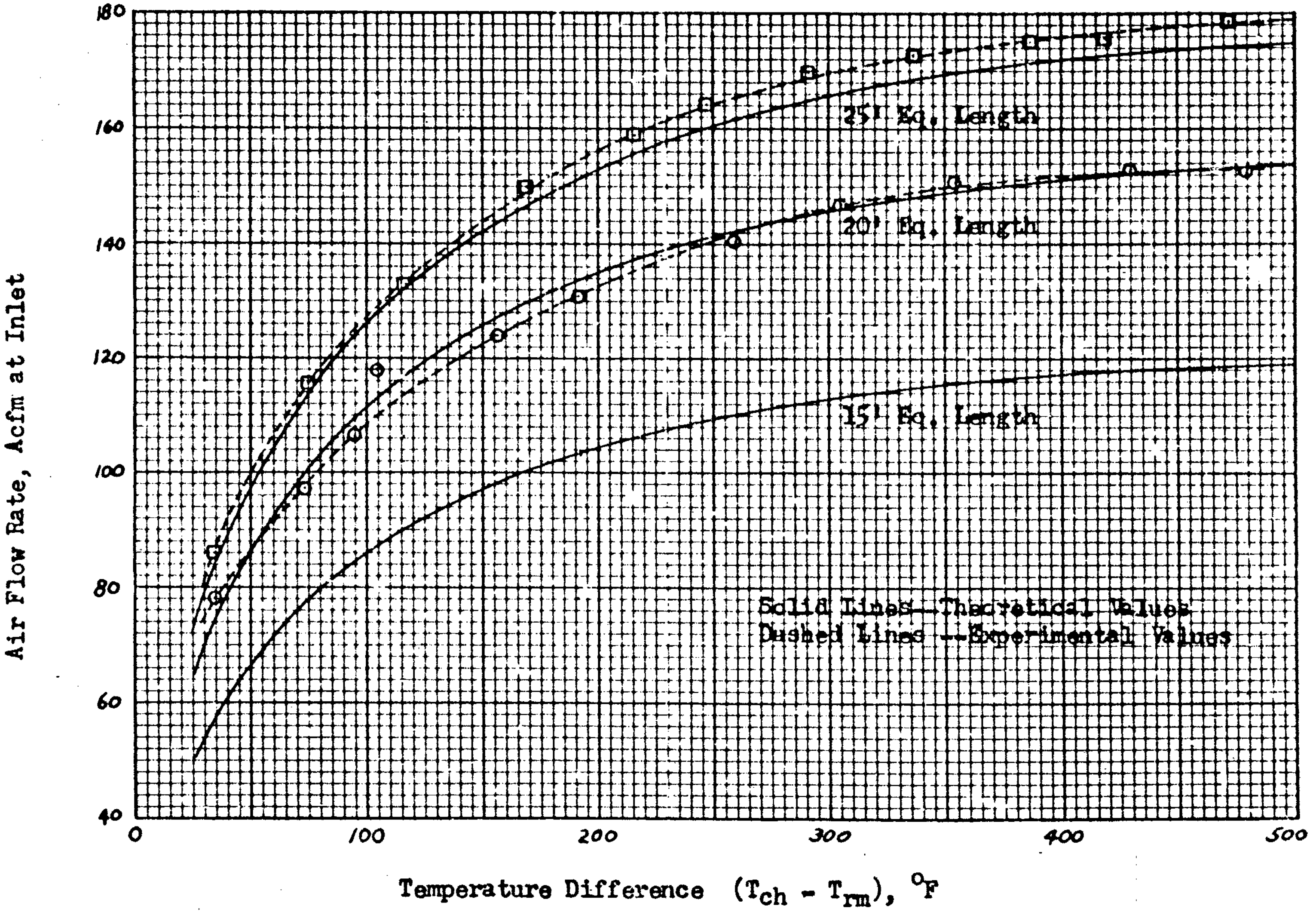


Figure 22. Air Flow vs. Temperature Difference for 8" Diameter Stack
Open Door Tests -- Elbowed Stack

tolerable limits. There are several wild points on the graph in Figure 21, especially at flows above [illegible] acfm. The erratic behavior of the pitot [illegible] readings is attributed to location of the pitot tube in the stack, only seven feet directly above the flame or point where the air velocity was established and thus, at high flows, in the path of very turbulent air. With the elbowed arrangement, the points of Figure 22 again follow a smooth curve above 150 acfm air flow. The elbows and short horizontal lengths of stack tend to straighten the flow by the time it reached the pitot tube.

Figure 23 on page 58 illustrates the effect of inlet restriction given by an 8 in. diameter intake duct on air flow in 6 and 8 in. stacks of 15 ft height. At a temperature difference of only 100° F, unrestricted flow for the 6 in. stack is reduced by 18 percent by an inlet restriction of only 0.0064 inches of water. Under the same conditions, unrestricted flow for the 8 in. stack is reduced by 32 percent by an inlet restriction of 0.0145 in. of water. It appears from this comparison that in actual shelter situations, if an intake duct is to be used, its cross-sectional area should be at least double that of the stack area in order to nearly eliminate any effect from inlet restriction. This "double the area" rule should be used as a rule-of-thumb for estimating purposes only.

To further investigate the effects of room $\Delta P$ in relation to $\Delta T$ and air flow, a test was conducted in which a piece of cardboard with several small holes through it was taped over the inlet end of the intake duct. This arrangement simulated an air filter, at least in its effect upon restraining flow. Pressure drop, temperatures, and air flow were measured. Results of the test appear in Figure 24. The curves show that a small pressure dorp causes a severe reduction in flow from that of the

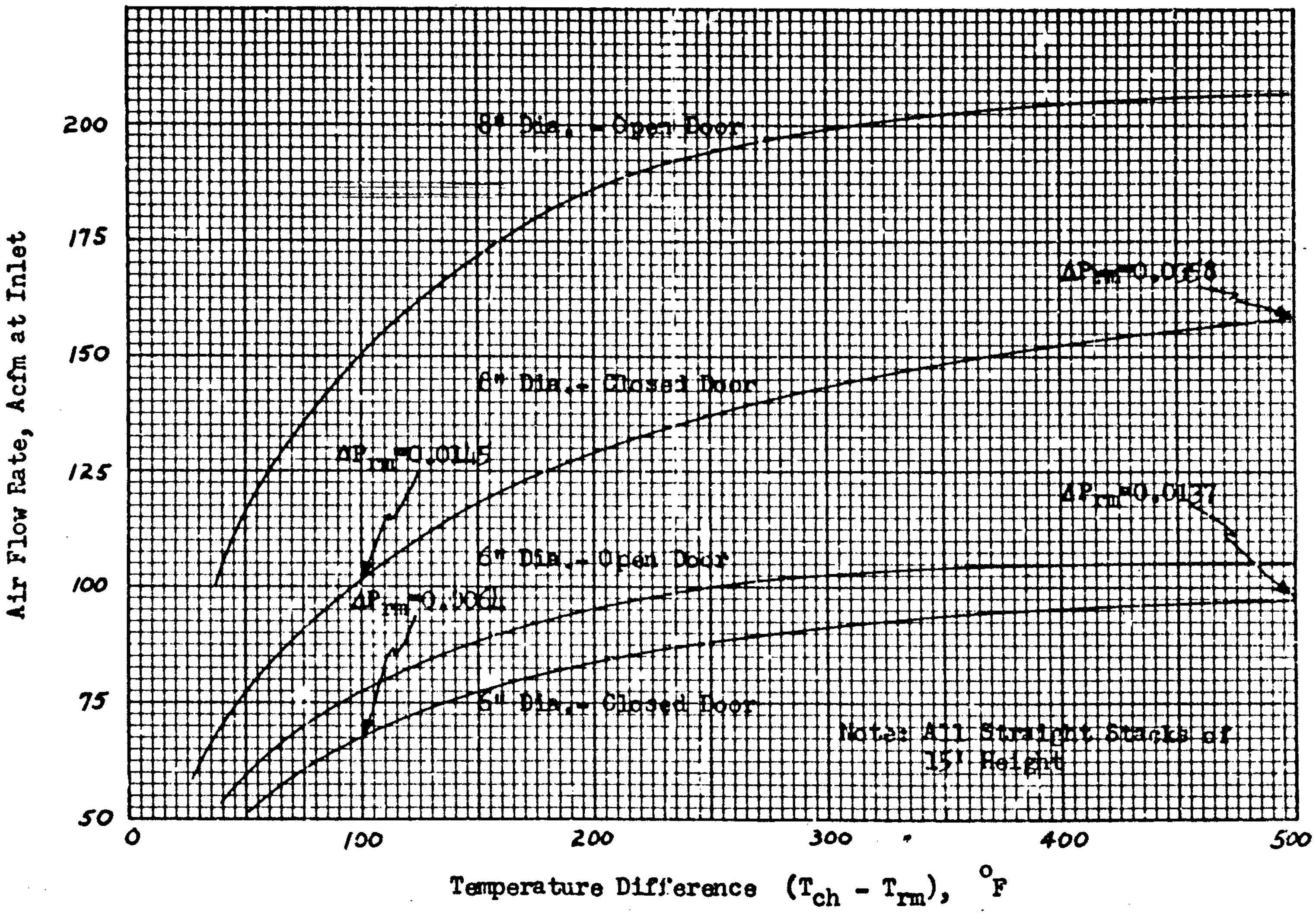


Figure 23. Comparison of Air Flows for Open & Closed Door Conditions to Illustrate Effect of Intake Restriction $\Delta P_{rm}$. Intake Duct -- 8" Diameter

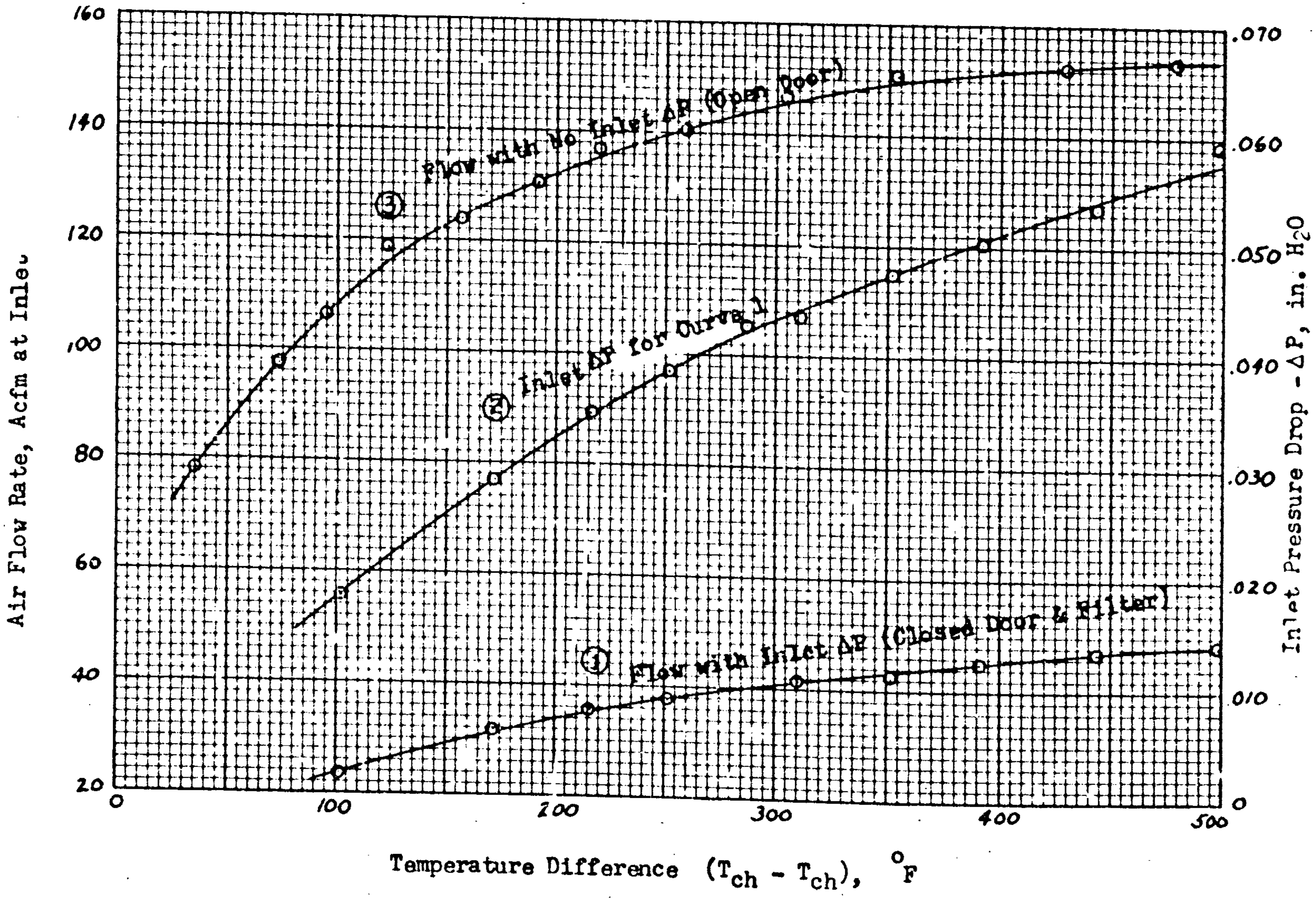


Figure 24. Effect of Inlet Restriction on Rate of Air Flow
8" Diameter - 20' Eq. Length Stack

unrestricted condition. At a $\Delta T$ of 500° F, for example, air flow is 154 acfm with an open door and 48 acfm with the restricted condition. The decrease in flow, almost 70 percent at a $\Delta T$ of 500° F, is caused by a $\Delta P_m$ of only 0.0577 inches of water. This indicates that filters cannot be used with the induced draft method of shelter ventilation because there are very few, if any, filters available that offer less than 0.1 inch of water restriction and retain reasonable efficiency at the air flow rates being considered. Thus it is recommended that only open door shelter situations be considered when designing with this system of ventilation.

The effect of altitude on air flow for any given temperature difference is negligible as shown in Figure 25. Values for these three sets of curves were taken from the computer results. Actural conditions for the 5000 ft altitude curves varied as follows; barometric pressure--24.59 to 25.22 in. Hg; inlet temperature--72 to 82° F. The sea level curves are for the standard conditions of 29.92 in. Hg barometer and 70° F temperature.

The decrease of standard air flow at 5000 ft altitude is less than 1.4 percent for any given temperature difference. This means that negligible error is introduced when air flow-temperature difference values from the curves are used for altitudes of zero to 5000 ft.

The curves in Figure 26 illustrate the effect on air flow of two types of ventilator stack caps. The Artis cap, from which air emerges horizontally at two sides only, does not produce any noticable change in air flow from that of the uncapped-stack condition. With the Belmont stack cap, air emerges from all sides in a downward direction, i.e., air flowing up the stack must reverse directions in order to leave the cap. This motion reduces the uncapped-stack flow by about 8 percent as shown in the curve.

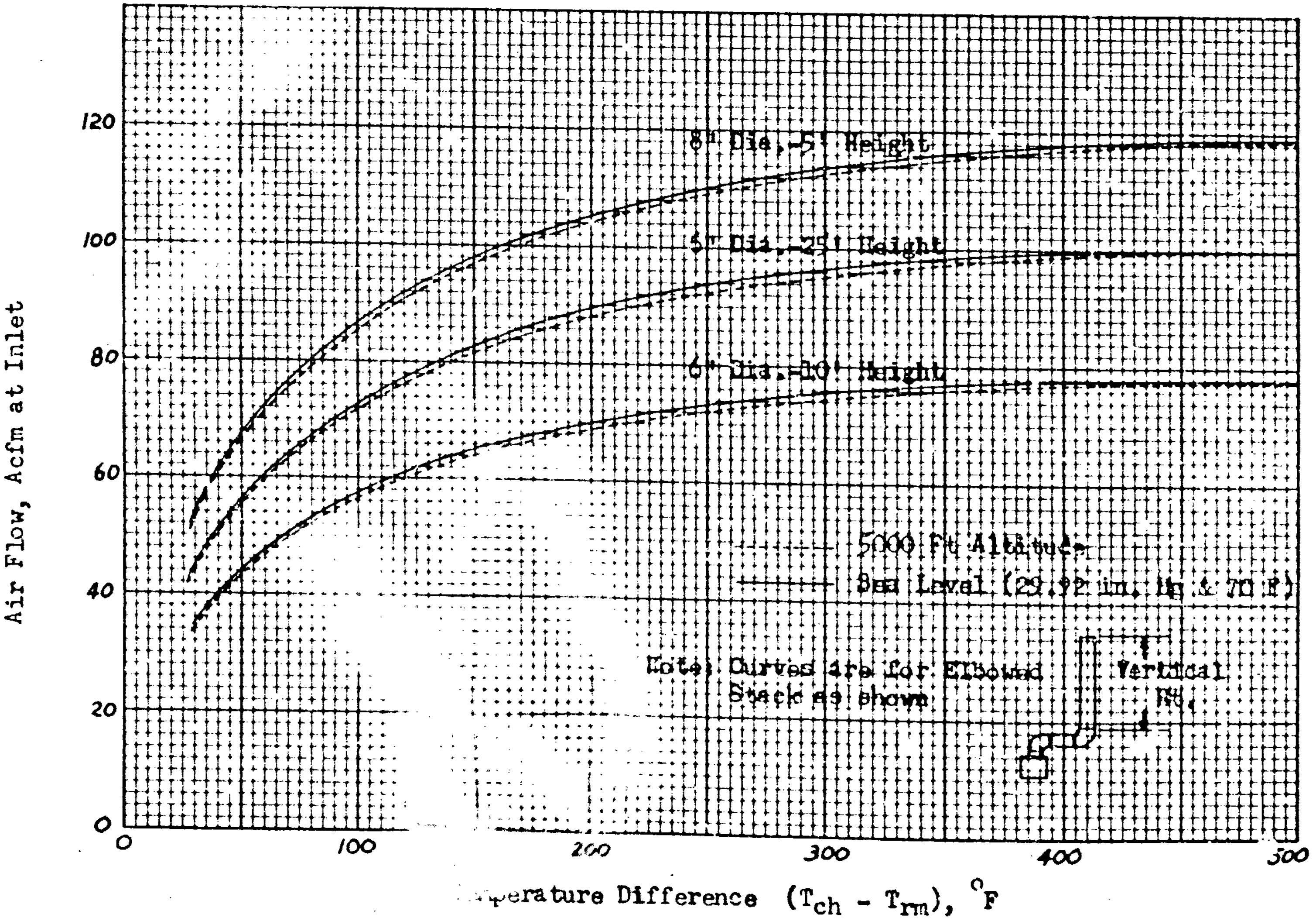


Figure 25. Effect of Altitude on Air Flow

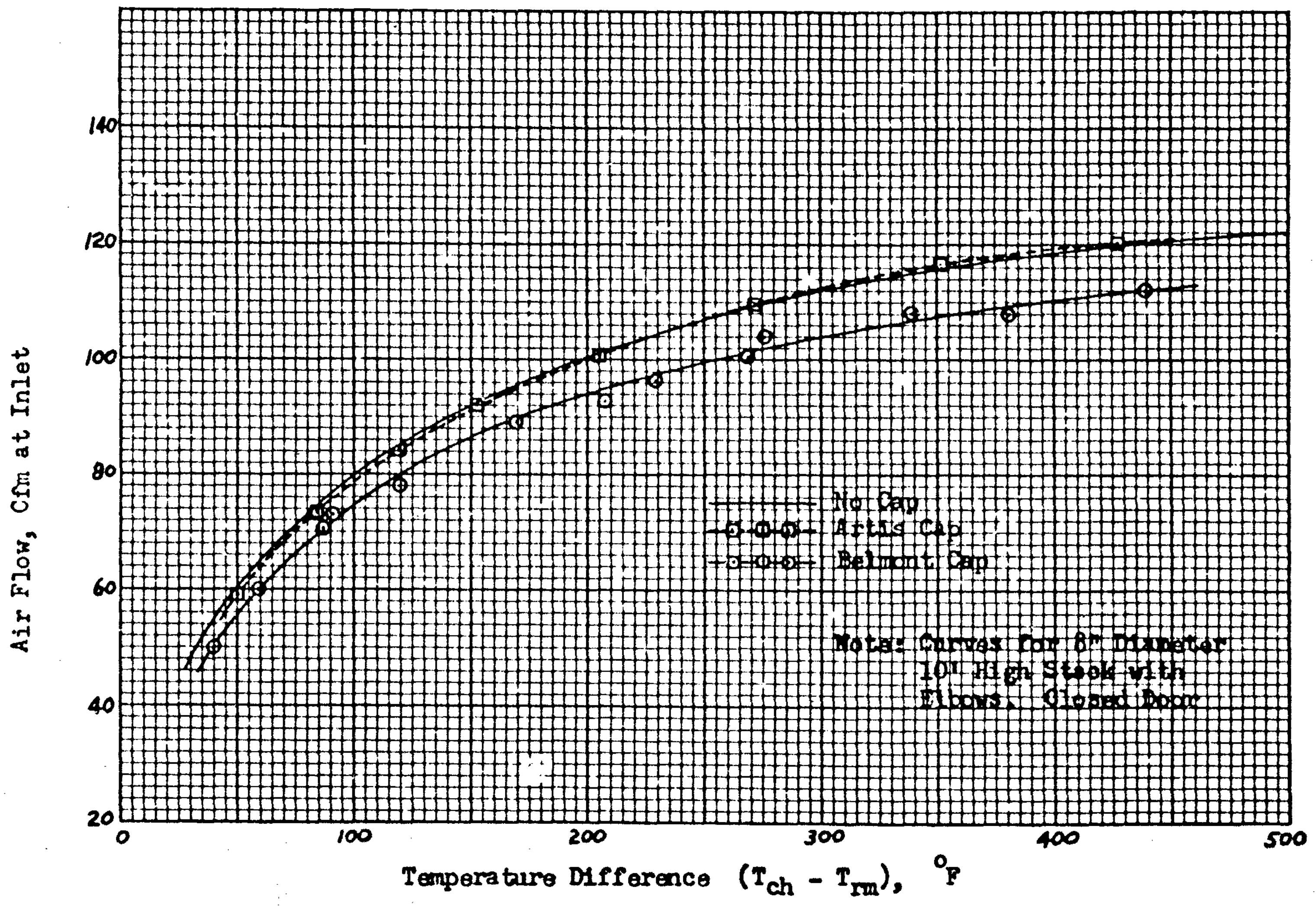


Figure 26. Effect of Ventilator Caps on Air Flow

The flow resistance offered by the Belmont cap amounts to approximately 5.5 ft equivalent length as calculated from the equation (9). Similar results were obtained from a straight stack test (not shown).

It should be remembered that the ventilator cap tests were conducted in the absence of wind. In actual shelter applications where wind conditions are present, the use of a Belmont cap or a type L Breidert Air-X-Hauster cap (built specifically for fallout shelters) will have less dampening effect on air flow than that shown by the curves. These caps are built so that the outflow of air, is actually increased by an aspirating effect of the wind regardless of the wind direction, i.e., the wind produces a suction at the cap outlet. Thus, in general, a good ventilator stack cap can be considered to offer little restriction to air flow at a shelter exhaust when used with the induced method of ventilation. To add a factor of safety, however, it is recommended that the cap equivalent length be accounted for in the shelter design.

Surface temperatures of the stack inside the shelter and of the hood were observed with and without insulation. At a mean stack temperature of 200° F, the surface of the top of the hood approached 400° F with no insulation. With one inch of fiberglass insulation and the same mean stack temperature, the surface temperature of the insulation on the hood was reduced to less than 100° F. This surface temperature reduction is important when trying to minimize heat addition by radiation.

There can be a substantial fuel savings with the use of insulation as indicated by the data presented in Figure 27 on page 64. Although this data is for a closed door arrangement which was ruled out in previous discussions and it represents savings realized from insulating two elbows,

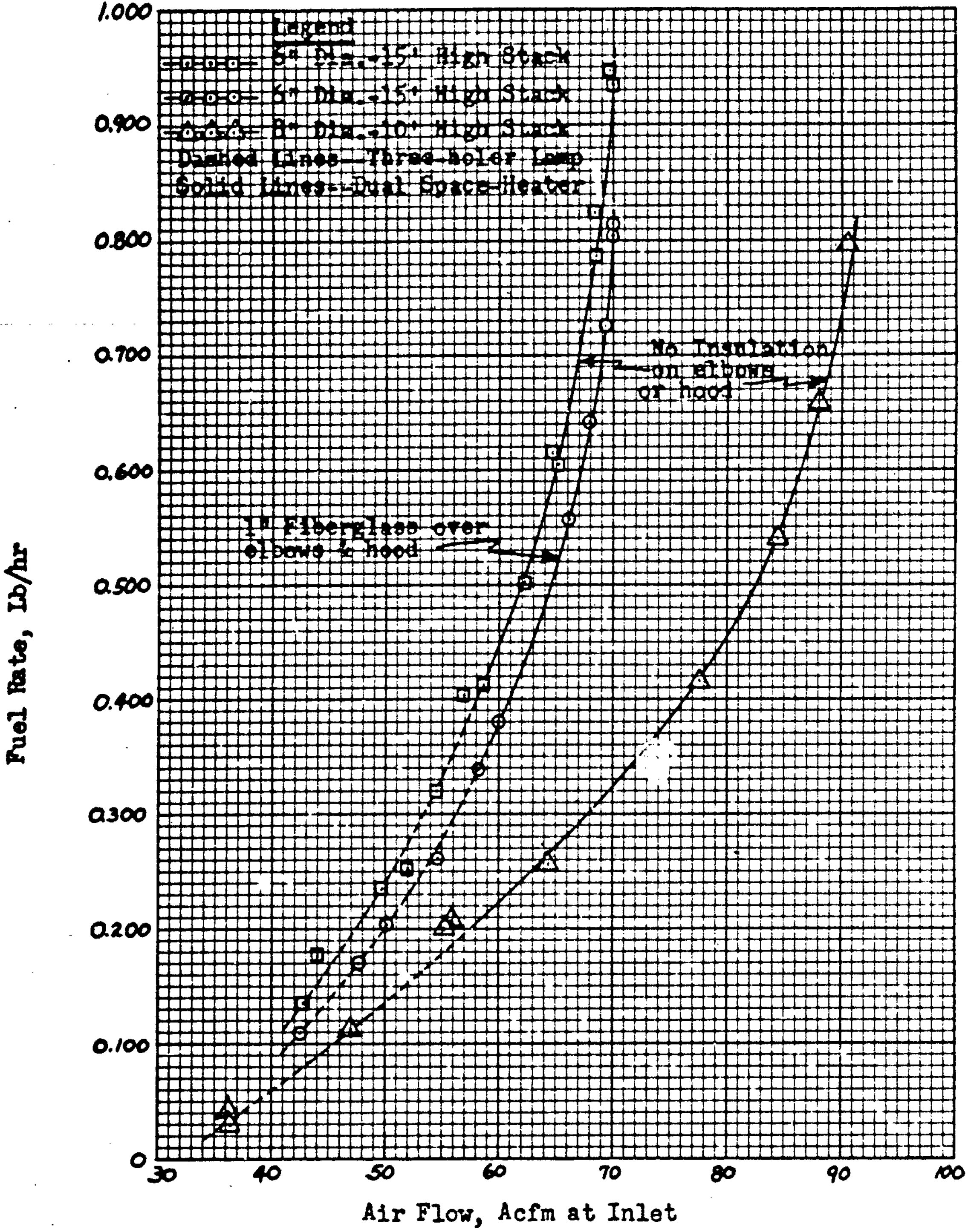


Figure 27. Fuel Rate vs. Air Flow -- Closed Door Test

horizontal stack and hood (not just hood and one elbow as would be normal), it is still significant.

The two curves for 6 in. stacks illustrate the effectiveness of insulation placed on the hood, elbows, and horizontal length of stack. For any given air flow covered by the two curves, the fuel (kerosene) consumption for the uninsulated stack is decreased by about 15 percent by the addition of 1 in. of fiberglass insulation. This 15 percent may not be realized in a normal installation because some of the horizontal piece and one elbow may be in soil or space that is much better conductor than the fiberglass. The percentage decrease in fuel rate is seen to apply over the entire flow range for the 6 in. stack condition described. Over an extended shelter occupancy, this savings could mean a considerable decrease in amount of fuel, and fuel cost. Also seen from Figure 27 is the relative effectiveness of the "three-holer" lamp and the dual space-heater burner.

This simple test indicates that stack insulation is very important. If a single walled stack is to be used, it should be insulated with a minimum of 1 in. of fiberglass in order to obtain maximum efficiency. Due to the high cost of insulation, an insulated single-wall stack would cost about the same as self-insulated Metal-Bestos stack. Metal-Bestos stack is easier to handle, install and requires less maintenance than an insulated single-wall stack.

A few tests were conducted using a white gas camp cook stove and a two mantle gas lantern. With both types of heaters it was observed that as the gas burned from the tanks, the tank pressure decreased. As a result the stack temperature and air flow decreased. Thus, gas stoves and gas lanterns are not recommended as heat generating equipment for shelters. This equipment requires frequent tank pressurizing to maintain constant air flow; the flame must be turned off to refuel the tank; and the fuel is inherently dangerous because of the possibility of explosion and fire in the shelter. In extreme emergency situations, however, gasoline-type heaters could be used if proper precautions are observed. A two mantle gas lantern will produce flows approximately equal to that of two kerosene lamps. A two-gas-burner camp stove will produce flows about equal to the two space heater unit.

Table 1 on page 67 indicates the relative merit of the kerosene burners used in this investigation. The column headed maximum temperature difference gives the minimum of the maximum values, i.e., the lowest values of maximum temperature difference that could be reached day after day without trimming the wicks. In some tests, higher maximum values were obtained but these were always shortly after the wicks were trimmed or new ones installed.

Figure 28 gives the relation between temperature difference and expected fuel rate in gallons of kerosene per hour for several stack arrangements.

Curves on the following pages are to be used for the design of induced draft ventilation systems. The four graphs of temperature difference versus flow rate are for 4, 6, 8, and 10 in. diameter zero equivalent length stacks, i.e., straight stacks-no elbows or caps, and for vertical heights of 5, 10, 15, 20, 25, and 30 ft. The values used in plotting these graphs were obtained from the computer program of the flow equation for the open door condition. The validity of the equation was previously established. The plots are for standard atmospheric conditions (29.92 in. Hg and 70° F) and straight stacks. Effects of barometric changes for altitudes between 0 and

TABLE 1

Maximum Temperature Difference Obtainable for 6 and 8 in. Diameter Straight Stacks of Various Lengths with Different Types of Burners

| Diameter Inches | Vertical Height Feet | Max. Temperature Difference, °F | Type of Burner |
|---|---|---|---|
| 6 | 5 | 42<br>81<br>167 | 3 Kerosene Lamps<br>1 Space Heater<br>2 Space Heaters |
| | 10 | 34<br>78<br>143 | 3 Kerosene Lamps<br>1 Space Heater<br>2 Space Heaters |
| | 15 | 32<br>70<br>112 | 3 Kerosene Lamps<br>1 Space Heater<br>2 Space Heaters |
| 8 | 5 | 24<br>42<br>55<br>120 | 2 Kerosene Lamps<br>3 Kerosene Lamps<br>1 Space Heater<br>2 Space Heaters |
| | 10 | 21<br>34<br>39<br>83 | 2 Kerosene Lamps<br>3 Kerosene Lamps<br>1 Space Heater<br>2 Space Heaters |
| | 15 | 32<br>35<br>71 | 3 Kerosene Lamps<br>1 Space Heater<br>2 Space Heaters |
| | 20 | 60 | 2 Space Heaters |

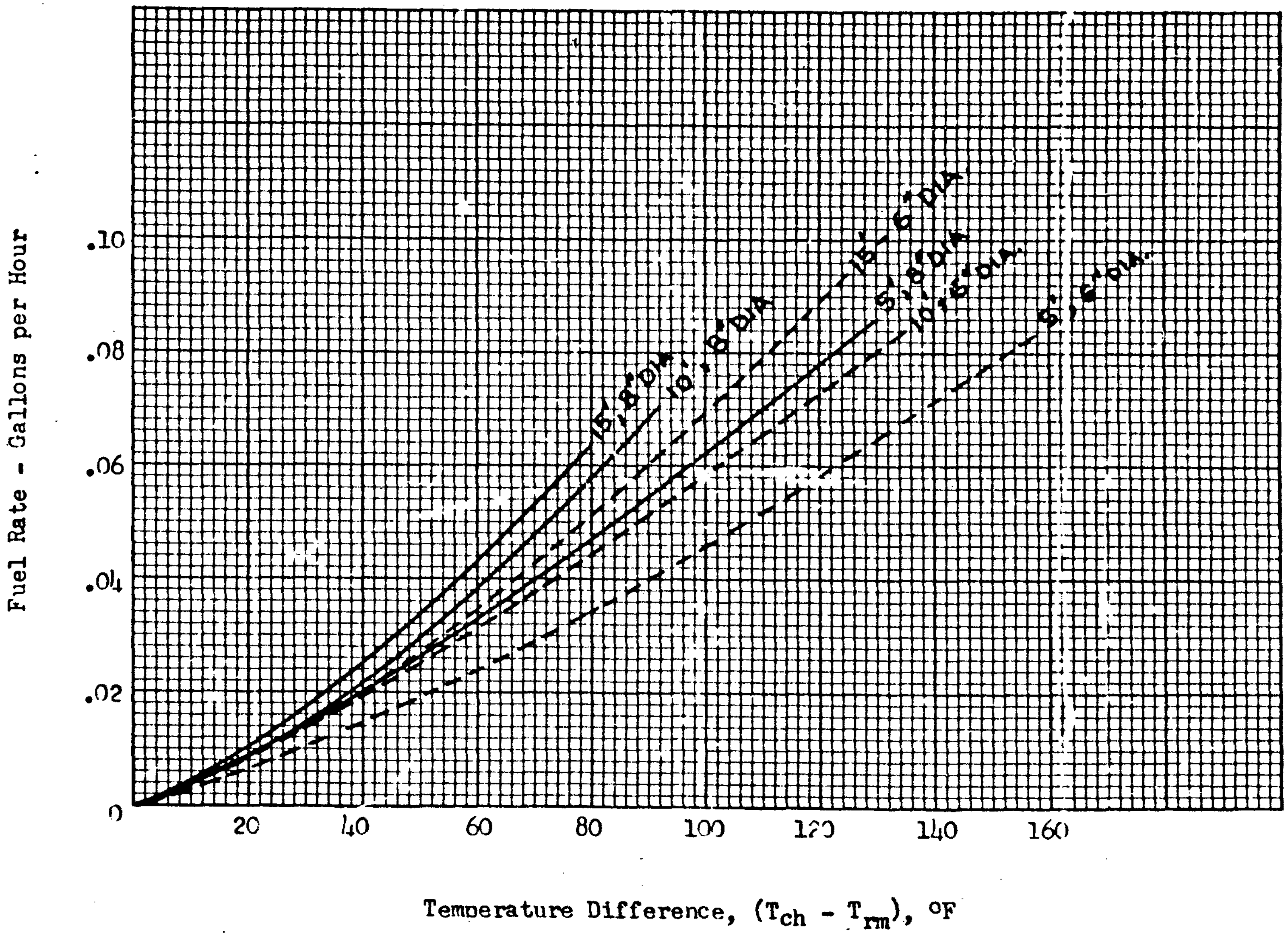


Figure 28. Fuel Consumption Rate vs Temperature Difference for 6" and 8" Diameter Stacks

5000 ft are so small that pressure corrections do not need to be applied to these graphs.

Because it is recommended that at least two elbows and a short length of horizontal stack be used, corrections to the straight stack curves must be made according to the equivalent length of the added restriction. The effect of adding elbows, horizontal lengths, and vent caps to the vertical stack can be taken into account by use of the correction factors given in Figures 29, 31, 33, and 35 or in Table 2. These correction factors were obtained by dividing the theoretical air flow rates obtained with a straight stack by the theoretical flow rate obtained with a stack system containing 0 to 21 equivalent feet of added restriction.

These factors are to be applied to the required cfm value before entering the graphs for straight stacks. The required cfm of air flow is known from the size of an actual shelter in which a ventilation stack is to be installed. The stack diameter, vertical height, number of elbows, length of horizontal run, and type of vent cap (if used) must be assumed as a starting point in the design.

A more complete explanation of the design curves, tables, and method of design is given by an example.

## Sample Design Problem

It is desired to design a ventilation system for a shelter which requires a total of 100 cfm of fresh air. Assume that the shelter is such that it will conveniently accommodate an 8 in. diameter, 15 ft high stack with two $90^\circ$ elbows and 3 ft of horizontal run. A Belmont cap is desired at stack outlet.

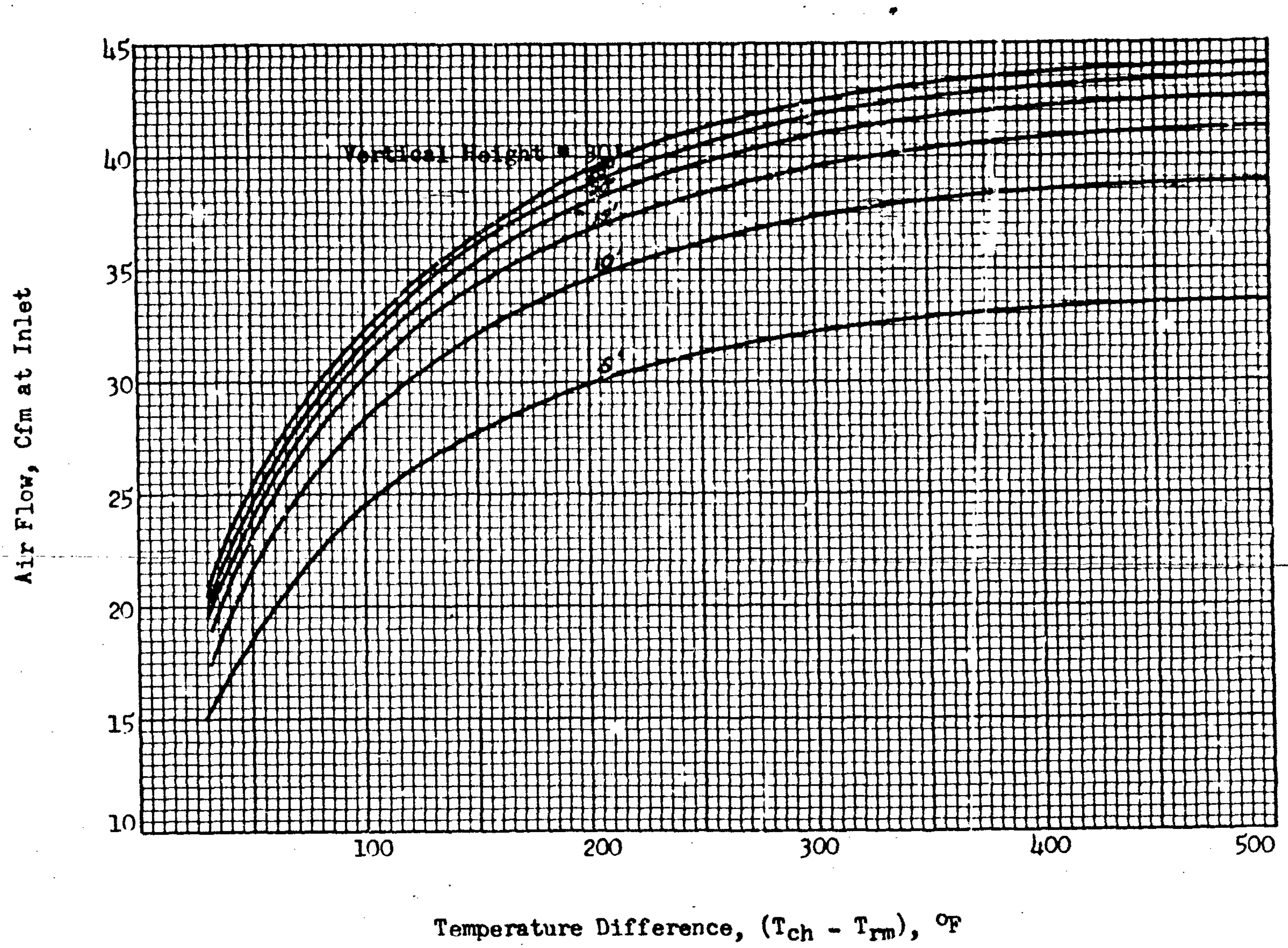


Figure 29. Air Flow vs Temperature Difference for 4" Dia. Straight Stack

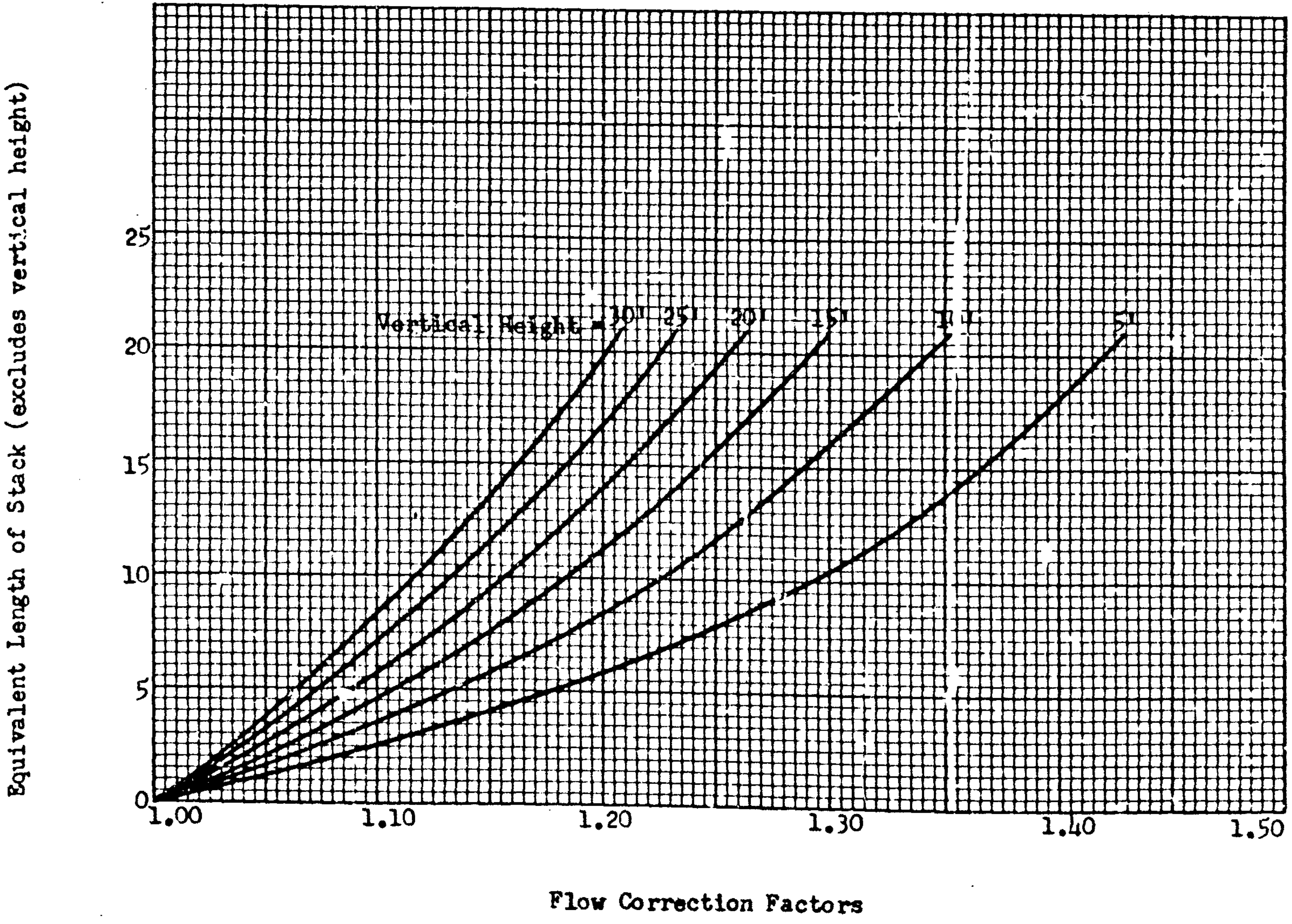


Figure 30. Flow Correction Factors vs Equivalent Length of Stack For 4" Dia. Stack

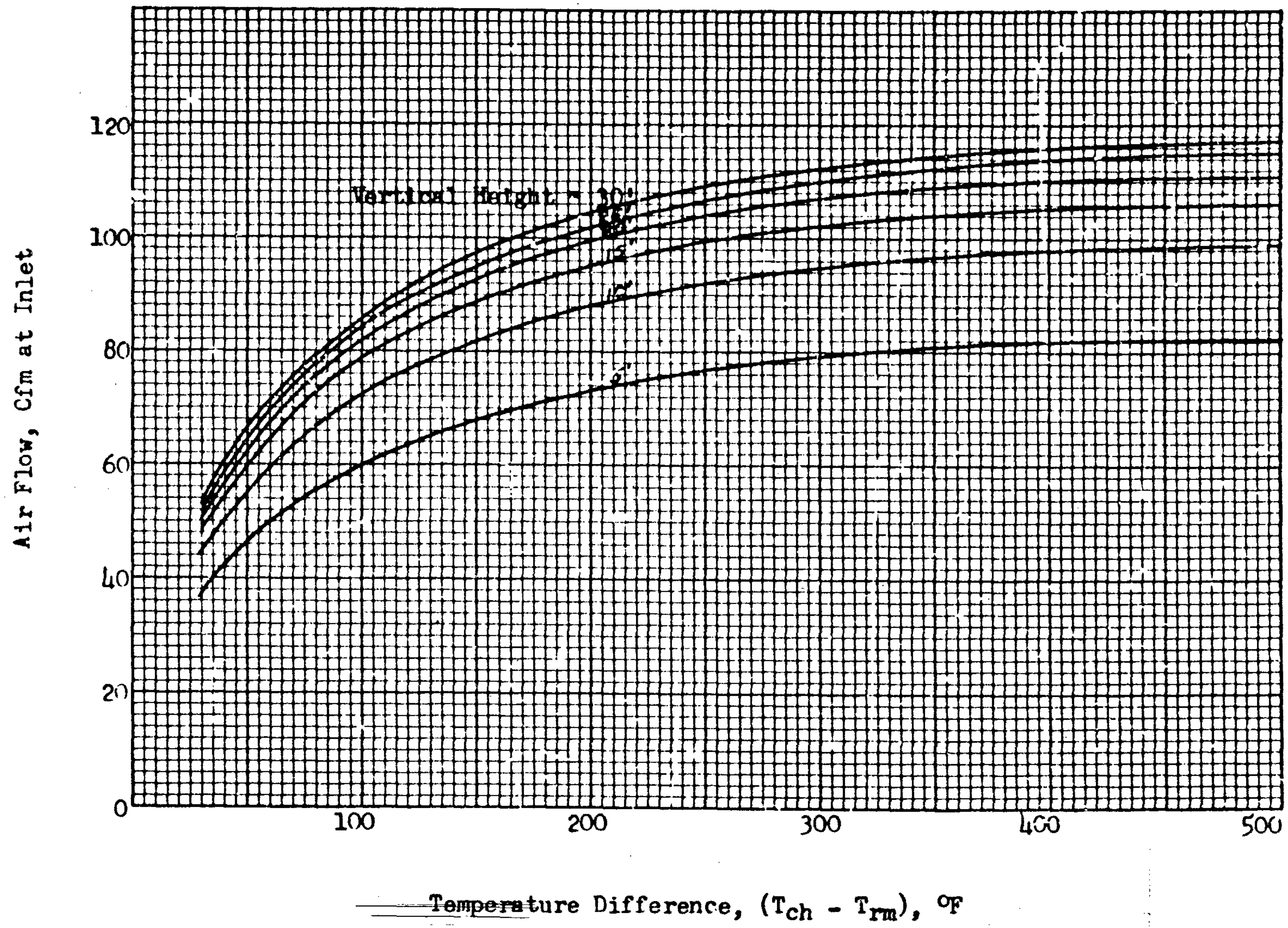


Figure 31. Air Flow vs Temperature Difference for 6" Dia. Straight Stack

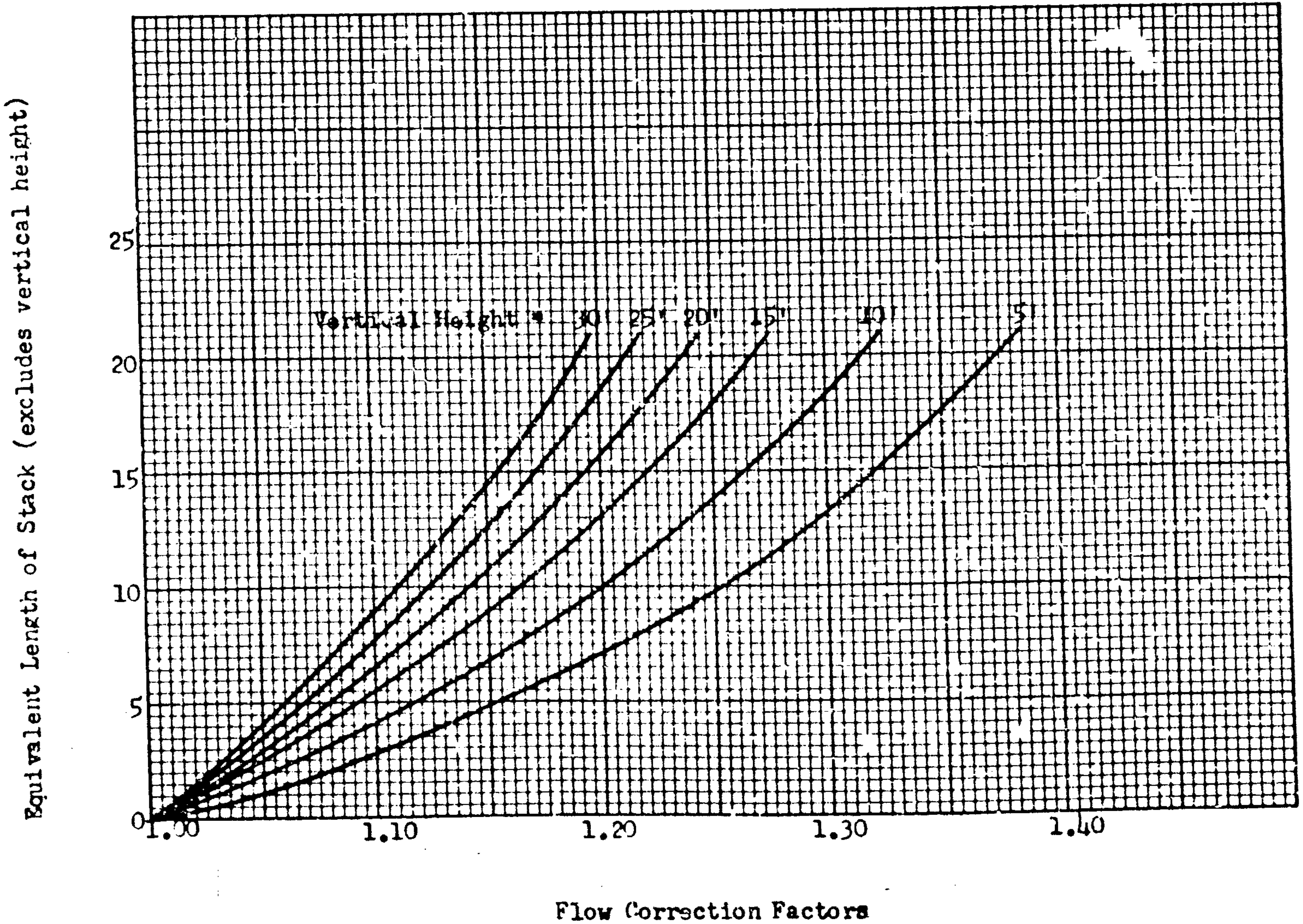


Figure 32. Flow Correction Factors vs Equivalent Length of Stack For 6" Dia. Stack

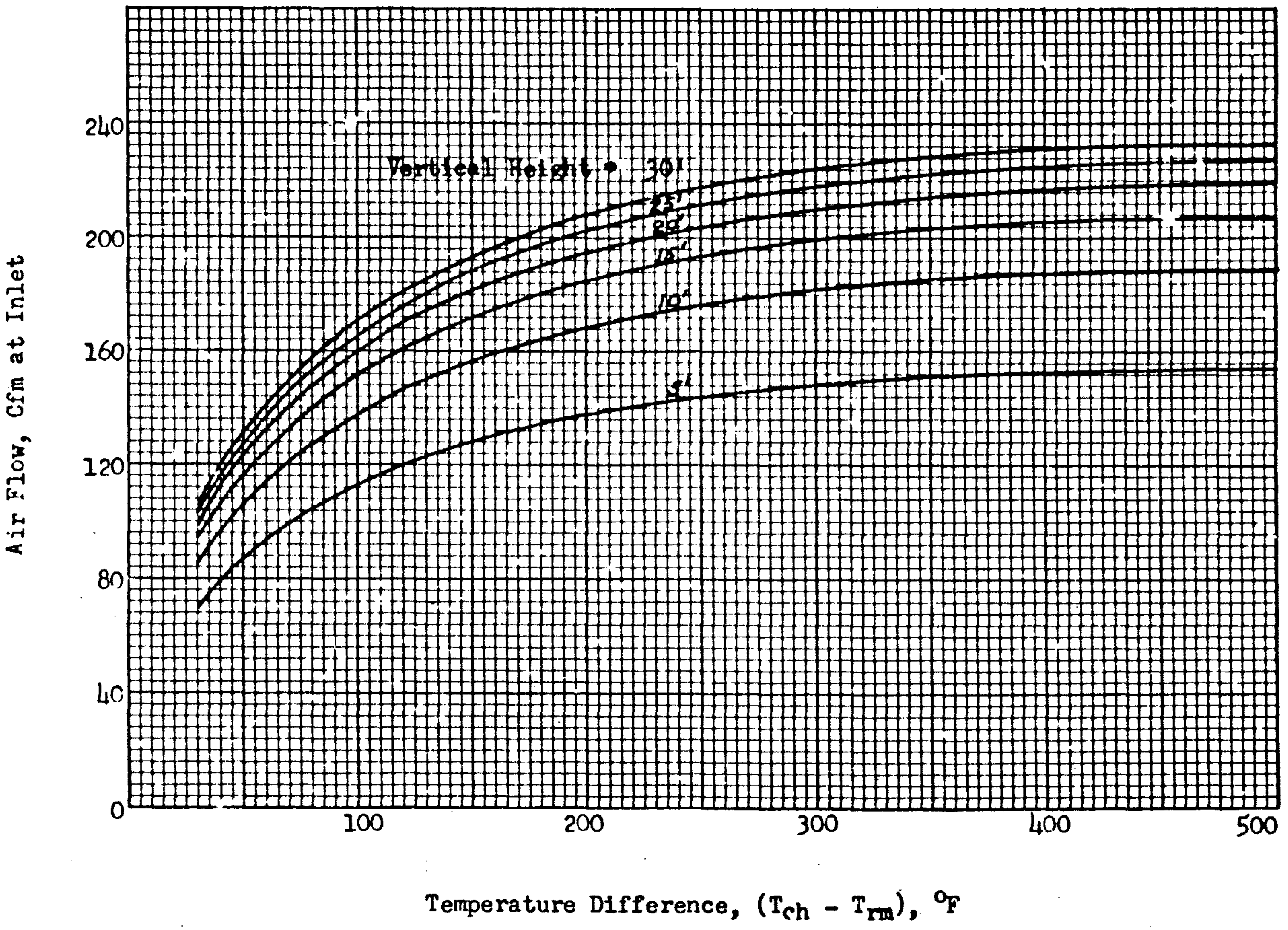


Figure 33. Air Flow vs Temperature Difference for 8" Dia. Straight Stack

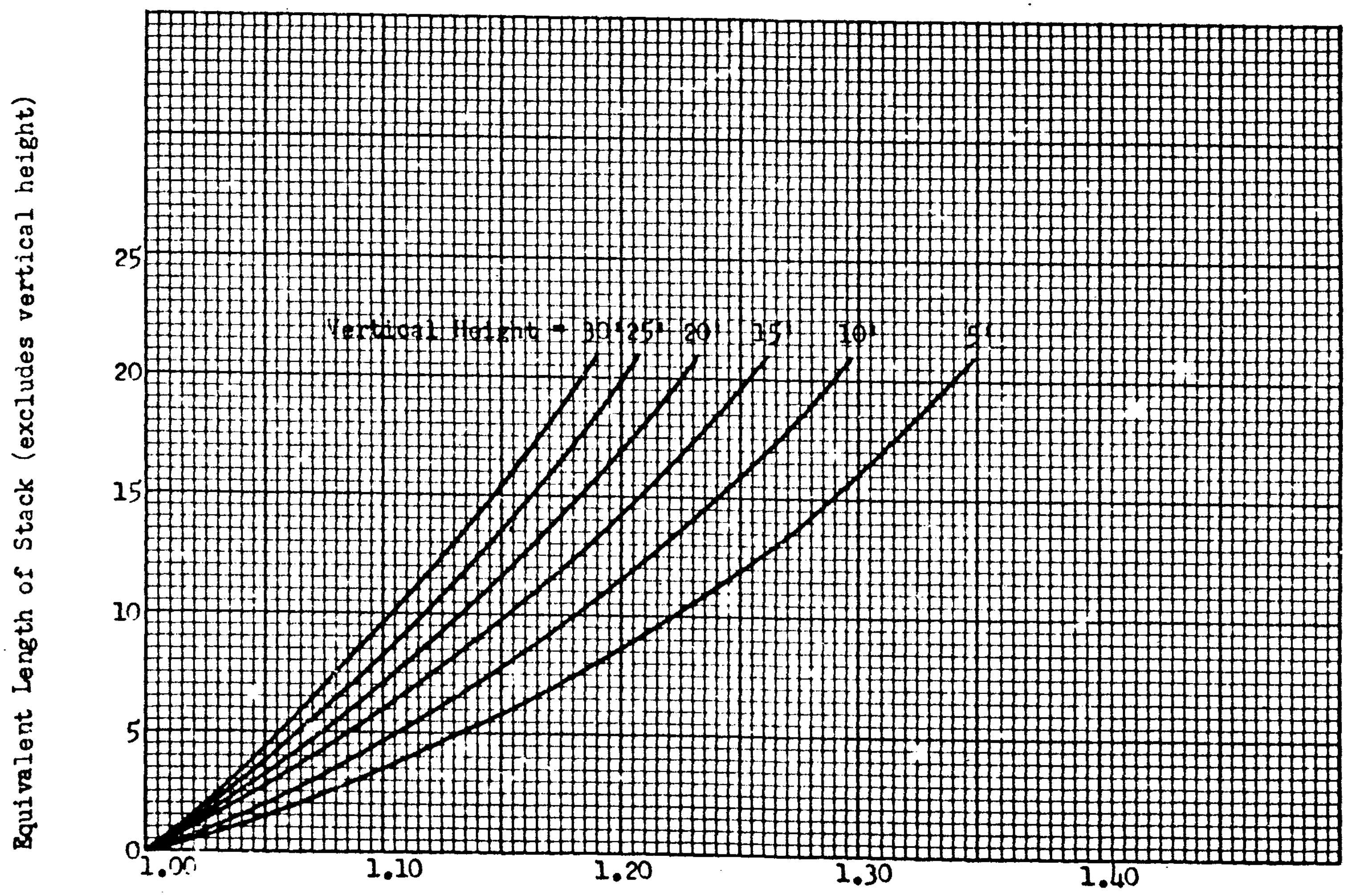


Figure 34. Flow Correction Factors vs Equivalent Length of Stack For 8" Dia. Stack

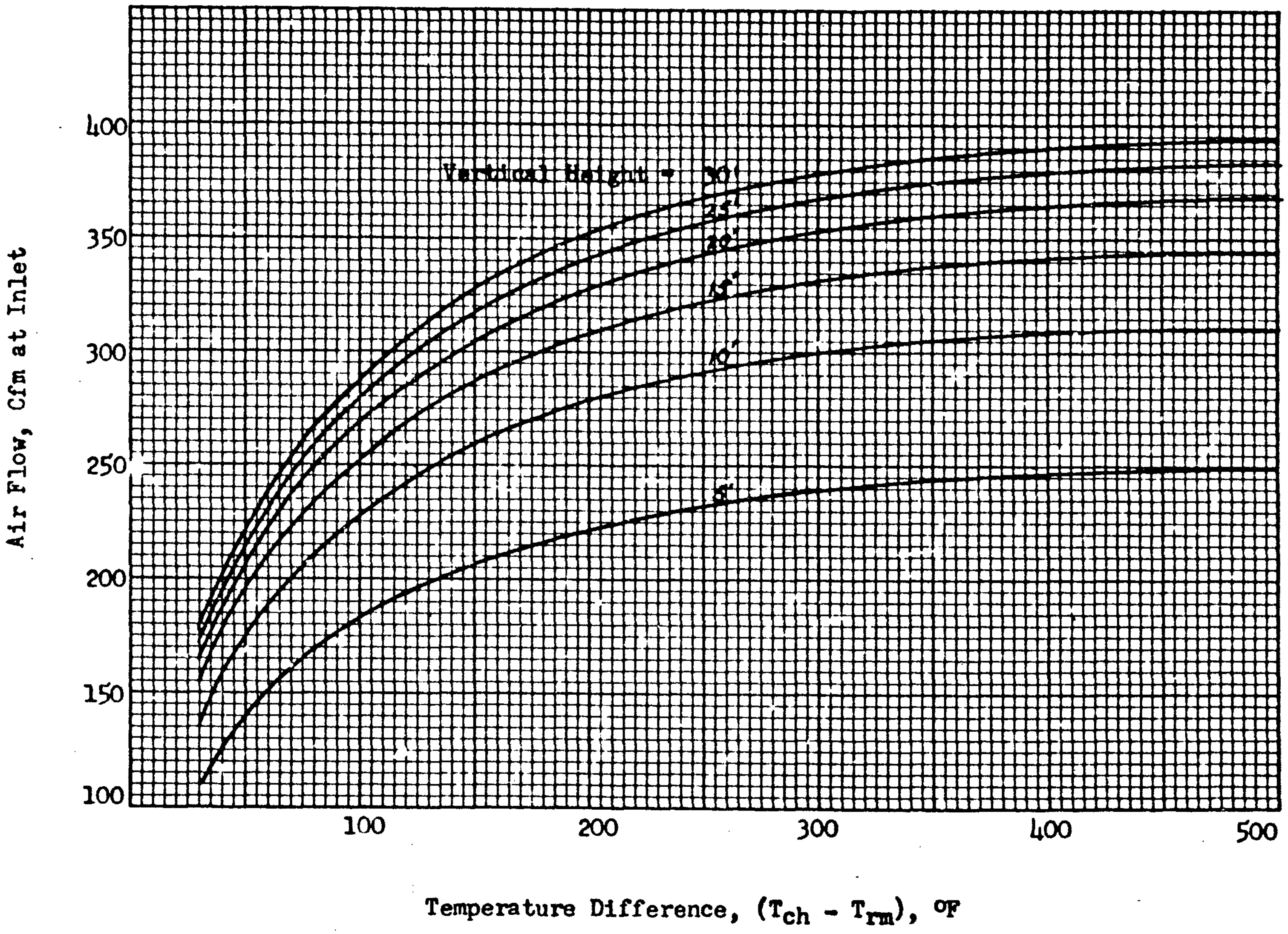


Figure 35. Air Flow vs Temperature Difference for 10" Dia. Straight Stack

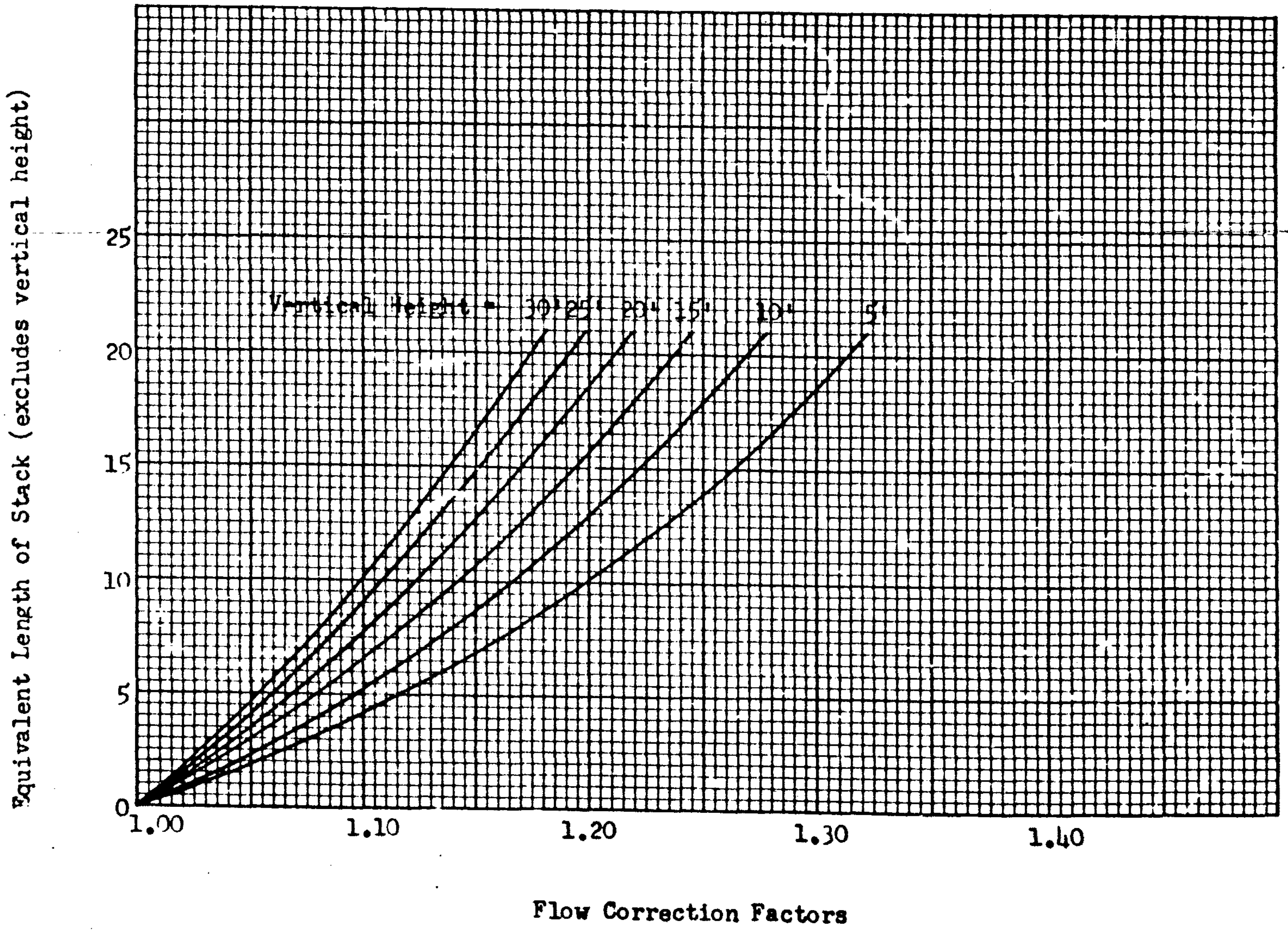


Figure 36. Flow Correction Factors vs Equivalent Length of Stack for 10" Dia. Stack

TABLE 2

Flow Correction Factors to be Applied to Zero Equivalent Length Cfm Curve for Effects of Added Stack Resistance

| Vertical Stack Height | Added Eq. Ft | Stack Diameter | | | |
|---|---|---|---|---|---|
| | | 4" | 6" | 8" | 10" |
| 5' | 0 | 1.000 | 1.000 | 1.000 | 1.000 |
| | 5 | 1.180 | 1.153 | 1.131 | 1.115 |
| | 9 | 1.271 | 1.234 | 1.205 | 1.184 |
| | 13 | 1.336 | 1.296 | 1.264 | 1.238 |
| | 17 | 1.387 | 1.345 | 1.309 | 1.285 |
| | 21 | 1.428 | 1.384 | 1.348 | 1.322 |
| 10' | 0 | 1.000 | 1.000 | 1.000 | 1.000 |
| | 5 | 1.133 | 1.117 | 1.104 | 1.095 |
| | 9 | 1.208 | 1.185 | 1.166 | 1.152 |
| | 13 | 1.264 | 1.240 | 1.217 | 1.201 |
| | 17 | 1.312 | 1.285 | 1.262 | 1.242 |
| | 21 | 1.352 | 1.323 | 1.297 | 1.278 |
| 15' | 0 | 1.000 | 1.000 | 1.000 | 1.000 |
| | 5 | 1.104 | 1.091 | 1.085 | 1.078 |
| | 9 | 1.169 | 1.150 | 1.141 | 1.130 |
| | 13 | 1.221 | 1.199 | 1.186 | 1.174 |
| | 17 | 1.264 | 1.240 | 1.227 | 1.212 |
| | 21 | 1.300 | 1.276 | 1.261 | 1.245 |
| 20' | 0 | 1.000 | 1.000 | 1.000 | 1.000 |
| | 5 | 1.087 | 1.080 | 1.174 | 1.068 |
| | 9 | 1.144 | 1.130 | 1.122 | 1.114 |
| | 13 | 1.189 | 1.193 | 1.163 | 1.152 |
| | 17 | 1.228 | 1.211 | 1.199 | 1.188 |
| | 21 | 1.264 | 1.244 | 1.232 | 1.219 |
| 25' | 0 | 1.000 | 1.000 | 1.000 | 1.000 |
| | 5 | 1.074 | 1.070 | 1.063 | 1.059 |
| | 9 | 1.122 | 1.114 | 1.107 | 1.099 |
| | 13 | 1.165 | 1.153 | 1.144 | 1.135 |
| | 17 | 1.201 | 1.188 | 1.182 | 1.168 |
| | 21 | 1.233 | 1.219 | 1.207 | 1.198 |
| 30' | 0 | 1.000 | 1.000 | 1.000 | 1.000 |
| | 5 | 1.064 | 1.061 | 1.057 | 1.053 |
| | 9 | 1.107 | 1.100 | 1.094 | 1.091 |
| | 13 | 1.146 | 1.137 | 1.130 | 1.124 |
| | 17 | 1.179 | 1.169 | 1.161 | 1.153 |
| | 21 | 1.209 | 1.197 | 1.190 | 1.181 |

Step (1) Calculate equivalent length of added restriction. From previous discussion it is known that:

1 90° elbow = 4.2 eq. ft

1 Belmont cap = 5.5 eq. ft

3 ft horizontal run = 3.0 eq. ft

Therefore, the total equivalent length of the added restrictions = 2 x 4.2 + 1x 5.5 + 3 = 16.9 eq. ft added restriction.

Step (2) Figure 34 which gives the correction factor to be applied to an 8 in. diameter straight stack to account for the equivalent length of added restrictions. From this graph at an equivalent length of 16.9 ft and a vertical height of 15 ft, read a correction factor of 1.225.

Step (3) Multiply the desired air flow by this correction factor.

100 x 1.225 = 122.5 cfm.

Step (4) Enter Figure 33 which gives the desired temperature difference to obtain 122.5 cfm with an 8 in. straight stack of 15 ft vertical height (already corrected for elbows, etc.). At 122.5 cfm we read a temperature difference of 57° F. (This means that if ambient air is at 80° F, the mean stack temperature must be 57 + 80 or 137° F.)

Step (5) From Figure 28 the fuel rate at a temperature difference 57° F for a 15 ft 8 in. diameter stack is about 0.04 gal per hour.

Step (6) Table 1 indicates that two space heaters will provide the required temperature difference and thus the desired 100 cfm of ventilation air.

When using this design procedure the designer should be aware that more than one set of conditions will provide the desired ventilation rate.

A thorough investigation of several of the possible sets of conditions should result in the most economical design. In considering the most economical design, the cost of the stack-system, fuel, and type of burner for each of the possible systems should be compared.

When deciding upon the type of burner and the fuel rates, the designer should remember that the values given in Figure 28 and Table 1 are approximate. This approximation results from laboratory results because of the difference in performance of the various available burners. The "golden rule" of over-designing should be observed in the last two design steps. As no fuel data is available for 4 and 10 in. diameter stacks the designer must reach a decision on the type of burner and the fuel rate without actual values. Figure 28 for 6 and 8 in. diameter stacks should be of some help in reaching this decision because it shows the trend followed by the fuel rate as it varies temperature and stack parameters.

As a sample shelter cost analysis, consider the system discussed in the design problem above. The following is a list of representative prices of equipment and materials.

| | | |
|---|---|---|
| 1 | 5 ft length 8 in. Metal-Bestos stack | $13.00 |
| 1 | 8 in. 90° elbow | 1.00 |
| 1 | 2 ft length 8 in. duct | 1.00 |
| 1 | 8 in. Belmont cap | 7.50 |
| 1 | Space Heater | 14.00 |
| 1 | sq ft fiberglass insulation 1 in. thick | .40 |
| Kerosene per gal | | .18 |
| Rectangular Hood | | 7.50 |

The cost of equipment and materials for the sample shelter is thus,

| | |
|---|---|
| 15 ft stack | $39.00 |
| 2 elbows | 2.00 |
| 3 ft horizontal run | 1.50 |
| 8 in. Belmont cap | 7.50 |
| 2 Space Heaters | 28.00 |
| Kerosene (13.5 gal/2 weeks) | 2.80 |
| Hood | 7.50 |
| 10 sq ft insulation | 4.00 |
| Total | $92.30 |

This total price is for the conditions described by one set of shelter parameters. Smaller diameter stacks lower the total cost - larger diameter stack increase the total cost. This analysis should be helpful in estimating the cost of any shelter ventilating system of this type.

## SUMMARY

As stated previously, the fallout shelter tested has an occupant capacity of 18 people and requires, as a bare minimum, at least 54 cfm of fresh ventilating air. It is concluded that this minimum ventilation rate can be obtained by burning kerosene in the base of a chimney or stack.

Results of this ventilation investigation indicate that the maximum air temperature difference between the inside and outside of the stack $(T_{ch} - T_{rm})$ that is of benefit for home shelter is around 300° F. With an ambient temperature of 70° F, this means that the maximum mean stack temperature of benefit is about 370° F. The return for higher stack gas temperatures is insignificant.

The highest stack temperature obtainable with the kerosene wick-type burners used in the test is about 230° F, depending upon stack diameters, length, number of elbows, etc. It is feasible that a wick-type burner could be designed to produce a maximum stack temperature of 370° F. Wick-type burners are desirable because they require essentially no pressure drop for efficient combustion and they can be used to light the shelter.

The lowest fuel comsumption rate is obtainable when the intake hood and the portion of the stack that is within the shelter is insulated. A minimum of one inch of common fiberglass insulation is recommended. For high efficiency and low maintenance cost, Metal-Bestos stack is recommended for that portion of the stack that is outside the shelter.

Family-type shelters in general can be adequately ventilated by the induced draft method if certain qualifications are observed. The shelter should be located in the basement of the house so that air can be drawn from the main part of the house. In this manner the house will serve as the radiation-particle filter for the shelter inlet. Outside air will infiltrate naturally into the house through window cracks, under doors, etc. in sufficient quantities to be available to ventilate the shelter. Filters should not be used at the shelter inlet because in general they offer too large of restriction to air flow and reduce ventilation rates to below minimum values. If an intake duct is used, its cross-sectional area should be at least twice that of the stack. An open door is recommended. The stack should contain at least two elbows and a short horizontal length of duct. This is essential for providing shielding from fallout radiation rays. A good ventilator stack cap should be used if the stack exhausts directly to the atmosphere to insure that fallout particles, rain, snow, and other debris do not enter the shelter through the stack. If a stack cap is not used, the stack should exhaust to a ventilated attic. The attic will minimize wind effects, eliminate fallout particles from entering stack, and prevent vitiated air from recirculating through the house and shelter.

Although kerosene wick-type burners are recommended for induced draft ventilation, it seems feasible that in an extreme emergency situation any flame from whatever equipment is available--such as a gasoline camp-cook stove-could be used to induce the draft. Ventilation efficiency and safety aspects would be reduced but perhaps, and most important, human lives could be saved.

An impingement-type filter which could possibly be used in some shelters was discovered at a date too late to investigate completely. The filter is produced by the Air-Maze Corporation and it offers less than 0.1 in $H_2O$

restriction at air velocities down to about 70 fpm. The efficiency is low at minimum velocities but perhaps it could be used to advantage. Further research is required to determine its feasibility.

Some aspects of family-type shelter ventilation by the induced draft method warrant further investigation. Future research should center around the following objectives:

1. Investigation of kerosene wick-type burner design with the intent of reaching 370° F stack temperatures.
2. Fuel investigation including storage and safety controls.
3. Economic analysis of all phases of the induced draft method of shelter ventilation.
4. Investigation of the possible use of a low restriction filtering system.

# APPENDIX

## THERMISTOR ANEMOMETRY

Extensive investigation was conducted concerning the possibility of using a bead-type thermistor as an air anemometer. The attempts were unsuccessful and the results useless as far as ventilation was concerned, but the research work was important and warrants recording.

Although nearly four and one-half months were spent investigating thermistors with no apparent useful results, it is felt that the time was justified for three principal reasons. First, thermistors, if applicable, would allow measurement of extremely low velocity air flows (starting at zero velocity) as well as high flows. No other method of flow measurement known permits, with sufficient accuracy, measurement of flows with a velocity lower than about 40 ft per min (nearly 15 cfm in an 8 in. duct). Thermistors would have allowed measurement of the natural ventilation through the shelter. Secondly, a permanent record of output voltage and thus of flow would be available with this method. This is desirable because it establishes a reference and affords one the opportunity to recheck measurements later on if the need arises. Thirdly, it is possible that thermistors other than the bead-type and circuits other than the bridge-type may be used successfully in air flow measurements. No more time could be spent on thermistor investigation, but the knowledge gained from this experience should be useful as a starting point in further thermistor research.

For use as an air measuring device, the thermistor was built into probe form. Two small parallel holes were drilled through the length of a two-inch long 1/2 in. diameter nylon rod which is pointed on one end. The fine wires of the bead thermistor were inserted through the holes in the rod and cemented in place. Only the bead protruded from the pointed end of the nylon rod. After wire leads were soldered to the bead wires, the rod was fastened into the end of 5 in. long piece of 9/16 in. diameter stiff cardboard cylinder, the bead remaining exposed. The entire probe was stuck through a one-inch diameter rubber cork. When the assembly was inserted into a hole in the side of the 8 inch intake duct, the bead was positioned in the air stream by adjusting the length of probe extending beyond the cork. The probe was held rigidly in place due to a tight fit between the rubber cork and the hole in the side of the intake duct.

Figure 36 on page 88 shows the original bridge circuit designed and build for the thermistor air anemometer. The circuit consists basically of a Wheatstone-bridge with the thermistor as one resistance leg. In a leg adjacent to the thermistor is a decade resistance which permits compensating for thermistor bead temperature changes caused by intake air temperature changes. In the leg opposite to the thermistor is an adjustable resistance used to zero the voltage output of the bridge. Two transistors, connected together thermally, are included to provide a constant current through the thermistor when a constant 40 volts is supplied to the bridge circut.

Output from the thermistor bridge was connected to a Leeds & Northrup Speedomax 0-10 millivolt recorder. Thermistor output is sensitive to air velocity, and because the cubic feet per minute of air flowing in a fixed-size duct depends directly on the velocity, the output can be plotted against air flow rate. Thus, the recorder provided a direct indication and a permanent record of air flow.

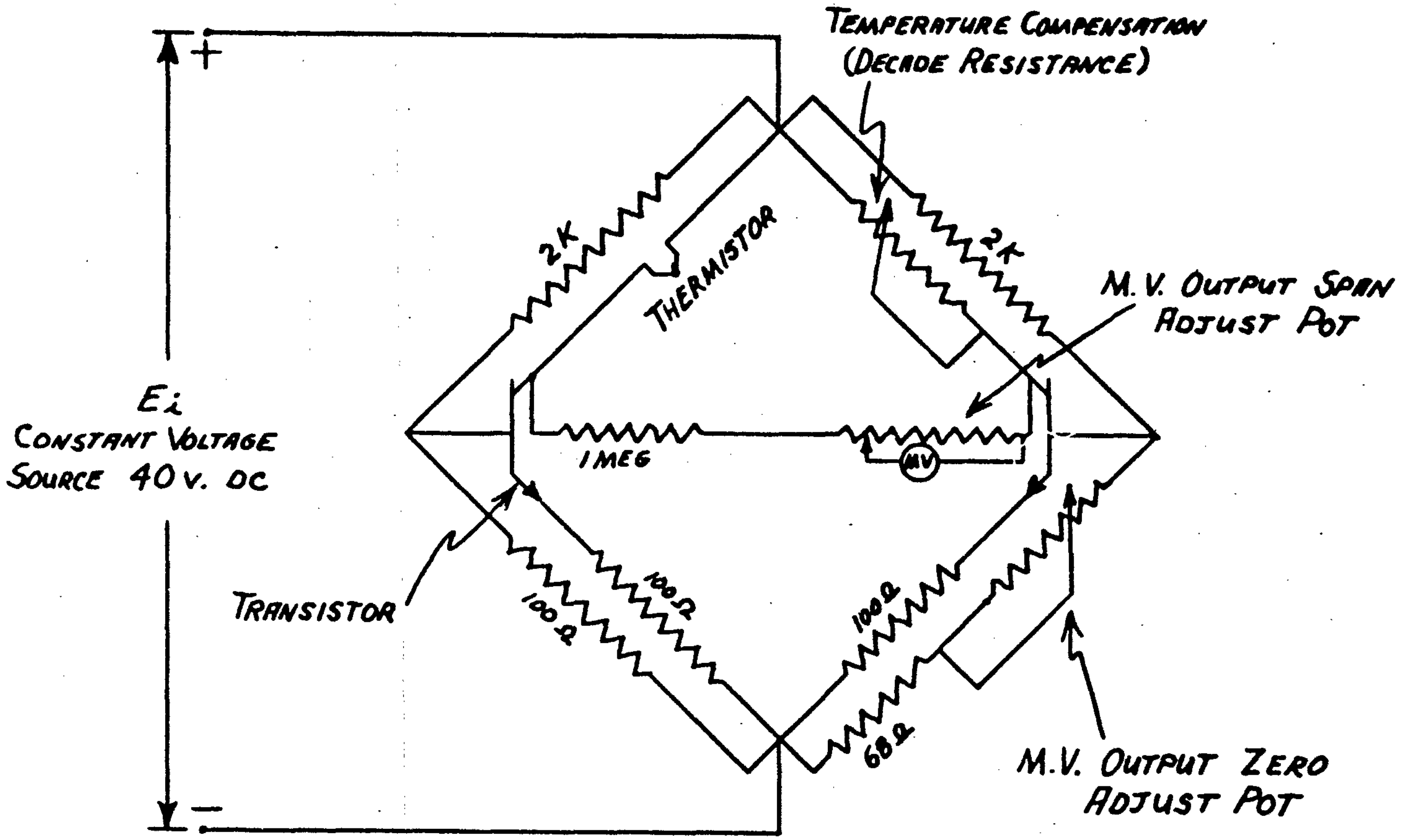


FIGURE 37. THERMISTOR BRIDGE CIRCUIT

During calibration of the thermistor, a laminar flow element, produced by the Meriam Instrument Company, was used with an accompanying centrifugal blower as the air flow standard. This laminar flow device, applicable to air flows from 0 to 200 standard cfm (at 29.92 in. Hg and 70° F), consists of parallel, capillary-size tubes through which the air flows. The pressure drop across the tubes has a straight-line relationship with the mass air flow. A linear calibration curve of this relationship, showing pressure drop across the tubes (in. of water) versus standard air flow (lb per min) is supplied with the element.

Equipment required to operate the thermistor included a 40 volt d.c. power supply, a voltmeter, two decade resistances for use in the bridge circuit, a millivolt recorder for recording thermistor output, and a thermocouple temperature recorder for determining temperature of air in the vicinity of the thermistor probe. This equipment, with the exception of the temperature recorder, is shown in Figure 37 on page 90 as arranged and used in the shelter.

To calibrate the thermistor, the blower and laminar flow element were connected at the exhaust of the shelter to draw air through the intake and shelter space. This permitted accurate calibration because it included any air leaks in the shelter. The calibration procedure for the thermistor probe located at the center of the eight-inch intake duct follows:

1. With probe in still air (cap ends of the 8 in. duct), set the output zero adjust on the bridge box until the millivolt output on recorder is zero.

2. Note temperature of air in duct, read the milliamps and volts through probe, and calculate by Ohms Law the resistance to be set on the temperature compensation decade box.

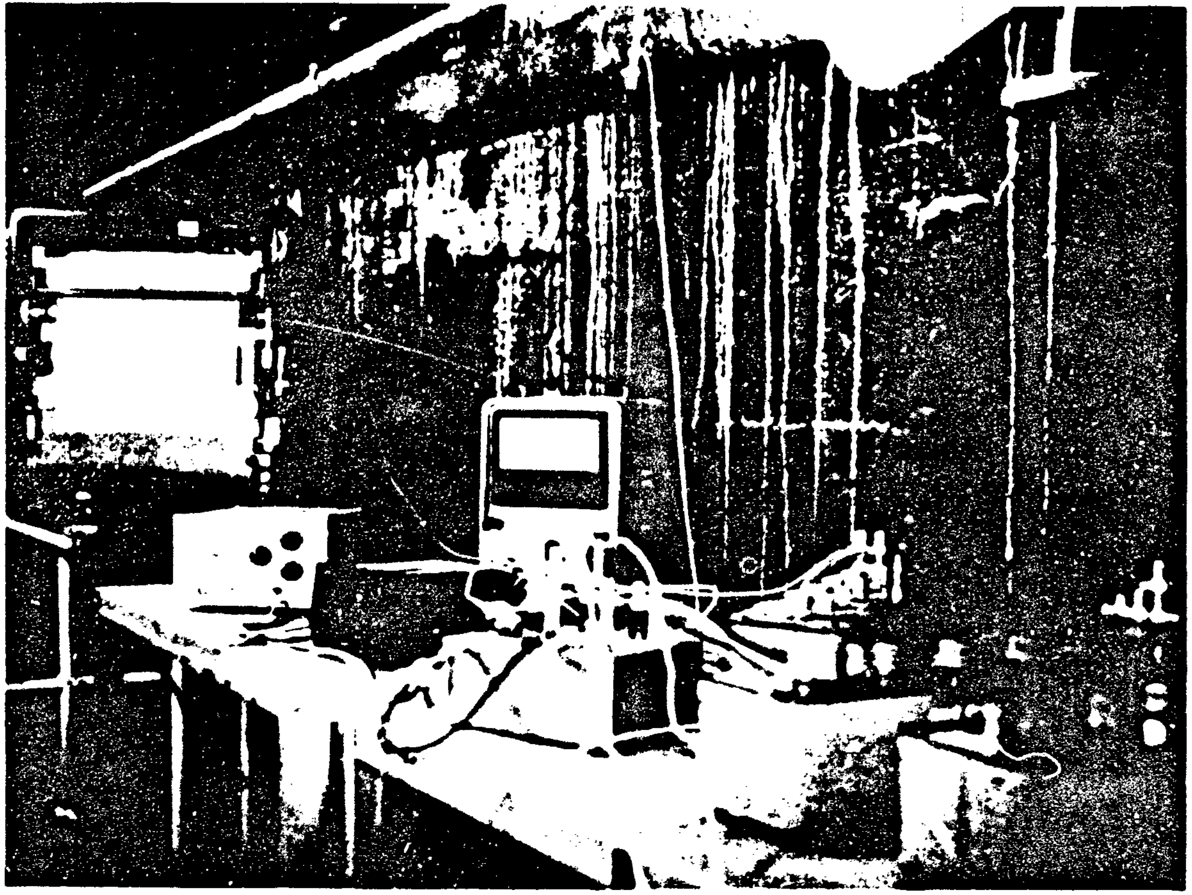


Figure 38. Equipment Used with Thermistor Anemometer

3. Uncap duct and set laminar flow element at a manometer reading which corresponds to the maximum flow desired. Set output span adjust on bridge box until about 10 mv show on recorder. Once output adjust is initially set, do not change.

4. Take readings at various points between zero and maximum flow. At each flow setting repeat step 2 and reset the temperature compensation decade resistance if temperature changes. At each reading record inches of water at manometer, duct temperature, and millivolt output. The barometric pressure should be recorded at start of calibration.

5. From the calibration curve supplied with the Meriam Instruction manual, read the standard air flow (pounds per minute at standard conditions of 29.92 in. Hg and 70° F) corresponding to manometer reading. Multiply standard pounds per minute by the barometric pressure correction factor and temperature-viscosity correction factor from instruction manual to obtain the real pounds per minute flowing at actual conditions of pressure and temperature. Find the actual cubic feet per minute (acfm) by applying the perfect gas law.

For a more complete description of the calibration procedure and related calculations, the reader is referred to the "Meriam Instruction Manual A-28836" published by the Meriam Instrument Company and supplied with their laminar flow instruments.

After collecting data as outlined above, a thermistor calibration curve of probe output (millivolts) versus flow (actual cubic feet per minute - acfm) was plotted. The curve, nearly linear and also approaching verticality, accommodated flows from zero to 150 acfm. Also drawn was a curve of resistance (ohms) versus intake temperature (°F) for use with the temperature compensation decade resistance box.

Two months were spent in conducting preliminary ventilation tests and becoming acquainted with the operation of various combustion equipment, temperature and pressure equipment, and the thermistor flow device. During this period of time results of low measurement had been fairly consistent and reproducible. Then for several days the zero setting of the thermistor in still air seemed to drift from conditions dictated by the temperature versus resistance calibration curve. Previous examination of literature on thermistors and comments by Electronics Research personnel indicated the possibility that thermistors may lose their reliability with use and time due to loss of calibration. No definite reasons for a possible calibration loss were cited except that perhaps the thermistor bead deteriorates enough to change the heat transfer characteristics of its surface.

To check out the above theory, it was decided to recalibrate the thermistor device. Two or three calibration runs, conducted according to the procedure outlined previously, covering the entire flow range from 0-150 acfm produced completely different and disassociated thermistor output readings. No sensible relationship between output and flow could be found. At this point we decided that the thermistor was completely deteriorated or "burned up". The surface of the bead appeared brown and somewhat charred.

Another thermistor bead similar to the first was acquired from the electronics laboratory. The only difference in the two thermistors was in the so-called response time. The second bead had a response of 25 seconds as compared to 2 seconds for the original bead. It was anticipated that the longer response time would decrease sensitivity enough to provide a more constant recording of output on the millivolt recorder, thus, making output easier to read.

In probe form, the second thermistor had an aluminum shield around the bead. The bead was located in the path of a diametral hole which ran through the hollow cylindrical shield. With the hole parallel to the air flow path, straighter flow lines around the bead than previously obtained were expected at all rates of flow.

Several calibration runs were conducted with the shielded probe installed in the intake duct. The millivolt recording deviated from a straight line by as much as three-fourths of a millivolt but readings were averaged with a polar planimeter. The flow-millivolt curve had many erratic points; enough that the results were unreliable.

It was again decided to use another thermistor. The third thermistor bead chosen required the same design voltage and current and had the same response time (2 seconds) as the original one. In order to retard the response time slightly, epoxy was added to the thermistor in the form of a thin coating over the bead.

Before starting to calibrate the new thermistor, further investigation of bridge circuits and instruments was carried out. It was discovered that current through the probe was not constant as had been originally planned during circuit design. It was strongly believed that this was the main cause for the wide variations in millivolt output from thermistor.

The designer of the original circuit was again contacted and the problems were discussed. As a possible solution, a new circuit which completely eliminated the thermistor bridge box was attempted. A number of decade resistances replaced the bridge, the idea being to obtain closer control of probe current. A calibration run proved, however, that the contrary was true. Current and voltage control through the probe was not only difficult to control but also unwieldy and inconvenient. Due to this fact, the third thermistor was overloaded with a power surge and burned out.

The train of thought returned to the original thermistor bridge circuit. After lengthy counseling with Professor Drummond of the Mechanical Engineering Department, it was agreed that the bridge should work satisfactorily if a few minor changes in operational methods were made. According to Fenwal Electronics, Inc., Framingham, Massachusetts, in their "Thermistor Manual" brochure, bead thermistors should be able to dissipate a maximum of about 850 milliwatts of power at a maximum safe continuous current of nearly 18 milliamps. With the first three thermistors operating with 40 volts at the supply, the probe current (about 12 m.a.) was well under the maximum allowable value. This indicated that previous burn-outs were caused either by power surges or by allowing the thermistor to set too long in still air with full power applied.

For the fourth thermistor probe the bridge supply voltage was increased to 47 volts which allowed nearly 15 milliamps through probe. This increased the possibility of bead "burn-out", but according to the thermistor characteristic curves, these power and current levels were tolerable. The main object of the power increase was to try to produce a more nearly horizontal calibration curve than was obtained originally.

Previous experience indicated that the method for calibrating the temperature compensation resistance or so-called zeroing of the millivolt output scale was deficient. The still air method originally used was changed somewhat by sealing the probe and a thermocouple in a pyrex beaker which in turn was immersed in a larger container of water. The temperature inside the beaker containing the thermistor was varied by changing the temperature of the water in the outer container. Readings of temperature and thermistor resistance were taken when conditions in the flask reached equilibrium. In this manner a calibration curve for temperature compensation was obtained for air temperatures ranging between 60° F and 100° F. Results of later spot checks revealed that points were reproducible within two percent of those on the curve.

Calibration of the thermistor for air flow measurement was again accomplished using the laminar flow element as before. Flow tests were again resumed using a flame in the stack. After one day of testing, the compensation resistance required to zero the output scale had drifted to the point where it was 30 ohms (about 20 percent) above what the calibration curve dictated. A check of the thermistor bead indicated it too had burned up or at least disintegrated beyond useful purposes.

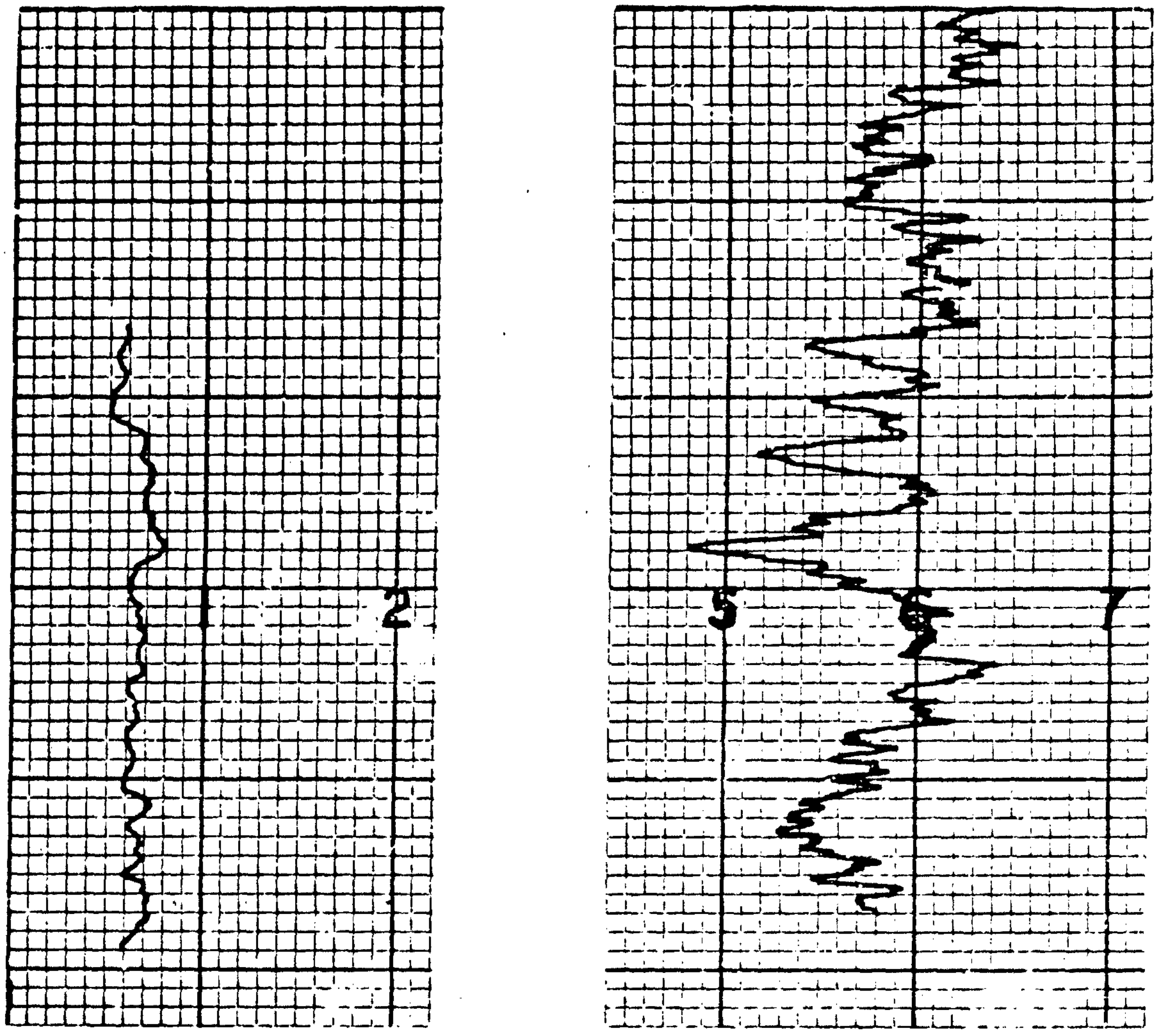
In an attempt to resolve the thermistor burn-out problem, it was discovered that the epoxy being used to coat the thermistor beads begins to deteriorate above a temperature of about 270° F. The thermistors had been operating at a temperature of nearly 350° F. Perhaps as the epoxy decays, the heat transfer characteristics of the unit change enough to adversely affect the resistance-temperature relationship of the thermistor. This phenomenon may account for the zero shift in output and add to the deterioration rate of the thermistor itself.

It was believed that the only way to check this theory was to try another thermistor without an epoxy coating. A probe of this type was built and installed in the intake duct. In order to decrease the possibility of further burn-up, the power through the bead was limited to 100 milliwatts which was 30 percent below the maximum tolerable level. A resistance of 2550 ohms, found by trial and error and connected in parallel with the thermistor, allowed operation at about 83 milliwatts with the original 40 volt bridge supply.

A temperature compensation calibration curve was again obtained by the previously described water immersion method. A flow check revealed, as had been anticipated, that the bare thermistor bead was too sensitive to air velocity changes. This was apparent from the millivolt output recording. Recorded millivolt values at flows above 80 cfm deviated as much as 15 percent from a straight line when plotted. Figure 39b on page 97 shows the degree and rapidity of millivolt output deviation. The chart speed during this particular run was six inches per minute.

In an attempt to reduce the sensitivity of the probe to the higher velocity air flows, two more 8 in. intake ducts, also about 4 ft long, were installed immediately above and below the first one. Still using only the single probe in the original duct, a complete calibration run with all ducts open was started. With the triple intake arrangement, the velocity past the probe should have been about one-third of the value previously obtained with a single duct. A spot test at about 100 acfm revealed that the output recording was as erratic with three ducts as with one. This is still not understood.

Another attempt to linearize the thermistor output consisted of filling the end of the center duct with one inch diameter aluminum foil tubes, twelve inches long, placed with their longitudinal axis parallel to the longitudinal axis of the main duct. The tubular "grid" ends about four



A. Low Flow. Output reading is 0.65 mv at 18.5 acfm.

B. High Flow. Output reading is about 5.8 mv at 86 acfm.

Figure 39. Comparison of Millivolt Output from Thermistor at Low and High Flows

inches from the thermistor. We found that the tube arrangement straightened the air flow path before it passed by the probe to the extent that the maximum millivolt output variation was under 7 percent at the highest air flow rates of 150 acfm. This was within tolerable limits because the output readings were averaged anyway by taking planimeter readings.

With some hope in the thermistor method of low measurement restored, calibration was continued. These hopes were again shattered near the end of the run when the temperature compensation resistance setting began drifting as it had with the epoxy-covered beads. From this behavior it was concluded that temperature compensation is not practical with this type of thermistor bridge circuit. A possible explanation is that the rate of heat transfer from the thermistor differs at different air temperatures and thus the thermistor resistance is perhaps not a constant for any particular temperature.

Endeavoring to find a solution, the compensating resistor of the bridge was arbitrarily fixed at 725 ohms and calibration tests conducted at several different but constant intake air temperatures. The final result was a family of linear calibration curves of millivolts versus flow, one curve for each temperature. Nearly all points for each curve were reproducible within ±5% which amounts to a maximum flow deviation of about 7 cfm. It was decided to proceed with ventilating tests and rely on this arrangement of air flow measurements, keeping in mind the accuracy of calibration.

After several days of testing, using kerosene lamps as the heat source at the stack, the millivolt recorder failed to operated. Several parts including tubes, fuses, a rectifier, and transformer had burned out.

Another recorder was borrowed from the Physics Department, Montana State University, which necessitated another calibration run. After this had been done, more test data collected, and graphs plotted of flow versus stack temperature, it was very evident that the thermistor method of measuring air flow, as it was arranged, was not accurate enough for practical purposes. The points on the experimental flow-temperature graph were so widely scattered that no reasonable curve could be drawn through them. Because stack temperature measurements were reasonably accurate, the major difficulty was assumed to arise from the thermistor and its related circuitry. Thus, at this point it was decided to abandon the idea of measuring air flow with bead thermistors.

The difficulties and problems encountered as outlined in this section caused additional people to investigate the possibility of thermistor air flow measurement. Further information on thermistors, their applications, and factors influencing flow measurement via thermistors, is given in a thesis by Mr. Bill Cousineau, "Thermistor Anemometry Including Effects of Ambient Pressure and Humidity", Montana State University, June 1965.

## EXPERIMENTAL DATA

The data tabulated on the following 23 pages constitute the experimental values used in preparing the various curves presented earlier. A list of symbols and their meaning are given for quick reference.

$T_{in}$ = air temperature entering shelter, °F
$T_{ch}$ = mean stack air temperature, °F
$T_{rm}$ = air temperature surrounding the stack, °F
$\Delta T$ = temperature difference, $(T_{ch} - T_{rm})$, °F
$\Delta P_{rm}$ = shelter inlet pressure drop, in. $H_2O$
$\Delta P$(pitot) = static and stagnation pressure difference as measured with pitot tube, in. $H_2O$
Acfm = actual cubic feet per minute of air flowing at inlet conditions
$P_B$ = barometric pressure, in. Hg

Date: 1/7/65 $P_B$ = 24.59 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 15 ft Straight Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | $\Delta P_{rm}$ in. $H_2O$ | Acfm ft$^3$/min | $\Delta P$(pitc in. $H_2O$ |
|---|---|---|---|---|---|---|---|
| 1 | 74.5 | 253 | 79 | 174 | .0093 | 82.0 | .0138 |
| 2 | 75.0 | 253 | 79 | 214 | .0110 | 88.5 | .0178 |
| 3 | 75.5 | 340 | 79 | 261 | .0114 | 92.5 | .0196 |
| 4 | 75.5 | 370 | 79 | 291 | .0116 | 94.0 | .0223 |
| 5 | 75.5 | 227 | 82 | 145 | .0088 | 78.5 | .0122 |
| 6 | 75.5 | 200 | 79 | 121 | .0077 | 74.5 | .0107 |
| 7 | 74.5 | 167 | 79 | 88 | .0052 | 66.5 | .0079 |
| 8 | 74.0 | 257 | 79 | 178 | .0098 | 84.0 | .0150 |
| 9 | 74.0 | 284 | 78 | 206 | .0105 | 88.5 | .0170 |
| 10 | 74.5 | 351 | 79 | 272 | .0118 | 94.5 | - - - |
| 11 | 74.5 | 434 | 80 | 354 | .0121 | 97.0 | .0259 |

Date: 1/9/65 $P_B$ = 25.18 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 15 ft Straight Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | $\Delta P_{rm}$ in. $H_2O$ | Acfm $ft^3/min$ | $\Delta P_{(pitot)}$ in. $H_2O$ |
|---|---|---|---|---|---|---|---|
| 1 | 74.0 | 185 | 79 | 106 | .0078 | 72.0 | .0100 |
| 2 | 75.5 | 242 | 79 | 163 | .0092 | 81.6 | .0141 |
| 3 | 76.0 | 274 | 81 | 193 | .0100 | 85.5 | .0158 |
| 4 | 76.0 | 310 | 82 | 228 | .0106 | 88.7 | .0184 |
| 5 | 76.0 | 333 | 82 | 251 | .0118 | 91.3 | .0204 |
| 6 | 76.0 | 359 | 82 | 277 | .0119 | 92.5 | .0210 |
| 7 | 76.0 | 407 | 83 | 324 | .0125 | 95.0 | .0222 |
| 8 | 76.0 | 213 | 87 | 126 | .0087 | 74.8 | .0112 |

Date: 1/12/65 $P_B$ = 25.01 in. Hg Heaters: 1 Space Heater

Conditions: Closed Door, 15 ft Straight Stack, 6 in. Dia.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 76.5 | 122 | 78 | 44 | .0036 | 47.0 | .0046 |
| 2 | 77.0 | 140 | 79 | 61 | .0045 | 54.6 | .0059 |
| 3 | 77.0 | 156 | 79 | 77 | .0051 | 59.4 | .0072 |
| 4 | 77.0 | 172 | 79 | 93 | .0060 | 63.7 | .0078 |

Date: 1/13/65 $P_B$ = 25.15 in. Hg Heaters: 2 Space Heaters

Conditions: Open Door, 15 ft Straight Stack, 6 in. Dia.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 77.0 | 118 | 78 | 40 | - - - | 69.5 | .0083 |
| 2 | 77.0 | 136 | 78 | 58 | - - - | 66.9 | .0079 |
| 3 | 77.0 | 154 | 78 | 76 | - - - | 71.5 | .0093 |
| 4 | 77.5 | 174 | 78 | 96 | - - - | 79.5 | .0118 |

Date: 1/14/65 $P_B$ = 25.22 in. Hg Heaters: 2 Space Heate

Conditions: Open Door, 15 ft Straight Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | $\Delta P_{rm}$ in. $H_2O$ | Acfm ft$^3$/min | $\Delta P_{(pitot)}$ in. $H_2O$ |
|---|---|---|---|---|---|---|---|
| 1 | 77 | 128 | 78 | 50 | - - - | 60.9 | .0065 |
| 2 | 77 | 142 | 77 | 65 | - - - | 66.5 | .0079 |
| 3 | 78 | 159 | 79 | 80 | - - - | 72.1 | .0096 |
| 4 | 78 | 210 | 80 | 130 | - - - | 84.6 | .0142 |

Same Conditions except Natural Gas Heaters

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | 78 | 155 | 80 | 75 | - - - | 70.3 | .0090 |
| 6 | 79 | 119 | 79 | 40 | - - - | 54.5 | .0051 |
| 7 | 79 | 139 | 79 | 60 | - - - | 67.3 | .0080 |
| 8 | 79 | 165 | 80 | 85 | - - - | 71.5 | .0095 |

Date: 1/14/65 $P_B$ = 25.22 in. Hg Heaters: 2 Space Heate

Conditions: Closed Door, 15 ft Straight Stack, 6 in. Dia.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 77 | 133 | 78 | 55.0 | .0042 | 51.8 | .0057 |
| 2 | 77 | 151 | 77 | 84.0 | .0050 | 58.8 | .0069 |
| 3 | 78 | 175 | 77 | 98.0 | .0071 | 65.0 | .0091 |
| 4 | 78 | 230 | 79 | 151.0 | .0084 | 76.0 | .0123 |

Same Conditions except Natural Gas Heaters

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | 79 | 122 | 79 | 43 | .0042 | 47.7 | .0047 |
| 6 | 78 | 150 | 78 | 72 | .0058 | 60.5 | .0069 |
| 7 | 79 | 186 | 79 | 107 | .0068 | 69.5 | .0091 |

Date: 1/19/65 $P_B$ = 25.19 in. Hg Heaters: Natural Gas

Conditions: Open Door, 15 ft Straight Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | $\Delta P_{rm}$ in. $H_2O$ | Acfm $ft^3/min$ | $\Delta P$(pitot) in. $H_2O$ |
|---|---|---|---|---|---|---|---|
| 1 | 74 | 181 | 67 | 114 | - - - | 81.4 | .0128 |
| 2 | 75 | 206 | 68 | 138 | - - - | 89.7 | .0159 |
| 3 | 75 | 238 | 69 | 169 | - - - | 91.8 | .0177 |
| 4 | 75 | 256 | 70 | 186 | - - - | 95.6 | .0197 |
| 5 | 75 | 282 | 71 | 211 | - - - | 95.2 | .0202 |
| 6 | 75 | 302 | 72 | 230 | - - - | 97.3 | .0218 |
| 7 | 75 | 339 | 72 | 267 | - - - | 101.7 | .0247 |
| 8 | 76 | 264 | 76 | 188 | - - - | 94.3 | .0190 |
| 9 | 76 | 287 | 77 | 210 | - - - | 95.5 | .0202 |
| 10 | 77 | 322 | 77 | 245 | - - - | 98.2 | .0223 |
| 11 | 76 | 347 | 78 | 269 | - - - | 100.0 | .0240 |
| 12 | 77 | 390 | 78 | 312 | - - - | 102.5 | .0263 |
| 13 | 77 | 413 | 78 | 335 | - - - | 103.8 | .0277 |

Date: 1/20/65 $P_B$ = 24.89 in. Hg Heaters: Natural Gas

Conditions: Open Door, 15 ft Straight Stack, 6 in. Dia.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 76 | 201 | 76 | 125 | - - - | 85.3 | .0142 |
| 2 | 76 | 247 | 77 | 170 | - - - | 92.1 | .0176 |
| 3 | 76 | 293 | 80 | 213 | - - - | 97.6 | .0211 |
| 4 | 76 | 378 | 79 | 299 | - - - | 102.0 | .0257 |
| 5 | 76 | 405 | 79 | 326 | - - - | 104.3 | .0259 |
| 6 | 76 | 460 | 79 | 381 | - - - | 109.0 | .0296 |

Date: 1/27/65 $P_B$ = 24.91 in. Hg Heaters: 2 Space Heater

Conditions: Closed Door, 15 ft High Elbowed Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | $\Delta P_{rm}$ in. $H_2O$ | Acfm $ft^3$/min | $\Delta P$(pitot) in. $H_2O$ | Fuel Rat lb/min |
|---|---|---|---|---|---|---|---|---|
| 1 | 71.5 | 118 | 71 | 47 | .0025 | 42.8 | .0040 | .00228 |
| 2 | 71.5 | 138 | 71 | 67 | .0038 | 49.7 | .0060 | .00389 |
| 3 | 72.0 | 175 | 73 | 102 | .0047 | 51.7 | .0068 | .00654 |
| 4 | 72.0 | 253 | 75 | 178 | .0059 | 68.3 | .0103 | .01372 |
| 5 | 72.0 | 225 | 76 | 149 | .0050 | 65.2 | .0084 | .01010 |
| 6 | 72.5 | 187 | 77 | 110 | .0047 | 58.8 | .0079 | .00688 |

Date: 1/28/65 $P_B$ = 24.90 in. Hg Heaters: 2 Space Heater

Conditions: Closed Door, 15 ft High Elbowed Stack, 6 in. Dia.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 73.5 | 216 | 71 | 145 | .0057 | 64.7 | .0093 | .01026 |
| 2 | 74.0 | 242 | 71 | 171 | .0062 | 68.5 | .0108 | .01312 |
| 3 | 74.5 | 175 | 74 | 101 | .0041 | 57.0 | .0064 | .00672 |
| 4 | 74.0 | 152 | 74 | 78 | .0033 | 52.0 | .0040 | .00420 |
| 5 | 74.0 | 132 | 77 | 55 | .0027 | 45.0 | .0038 | .00296 |
| 6 | 74.0 | 224 | 79 | 145 | .0049 | 65.1 | .0089 | - - - |
| 7 | 74.5 | 282 | 80 | 202 | .0063 | 71.5 | .0115 | - - - |
| 8 | 74.5 | 318 | 80 | 238 | .0068 | 74.0 | .0130 | - - - |
| 9 | 75.5 | 340 | 80 | 260 | .0068 | 75.2 | .0145 | - - - |

Date: 2/3/65 $P_B$ = 25.07 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 15 ft High Elbowed Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | $\Delta P_{rm}$ in. $H_2O$ | $\Delta P$(pitot) in. $H_2O$ | Acfm ft$^3$/min |
|---|---|---|---|---|---|---|---|
| 1 | 76.5 | 320 | 82 | 238 | .0073 | .0180 | 74.0 |
| 2 | 76.5 | 395 | 82 | 313 | .0076 | .0183 | 77.8 |
| 3 | 77.0 | 442 | 83 | 359 | .0077 | .0187 | 79.8 |
| 4 | 77.5 | 476 | 83 | 393 | .0078 | .0194 | 80.3 |
| 5 | 77.5 | 503 | 83 | 420 | .0078 | .0201 | 80.3 |

Date: 2/4/65 $P_B$ = 24.94 in. Hg Heaters: Natural Gas

Conditions: Open Door, 15 ft High Elbowed Stack, 6 in. Dia.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 78.0 | 175 | 82 | 93 | - - - | .0080 | 63.6 |
| 2 | 78.0 | 212 | 81 | 131 | - - - | .0107 | 71.4 |
| 3 | 78.5 | 245 | 82 | 163 | - - - | .0124 | 75.3 |
| 4 | 78.5 | 272 | 82 | 190 | - - - | .0137 | 77.4 |
| 5 | 79.0 | 300 | 84 | 216 | - - - | .0153 | 80.6 |
| 6 | 79.0 | 318 | 85 | 233 | - - - | .0162 | 81.8 |
| 7 | 79.5 | 373 | 86 | 287 | - - - | .0185 | 84.6 |
| 8 | 79.5 | 399 | 85 | 314 | - - - | .0194 | 85.5 |
| 9 | 78.5 | 435 | 81 | 354 | - - - | .0212 | 86.9 |
| 10 | 79.0 | 502 | 79 | 423 | - - - | .0225 | 88.1 |

Date: 2/9/65 $P_B$ = 24.95 in. Hg Heaters: 2 Space Heaters

Conditions: Closed Door, 15 High Elbowed Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | $\Delta P_{rm}$ in. $H_2O$ | Acfm $ft^3$/min | Full Rate lb/min |
|---|---|---|---|---|---|---|---|
| 1 | 74.0 | 267 | 75 | 192 | .0071 | 70.0 | .0159 |
| 2 | 75.5 | 268 | 76 | 192 | .0072 | 70.0 | .0160 |
| 3 | 75.0 | 264 | 76 | 188 | .0070 | 69.5 | .0143 |
| 4 | 75.0 | 262 | 76 | 186 | .0070 | 70.0 | .0152 |
| 5 | 75.0 | 261 | 76 | 185 | .0070 | 69.5 | .0162 |
| 6 | 75.0 | 259 | 77 | 182 | .0068 | 68.5 | .0158 |
| 7 | 75.5 | 251 | 77 | 174 | .0062 | 68.2 | .0149 |
| 8 | 76.0 | 246 | 77 | 169 | .0062 | 68.0 | .0125 |

Date: 2/11/65 $P_B$ = 25.11 in. Hg Heaters: 2 Space Heaters

Conditions: Closed Door, 15 ft High Elbowed Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | Fuel Rate lb/min | $T_A$, °F* | $T_B$, °F** |
|---|---|---|---|---|---|---|---|---|
| 1 | 75.0 | 268 | 73 | 195 | 70.5 | .0156 | 450 | 225 |
| 2 | 75.0 | 262 | 73 | 189 | 69.5 | .0159 | 460 | 221 |

Same conditions as above except 1 in. of fiber glass insulation was added to surface of hood, elbows, and horizontal length.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 74.0 | 259 | 70 | 189 | 69.5 | .01352 | 140 | 104 |
| 4 | 74.0 | 266 | 72 | 194 | 70.0 | 101364 | 157 | 108 |
| 5 | 77.5 | 263 | 77 | 186 | 70.0 | .01353 | 146 | 103 |

*$T_A$ = surface temperature of top of entrance hood.

**$T_B$ = surface temperature of top side of horizontal length.

Date: 2/18/65 $P_B$ = 25.34 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 10 ft High Elbowed Stack, 6 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | ΔT, °F | Acfm ft³/min | $\Delta P_{rm}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 77.0 | 120 | 79 | 41 | 34.5 | .0015 |
| 2 | 77.0 | 176 | 79 | 97 | 49.5 | .0040 |
| 3 | 77.5 | 149 | 80 | 69 | 43.0 | .0025 |
| 4 | 75.0 | 196 | 74 | 122 | 53.5 | .0047 |
| 5 | 76.5 | 238 | 74 | 164 | 59.0 | .0052 |
| 6 | 77.0 | 291 | 77 | 214 | 63.7 | .0063 |
| 7 | 77.5 | 350 | 77 | 273 | 66.5 | .0062 |
| 8 | 73.5 | 382 | 76 | 306 | 68.0 | .0063 |
| 9 | 78.0 | 470 | 78 | 392 | 70.0 | .0067 |
| 10 | 78.0 | 574 | 79 | 495 | 71.5 | .0065 |

Date: 2/22/65 $P_B$ = 24.86 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 5 ft High Elbowed Stack, 6 in. Dia.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 78.5 | 118 | 77 | 41 | 26.0 | .0011 |
| 2 | 78.5 | 146 | 78 | 68 | 33.5 | .0013 |
| 3 | 70.0 | 182 | 70 | 112 | 39.0 | .0020 |
| 4 | 70.0 | 239 | 72 | 167 | 46.3 | .0028 |
| 5 | 69.5 | 287 | 72 | 215 | 49.0 | .0032 |
| 6 | 70.5 | 362 | 72 | 290 | 52.0 | .0035 |
| 7 | 70.5 | 412 | 72 | 340 | 53.5 | .0035 |
| 8 | 70.5 | 491 | 72 | 419 | 54.7 | .0035 |
| 9 | 70.5 | 570 | 72 | 498 | 55.7 | .0035 |

**Date:** 2/25/65 $P_B$ = 25.15 in. Hg **Heaters:** Kerosene Lamps

**Conditions:** Closed Door, 15 ft Straight Stack, 8 in. Dia.

| Run No. | No. of Lamps | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | ΔT, °F | $P_{rm}$ in. $H_2O$ | Acfm ft$^3$/min | ΔP(pitot) in. $H_2O$ | Fuel lb/mi |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 67.0 | 91 | 63 | 28 | .0038 | 54.0 | .0012 | - - |
| 2 | 2 | 68.0 | 102 | 68 | 34 | .0064 | 66.2 | .0027 | - - |
| 3 | 3 | 70.0 | 112 | 71 | 41 | .0078 | 72.7 | .0035 | .003 |
| Same Conditions except Natural Gas Heaters | | | | | | | | | |
| 4 | - | 72.0 | 137 | 67 | 70 | .0078 | 72.7 | .0035 | - - |
| 5 | - | 71.5 | 168 | 68 | 100 | .0150 | 107.2 | .0070 | - - |
| 6 | - | 72.0 | 209 | 71 | 138 | .0200 | 126.0 | .0098 | - - |
| 7 | - | 72.0 | 246 | 69 | 177 | .0230 | 137.5 | .0118 | - - |

**Date:** 3/2/65 $P_B$ = 25.27 in. Hg **Heaters:** Kerosene Lamps

**Conditions:** Closed Door, 10 ft Straight Stack, 8 in. Dia.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 71.0 | 96 | 78 | 18 | .0024 | 36.2 | .0011 | - - |
| 2 | 2 | 72.0 | 107 | 79 | 28 | .0034 | 47.5 | .0013 | - - |
| 3 | 3 | 72.0 | 119 | 80 | 39 | .0049 | 55.8 | .0023 | .003 |
| Same Conditions except Natural Gas Heaters | | | | | | | | | |
| 4 | - | 72.5 | 149 | 81 | 68 | .0077 | 73.5 | .0028 | - - |
| 5 | - | 73.0 | 179 | 81 | 98 | .0100 | 86.0 | .0044 | - - |
| 6 | - | 73.0 | 208 | 81 | 127 | .0127 | 96.2 | .0059 | - - |
| 7 | - | 73.0 | 279 | 83 | 196 | .0178 | 115.5 | .0092 | - - |
| 8 | - | 73.5 | 320 | 83 | 237 | .0193 | 122.3 | .0110 | - - |
| 9 | - | 72.0 | 384 | 82 | 302 | .0219 | 128.5 | .0124 | - - |
| 10 | - | 74.0 | 438 | 74 | 364 | .0329 | 139.0 | .0167 | - - |

Date: 3/2/65 $P_B$ = 25.21 in. Hg Heaters: Natural Gas

Conditions: Open Door, 10 ft Straight Stack, 8 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | $\Delta P$(pitot) in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 73.0 | 118 | 71 | 47 | 103.0 | .0060 |
| 2 | 73.0 | 162 | 71 | 91 | 129.0 | .0110 |
| 3 | 73.0 | 203 | 71 | 132 | 150.0 | .0147 |
| 4 | 73.5 | 235 | 71 | 164 | 153.0 | .0160 |
| 5 | 73.5 | 280 | 72 | 208 | 162.0 | .0191 |
| 6 | 74.0 | 338 | 73 | 265 | 190.0 | .0245 |
| 7 | 74.0 | 390 | 74 | 316 | 195.0 | .0280 |
| 8 | 74.0 | 280 | 72 | 208 | 172.0 | .0209 |
| 9 | 74.0 | 245 | 72 | 173 | 162.0 | .0182 |

Date: 3/3/65 $P_B$ = 25.24 in. Hg Heaters: Natural Gas

Conditions: Same as above.

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | 71.0 | 90 | 76 | 14 | 58.0 | .0019 |
| 11 | 71.5 | 126 | 76 | 50 | 103.5 | .0062 |
| 12 | 72.0 | 156 | 78 | 78 | 118.5 | .0084 |
| 13 | 72.0 | 202 | 79 | 123 | 138.0 | .0125 |
| 14 | 72.0 | 230 | 80 | 150 | 153.0 | .0159 |
| 15 | 72.5 | 295 | 82 | 213 | 169.0 | .0213 |
| 16 | 72.5 | 340 | 83 | 257 | 170.5 | .0229 |
| 17 | 73.0 | 381 | 84 | 297 | 178.0 | .0262 |
| 18 | 73.5 | 425 | 87 | 338 | 179.0 | .0278 |

**Date:** 3/4/65 $P_B$ = 25.31 in. Hg **Heaters:** Natural Gas

**Conditions:** Closed Door, 5 ft Straight Stack, 8 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm ft$^3$/min | $\Delta P_{rm}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 74.0 | 120 | 79 | 41 | 40.3 | .0031 |
| 2 | 73.5 | 147 | 83 | 64 | 54.5 | .0049 |
| 3 | 73.5 | 190 | 84 | 106 | 67.5 | .0070 |
| 4 | 72.5 | 248 | 71 | 177 | 82.0 | .0087 |
| 5 | 73.0 | 278 | 71 | 207 | 89.5 | .0105 |
| 6 | 73.0 | 312 | 72 | 240 | 93.2 | .0117 |
| 7 | 73.5 | 360 | 72 | 288 | 98.7 | .0130 |
| 8 | 73.5 | 455 | 75 | 380 | 107.0 | .0152 |
| 9 | 73.5 | 532 | 76 | 456 | 111.0 | .0159 |

**Date:** 3/6/65 $P_B$ = 25.32 in. Hg **Heaters:** Natural Gas

**Conditions:** Closed Door, 10 ft Straight Stack, 8 in. Dia.
Filter Restriction

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 70.5 | 170 | 68 | 102 | 23.7 | .0179 |
| 2 | 72.0 | 240 | 68 | 172 | 31.5 | .0283 |
| 3 | 72.0 | 283 | 68 | 215 | 25.5 | .0347 |
| 4 | 72.0 | 320 | 69 | 251 | 38.0 | .0386 |
| 5 | 72.0 | 355 | 69 | 286 | 40.0 | .0428 |
| 6 | 72.0 | 380 | 70 | 310 | 41.2 | .0434 |
| 7 | 72.0 | 420 | 69 | 351 | 42.5 | .0472 |
| 8 | 72.0 | 460 | 69 | 391 | 45.0 | .0501 |
| 9 | 72.0 | 512 | 69 | 443 | 47.2 | .0532 |
| 10 | 68.0 | 575 | 69 | 506 | 49.0 | .0592 |

Date: 3/9/65 $P_B$ = 25.16 in. Hg Heaters: K.L.*, S.H.**, and N.G.***.

Conditions: Closed Door, 10 ft High Elbowed Stack, 8 in. Dia.

| Run.No. | No. of Heaters | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | $\Delta P$(pitot) in. $H_2O$ | Fuel Ra lb/min |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 K.L. | 74.0 | 97 | 74 | 23 | 38.8 | .0008 | - - - |
| 2 | 2 K.L. | 75.0 | 110 | 78 | 32 | 48.0 | .0015 | - - - |
| 3 | 3 K.L. | 75.0 | 120 | 76 | 44 | 55.5 | .0019 | .00334 |
| 4 | 1 S.H. | 76.0 | 157 | 82 | 75 | 73.0 | .0031 | - - - |
| 5 | 2 S.H. | 76.0 | 198 | 82 | 116 | 84.5 | .0051 | .00910 |
| 6 | 2 S.H. | 77.0 | 228 | 85 | 143 | 90.5 | .0058 | .01330 |
| 7 | N.G. | 77.5 | 240 | 88 | 152 | 91.8 | .0055 | - - - |
| 8 | N.G. | 79.0 | 310 | 88 | 222 | 105.0 | .0070 | - - - |
| 9 | N.G. | 70.0 | 382 | 89 | 293 | 113.5 | .0091 | - - - |
| 10 | N.G. | 79.0 | 420 | 89 | 331 | 116.3 | .0150 | - - - |
| 11 | N.G. | 79.0 | 559 | 89 | 470 | 125.0 | .0134 | - - - |
| 12 | N.G. | 76.0 | 250 | 81 | 169 | 97.7 | .0059 | - - - |

Date: 3/11/65 $P_B$ = 25.03 in. Hg Heaters: Natural Gas

Conditions: Open Door, 10 ft High Elbowed Stack, 8 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | $\Delta P$(pitot) in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 78.0 | 116 | 81 | 35 | 78.0 | .0031 |
| 2 | 78.0 | 154 | 81 | 73 | 97.1 | .0051 |
| 3 | 79.5 | 178 | 83 | 95 | 106.5 | .0064 |

*K.L. = Kerosene Lamps

**S.H. = Space Heater

***N.G. = Natural Gas

Date: 3/11/65 (continued)

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm ft$^3$/min | $\Delta P_{(pitot)}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 4 | 78.0 | 185 | 81 | 104 | 118.0 | .0079 |
| 5 | 78.5 | 206 | 83 | 123 | 119.0 | .0078 |
| 6 | 78.0 | 238 | 81 | 157 | 124.0 | .0097 |
| 7 | 78.0 | 273 | 81 | 192 | 131.0 | .0112 |
| 8 | 78.0 | 300 | 81 | 219 | 136.8 | .0125 |
| 9 | 78.0 | 340 | 81 | 259 | 140.5 | .0139 |
| 10 | 78.0 | 385 | 80 | 305 | 146.6 | .0160 |
| 11 | 78.0 | 435 | 81 | 354 | 151.0 | .0180 |
| 12 | 78.5 | 508 | 81 | 429 | 152.5 | .0200 |
| 13 | 79.0 | 560 | 81 | 479 | 153.5 | .0212 |

Date: 3/11/65 $P_B$ = 25.03 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 15 ft High Elbowed Stack, 8 in. Dia.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 79.0 | 120 | 83 | 37 | 59.5 | .0023 |
| 2 | 79.0 | 144 | 82 | 62 | 77.0 | .0040 |
| 3 | 79.0 | 184 | 82 | 102 | 95.0 | .0055 |
| 4 | 79.0 | 228 | 82 | 146 | 110.2 | .0072 |
| 5 | 79.0 | 265 | 83 | 182 | 118.0 | .0083 |
| 6 | 78.0 | 321 | 83 | 238 | 128.5 | .0107 |
| 7 | 78.5 | 353 | 83 | 270 | 133.0 | .0118 |

Date: 3/12/65 $P_B$ = 25.12 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 15 ft High Elbowed Stack, 8 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm ft3/min | $\Delta P_{(pitot)}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 8 | 74.0 | 379 | 78 | 301 | 138.0 | .0127 |
| 9 | 75.5 | 417 | 77 | 340 | 137.7 | .0152 |
| 10 | 75.5 | 450 | 78 | 372 | 138.5 | .0159 |
| 11 | 75.5 | 469 | 77 | 392 | 141.5 | .0183 |
| 12 | 75.5 | 572 | 78 | 494 | 149.0 | .0193 |
| 13 | 75.5 | 392 | 78 | 314 | 139.2 | .0139 |
| 14 | 74.0 | 448 | 78 | 370 | 143.7 | .0162 |
| 15 | 75.0 | 491 | 78 | 413 | 146.6 | .0175 |

Date: 3/13/65 $P_B$ = 25.09 in. Hg Heaters: Natural Gas

Conditions: Open Door, 15 ft High Elbowed Stack, 8 in. Dia.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 72.0 | 102 | 67 | 35 | 85.4 | .0036 |
| 2 | 73.0 | 143 | 68 | 75 | 115.0 | .0070 |
| 3 | 73.5 | 187 | 70 | 117 | 132.5 | .0100 |
| 4 | 73.5 | 240 | 71 | 169 | 150.2 | .0138 |
| 5 | 73.5 | 287 | 71 | 216 | 159.0 | .0166 |
| 6 | 73.5 | 367 | 75 | 292 | 170.0 | .0210 |
| 7 | 74.0 | 413 | 77 | 336 | 172.7 | .0229 |
| 8 | 74.0 | 464 | 78 | 386 | 175.8 | .0250 |
| 9 | 74.5 | 551 | 80 | 471 | 179.2 | .0283 |
| 10 | 75.0 | 498 | 80 | 418 | 176.0 | .0259 |

Date: 3/15/65 $P_B$ = 24.80 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 5 ft High Elbowed Stack, 8 in. Dia.

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | $\Delta P_{rm}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 76.0 | 130 | 80 | 50 | 45.0 | .0035 |
| 2 | 76.0 | 152 | 80 | 72 | 53.5 | .0040 |
| 3 | 76.0 | 212 | 80 | 132 | 68.8 | .0069 |
| 4 | 67.5 | 262 | 65 | 197 | 80.2 | .0085 |
| 5 | 69.0 | 320 | 65 | 255 | 87.0 | .0096 |
| 6 | 69.0 | 368 | 65 | 303 | 91.5 | .0110 |
| 7 | 69.5 | 414 | 65 | 349 | 93.9 | .0112 |
| 8 | 69.5 | 467 | 66 | 401 | 95.5 | .0115 |
| 9 | 69.5 | 542 | 67 | 475 | 97.7 | .0119 |

Date: 4/7/65 $P_B$ = 24.82 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 10 ft Straight Stack, 8 in. Dia., Artis Vent Cap at Stack Outlet

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 69.5 | 113 | 69 | 44 | 63.5 | .0063 |
| 2 | 70.0 | 158 | 69 | 89 | 85.5 | .0100 |
| 3 | 80.0 | 205 | 69 | 136 | 99.0 | .0132 |
| 4 | 69.0 | 263 | 70 | 193 | 108.3 | .0162 |
| 5 | 69.5 | 295 | 71 | 224 | 116.0 | .0171 |
| 6 | 69.5 | 360 | 70 | 290 | 124.7 | .0201 |
| 7 | 71.0 | 391 | 71 | 320 | 129.3 | .0209 |
| 8 | 69.0 | 465 | 71 | 394 | 133.5 | .0218 |
| 9 | 70.0 | 550 | 71 | 479 | 135.0 | .0219 |

**Date:** 4/7/65 $P_B$ = 24.82 in. Hg **Heaters:** Natural Gas

**Conditions:** Closed Door, 10 ft Straight Stack, 8 in. Dia., Belmont Vent Cap at Stack Outlet

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3/min$ | $\Delta P_{rm}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 71.0 | 134 | 77 | 57 | 67.5 | .0065 |
| 2 | 71.5 | 210 | 78 | 132 | 92.5 | .0116 |
| 3 | 71.5 | 160 | 80 | 80 | 77.0 | .0084 |
| 4 | 71.5 | 250 | 80 | 170 | 100.0 | .0137 |
| 5 | 72.0 | 310 | 80 | 230 | 109.0 | .0160 |
| 6 | 72.0 | 370 | 80 | 290 | 116.5 | .0173 |
| 7 | 72.0 | 458 | 80 | 378 | 122.5 | .0180 |
| 8 | 72.0 | 540 | 80 | 460 | 126.0 | .0192 |

**Date:** 4/8/65 $P_B$ = 24.79 in. Hg **Heaters:** Natural Gas

**Conditions:** Closed Door, 10 ft High Elbowed Stack, 8 in. Dia., Belmont Vent Cap

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 73.0 | 141 | 83 | 58 | 60.0 | .0055 |
| 2 | 73.5 | 202 | 83 | 119 | 78.0 | .0092 |
| 3 | 74.0 | 252 | 83 | 169 | 89.0 | .0111 |
| 4 | 74.0 | 311 | 83 | 228 | 96.8 | .0129 |
| 5 | 74.0 | 350 | 83 | 267 | 100.5 | .0133 |
| 6 | 74.0 | 464 | 83 | 381 | 108.0 | .0155 |
| 7 | 74.5 | 527 | 83 | 444 | 111.5 | .0155 |
| 8 | 73.5 | 170 | 83 | 87 | 70.5 | .0077 |

Date: 4/12/65 $P_B$ = 25.13 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 10 ft High Elbowed Stack, 8 in. Dia., Artis Vent Cap

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3/min$ | $\Delta P_{rm}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 64.0 | 112 | 62 | 50 | 58.0 | .0057 |
| 2 | 65.0 | 145 | 62 | 83 | 73.8 | .0078 |
| 3 | 65.5 | 180 | 62 | 118 | 84.0 | .0100 |
| 4 | 65.5 | 214 | 62 | 152 | 92.0 | .0109 |
| 5 | 66.0 | 268 | 63 | 205 | 101.0 | .0134 |
| 6 | 66.0 | 336 | 64 | 272 | 109.5 | .0150 |
| 7 | 66.5 | 415 | 64 | 351 | 116.5 | .0169 |
| 8 | 66.5 | 492 | 65 | 427 | 119.5 | .0173 |

Date: 4/13/65 $P_B$ = 24.79 in. Hg Heaters: Natural Gas

Same Conditions except Belmont Cap replaced Artis Cap

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 69.0 | 112 | 72 | 40 | 50.0 | .0045 |
| 2 | 70.0 | 165 | 73 | 92 | 73.0 | .0075 |
| 3 | 70.5 | 227 | 74 | 153 | 81.8 | .0112 |
| 4 | 70.5 | 281 | 74 | 207 | 93.7 | .0127 |
| 5 | 70.5 | 352 | 76 | 276 | 104.0 | .0142 |
| 6 | 71.0 | 417 | 78 | 339 | 108.3 | .0149 |
| 7 | 71.0 | 522 | 79 | 443 | 112.2 | .0158 |
| 8 | 71.0 | 266 | 79 | 187 | 95.3 | .0113 |

Date: 4/13/65 $P_B$ = 24.79 in. Hg Heaters: Natural Gas

Conditions: Closed Door, 10 ft High Elbowed Stack 8 in. Dia., No Vent Cap

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | $\Delta P_{rm}$ in. $H_2O$ |
|---|---|---|---|---|---|---|
| 1 | 69.5 | 112 | 72 | 40 | 52.0 | .0045 |
| 2 | 70.0 | 163 | 73 | 90 | 76.5 | .0080 |
| 3 | 70.5 | 219 | 75 | 144 | 93.3 | .0118 |
| 4 | 71.0 | 334 | 77 | 257 | 110.7 | .0160 |
| 5 | 71.0 | 398 | 78 | 320 | 115.8 | .0169 |
| 6 | 71.5 | 497 | 79 | 418 | 121.5 | .0182 |

Same Conditions except Straight Stack

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 71.0 | 133 | 80 | 53 | 69.0 | .0075 |
| 2 | 71.0 | 167 | 80 | 87 | 84.0 | .0116 |
| 3 | 71.5 | 222 | 80 | 142 | 102.0 | .0160 |
| 4 | 71.5 | 292 | 80 | 212 | 116.5 | .0192 |
| 5 | 71.5 | 338 | 80 | 258 | 127.5 | .0225 |
| 6 | 72.0 | 402 | 80 | 322 | 136.0 | .0247 |

Conditions: Closed Door, 10 ft Straight Stack, 8 in. Dia., Belmont Cap

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 71.0 | 136 | 80 | 56 | 66.5 | .0068 |
| 2 | 71.0 | 173 | 80 | 93 | 80.5 | .0112 |
| 3 | 71.5 | 236 | 80 | 156 | 98.0 | .0146 |
| 4 | 71.5 | 309 | 80 | 229 | 108.0 | .0168 |
| 5 | 71.5 | 363 | 80 | 283 | 117.5 | .0200 |
| 6 | 72.0 | 438 | 80 | 358 | 123.0 | .0210 |

Date: 4/21/65 $P_B$ = 24.81 in. Hg Fuel Data

Conditions: Open Door, Various Lengths of 8 in. Dia.,
Straight Stack

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | Fuel Rate lb/hr | Stack Height, ft | Heaters |
|---|---|---|---|---|---|---|---|---|
| 1 | 69.0 | 110 | 77 | 33 | 72 | .2015 | 5 | 3 K.L. |
| 2 | 69.0 | 109 | 76 | 33 | 72 | .2105 | 5 | 3 K.L. |
| 3 | 69.0 | 104 | 77 | 27 | 82 | .2060 | 10 | 3 K.L. |
| 4 | 69.5 | 103 | 78 | 25 | 80 | .2080 | 10 | 3 K.L. |
| 5 | 70.0 | 101 | 78 | 23 | 83 | .2075 | 15 | 3 K.L. |
| 6 | 71.0 | 133 | 73 | 60 | 114 | .5190 | 20 | 2 S.H. |
| 7 | 71.0 | 131 | 72 | 59 | 113 | .5280 | 20 | 2 S.H. |
| 8 | 71.5 | 140 | 73 | 67 | 131 | .5400 | 15 | 2 S.H. |
| 9 | 71.5 | 140 | 75 | 65 | 130 | .5260 | 15 | 2 S.H. |
| 10 | 71.5 | 140 | 75 | 65 | 130 | .5310 | 15 | 2 S.H. |
| 11 | 71.5 | 155 | 75 | 80 | 127 | .6670 | 10 | 2 S.H. |

Date: 4/23/65 $P_B$ = 24.67 in. Hg Fuel Data

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12 | 69.5 | 132 | 69 | 63 | 128 | .5350 | 15 | 2 S.H. |
| 13 | 70.0 | 132 | 69 | 63 | 128 | .5550 | 15 | 2 S.H. |
| 14 | 69.0 | 158 | 72 | 86 | 131 | .6720 | 10 | 2 S.H. |
| 15 | 70.5 | 150 | 72 | 78 | 126 | .6660 | 10 | 2 S.H. |
| 16 | 70.5 | 190 | 71 | 119 | 120 | .7250 | 5 | 2 S.H. |
| 17 | 70.5 | 190 | 71 | 119 | 120 | .7380 | 5 | 2 S.H. |

Date: 4/26/65 $P_B$ = 25.30 in. Hg Fuel Data (Kerosene)

Conditions: Open Door, Various Lengths of 8 in. Dia., Elbowed Stack

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | ΔT, °F | Acfm ft³/min | Fuel Rate lb/hr | Stack Height, ft | Heaters |
|---|---|---|---|---|---|---|---|---|
| 1 | 68.5 | 105 | 63 | 42 | 64.5 | .2150 | 5 | 3 K.L. |
| 2 | 69.0 | 101 | 67 | 34 | 76.0 | .2035 | 10 | 3 K.L. |
| 3 | 69.0 | 101 | 69 | 32 | 83.1 | .2085 | 15 | 3 K.L. |
| 4 | 69.0 | 167 | 69 | 98 | 129.6 | .6450 | 15 | 2 S.H. |
| 5 | 69.0 | 179 | 69 | 110 | 120.2 | .6840 | 10 | 2 S.H. |
| 6 | 69.0 | 202 | 69 | 133 | 101.0 | .7620 | 5 | 2 S.H. |

Date: 27/65 $P_B$ = 25.16 in. Hg Fuel Data (White Gasoline)

Conditions: Open Door, Various Length of 8 in. Dia. Elbowed Stack

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 69.5 | 96 | 72 | 24 | 51.4 | .1038 | 5 | 2 M.G.L.* |
| 2 | 70.0 | 91 | 70 | 21 | 59.9 | .0998 | 10 | 2 M.G.L. |
| 3 | 71.5 | 178 | 85 | 93 | 113.0 | .5400 | 10 | 2 G.B.C.S.** |
| 4 | 71.5 | 157 | 86 | 71 | 115.0 | .5090 | 15 | 2 G.B.C.S. |
| 5 | 71.5 | 167 | 91 | 76 | 83.2 | .4510 | 5 | 2 G.B.C.S. |

Date: 4/28/65 $P_B$ = 25.15 in. Hg Same Conditions

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | 71.5 | 201 | 73 | 128 | 99.5 | .7180 | 5 | 2 G.B.C.S. |
| 7 | 70.5 | 185 | 75 | 110 | 119.8 | .7530 | 10 | 2 G.B.C.S. |
| 8 | 71.0 | 188 | 75 | 113 | 121.5 | .8060 | 10 | 2 G.B.C.S. |

*2 M.G.L. = 2 - Mantle Gasoline Lantern

**2 G.B.C.S. = 2 - Gas-Burner Camp Stove

**Date:** 4/28/65 $P_B$ = 25.15 in. Hg **Fuel Data (Kerosene)**

**Conditions:** Open Door, Various Lengths of 8 in. Dia., Elbowed Stack

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm ft$^3$/min | Fuel Rate lb/hr | Stack Height, ft | Heaters |
|---|---|---|---|---|---|---|---|---|
| 1 | 71.0 | 145 | 75 | 70 | 115.0 | .4720 | 15 | 2 S.H. |
| 2 | 71.0 | 160 | 77 | 83 | 122.8 | .5880 | 15 | 2 S.H. |
| 3 | 71.0 | 173 | 79 | 94 | 128.0 | .6770 | 15 | 2 S.H. |
| 4 | 71.0 | 177 | 79 | 98 | 129.5 | .6810 | 15 | 2 S.H. |
| 5 | 71.0 | 135 | 80 | 55 | 104.7 | .3480 | 15 | 2 S.H. |
| 6 | 73.5 | 109 | 79 | 30 | 71.8 | .1363 | 10 | 1 S.H. |
| 7 | 73.5 | 123 | 79 | 44 | 85.4 | .2280 | 10 | 1 S.H. |
| 8 | 73.5 | 140 | 78 | 62 | 97.2 | .3190 | 10 | 1 S.H. |
| 9 | 73.5 | 169 | 76 | 93 | 112.2 | .5220 | 10 | 2 S.H. |
| 10 | 74.0 | 181 | 74 | 107 | 119.1 | .6200 | 10 | 2 S.H. |
| 11 | 74.0 | 189 | 72 | 117 | 123.2 | .6960 | 10 | 2 S.H. |
| 12 | 69.5 | 133 | 62 | 71 | 102.0 | .3420 | 10 | 1 S.H. |

**Date:** 5/3/65 $P_B$ = 25.02 in. Hg Same Conditions

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm ft$^3$/min | Fuel Rate lb/hr | Stack Height, ft | Heaters |
|---|---|---|---|---|---|---|---|---|
| 13 | 70.5 | 100 | 63 | 37 | 62.0 | .0991 | 5 | 1 S.H. |
| 14 | 70.5 | 145 | 68 | 77 | 84.1 | .3060 | 5 | 1 S.H. |
| 15 | 72.0 | 130 | 69 | 61 | 75.8 | .2080 | 5 | 2 S.H. |
| 16 | 72.0 | 169 | 70 | 99 | 92.2 | .4540 | 5 | 2 S.H. |
| 17 | 73.0 | 215 | 72 | 143 | 103.6 | .9150 | 5 | 2 S.H. |
| 18 | 73.0 | 177 | 72 | 105 | 93.8 | .6300 | 5 | 2 S.H. |
| 19 | 72.5 | 208 | 72 | 136 | 101.8 | .7850 | 5 | 2 S.H. |
| 20 | 73.5 | 191 | 75 | 116 | 96.7 | .6050 | 5 | 2 S.H. |

Date: 5/5/65 $P_B$ = 24.80 in. Hg Fuel Data (Kerosene)

Conditions: Open Door, Various Length of 8 in. Dia, Straight Stack

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm ft$^3$/min | Fuel Rate lb/hr | Stack Height, ft | Heater |
|---|---|---|---|---|---|---|---|---|
| 1 | 71.5 | 115 | 75 | 40 | 78.0 | .1926 | 5 | 1 S.H. |
| 2 | 71.0 | 129 | 74 | 55 | 90.0 | .3200 | 5 | 1 S.H. |
| 3 | 71.0 | 172 | 75 | 97 | 112.0 | .6470 | 5 | 2 S.H. |

Date: 5/6/65 $P_B$ = 24.98 in. Hg Same Conditions

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4 | 67.5 | 160 | 60 | 100 | 113.0 | .6400 | 5 | 2 S.H. |
| 5 | 67.5 | 181 | 61 | 120 | 120.0 | .7630 | 5 | 2 S.H. |
| 6 | 68.0 | 142 | 60 | 82 | 127.0 | .6110 | 10 | 2 S.H. |
| 7 | 68.0 | 131 | 61 | 70 | 121.0 | .4280 | 10 | 2 S.H. |
| 8 | 68.0 | 100 | 61 | 39 | 96.5 | .2200 | 10 | 1 S.H. |
| 9 | 68.0 | 96 | 61 | 35 | 100.0 | .2160 | 15 | 1 S.H. |
| 10 | 68.5 | 125 | 62 | 63 | 128.1 | .5140 | 15 | 2 S.H. |
| 11 | 68.0 | 133 | 62 | 71 | 133.0 | .5460 | 15 | 2 S.H. |
| 12 | 68.5 | 113 | 62 | 51 | 117.5 | .3330 | 15 | 2 S.H. |

Date: 5/10/65 $P_B$ = 25.14 in. Hg Fuel Data (Kerosene)

Conditions: Open Door, Various Length of 6 in. Dia., Straight Stack

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 72.0 | 120 | 85 | 35 | 40.0 | .1329 | 5 | 1 S.H. |
| 2 | 72.0 | 163 | 82 | 81 | 56.2 | .3445 | 5 | 1 S.H. |
| 3 | 72.5 | 220 | 82 | 138 | 67.0 | .7850 | 5 | 2 S.H. |
| 4 | 73.0 | 248 | 81 | 167 | 70.0 | .8360 | 5 | 2 S.H. |
| 5 | 74.0 | 202 | 84 | 118 | 63.5 | .5420 | 5 | 2 S.H. |

Date: 5/11/65 $P_B$ = 25.14 in. Hg Fuel Date (Kerosene)

Conditions: Open Door, Various Length of 6 in. Dia., Straight Stack

| Run No. | $T_{in}$, °F | $T_{ch}$, °F | $T_{rm}$, °F | $\Delta T$, °F | Acfm $ft^3$/min | Fuel Rate lb/min | Stack Height, ft | Heater |
|---|---|---|---|---|---|---|---|---|
| 1 | 75.0 | 126 | 93 | 33 | 46.0 | .1630 | 10 | 1 S.H |
| 2 | 75.0 | 170 | 92 | 78 | 66.0 | .4200 | 10 | 1 S.H |
| 3 | 75.5 | 215 | 90 | 125 | 77.5 | .8020 | 10 | 2 S.H |
| 4 | 76.0 | 233 | 90 | 143 | 81.0 | .8140 | 10 | 2 S.H |
| 5 | 76.0 | 130 | 89 | 41 | 54.5 | .2300 | 15 | 1 S.H |
| Date: 5/12/65 | | | $P_B$ = 25.03 in. Hg | | | Same Conditions | | |
| 6 | 76.0 | 165 | 87 | 78 | 71.0 | .4610 | 15 | 1 S.H |
| 7 | 76.5 | 203 | 91 | 112 | 81.5 | .8210 | 15 | 2 S.H |

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VENTILATION OF FAMILY SHELTERS BY INDUCED DRAFT METHOD
THEORETICAL RESULTS FOR OPEN DOOR AT STANDARD CONDITIONS
NOTATION FOR THE FOLLOWING DATA
NO=RUN NUMBER
 L=STACK DIAMETER, INCHES
 I=STACK VERTICAL HEIGHT, FT
 K=ADDITIONAL EQUIVALENT STACK LENGTH, FT
 Q=AIR FLOW, LB/MIN
QCH=AIR FLOW THROUGH CHIMNEY OR STACK, CFM
QE=AIR FLOW THROUGH SHELTER INLET, CFM
TD=TEMPERATURE DIFFERENCE (TCH-TR), DEGREES F
IV=AIR VELOCITY IN STACK, FT/MIN


NO     L     I     K     Q           QCH         QE           TD          IV

 1     4     5     1 1.077E-00 1.521E+01 1.439E+01 3.000E+01    174
 1     4    10     1 1.266E-00 1.789E+01 1.693E+01 3.000E+01    205
 1     4    15     1 1.356E-00 1.915E+01 1.813E+01 3.000E+01    220
 1     4    20     1 1.408E-00 1.989E+01 1.883E+01 3.000E+01    228
 1     4    25     1 1.443E-00 2.038E+01 1.929E+01 3.000E+01    234
 1     4    30     1 1.467E-00 2.073E+01 1.962E+01 3.000E+01    238
 1     4     5     5 9.246E-01 1.306E+01 1.236E+01 3.000E+01    150
 1     4    10     5 1.134E-00 1.602E+01 1.516E+01 3.000E+01    184
 1     4    15     5 1.243E-00 1.757E+01 1.662E+01 3.000E+01    201
 1     4    20     5 1.312E-00 1.853E+01 1.754E+01 3.000E+01    212
 1     4    25     5 1.358E-00 1.919E+01 1.816E+01 3.000E+01    220
 1     4    30     5 1.392E-00 1.967E+01 1.862E+01 3.000E+01    226
 1     4     5     9 8.227E-01 1.162E+01 1.099E+01 3.000E+01    133
 1     4    10     9 1.036E-00 1.464E+01 1.385E+01 3.000E+01    168
 1     4    15     9 1.155E-00 1.632E+01 1.544E+01 3.000E+01    187
 1     4    20     9 1.233E-00 1.741E+01 1.648E+01 3.000E+01    200
 1     4    25     9 1.287E-00 1.818E+01 1.721E+01 3.000E+01    209
 1     4    30     9 1.328E-00 1.876E+01 1.775E+01 3.000E+01    215
 1     4     5    13 7.484E-01 1.057E+01 1.000E+01 3.000E+01    121
 1     4    10    13 9.601E-01 1.356E+01 1.283E+01 3.000E+01    155
 1     4    15    13 1.083E-00 1.530E+01 1.448E+01 3.000E+01    176
 1     4    20    13 1.166E-00 1.648E+01 1.559E+01 3.000E+01    189
 1     4    25    13 1.226E-00 1.732E+01 1.639E+01 3.000E+01    199
 1     4    30    13 1.272E-00 1.796E+01 1.700E+01 3.000E+01    206
 1     4     5    17 6.912E-01 9.764E-00 9.241E-00 3.000E+01    112
 1     4    10    17 8.985E-01 1.269E+01 1.201E+01 3.000E+01    146
 1     4    15    17 1.023E-00 1.446E+01 1.368E+01 3.000E+01    166
 1     4    20    17 1.110E-00 1.568E+01 1.484E+01 3.000E+01    180
 1     4    25    17 1.173E-00 1.657E+01 1.568E+01 3.000E+01    190
 1     4    30    17 1.222E-00 1.726E+01 1.634E+01 3.000E+01    198
 1     4     5    21 6.454E-01 9.117E-00 8.629E-00 3.000E+01    105
 1     4    10    21 8.474E-01 1.197E+01 1.132E+01 3.000E+01    137
 1     4    15    21 9.729E-01 1.374E+01 1.300E+01 3.000E+01    158
 1     4    20    21 1.060E-00 1.498E+01 1.418E+01 3.000E+01    172
 1     4    25    21 1.126E-00 1.591E+01 1.506E+01 3.000E+01    182
 1     4    30    21 1.178E-00 1.664E+01 1.574E+01 3.000E+01    191
 1     6     5     1 2.673E-00 3.776E+01 3.574E+01 3.000E+01    192
 1     6    10     1 3.239E-00 4.576E+01 4.331E+01 3.000E+01    233
 1     6    15     1 3.526E-00 4.981E+01 4.715E+01 3.000E+01    254
 1     6    20     1 3.702E-00 5.229E+01 4.949E+01 3.000E+01    266
 1     6    25     1 3.821E-00 5.397E+01 5.108E+01 3.000E+01    275
 1     6    30     1 3.906E-00 5.518E+01 5.223E+01 3.000E+01    281
 1     6     5     5 2.354E-00 3.325E+01 3.147E+01 3.000E+01    169
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NO     L     I     K     Q          QCH        QE         TD          IV

 1     6    10     5 2.942E-00  4.155E+01  3.933E+01  3.000E+01    212
 1     6    15     5 3.263E-00  4.609E+01  4.362E+01  3.000E+01    235
 1     6    20     5 3.469E-00  4.900E+01  4.638E+01  3.000E+01    250
 1     6    25     5 3.613E-00  5.103E+01  4.830E+01  3.000E+01    260
 1     6    30     5 3.719E-00  5.254E+01  4.973E+01  3.000E+01    268
 1     6     5     9 2.127E-00  3.005E+01  2.844E+01  3.000E+01    153
 1     6    10     9 2.713E-00  3.833E+01  3.627E+01  3.000E+01    195
 1     6    15     9 3.051E-00  4.310E+01  4.079E+01  3.000E+01    220
 1     6    20     9 3.275E-00  4.626E+01  4.378E+01  3.000E+01    236
 1     6    25     9 3.436E-00  4.853E+01  4.593E+01  3.000E+01    247
 1     6    30     9 3.557E-00  5.025E+01  4.755E+01  3.000E+01    256
 1     6     5    13 1.955E-00  2.762E+01  2.614E+01  3.000E+01    141
 1     6    10    13 2.531E-00  3.575E+01  3.384E+01  3.000E+01    182
 1     6    15    13 2.875E-00  4.062E+01  3.844E+01  3.000E+01    207
 1     6    20    13 3.110E-00  4.394E+01  4.158E+01  3.000E+01    224
 1     6    25    13 3.282E-00  4.636E+01  4.388E+01  3.000E+01    236
 1     6    30    13 3.414E-00  4.823E+01  4.564E+01  3.000E+01    246
 1     6     5    17 1.819E-00  2.570E+01  2.432E+01  3.000E+01    131
 1     6    10    17 2.381E-00  3.364E+01  3.184E+01  3.000E+01    171
 1     6    15    17 2.727E-00  3.852E+01  3.646E+01  3.000E+01    196
 1     6    20    17 2.968E-00  4.193E+01  3.968E+01  3.000E+01    214
 1     6    25    17 3.148E-00  4.446E+01  4.208E+01  3.000E+01    227
 1     6    30    17 3.287E-00  4.643E+01  4.395E+01  3.000E+01    237
 1     6     5    21 1.708E-00  2.413E+01  2.284E+01  3.000E+01    123
 1     6    10    21 2.255E-00  3.186E+01  3.015E+01  3.000E+01    162
 1     6    15    21 2.600E-00  3.672E+01  3.476E+01  3.000E+01    187
 1     6    20    21 2.844E-00  4.017E+01  3.802E+01  3.000E+01    205
 1     6    25    21 3.028E-00  4.278E+01  4.049E+01  3.000E+01    218
 1     6    30    21 3.173E-00  4.483E+01  4.242E+01  3.000E+01    228
 1     8     5     1 5.034E-00  7.111E+01  6.730E+01  3.000E+01    204
 1     8    10     1 6.233E-00  8.804E+01  8.333E+01  3.000E+01    252
 1     8    15     1 6.873E-00  9.709E+01  9.189E+01  3.000E+01    278
 1     8    20     1 7.278E-00  1.028E+02  9.730E+01  3.000E+01    295
 1     8    25     1 7.558E-00  1.067E+02  1.010E+02  3.000E+01    306
 1     8    30     1 7.763E-00  1.096E+02  1.037E+02  3.000E+01    314
 1     8     5     5 4.514E-00  6.376E+01  6.035E+01  3.000E+01    183
 1     8    10     5 5.721E-00  8.082E+01  7.649E+01  3.000E+01    232
 1     8    15     5 6.405E-00  9.048E+01  8.564E+01  3.000E+01    259
 1     8    20     5 6.854E-00  9.683E+01  9.164E+01  3.000E+01    278
 1     8    25     5 7.174E-00  1.013E+02  9.591E+01  3.000E+01    290
 1     8    30     5 7.413E-00  1.047E+02  9.911E+01  3.000E+01    300
 1     8     5     9 4.127E-00  5.831E+01  5.518E+01  3.000E+01    167
 1     8    10     9 5.318E-00  7.512E+01  7.110E+01  3.000E+01    215
 1     8    15     9 6.022E-00  8.506E+01  8.051E+01  3.000E+01    244
 1     8    20     9 6.497E-00  9.178E+01  8.686E+01  3.000E+01    263
 1     8    25     9 6.843E-00  9.667E+01  9.149E+01  3.000E+01    277
 1     8    30     9 7.107E-00  1.003E+02  9.502E+01  3.000E+01    288
 1     8     5    13 3.826E-00  5.405E+01  5.115E+01  3.000E+01    155
 1     8    10    13 4.990E-00  7.048E+01  6.671E+01  3.000E+01    202
 1     8    15    13 5.700E-00  8.051E+01  7.620E+01  3.000E+01    231
 1     8    20    13 6.191E-00  8.745E+01  8.277E+01  3.000E+01    251
 1     8    25    13 6.554E-00  9.259E+01  8.763E+01  3.000E+01    265
 1     8    30    13 6.836E-00  9.656E+01  9.139E+01  3.000E+01    277
 1     8     5    17 3.582E-00  5.060E+01  4.789E+01  3.000E+01    145
 1     8    10    17 4.715E-00  6.661E+01  6.304E+01  3.000E+01    191
 1     8    15    17 5.424E-00  7.662E+01  7.252E+01  3.000E+01    220
 1     8    20    17 5.924E-00  8.368E+01  7.920E+01  3.000E+01    240
 1     8    25    17 6.299E-00  8.898E+01  8.422E+01  3.000E+01    255
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 NO     L     I     K      Q           QCH          QE           TO          IV

  1     8    30    17 6.593E-00  9.314E+01  8.815E+01  3.000E+01     267
  1     8     5    21 3.380E-00  4.774E+01  4.518E+01  3.000E+01     137
  1     8    10    21 4.482E-00  6.331E+01  5.992E+01  3.000E+01     181
  1     8    15    21 5.185E-00  7.325E+01  6.932E+01  3.000E+01     210
  1     8    20    21 5.689E-00  8.036E+01  7.605E+01  3.000E+01     230
  1     8    25    21 6.072E-00  8.577E+01  8.118E+01  3.000E+01     246
  1     8    30    21 6.375E-00  9.005E+01  8.523E+01  3.000E+01     258
  1    10     5     1 8.170E-00  1.154E+02  1.092E+02  3.000E+01     212
  1    10    10     1 1.028E+01  1.452E+02  1.374E+02  3.000E+01     266
  1    10    15     1 1.145E+01  1.618E+02  1.531E+02  3.000E+01     297
  1    10    20     1 1.221E+01  1.725E+02  1.633E+02  3.000E+01     317
  1    10    25     1 1.275E+01  1.801E+02  1.705E+02  3.000E+01     331
  1    10    30     1 1.315E+01  1.858E+02  1.758E+02  3.000E+01     341
  1    10     5     5 7.426E-00  1.049E+02  9.928E+01  3.000E+01     192
  1    10    10     5 9.519E-00  1.344E+02  1.272E+02  3.000E+01     247
  1    10    15     5 1.076E+01  1.517E+02  1.435E+02  3.000E+01     278
  1    10    20     5 1.155E+01  1.632E+02  1.545E+02  3.000E+01     299
  1    10    25     5 1.214E+01  1.715E+02  1.624E+02  3.000E+01     315
  1    10    30     5 1.259E+01  1.779E+02  1.683E+02  3.000E+01     326
  1    10     5     9 6.854E-00  9.683E+01  9.164E+01  3.000E+01     178
  1    10    10     9 8.905E-00  1.257E+02  1.190E+02  3.000E+01     231
  1    10    15     9 1.014E+01  1.432E+02  1.356E+02  3.000E+01     263
  1    10    20     9 1.099E+01  1.552E+02  1.469E+02  3.000E+01     285
  1    10    25     9 1.161E+01  1.641E+02  1.553E+02  3.000E+01     301
  1    10    30     9 1.210E+01  1.709E+02  1.617E+02  3.000E+01     314
  1    10     5    13 6.397E-00  9.037E+01  8.553E+01  3.000E+01     166
  1    10    10    13 8.396E-00  1.186E+02  1.122E+02  3.000E+01     218
  1    10    15    13 9.636E-00  1.361E+02  1.288E+02  3.000E+01     250
  1    10    20    13 1.050E+01  1.483E+02  1.404E+02  3.000E+01     272
  1    10    25    13 1.115E+01  1.575E+02  1.491E+02  3.000E+01     289
  1    10    30    13 1.166E+01  1.647E+02  1.559E+02  3.000E+01     302
  1    10     5    17 6.021E-00  8.505E+01  8.049E+01  3.000E+01     156
  1    10    10    17 7.965E-00  1.125E+02  1.064E+02  3.000E+01     206
  1    10    15    17 9.198E-00  1.299E+02  1.229E+02  3.000E+01     238
  1    10    20    17 1.007E+01  1.423E+02  1.347E+02  3.000E+01     261
  1    10    25    17 1.074E+01  1.517E+02  1.436E+02  3.000E+01     278
  1    10    30    17 1.126E+01  1.591E+02  1.506E+02  3.000E+01     292
  1    10     5    21 5.704E-00  8.057E+01  7.626E+01  3.000E+01     148
  1    10    10    21 7.595E-00  1.072E+02  1.015E+02  3.000E+01     197
  1    10    15    21 8.815E-00  1.245E+02  1.178E+02  3.000E+01     228
  1    10    20    21 9.696E-00  1.369E+02  1.296E+02  3.000E+01     251
  1    10    25    21 1.037E+01  1.465E+02  1.386E+02  3.000E+01     269
  1    10    30    21 1.090E+01  1.540E+02  1.458E+02  3.000E+01     283
  2     4     5     1 1.396E-00  2.059E+01  1.866E+01  5.500E+01     236
  2     4    10     1 1.641E-00  2.422E+01  2.194E+01  5.500E+01     278
  2     4    15     1 1.757E-00  2.593E+01  2.349E+01  5.500E+01     297
  2     4    20     1 1.825E-00  2.694E+01  2.440E+01  5.500E+01     309
  2     4    25     1 1.870E-00  2.760E+01  2.500E+01  5.500E+01     316
  2     4    30     1 1.902E-00  2.807E+01  2.543E+01  5.500E+01     322
  2     4     5     5 1.198E-00  1.768E+01  1.602E+01  5.500E+01     203
  2     4    10     5 1.470E-00  2.169E+01  1.965E+01  5.500E+01     249
  2     4    15     5 1.612E-00  2.379E+01  2.155E+01  5.500E+01     273
  2     4    20     5 1.700E-00  2.509E+01  2.273E+01  5.500E+01     288
  2     4    25     5 1.761E-00  2.598E+01  2.354E+01  5.500E+01     298
  2     4    30     5 1.805E-00  2.664E+01  2.413E+01  5.500E+01     305
  2     4     5     9 1.066E-00  1.573E+01  1.425E+01  5.500E+01     180
  2     4    10     9 1.343E-00  1.982E+01  1.795E+01  5.500E+01     227
  2     4    15     9 1.497E-00  2.210E+01  2.002E+01  5.500E+01     253
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 NO     L      I      K      Q           QCH         QE          TD              IV

  2     4     20      9 1.598E-00 2.358E+01 2.136E+01 5.500E+01     270
  2     4     25      9 1.668E-00 2.462E+01 2.231E+01 5.500E+01     282
  2     4     30      9 1.721E-00 2.540E+01 2.301E+01 5.500E+01     291
  2     4      5     13 9.701E-01 1.431E+01 1.296E+01 5.500E+01     164
  2     4     10     13 1.244E-00 1.836E+01 1.663E+01 5.500E+01     211
  2     4     15     13 1.404E-00 2.072E+01 1.877E+01 5.500E+01     238
  2     4     20     13 1.512E-00 2.231E+01 2.021E+01 5.500E+01     256
  2     4     25     13 1.589E-00 2.346E+01 2.125E+01 5.500E+01     269
  2     4     30     13 1.648E-00 2.433E+01 2.204E+01 5.500E+01     279
  2     4      5     17 8.959E-01 1.322E+01 1.197E+01 5.500E+01     152
  2     4     10     17 1.164E-00 1.718E+01 1.556E+01 5.500E+01     197
  2     4     15     17 1.327E-00 1.958E+01 1.774E+01 5.500E+01     225
  2     4     20     17 1.438E-00 2.123E+01 1.923E+01 5.500E+01     243
  2     4     25     17 1.521E-00 2.244E+01 2.033E+01 5.500E+01     257
  2     4     30     17 1.584E-00 2.337E+01 2.118E+01 5.500E+01     268
  2     4      5     21 8.366E-01 1.234E+01 1.118E+01 5.500E+01     142
  2     4     10     21 1.098E-00 1.620E+01 1.468E+01 5.500E+01     186
  2     4     15     21 1.261E-00 1.860E+01 1.685E+01 5.500E+01     213
  2     4     20     21 1.375E-00 2.029E+01 1.838E+01 5.500E+01     233
  2     4     25     21 1.460E-00 2.155E+01 1.952E+01 5.500E+01     247
  2     4     30     21 1.526E-00 2.253E+01 2.041E+01 5.500E+01     258
  2     6      5      1 3.465E-00 5.113E+01 4.632E+01 5.500E+01     261
  2     6     10      1 4.199E-00 6.196E+01 5.614E+01 5.500E+01     316
  2     6     15      1 4.571E-00 6.745E+01 6.111E+01 5.500E+01     344
  2     6     20      1 4.798E-00 7.081E+01 6.415E+01 5.500E+01     361
  2     6     25      1 4.952E-00 7.306E+01 6.621E+01 5.500E+01     372
  2     6     30      1 5.063E-00 7.472E+01 6.769E+01 5.500E+01     381
  2     6      5      5 3.051E-00 4.502E+01 4.079E+01 5.500E+01     229
  2     6     10      5 3.813E-00 5.627E+01 5.098E+01 5.500E+01     287
  2     6     15      5 4.229E-00 6.241E+01 5.654E+01 5.500E+01     318
  2     6     20      5 4.496E-00 6.635E+01 6.011E+01 5.500E+01     338
  2     6     25      5 4.683E-00 6.910E+01 6.261E+01 5.500E+01     352
  2     6     30      5 4.021E-00 7.114E+01 6.445E+01 5.500E+01     363
  2     6      5      9 2.757E-00 4.069E+01 3.686E+01 5.500E+01     207
  2     6     10      9 3.517E-00 5.190E+01 4.702E+01 5.500E+01     264
  2     6     15      9 3.955E-00 5.836E+01 5.287E+01 5.500E+01     297
  2     6     20      9 4.245E-00 6.264E+01 5.675E+01 5.500E+01     319
  2     6     25      9 4.453E-00 6.571E+01 5.954E+01 5.500E+01     335
  2     6     30      9 4.610E-00 6.803E+01 6.164E+01 5.500E+01     347
  2     6      5     13 2.534E-00 3.740E+01 3.388E+01 5.500E+01     191
  2     6     10     13 3.281E-00 4.841E+01 4.386E+01 5.500E+01     247
  2     6     15     13 3.727E-00 5.500E+01 4.983E+01 5.500E+01     280
  2     6     20     13 4.031E-00 5.949E+01 5.390E+01 5.500E+01     303
  2     6     25     13 4.254E-00 6.278E+01 5.688E+01 5.500E+01     320
  2     6     30     13 4.425E-00 6.530E+01 5.916E+01 5.500E+01     333
  2     6      5     17 2.358E-00 3.480E+01 3.153E+01 5.500E+01     177
  2     6     10     17 3.086E-00 4.555E+01 4.126E+01 5.500E+01     232
  2     6     15     17 3.535E-00 5.216E+01 4.726E+01 5.500E+01     266
  2     6     20     17 3.847E-00 5.677E+01 5.144E+01 5.500E+01     289
  2     6     25     17 4.080E-00 6.021E+01 5.455E+01 5.500E+01     307
  2     6     30     17 4.261E-00 6.287E+01 5.696E+01 5.500E+01     320
  2     6      5     21 2.214E-00 3.268E+01 2.961E+01 5.500E+01     167
  2     6     10     21 2.923E-00 4.314E+01 3.908E+01 5.500E+01     220
  2     6     15     21 3.370E-00 4.973E+01 4.505E+01 5.500E+01     253
  2     6     20     21 3.686E-00 5.440E+01 4.928E+01 5.500E+01     277
  2     6     25     21 3.925E-00 5.793E+01 5.248E+01 5.500E+01     295
  2     6     30     21 4.113E-00 6.070E+01 5.499E+01 5.500E+01     309
  2     8      5      1 6.525E-00 9.626E+01 8.723E+01 5.500E+01     276
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   NC     L     I     K     Q          QCH        QE         TD           IV

   2      8    10     1 8.079E-00 1.192E+02 1.080E+02 5.500E+01        342
   2      8    15     1 8.909E-00 1.314E+02 1.191E+02 5.500E+01        377
   2      8    20     1 9.433E-00 1.392E+02 1.261E+02 5.500E+01        399
   2      8    25     1 9.796E-00 1.445E+02 1.309E+02 5.500E+01        414
   2      8    30     1 1.006E+01 1.484E+02 1.345E+02 5.500E+01        426
   2      8     5     5 5.851E-00 8.634E+01 7.822E+01 5.500E+01        247
   2      8    10     5 7.416E-00 1.094E+02 9.914E+01 5.500E+01        314
   2      8    15     5 8.303E-00 1.225E+02 1.110E+02 5.500E+01        351
   2      8    20     5 8.885E-00 1.311E+02 1.187E+02 5.500E+01        376
   2      8    25     5 9.299E-00 1.372E+02 1.243E+02 5.500E+01        393
   2      8    30     5 9.609E-00 1.418E+02 1.284E+02 5.500E+01        406
   2      8     5     9 5.350E-00 7.895E+01 7.152E+01 5.500E+01        226
   2      8    10     9 6.893E-00 1.017E+02 9.216E+01 5.500E+01        292
   2      8    15     9 7.805E-00 1.151E+02 1.043E+02 5.500E+01        330
   2      8    20     9 8.422E-00 1.242E+02 1.125E+02 5.500E+01        356
   2      8    25     9 8.870E-00 1.308E+02 1.185E+02 5.500E+01        375
   2      8    30     9 9.212E-00 1.359E+02 1.231E+02 5.500E+01        390
   2      8     5    13 4.959E-00 7.318E+01 6.630E+01 5.500E+01        210
   2      8    10    13 6.467E-00 9.544E+01 8.646E+01 5.500E+01        274
   2      8    15    13 7.388E-00 1.090E+02 9.877E+01 5.500E+01        312
   2      8    20    13 8.024E-00 1.184E+02 1.072E+02 5.500E+01        339
   2      8    25    13 8.496E-00 1.253E+02 1.135E+02 5.500E+01        359
   2      8    30    13 8.8[illegible]E-00 1.307E+02 1.184E+02 5.500E+01        375
   2      8     5    17 4.643E-00 6.852E+01 6.207E+01 5.500E+01        196
   2      8    10    17 6.112E-00 9.019E+01 8.171E+01 5.500E+01        259
   2      8    15    17 7.031E-00 1.037E+02 9.399E+01 5.500E+01        297
   2      8    20    17 7.678E-00 1.133E+02 1.026E+02 5.500E+01        325
   2      8    25    17 8.165E-00 1.204E+02 1.091E+02 5.500E+01        345
   2      8    30    17 8.546E-00 1.261E+02 1.142E+02 5.500E+01        361
   2      8     5    21 4.381E-00 6.464E+01 5.857E+01 5.500E+01        185
   2      8    10    21 5.809E-00 6.573E+01 7.767E+01 5.500E+01        246
   2      8    15    21 6.721E-00 9.918E+01 8.985E+01 5.500E+01        284
   2      8    20    21 7.37[illegible]E-00 1.088E+02 9.858E+01 5.500E+01        312
   2      8    25    21 7.870E-00 1.161E+02 1.052E+02 5.500E+01        333
   2      8    30    21 8.263E-00 1.219E+02 1.104E+02 5.500E+01        350
   2     10     5     1 1.058E+01 1.562E+02 1.415E+02 5.500E+01        287
   2     10    10     1 1.332E+01 1.966E+02 1.781E+02 5.500E+01        361
   2     10    15     1 1.484E+01 2.191E+02 1.985E+02 5.500E+01        402
   2     10    20     1 1.583E+01 2.336E+02 2.117E+02 5.500E+01        429
   2     10    25     1 1.653E+01 2.439E+02 2.210E+02 5.500E+01        448
   2     10    30     1 1.705E+01 2.516E+02 2.279E+02 5.500E+01        462
   2     10     5     5 9.626E-00 1.420E+02 1.286E+02 5.500E+01        261
   2     10    10     5 1.233E+01 1.820E+02 1.649E+02 5.500E+01        334
   2     10    15     5 1.392E+01 2.054E+02 1.861E+02 5.500E+01        377
   2     10    20     5 1.498E+01 2.210E+02 2.002E+02 5.500E+01        406
   2     10    25     5 1.574E+01 2.323E+02 2.104E+02 5.500E+01        426
   2     10    30     5 1.632E+01 2.409E+02 2.182E+02 5.500E+01        442
   2     10     5     9 8.885E-00 1.311E+02 1.187E+02 5.500E+01        241
   2     10    10     9 1.154E+01 1.703E+02 1.543E+02 5.500E+01        312
   2     10    15     9 1.314E+01 1.940E+02 1.757E+02 5.500E+01        356
   2     10    20     9 1.424E+01 2.102E+02 1.905E+02 5.500E+01        386
   2     10    25     9 1.506E+01 2.222E+02 2.013E+02 5.500E+01        408
   2     10    30     9 1.568E+01 2.314E+02 2.096E+02 5.500E+01        425
   2     10     5    13 8.292E-00 1.223E+02 1.108E+02 5.500E+01        224
   2     10    10    13 1.088E+01 1.605E+02 1.454E+02 5.500E+01        295
   2     10    15    13 1.249E+01 1.843E+02 1.669E+02 5.500E+01        338
   2     10    20    13 1.361E+01 2.009E+02 1.820E+02 5.500E+01        369
   2     10    25    13 1.445E+01 2.133E+02 1.932E+02 5.500E+01        391
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NO    L    I    K    Q          QCH        QE         TD           IV

 2   10   30   13 1.511E+01 2.230E+02 2.020E+02 5.500E+01      409
 2   10    5   17 7.804E-00 1.151E+02 1.043E+02 5.500E+01      211
 2   10   10   17 1.032E+01 1.523E+02 1.380E+02 5.500E+01      279
 2   10   15   17 1.192E+01 1.759E+02 1.593E+02 5.500E+01      323
 2   10   20   17 1.306E+01 1.927E+02 1.746E+02 5.500E+01      354
 2   10   25   17 1.392E+01 2.054E+02 1.861E+02 5.500E+01      377
 2   10   30   17 1.460E+01 2.154E+02 1.952E+02 5.500E+01      395
 2   10    5   21 7.393E-00 1.091E+02 9.884E+01 5.500E+01      200
 2   10   10   21 9.844E-00 1.452E+02 1.316E+02 5.500E+01      266
 2   10   15   21 1.142E+01 1.685E+02 1.527E+02 5.500E+01      309
 2   10   20   21 1.256E+01 1.854E+02 1.680E+02 5.500E+01      340
 2   10   25   21 1.344E+01 1.983E+02 1.797E+02 5.500E+01      364
 2   10   30   21 1.413E+01 2.086E+02 1.890E+02 5.500E+01      383
 3    4    5    1 1.855E-00 3.042E+01 2.481E+01 1.200E+02      349
 3    4   10    1 2.182E-00 3.578E+01 2.917E+01 1.200E+02      410
 3    4   15    1 2.336E-00 3.831E+01 3.124E+01 1.200E+02      439
 3    4   20    1 2.427E-00 3.979E+01 3.245E+01 1.200E+02      456
 3    4   25    1 2.486E-00 4.077E+01 3.324E+01 1.200E+02      467
 3    4   30    1 2.529E-00 4.146E+01 3.381E+01 1.200E+02      475
 3    4    5    5 1.593E-00 2.612E+01 2.129E+01 1.200E+02      299
 3    4   10    5 1.954E-00 3.204E+01 2.613E+01 1.200E+02      367
 3    4   15    5 2.143E-00 3.514E+01 2.865E+01 1.200E+02      403
 3    4   20    5 2.260E-00 3.706E+01 3.022E+01 1.200E+02      425
 3    4   25    5 2.341E-00 3.838E+01 3.130E+01 1.200E+02      440
 3    4   30    5 2.400E-00 3.935E+01 3.208E+01 1.200E+02      451
 3    4    5    9 1.417E-00 2.324E+01 1.895E+01 1.200E+02      266
 3    4   10    9 1.785E-00 2.928E+01 2.387E+01 1.200E+02      336
 3    4   15    9 1.991E-00 3.264E+01 2.662E+01 1.200E+02      374
 3    4   20    9 2.124E-00 3.483E+01 2.840E+01 1.200E+02      399
 3    4   25    9 2.218E-00 3.637E+01 2.966E+01 1.200E+02      417
 3    4   30    9 2.288E-00 3.752E+01 3.060E+01 1.200E+02      430
 3    4    5   13 1.289E-00 2.114E+01 1.724E+01 1.200E+02      242
 3    4   10   13 1.654E-00 2.712E+01 2.211E+01 1.200E+02      311
 3    4   15   13 1.867E-00 3.061E+01 2.496E+01 1.200E+02      351
 3    4   20   13 2.010E-00 3.296E+01 2.687E+01 1.200E+02      378
 3    4   25   13 2.113E-00 3.465E+01 2.825E+01 1.200E+02      397
 3    4   30   13 2.191E-00 3.593E+01 2.930E+01 1.200E+02      412
 3    4    5   17 1.191E-00 1.952E+01 1.592E+01 1.200E+02      224
 3    4   10   17 1.548E-00 2.538E+01 2.069E+01 1.200E+02      291
 3    4   15   17 1.764E-00 2.892E+01 2.358E+01 1.200E+02      332
 3    4   20   17 1.912E-00 3.136E+01 2.557E+01 1.200E+02      360
 3    4   25   17 2.022E-00 3.315E+01 2.703E+01 1.200E+02      380
 3    4   30   17 2.106E-00 3.453E+01 2.815E+01 1.200E+02      396
 3    4    5   21 1.112E-00 1.823E+01 1.486E+01 1.200E+02      209
 3    4   10   21 1.460E-00 2.394E+01 1.952E+01 1.200E+02      274
 3    4   15   21 1.676E-00 2.748E+01 2.241E+01 1.200E+02      315
 3    4   20   21 1.828E-00 2.997E+01 2.443E+01 1.200E+02      344
 3    4   25   21 1.941E-00 3.183E+01 2.595E+01 1.200E+02      365
 3    4   30   21 2.029E-00 3.328E+01 2.713E+01 1.200E+02      382
 3    6    5    1 4.606E-00 7.553E+01 6.158E+01 1.200E+02      385
 3    6   10    1 5.582E-00 9.153E+01 7.463E+01 1.200E+02      466
 3    6   15    1 6.077E-00 9.963E+01 8.124E+01 1.200E+02      508
 3    6   20    1 6.379E-00 1.045E+02 8.528E+01 1.200E+02      533
 3    6   25    1 6.583E-00 1.079E+02 8.802E+01 1.200E+02      550
 3    6   30    1 6.731E-00 1.103E+02 8.999E+01 1.200E+02      562
 3    6    5    5 4.056E-00 6.651E+01 5.423E+01 1.200E+02      339
 3    6   10    5 5.069E-00 8.311E+01 6.777E+01 1.200E+02      424
 3    6   15    5 5.623E-00 9.219E+01 7.517E+01 1.200E+02      470
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  NO     L     I     K     Q          QCH        QE         TD          IV

   3     6    20     5 5.977E-00 9.601E+01 7.991E+01 1.200E+02     499
   3     6    25     5 6.225E-00 1.020E+02 8.323E+01 1.200E+02     520
   3     6    30     5 6.409E-00 1.050E+02 8.568E+01 1.200E+02     535
   3     6     5     9 3.665E-00 6.010E+01 4.900E+01 1.200E+02     306
   3     6    10     9 4.676E-00 7.666E+01 6.251E+01 1.200E+02     391
   3     6    15     9 5.257E-00 8.620E+01 7.029E+01 1.200E+02     439
   3     6    20     9 5.643E-00 9.253E+01 7.545E+01 1.200E+02     472
   3     6    25     9 5.920E-00 9.707E+01 7.915E+01 1.200E+02     495
   3     6    30     9 6.129E-00 1.005E+02 8.194E+01 1.200E+02     512
   3     6     5    13 3.369E-00 5.525E+01 4.505E+01 1.200E+02     282
   3     6    10    13 4.362E-00 7.151E+01 5.831E+01 1.200E+02     364
   3     6    15    13 4.955E-00 8.124E+01 6.624E+01 1.200E+02     414
   3     6    20    13 5.360E-00 8.788E+01 7.165E+01 1.200E+02     448
   3     6    25    13 5.656E-00 9.273E+01 7.561E+01 1.200E+02     473
   3     6    30    13 5.883E-00 9.646E+01 7.865E+01 1.200E+02     492
   3     6     5    17 3.135E-00 5.141E+01 4.192E+01 1.200E+02     262
   3     6    10    17 4.103E-00 6.728E+01 5.486E+01 1.200E+02     343
   3     6    15    17 4.699E-00 7.705E+01 6.283E+01 1.200E+02     393
   3     6    20    17 5.115E-00 8.386E+01 6.838E+01 1.200E+02     427
   3     6    25    17 5.424E-00 8.893E+01 7.251E+01 1.200E+02     453
   3     6    30    17 5.664E-00 9.287E+01 7.573E+01 1.200E+02     473
   3     6     5    21 2.944E-00 4.827E+01 3.936E+01 1.200E+02     246
   3     6    10    21 3.886E-00 6.372E+01 5.195E+01 1.200E+02     325
   3     6    15    21 4.480E-00 7.345E+01 5.989E+01 1.200E+02     374
   3     6    20    21 4.901E-00 8.035E+01 6.552E+01 1.200E+02     409
   3     6    25    21 5.218E-00 8.556E+01 6.977E+01 1.200E+02     436
   3     6    30    21 5.468E-00 8.966E+01 7.311E+01 1.200E+02     457
   3     8     5     1 8.674E-00 1.422E+02 1.159E+02 1.200E+02     408
   3     8    10     1 1.074E+01 1.760E+02 1.435E+02 1.200E+02     505
   3     8    15     1 1.184E+01 1.941E+02 1.583E+02 1.200E+02     557
   3     8    20     1 1.254E+01 2.056E+02 1.676E+02 1.200E+02     589
   3     8    25     1 1.302E+01 2.135E+02 1.741E+02 1.200E+02     612
   3     8    30     1 1.337E+01 2.193E+02 1.788E+02 1.200E+02     629
   3     8     5     5 7.778E-00 1.275E+02 1.039E+02 1.200E+02     366
   3     8    10     5 9.859E-00 1.616E+02 1.318E+02 1.200E+02     463
   3     8    15     5 1.103E+01 1.809E+02 1.475E+02 1.200E+02     519
   3     8    20     5 1.181E+01 1.936E+02 1.579E+02 1.200E+02     555
   3     8    25     5 1.236E+01 2.026E+02 1.652E+02 1.200E+02     581
   3     8    30     5 1.277E+01 2.094E+02 1.707E+02 1.200E+02     600
   3     8     5     9 7.112E-00 1.166E+02 9.509E+01 1.200E+02     334
   3     8    10     9 9.164E-00 1.502E+02 1.225E+02 1.200E+02     431
   3     8    15     9 1.037E+01 1.701E+02 1.387E+02 1.200E+02     488
   3     8    20     9 1.119E+01 1.835E+02 1.496E+02 1.200E+02     526
   3     8    25     9 1.179E+01 1.933E+02 1.576E+02 1.200E+02     554
   3     8    30     9 1.224E+01 2.007E+02 1.637E+02 1.200E+02     576
   3     8     5    13 6.593E-00 1.081E+02 8.814E+01 1.200E+02     310
   3     8    10    13 8.598E-00 1.409E+02 1.149E+02 1.200E+02     404
   3     8    15    13 9.821E-00 1.610E+02 1.313E+02 1.200E+02     462
   3     8    20    13 1.066E+01 1.749E+02 1.426E+02 1.200E+02     501
   3     8    25    13 1.129E+01 1.851E+02 1.509E+02 1.200E+02     531
   3     8    30    13 1.177E+01 1.931E+02 1.574E+02 1.200E+02     554
   3     8     5    17 6.173E-00 1.012E+02 8.252E+01 1.200E+02     290
   3     8    10    17 8.125E-00 1.332E+02 1.086E+02 1.200E+02     382
   3     8    15    17 9.347E-00 1.532E+02 1.249E+02 1.200E+02     439
   3     8    20    17 1.020E+01 1.673E+02 1.364E+02 1.200E+02     480
   3     8    25    17 1.085E+01 1.779E+02 1.451E+02 1.200E+02     510
   3     8    30    17 1.136E+01 1.862E+02 1.518E+02 1.200E+02     534
   3     8     5    21 5.824E-00 9.549E+01 7.785E+01 1.200E+02     274
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 NO    L    I    K      Q          CCH        QE         TO          SV

  3    8   10   21 7.723E-00 1.266E+02 1.032E+02 1.200E+02        363
  3    8   15   21 8.935E-00 1.465E+02 1.194E+02 1.200E+02        420
  3    8   20   21 9.803E-00 1.607E+02 1.310E+02 1.200E+02        461
  3    8   25   21 1.046E+01 1.715E+02 1.398E+02 1.200E+02        492
  3    8   30   21 1.096E+01 1.801E+02 1.468E+02 1.200E+02        516
  3   10    5    1 1.407E+01 2.308E+02 1.882E+02 1.200E+02        423
  3   10   10    1 1.771E+01 2.904E+02 2.368E+02 1.200E+02        533
  3   10   15    1 1.974E+01 3.236E+02 2.639E+02 1.200E+02        594
  3   10   20    1 2.105E+01 3.451E+02 2.814E+02 1.200E+02        633
  3   10   25    1 2.197E+01 3.603E+02 2.938E+02 1.200E+02        661
  3   10   30    1 2.266E+01 3.716E+02 3.030E+02 1.200E+02        682
  3   10    5    5 1.279E+01 2.098E+02 1.710E+02 1.200E+02        385
  3   10   10    5 1.640E+01 2.689E+02 2.192E+02 1.200E+02        493
  3   10   15    5 1.850E+01 3.034E+02 2.474E+02 1.200E+02        557
  3   10   20    5 1.991E+01 3.265E+02 2.662E+02 1.200E+02        599
  3   10   25    5 2.093E+01 3.431E+02 2.798E+02 1.200E+02        630
  3   10   30    5 2.170E+01 3.558E+02 2.901E+02 1.200E+02        653
  3   10    5    9 1.181E+01 1.[illegible]6E+02 1.579E+02 1.200E+02        355
  3   10   10    9 1.534E+01 2.515E+02 2.051E+02 1.200E+02        462
  3   10   15    9 1.747E+01 2.865E+02 2.336E+02 1.200E+02        526
  3   10   20    9 1.894E+01 3.105E+02 2.532E+02 1.200E+02        570
  3   10   25    9 2.002E+01 3.282E+02 2.676E+02 1.200E+02        602
  3   10   30    9 2.085E+01 3.418E+02 2.787E+02 1.200E+02        627
  3   10    5   13 1.102E+01 1.807E+02 1.473E+02 1.200E+02        332
  3   10   10   13 1.446E+01 2.372E+02 1.934E+02 1.200E+02        435
  3   10   15   13 1.660E+01 2.722E+02 2.219E+02 1.200E+02        499
  3   10   20   13 1.810E+01 2.967E+02 2.419E+02 1.200E+02        544
  3   10   25   13 1.922E+01 3.151E+02 2.569E+02 1.200E+02        578
  3   10   30   13 2.009E+01 3.294E+02 2.686E+02 1.200E+02        604
  3   10    5   17 1.037E+01 1.701E+02 1.387E+02 1.200E+02        312
  3   10   10   17 1.372E+01 2.250E+02 1.834E+02 1.200E+02        413
  3   10   15   17 1.584E+01 2.598E+02 2.118E+02 1.200E+02        477
  3   10   20   17 1.736E+01 2.846E+02 2.321E+02 1.200E+02        522
  3   10   25   17 1.850E+01 3.034E+02 2.474E+02 1.200E+02        557
  3   10   30   17 1.941E+01 3.182E+02 2.595E+02 1.200E+02        584
  3   10    5   21 9.829E-00 1.611E+02 1.314E+02 1.200E+02        296
  3   10   10   21 1.308E+01 2.145E+02 1.749E+02 1.200E+02        394
  3   10   15   21 1.518E+01 2.490E+02 2.030E+02 1.200E+02        457
  3   10   20   21 1.670E+01 2.739E+02 2.233E+02 1.200E+02        503
  3   10   25   21 1.787E+01 2.930E+02 2.389E+02 1.200E+02        537
  3   10   30   21 1.879E+01 3.081E+02 2.512E+02 1.200E+02        565
  4    4    5    1 2.133E-00 3.928E+01 2.852E+01 2.000E+02        450
  4    4   10    1 2.508E-00 4.619E+01 3.354E+01 2.000E+02        530
  4    4   15    1 2.686E-00 4.946E+01 3.591E+01 2.000E+02        567
  4    4   20    1 2.790E-00 5.137E+01 3.730E+01 2.000E+02        589
  4    4   25    1 2.858E-00 5.264E+01 3.821E+01 2.000E+02        604
  4    4   30    1 2.907E-00 5.353E+01 3.886E+01 2.000E+02        614
  4    4    5    5 1.831E-00 3.372E+01 2.448E+01 2.000E+02        387
  4    4   10    5 2.246E-00 4.137E+01 3.003E+01 2.000E+02        474
  4    4   15    5 2.463E-00 4.536E+01 3.293E+01 2.000E+02        520
  4    4   20    5 2.598E-00 4.785E+01 3.474E+01 2.000E+02        549
  4    4   25    5 2.691E-00 4.956E+01 3.598E+01 2.000E+02        568
  4    4   30    5 2.758E-00 5.080E+01 3.688E+01 2.000E+02        582
  4    4    5    9 1.629E-00 3.000E+01 2.178E+01 2.000E+02        344
  4    4   10    9 2.052E-00 3.780E+01 2.744E+01 2.000E+02        433
  4    4   15    9 2.288E-00 4.214E+01 3.060E+01 2.000E+02        483
  4    4   20    9 2.442E-00 4.497E+01 3.265E+01 2.000E+02        516
  4    4   25    9 2.550E-00 4.696E+01 3.409E+01 2.000E+02        538
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 NO     L     I    K      Q          QCH         QE          TD          IV

  4     4    30    9 2.631E-00 4.844E+01 3.517E+01 2.000E+02      555
  4     4     5   13 1.482E-00 2.729E+01 1.981E+01 2.000E+02      313
  4     4    10   13 1.901E-00 3.501E+01 2.542E+01 2.000E+02      401
  4     4    15   13 2.146E-00 3.952E+01 2.869E+01 2.000E+02      453
  4     4    20   13 2.310E-00 4.255E+01 3.089E+01 2.000E+02      488
  4     4    25   13 2.429E-00 4.473E+01 3.248E+01 2.000E+02      513
  4     4    30   13 2.519E-00 4.639E+01 3.368E+01 2.000E+02      532
  4     4     5   17 1.369E-00 2.521E+01 1.830E+01 2.000E+02      289
  4     4    10   17 1.779E-00 3.277E+01 2.379E+01 2.000E+02      376
  4     4    15   17 2.027E-00 3.734E+01 2.711E+01 2.000E+02      428
  4     4    20   17 2.198E-00 4.048E+01 2.939E+01 2.000E+02      464
  4     4    25   17 2.324E-00 4.280E+01 3.107E+01 2.000E+02      491
  4     4    30   17 2.421E-00 4.458E+01 3.236E+01 2.000E+02      511
  4     4     5   21 1.278E-00 2.354E+01 1.709E+01 2.000E+02      270
  4     4    10   21 1.678E-00 3.090E+01 2.244E+01 2.000E+02      354
  4     4    15   21 1.927E-00 3.548E+01 2.576E+01 2.000E+02      407
  4     4    20   21 2.101E-00 3.869E+01 2.809E+01 2.000E+02      444
  4     4    25   21 2.231E-00 4.109E+01 2.983E+01 2.000E+02      471
  4     4    30   21 2.333E-00 4.296E+01 3.119E+01 2.000E+02      493
  4     6     5    1 5.295E-00 9.751E+01 7.079E+01 2.000E+02      497
  4     6    10    1 6.417E-00 1.181E+02 8.579E+01 2.000E+02      602
  4     6    15    1 6.985E-00 1.286E+02 9.339E+01 2.000E+02      655
  4     6    20    1 7.333E-00 1.350E+02 9.803E+01 2.000E+02      688
  4     6    25    1 7.568E-00 1.393E+02 1.011E+02 2.000E+02      710
  4     6    30    1 7.738E-00 1.424E+02 1.034E+02 2.000E+02      726
  4     6     5    5 4.665E-00 8.586E+01 6.234E+01 2.000E+02      438
  4     6    10    5 5.827E-00 1.073E+02 7.790E+01 2.000E+02      547
  4     6    15    5 6.463E-00 1.190E+02 8.641E+01 2.000E+02      606
  4     6    20    5 6.871E-00 1.265E+02 9.186E+01 2.000E+02      645
  4     6    25    5 7.156E-00 1.317E+02 9.567E+01 2.000E+02      672
  4     6    30    5 7.367E-00 1.356E+02 9.850E+01 2.000E+02      691
  4     6     5    9 4.214E-00 7.759E+01 5.633E+01 2.000E+02      395
  4     6    10    9 5.375E-00 9.897E+01 7.186E+01 2.000E+02      504
  4     6    15    9 6.043E-00 1.112E+02 8.080E+01 2.000E+02      567
  4     6    20    9 6.487E-00 1.194E+02 8.673E+01 2.000E+02      609
  4     6    25    9 6.805E-00 1.253E+02 9.098E+01 2.000E+02      639
  4     6    30    9 7.046E-00 1.297E+02 9.419E+01 2.000E+02      661
  4     6     5   13 3.873E-00 7.133E+01 5.178E+01 2.000E+02      363
  4     6    10   13 5.014E-00 9.233E+01 6.703E+01 2.000E+02      470
  4     6    15   13 5.696E-00 1.048E+02 7.615E+01 2.000E+02      534
  4     6    20   13 6.161E-00 1.134E+02 8.237E+01 2.000E+02      578
  4     6    25   13 6.501E-00 1.197E+02 8.692E+01 2.000E+02      610
  4     6    30   13 6.763E-00 1.245E+02 9.041E+01 2.000E+02      635
  4     6     5   17 3.604E-00 6.637E+01 4.818E+01 2.000E+02      338
  4     6    10   17 4.717E-00 8.686E+01 6.306E+01 2.000E+02      443
  4     6    15   17 5.402E-00 9.948E+01 7.222E+01 2.000E+02      507
  4     6    20   17 5.880E-00 1.082E+02 7.861E+01 2.000E+02      552
  4     6    25   17 6.235E-00 1.148E+02 8.336E+01 2.000E+02      585
  4     6    30   17 6.511E-00 1.199E+02 8.705E+01 2.000E+02      611
  4     6     5   21 3.384E-00 6.232E+01 4.524E+01 2.000E+02      318
  4     6    10   21 4.467E-00 8.226E+01 5.972E+01 2.000E+02      419
  4     6    15   21 5.150E-00 9.483E+01 6.885E+01 2.000E+02      483
  4     6    20   21 5.633E-00 1.037E+02 7.532E+01 2.000E+02      529
  4     6    25   21 5.999E-00 1.104E+02 8.020E+01 2.000E+02      563
  4     6    30   21 6.286E-00 1.157E+02 8.404E+01 2.000E+02      590
  4     8     5    1 9.971E-00 1.836E+02 1.333E+02 2.000E+02      526
  4     8    10    1 1.234E+01 2.273E+02 1.650E+02 2.000E+02      652
  4     8    15    1 1.361E+01 2.507E+02 1.820E+02 2.000E+02      719
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NO     L     I     K     Q          QCH        QE         TD           IV

 4     8    20     1 1.441E+01  2.654E+02  1.927E+02  2.000E+02     761
 4     8    25     1 1.497E+01  2.756E+02  2.001E+02  2.000E+02     790
 4     8    30     1 1.537E+01  2.831E+02  2.055E+02  2.000E+02     812
 4     8     5     5 8.941E-00  1.646E+02  1.195E+02  2.000E+02     472
 4     8    10     5 1.133E+01  2.086E+02  1.515E+02  2.000E+02     598
 4     8    15     5 1.268E+01  2.336E+02  1.696E+02  2.000E+02     670
 4     8    20     5 1.357E+01  2.500E+02  1.815E+02  2.000E+02     717
 4     8    25     5 1.421E+01  2.616E+02  1.899E+02  2.000E+02     750
 4     8    30     5 1.468E+01  2.704E+02  1.963E+02  2.000E+02     775
 4     8     5     9 8.176E-00  1.505E+02  1.093E+02  2.000E+02     432
 4     8    10     9 1.053E+01  1.939E+02  1.408E+02  2.000E+02     556
 4     8    15     9 1.192E+01  2.196E+02  1.594E+02  2.000E+02     630
 4     8    20     9 1.287E+01  2.369E+02  1.720E+02  2.000E+02     679
 4     8    25     9 1.355E+01  2.496E+02  1.812E+02  2.000E+02     715
 4     8    30     9 1.407E+01  2.592E+02  1.882E+02  2.000E+02     743
 4     8     5    13 7.579E-00  1.395E+02  1.013E+02  2.000E+02     400
 4     8    10    13 9.883E-00  1.820E+02  1.321E+02  2.000E+02     522
 4     8    15    13 1.129E+01  2.078E+02  1.509E+02  2.000E+02     596
 4     8    20    13 1.226E+01  2.258E+02  1.639E+02  2.000E+02     647
 4     8    25    13 1.298E+01  2.390E+02  1.735E+02  2.000E+02     685
 4     8    30    13 1.354E+01  2.493E+02  1.810E+02  2.000E+02     715
 4     8     5    17 7.096E-00  1.306E+02  9.486E+01  2.000E+02     375
 4     8    10    17 9.340E-00  1.719E+02  1.248E+02  2.000E+02     493
 4     8    15    17 1.074E+01  1.978E+02  1.436E+02  2.000E+02     567
 4     8    20    17 1.173E+01  2.160E+02  1.568E+02  2.000E+02     619
 4     8    25    17 1.247E+01  2.297E+02  1.668E+02  2.000E+02     659
 4     8    30    17 1.306E+01  2.404E+02  1.746E+02  2.000E+02     689
 4     8     5    21 6.694E-00  1.232E+02  8.950E+01  2.000E+02     353
 4     8    10    21 8.878E-00  1.634E+02  1.186E+02  2.000E+02     469
 4     8    15    21 1.027E+01  1.891E+02  1.373E+02  2.000E+02     542
 4     8    20    21 1.126E+01  2.075E+02  1.506E+02  2.000E+02     595
 4     8    25     1 1.202E+01  2.214E+02  1.607E+02  2.000E+02     635
 4     8    30    21 1.262E+01  2.325E+02  1.688E+02  2.000E+02     666
 4    10     5     1 1.618E+01  2.979E+02  2.163E+02  2.000E+02     547
 4    10    10     1 2.036E+01  3.750E+02  2.722E+02  2.000E+02     688
 4    10    15     1 2.269E+01  4.178E+02  3.033E+02  2.000E+02     767
 4    10    20     1 2.420E+01  4.456E+02  3.235E+02  2.000E+02     817
 4    10    25     1 2.526E+01  4.652E+02  3.377E+02  2.000E+02     853
 4    10    30     1 2.605E+01  4.798E+03  3.483E+02  2.000E+02     880
 4    10     5     5 1.471E+01  2.708E+02  1.966E+02  2.000E+02     497
 4    10    10     5 1.885E+01  3.472E+02  2.520E+02  2.000E+02     637
 4    10    15     5 2.127E+01  3.917E+02  2.844E+02  2.000E+02     719
 4    10    20     5 2.289E+01  4.215E+02  3.060E+02  2.000E+02     773
 4    10    25     5 2.406E+01  4.430E+02  3.216E+02  2.000E+02     813
 4    10    30     5 2.494E+01  4.593E+02  3.335E+02  2.000E+02     843
 4    10     5     9 1.357E+01  2.500E+02  1.815E+02  2.000E+02     459
 4    10    10     9 1.763E+01  3.248E+02  2.358E+02  2.000E+02     596
 4    10    15     9 2.009E+01  3.699E+02  2.686E+02  2.000E+02     679
 4    10    20     9 2.177E+01  4.009E+02  2.911E+02  2.000E+02     736
 4    10    25     9 2.301E+01  4.237E+02  3.076E+02  2.000E+02     777
 4    10    30     9 2.396E+01  4.413E+02  3.204E+02  2.000E+02     810
 4    10     5    13 1.267E+01  2.333E+02  1.694E+02  2.000E+02     428
 4    10    10    13 1.663E+01  3.062E+02  2.223E+02  2.000E+02     562
 4    10    15    13 1.908E+01  3.514E+02  2.551E+02  2.000E+02     645
 4    10    20    13 2.080E+01  3.831E+02  2.781E+02  2.000E+02     703
 4    10    25    13 2.209E+01  4.068E+02  2.953E+02  2.000E+02     746
 4    10    30    13 2.309E+01  4.253E+02  3.087E+02  2.000E+02     780
 4    10     5    17 1.192E+01  2.196E+02  1.594E+02  2.000E+02     403
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 NO     L      I      K     O          QCH         QE          TD           IV

  4    10     10     17 1.577E+01 2.905E+02 2.109E+02 2.000E+02        533
  4    10     15     17 1.821E+01 3.354E+02 2.435E+02 2.000E+02        615
  4    10     20     17 1.995E+01 3.675E+02 2.668E+02 2.000E+02        674
  4    10     25     17 2.127E+01 3.917E+02 2.844E+02 2.000E+02        719
  4    10     30     17 2.231E+01 4.109E+02 2.983E+02 2.000E+02        754
  4    10      5     21 1.129E+01 2.080E+02 1.510E+02 2.000E+02        382
  4    10     10     21 1.504E+01 2.770E+02 2.011E+02 2.000E+02        503
  4    10     15     21 1.746E+01 3.215E+02 2.334E+02 2.000E+02        590
  4    10     20     21 1.920E+01 3.536E+02 2.567E+02 2.000E+02        649
  4    10     25     21 2.054E+01 3.782E+02 2.746E+02 2.000E+02        694
  4    10     30     21 2.160E+01 3.978E+02 2.888E+02 2.000E+02        730
  5     4      5      1 2.247E-00 4.478E+01 3.004E+01 2.600E+02        514
  5     4     10      1 2.643E-00 5.267E+01 3.533E+01 2.600E+02        604
  5     4     15      1 2.830E-00 5.639E+01 3.783E+01 2.600E+02        647
  5     4     20      1 2.939E-00 5.858E+01 3.930E+01 2.600E+02        672
  5     4     25      1 3.011E-00 6.001E+01 4.026E+01 2.600E+02        688
  5     4     30      1 3.063E-00 6.103E+01 4.095E+01 2.600E+02        700
  5     4      5      5 1.929E-00 3.845E+01 2.579E+01 2.600E+02        441
  5     4     10      5 2.367E-00 4.717E+01 3.164E+01 2.600E+02        541
  5     4     15      5 2.595E-00 5.172E+01 3.470E+01 2.600E+02        593
  5     4     20      5 2.738E-00 5.456E+01 3.660E+01 2.600E+02        626
  5     4     25      5 2.835E-00 5.650E+01 3.790E+01 2.600E+02        648
  5     4     30      5 2.906E-00 5.792E+01 3.886E+01 2.600E+02        664
  5     4      5      9 1.716E-00 3.421E+01 2.295E+01 2.600E+02        392
  5     4     10      9 2.162E-00 4.309E+01 2.891E+01 2.600E+02        494
  5     4     15      9 2.411E-00 4.805E+01 3.224E+01 2.600E+02        551
  5     4     20      9 2.573E-00 5.127E+01 3.439E+01 2.600E+02        588
  5     4     25      9 2.687E-00 5.354E+01 3.592E+01 2.600E+02        614
  5     4     30      9 2.772E-00 5.524E+01 3.706E+01 2.600E+02        633
  5     4      5     13 1.561E-00 3.112E+01 2.088E+01 2.600E+02        357
  5     4     10     13 2.003E-00 3.992E+01 2.678E+01 2.600E+02        458
  5     4     15     13 2.261E-00 4.506E+01 3.023E+01 2.600E+02        517
  5     4     20     13 2.434E-00 4.851E+01 3.254E+01 2.600E+02        556
  5     4     25     13 2.559E-00 5.100E+01 3.422E+01 2.600E+02        585
  5     4     30     13 2.654E-00 5.290E+01 3.548E+01 2.600E+02        606
  5     4      5     17 1.442E-00 2.874E+01 1.928E+01 2.600E+02        330
  5     4     10     17 1.875E-00 3.736E+01 2.506E+01 2.600E+02        428
  5     4     15     17 2.136E-00 4.257E+01 2.856E+01 2.600E+02        488
  5     4     20     17 2.316E-00 4.616E+01 3.096E+01 2.600E+02        529
  5     4     25     17 2.448E-00 4.879E+01 3.273E+01 2.600E+02        559
  5     4     30     17 2.550E-00 5.083E+01 3.410E+01 2.600E+02        583
  5     4      5     21 1.346E-00 2.684E+01 1.800E+01 2.600E+02        308
  5     4     10     21 1.768E-00 3.524E+01 2.364E+01 2.600E+02        404
  5     4     15     21 2.030E-00 4.045E+01 2.714E+01 2.600E+02        464
  5     4     20     21 2.213E-00 4.411E+01 2.959E+01 2.600E+02        506
  5     4     25     21 2.351E-00 4.685E+01 3.143E+01 2.600E+02        537
  5     4     30     21 2.458E-00 4.899E+01 3.286E+01 2.600E+02        562
  5     6      5      1 5.579E-00 1.111E+02 7.459E+01 2.600E+02        567
  5     6     10      1 6.761E-00 1.347E+02 9.038E+01 2.600E+02        687
  5     6     15      1 7.360E-00 1.466E+02 9.839E+01 2.600E+02        747
  5     6     20      1 7.726E-00 1.539E+02 1.032E+02 2.600E+02        785
  5     6     25      1 7.973E-00 1.588E+02 1.066E+02 2.600E+02        810
  5     6     30      1 8.132E-00 1.624E+02 1.089E+02 2.600E+02        828
  5     6      5      5 4.913E-00 9.790E+01 6.568E+01 2.600E+02        499
  5     6     10      5 6.139E-00 1.223E+02 8.208E+01 2.600E+02        623
  5     6     15      5 6.810E-00 1.357E+02 9.104E+01 2.600E+02        692
  5     6     20      5 7.239E-00 1.442E+02 9.678E+01 2.600E+02        735
  5     6     25      5 7.540E-00 1.502E+02 1.008E+02 2.600E+02        766
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 NO    L     I     K      Q          QCH         QE          TD          IV

  5    6    30     5 7.762E-00  1.546E+02  1.037E+02  2.600E+02       788
  5    6     5     9 4.439E-00  8.847E+01  5.935E+01  2.600E+02       451
  5    6    10     9 5.663E-00  1.128E+02  7.571E+01  2.600E+02       575
  5    6    15     9 6.367E-00  1.268E+02  8.512E+01  2.600E+02       617
  5    6    20     9 6.835E-00  1.362E+02  9.137E+01  2.600E+02       694
  5    6    25     9 7.170E-00  1.428E+02  9.586E+01  2.600E+02       728
  5    6    30     9 7.425E-00  1.479E+02  9.924E+01  2.600E+02       754
  5    6     5    13 4.081E-00  8.133E+01  5.456E+01  2.600E+02       414
  5    6    10    13 5.282E-00  1.052E+02  7.062E+01  2.600E+02       536
  5    6    15    13 6.001E-00  1.195E+02  8.023E+01  2.600E+02       609
  5    6    20    13 6.491E-00  1.293E+02  8.678E+01  2.600E+02       659
  5    6    25    13 6.850E-00  1.365E+02  9.158E+01  2.600E+02       696
  5    6    30    13 7.125E-00  1.419E+02  9.525E+01  2.600E+02       724
  5    6     5    17 3.797E-00  7.567E+01  5.077E+01  2.600E+02       386
  5    6    10    17 4.970E-00  9.904E+01  6.644E+01  2.600E+02       505
  5    6    15    17 5.692E-00  1.134E+02  7.609E+01  2.600E+02       578
  5    6    20    17 6.195E-00  1.234E+02  8.262E+01  2.600E+02       629
  5    6    25    17 6.569E-00  1.309E+02  8.782E+01  2.600E+02       667
  5    6    30    17 6.860E-00  1.367E+02  9.171E+01  2.600E+02       697
  5    6     5    21 3.565E-00  7.106E+01  4.767E+01  2.600E+02       362
  5    6    10    21 4.707E-00  9.379E+01  6.292E+01  2.600E+02       478
  5    6    15    21 5.426E-00  1.081E+02  7.254E+01  2.600E+02       551
  5    6    20    21 5.935E-00  1.182E+02  7.935E+01  2.600E+02       603
  5    6    25    21 6.320E-00  1.259E+02  8.450E+01  2.600E+02       642
  5    6    30    21 6.625E-00  1.319E+02  8.854E+01  2.600E+02       673
  5    8     5     1 1.050E+01  2.093E+02  1.404E+02  2.600E+02       600
  5    8    10     1 1.300E+01  2.592E+02  1.739E+02  2.600E+02       743
  5    8    15     1 1.434E+01  2.857E+02  1.917E+02  2.600E+02       819
  5    8    20     1 1.518E+01  3.026E+02  2.030E+02  2.600E+02       868
  5    8    25     1 1.577E+01  3.143E+02  2.108E+02  2.600E+02       901
  5    8    30     1 1.620E+01  3.228E+02  2.165E+02  2.600E+02       925
  5    8     5     5 9.420E-00  1.877E+02  1.259E+02  2.600E+02       538
  5    8    10     5 1.194E+01  2.379E+02  1.596E+02  2.600E+02       682
  5    8    15     5 1.336E+01  2.663E+02  1.787E+02  2.600E+02       764
  5    8    20     5 1.430E+01  2.850E+02  1.912E+02  2.600E+02       817
  5    8    25     5 1.497E+01  2.983E+02  2.001E+02  2.600E+02       855
  5    8    30     5 1.547E+01  3.083E+02  2.068E+02  2.600E+02       884
  5    8     5     9 8.614E-00  1.716E+02  1.151E+02  2.600E+02       492
  5    8    10     9 1.109E+01  2.211E+02  1.483E+02  2.600E+02       634
  5    8    15     9 1.256E+01  2.504E+02  1.680E+02  2.600E+02       718
  5    8    20     9 1.355E+01  2.702E+02  1.812E+02  2.600E+02       774
  5    8    25     9 1.428E+01  2.845E+02  1.909E+02  2.600E+02       816
  5    8    30     9 1.483E+01  2.955E+02  1.982E+02  2.600E+02       847
  5    8     5    13 7.985E-00  1.591E+02  1.067E+02  2.600E+02       456
  5    8    10    13 1.041E+01  2.075E+02  1.392E+02  2.600E+02       595
  5    8    15    13 1.189E+01  2.370E+02  1.590E+02  2.600E+02       679
  5    8    20    13 1.292E+01  2.574E+02  1.727E+02  2.600E+02       738
  5    8    25    13 1.367E+01  2.725E+02  1.828E+02  2.600E+02       781
  5    8    30    13 1.426E+01  2.842E+02  1.907E+02  2.600E+02       815
  5    8     5    17 7.476E-00  1.489E+02  9.994E+01  2.600E+02       427
  5    8    10    17 9.841E-00  1.961E+02  1.315E+02  2.600E+02       562
  5    8    15    17 1.132E+01  2.255E+02  1.513E+02  2.600E+02       647
  5    8    20    17 1.236E+01  2.463E+02  1.652E+02  2.600E+02       706
  5    8    25    17 1.314E+01  2.619E+02  1.757E+02  2.600E+02       751
  5    8    30    17 1.376E+01  2.742E+02  1.839E+02  2.600E+02       786
  5    8     5    21 7.053E-00  1.405E+02  9.430E+01  2.600E+02       403
  5    8    10    21 9.353E-00  1.863E+02  1.250E+02  2.600E+02       534
  5    8    15    21 1.082E+01  2.156E+02  1.446E+02  2.600E+02       618
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 NO     L      I      K      Q           QCH          QE           TD             IV

  5     8     20     21  1.187E+01  2.365E+02  1.587E+02  2.600E+02         678
  5     8     25     21  1.267E+01  2.525E+02  1.694E+02  2.600E+02         724
  5     8     30     21  1.330E+01  2.651E+02  1.778E+02  2.600E+02         760
  5    10      5      1  1.705E+01  3.397E+02  2.279E+02  2.600E+02         623
  5    10     10      1  2.145E+01  4.275E+02  2.868E+02  2.600E+02         784
  5    10     15      1  2.390E+01  4.764E+02  3.196E+02  2.600E+02         874
  5    10     20      1  2.549E+01  5.080E+02  3.408E+02  2.600E+02         932
  5    10     25      1  2.661E+01  5.304E+02  3.558E+02  2.600E+02         973
  5    10     30      1  2.745E+01  5.470E+02  3.670E+02  2.600E+02        1004
  5    10      5      5  1.549E+01  3.088E+02  2.071E+02  2.600E+02         567
  5    10     10      5  1.986E+01  3.958E+02  2.655E+02  2.600E+02         726
  5    10     15      5  2.241E+01  4.466E+02  2.996E+02  2.600E+02         819
  5    10     20      5  2.411E+01  4.806E+02  3.224E+02  2.600E+02         882
  5    10     25      5  2.535E+01  5.051E+02  3.389E+02  2.600E+02         927
  5    10     30      5  2.628E+01  5.237E+02  3.513E+02  2.600E+02         961
  5    10      5      9  1.430E+01  2.850E+02  1.912E+02  2.600E+02         523
  5    10     10      9  1.858E+01  3.703E+02  2.484E+02  2.600E+02         679
  5    10     15      9  2.116E+01  4.218E+02  2.829E+02  2.600E+02         774
  5    10     20      9  2.294E+01  4.571E+02  3.067E+02  2.600E+02         839
  5    10     25      9  2.424E+01  4.832E+02  3.241E+02  2.600E+02         886
  5    10     30      9  2.525E+01  5.032E+02  3.376E+02  2.600E+02         923
  5    10      5     13  1.335E+01  2.660E+02  1.784E+02  2.600E+02         488
  5    10     10     13  1.752E+01  3.491E+02  2.342E+02  2.600E+02         641
  5    10     15     13  2.010E+01  4.007E+02  2.688E+02  2.600E+02         735
  5    10     20     13  2.192E+01  4.368E+02  2.930E+02  2.600E+02         801
  5    10     25     13  2.327E+01  4.638E+02  3.112E+02  2.600E+02         851
  5    10     30     13  2.433E+01  4.849E+02  3.253E+02  2.600E+02         890
  5    10      5     17  1.256E+01  2.503E+02  1.679E+02  2.600E+02         459
  5    10     10     17  1.662E+01  3.312E+02  2.222E+02  2.600E+02         608
  5    10     15     17  1.919E+01  3.825E+02  2.566E+02  2.600E+02         702
  5    10     20     17  2.102E+01  4.190E+02  2.811E+02  2.600E+02         769
  5    10     25     17  2.241E+01  4.466E+02  2.996E+02  2.600E+02         819
  5    10     30     17  2.351E+01  4.685E+02  3.143E+02  2.600E+02         859
  5    10      5     21  1.190E+01  2.372E+02  1.591E+02  2.600E+02         435
  5    10     10     21  1.584E+01  3.158E+02  2.118E+02  2.600E+02         579
  5    10     15     21  1.839E+01  3.665E+02  2.459E+02  2.600E+02         672
  5    10     20     21  2.023E+01  4.032E+02  2.705E+02  2.600E+02         740
  5    10     25     21  2.164E+01  4.312E+02  2.893E+02  2.600E+02         791
  5    10     30     21  2.276E+01  4.536E+02  3.043E+02  2.600E+02         832
  6     4      5      1  2.368E-00  5.555E+01  3.167E+01  4.000E+02         637
  6     4     10      1  2.784E-00  6.533E+01  3.723E+01  4.000E+02         749
  6     4     15      1  2.981E-00  6.995E+01  3.986E+01  4.000E+02         802
  6     4     20      1  3.097E-00  7.265E+01  4.140E+01  4.000E+02         833
  6     4     25      1  3.173E-00  7.444E+01  4.242E+01  4.000E+02         854
  6     4     30      1  3.227E-00  7.571E+01  4.314E+01  4.000E+02         868
  6     4      5      5  2.033E-00  4.769E+01  2.717E+01  4.000E+02         547
  6     4     10      5  2.494E-00  5.851E+01  3.334E+01  4.000E+02         671
  6     4     15      5  2.735E-00  6.416E+01  3.656E+01  4.000E+02         736
  6     4     20      5  2.884E-00  6.767E+01  3.856E+01  4.000E+02         776
  6     4     25      5  2.987E-00  7.008E+01  3.994E+01  4.000E+02         804
  6     4     30      5  3.062E-00  7.184E+01  4.094E+01  4.000E+02         824
  6     4      5      9  1.808E-00  4.243E+01  2.418E+01  4.000E+02         487
  6     4     10      9  2.278E-00  5.345E+01  3.046E+01  4.000E+02         613
  6     4     15      9  2.540E-00  5.960E+01  3.396E+01  4.000E+02         683
  6     4     20      9  2.711E-00  6.359E+01  3.624E+01  4.000E+02         729
  6     4     25      9  2.831E-00  6.641E+01  3.785E+01  4.000E+02         761
  6     4     30      9  2.920E-00  6.851E+01  3.904E+01  4.000E+02         786
  6     4      5     13  1.645E-00  3.860E+01  2.200E+01  4.000E+02         443
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 NO    L    I    K     Q          QCH         QE          TD          IV

  6    4   10   13  2.111E-00  4.952E+01  2.822E+01  4.000E+02    568
  6    4   15   13  2.382E-00  5.590E+01  3.185E+01  4.000E+02    641
  6    4   20   13  2.565E-00  6.017E+01  3.429E+01  4.000E+02    690
  6    4   25   13  2.696E-00  6.326E+01  3.605E+01  4.000E+02    725
  6    4   30   13  2.797E-00  6.561E+01  3.739E+01  4.000E+02    752
  6    4    5   17  1.519E-00  3.565E+01  2.032E+01  4.000E+02    409
  6    4   10   17  1.975E-00  4.634E+01  2.641E+01  4.000E+02    531
  6    4   15   17  2.251E-00  5.281E+01  3.009E+01  4.000E+02    605
  6    4   20   17  2.440E-00  5.725E+01  3.262E+01  4.000E+02    656
  6    4   25   17  2.580E-00  6.052E+01  3.449E+01  4.000E+02    694
  6    4   30   17  2.687E-00  6.305E+01  3.593E+01  4.000E+02    723
  6    4    5   21  1.419E-00  3.329E+01  1.897E+01  4.000E+02    382
  6    4   10   21  1.863E-00  4.371E+01  2.491E+01  4.000E+02    501
  6    4   15   21  2.139E-00  5.016E+01  2.859E+01  4.000E+02    575
  6    4   20   21  2.332E-00  5.472E+01  3.118E+01  4.000E+02    627
  6    4   25   21  2.477E-00  5.811E+01  3.312E+01  4.000E+02    666
  6    4   30   21  2.590E-00  6.076E+01  3.463E+01  4.000E+02    697
  6    6    5    1  5.878E-00  1.379E+02  7.859E+01  4.000E+02    703
  6    6   10    1  7.123E-00  1.671E+02  9.523E+01  4.000E+02    852
  6    6   15    1  7.754E-00  1.819E+02  1.036E+02  4.000E+02    927
  6    6   20    1  8.140E-00  1.909E+02  1.088E+02  4.000E+02    973
  6    6   25    1  8.401E-00  1.970E+02  1.123E+02  4.000E+02   1004
  6    6   30    1  8.590E-00  2.015E+02  1.148E+02  4.000E+02   1027
  6    6    5    5  5.176E-00  1.214E+02  6.920E+01  4.000E+02    619
  6    6   10    5  6.468E-00  1.517E+02  8.648E+01  4.000E+02    773
  6    6   15    5  7.175E-00  1.683E+02  9.592E+01  4.000E+02    858
  6    6   20    5  7.628E-00  1.789E+02  1.019E+02  4.000E+02    912
  6    6   25    5  7.944E-00  1.863E+02  1.062E+02  4.000E+02    950
  6    6   30    5  8.178E-00  1.918E+02  1.093E+02  4.000E+02    978
  6    6    5    9  4.677E-00  1.097E+02  6.253E+01  4.000E+02    559
  6    6   10    9  5.966E-00  1.399E+02  7.977E+01  4.000E+02    713
  6    6   15    9  6.709E-00  1.573E+02  8.969E+01  4.000E+02    802
  6    6   20    9  7.201E-00  1.689E+02  9.628E+01  4.000E+02    861
  6    6   25    9  7.555E-00  1.772E+02  1.010E+02  4.000E+02    903
  6    6   30    9  7.821E-00  1.834E+02  1.045E+02  4.000E+02    935
  6    6    5   13  4.300E-00  1.008E+02  5.749E+01  4.000E+02    514
  6    6   10   13  5.566E-00  1.305E+02  7.441E+01  4.000E+02    665
  6    6   15   13  6.323E-00  1.483E+02  8.453E+01  4.000E+02    756
  6    6   20   13  6.839E-00  1.604E+02  9.144E+01  4.000E+02    818
  6    6   25   13  7.217E-00  1.693E+02  9.649E+01  4.000E+02    863
  6    6   30   13  7.507E-00  1.761E+02  1.003E+02  4.000E+02    897
  6    6    5   17  4.001E-00  9.386E+01  5.349E+01  4.000E+02    478
  6    6   10   17  5.236E-00  1.228E+02  7.000E+01  4.000E+02    626
  6    6   15   17  5.997E-00  1.406E+02  8.017E+01  4.000E+02    717
  6    6   20   17  6.527E-00  1.531E+02  8.726E+01  4.000E+02    780
  6    6   25   17  6.921E-00  1.623E+02  9.253E+01  4.000E+02    827
  6    6   30   17  7.228E-00  1.695E+02  9.665E+01  4.000E+02    864
  6    6    5   21  3.757E-00  8.814E+01  5.023E+01  4.000E+02    449
  6    6   10   21  4.959E-00  1.163E+02  6.630E+01  4.000E+02    593
  6    6   15   21  5.717E-00  1.341E+02  7.643E+01  4.000E+02    683
  6    6   20   21  6.254E-00  1.467E+02  8.361E+01  4.000E+02    748
  6    6   25   21  6.659E-00  1.562E+02  8.903E+01  4.000E+02    796
  6    6   30   21  6.978E-00  1.637E+02  9.329E+01  4.000E+02    834
  6    8    5    1  1.106E+01  2.596E+02  1.479E+02  4.000E+02    744
  6    8   10    1  1.370E+01  3.215E+02  1.832E+02  4.000E+02    922
  6    8   15    1  1.511E+01  3.545E+02  2.020E+02  4.000E+02   1016
  6    8   20    1  1.600E+01  3.754E+02  2.139E+02  4.000E+02   1076
  6    8   25    1  1.661E+01  3.898E+02  2.221E+02  4.000E+02   1117
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  NO     L     I     K       Q          QCH          QE           TD          IV

   6     8    30     1 1.707E+01  4.004E+02  2.282E+02  4.000E+02        1146
   6     8     5     5 9.925E-00  2.328E+02  1.326E+02  4.000E+02         667
   6     8    10     5 1.258E+01  2.951E+02  1.681E+02  4.000E+02         846
   6     8    15     5 1.408E+01  3.304E+02  1.883E+02  4.000E+02         947
   6     8    20     5 1.507E+01  3.535E+02  2.015E+02  4.000E+02        1013
   6     8    25     5 1.577E+01  3.700E+02  2.108E+02  4.000E+02        1061
   6     8    30     5 1.630E+01  3.824E+02  2.179E+02  4.000E+02        1096
   6     8     5     9 9.076E-00  2.129E+02  1.213E+02  4.000E+02         610
   6     8    10     9 1.169E+01  2.743E+02  1.563E+02  4.000E+02         786
   6     8    15     9 1.324E+01  3.106E+02  1.770E+02  4.000E+02         890
   6     8    20     9 1.428E+01  3.351E+02  1.910E+02  4.000E+02         961
   6     8    25     9 1.504E+01  3.529E+02  2.011E+02  4.000E+02        1012
   6     8    30     9 1.562E+01  3.666E+02  2.089E+02  4.000E+02        1051
   6     8     5    13 8.413E-00  1.973E+02  1.124E+02  4.000E+02         566
   6     8    10    13 1.097E+01  2.573E+02  1.466E+02  4.000E+02         738
   6     8    15    13 1.253E+01  2.940E+02  1.675E+02  4.000E+02         843
   6     8    20    13 1.361E+01  3.193E+02  1.819E+02  4.000E+02         915
   6     8    25    13 1.441E+01  3.381E+02  1.926E+02  4.000E+02         969
   6     8    30    13 1.503E+01  3.526E+02  2.009E+02  4.000E+02        1011
   6     8     5    17 7.877E-00  1.847E+02  1.053E+02  4.000E+02         530
   6     8    10    17 1.036E+01  2.432E+02  1.386E+02  4.000E+02         697
   6     8    15    17 1.192E+01  2.796E+02  1.594E+02  4.000E+02         802
   6     8    20    17 1.302E+01  3.055E+02  1.741E+02  4.000E+02         876
   6     8    25    17 1.385E+01  3.249E+02  1.851E+02  4.000E+02         931
   6     8    30    17 1.449E+01  3.401E+02  1.938E+02  4.000E+02         975
   6     8     5    21 7.431E-00  1.743E+02  9.935E+01  4.000E+02         500
   6     8    10    21 9.855E-00  2.311E+02  1.317E+02  4.000E+02         663
   6     8    15    21 1.140E+01  2.674E+02  1.524E+02  4.000E+02         767
   6     8    20    21 1.250E+01  2.934E+02  1.672E+02  4.000E+02         841
   6     8    25    21 1.335E+01  3.132E+02  1.784E+02  4.000E+02         898
   6     8    30    21 1.401E+01  3.288E+02  1.874E+02  4.000E+02         943
   6    10     5     1 1.796E+01  4.214E+02  2.401E+02  4.000E+02         773
   6    10    10     1 2.260E+01  5.303E+02  3.022E+02  4.000E+02         973
   6    10    15     1 2.519E+01  5.909E+02  3.367E+02  4.000E+02        1084
   6    10    20     1 2.686E+01  6.302E+02  3.591E+02  4.000E+02        1156
   6    10    25     1 2.804E+01  6.579E+02  3.749E+02  4.000E+02        1207
   6    10    30     1 2.892E+01  6.785E+02  3.866E+02  4.000E+02        1245
   6    10     5     5 1.632E+01  3.830E+02  2.183E+02  4.000E+02         703
   6    10    10     5 2.093E+01  4.910E+02  2.798E+02  4.000E+02         901
   6    10    15     5 2.361E+01  5.539E+02  3.157E+02  4.000E+02        1016
   6    10    20     5 2.541E+01  5.961E+02  3.397E+02  4.000E+02        1094
   6    10    25     5 2.671E+01  6.265E+02  3.570E+02  4.000E+02        1149
   6    10    30     5 2.769E+01  6.496E+02  3.702E+02  4.000E+02        1192
   6    10     5     9 1.507E+01  3.535E+02  2.015E+02  4.000E+02         649
   6    10    10     9 1.958E+01  4.593E+02  2.617E+02  4.000E+02         843
   6    10    15     9 2.230E+01  5.232E+02  2.981E+02  4.000E+02         960
   6    10    20     9 2.417E+01  5.670E+02  3.231E+02  4.000E+02        1040
   6    10    25     9 2.554E+01  5.993E+02  3.415E+02  4.000E+02        1099
   6    10    30     9 2.660E+01  6.241E+02  3.557E+02  4.000E+02        1145
   6    10     5    13 1.406E+01  3.299E+02  1.880E+02  4.000E+02         605
   6    10    10    13 1.846E+01  4.330E+02  2.468E+02  4.000E+02         794
   6    10    15    13 2.118E+01  4.970E+02  2.832E+02  4.000E+02         912
   6    10    20    13 2.309E+01  5.418E+02  3.088E+02  4.000E+02         994
   6    10    25    13 2.452E+01  5.753E+02  3.278E+02  4.000E+02        1055
   6    10    30    13 2.564E+01  6.014E+02  3.427E+02  4.000E+02        1103
   6    10     5    17 1.323E+01  3.105E+02  1.769E+02  4.000E+02         570
   6    10    10    17 1.751E+01  4.106E+02  2.341E+02  4.000E+02         754
   6    10    15    17 2.022E+01  4.744E+02  2.703E+02  4.000E+02         870
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 NO    L    I    K     Q          QCH        QE         TD          IV

  6   10   20   17 2.215E+01 5.197E+02 2.961E+02 4.000E+02     953
  6   10   25   17 2.361E+01 5.540E+02 3.157E+02 4.000E+02    1016
  6   10   30   17 2.477E+01 5.811E+02 3.311E+02 4.000E+02    1066
  6   10    5   21 1.254E+01 2.942E+02 1.676E+02 4.000E+02     540
  6   10   10   21 1.669E+01 3.917E+02 2.232E+02 4.000E+02     719
  6   10   15   21 1.938E+01 4.546E+02 2.591E+02 4.000E+02     834
  6   10   20   21 2.131E+01 5.001E+02 2.850E+02 4.000E+02     917
  6   10   25   21 2.280E+01 5.349E+02 3.048E+02 4.000E+02     981
  6   10   30   21 2.398E+01 5.626E+02 3.206E+02 4.000E+02    1032
  7    4    5    1 2.390E-00 6.211E+01 3.196E+01 5.000E+02     712
  7    4   10    1 2.811E-00 7.304E+01 3.758E+01 5.000E+02     837
  7    4   15    1 3.010E-00 7.820E+01 4.024E+01 5.000E+02     897
  7    4   20    1 3.126E-00 8.123E+01 4.180E+01 5.000E+02     931
  7    4   25    1 3.203E-00 8.323E+01 4.282E+01 5.000E+02     954
  7    4   30    1 3.258E-00 8.464E+01 4.355E+01 5.000E+02     970
  7    4    5    5 2.052E-00 5.332E+01 2.743E+01 5.000E+02     611
  7    4   10    5 2.517E-00 6.541E+01 3.366E+01 5.000E+02     750
  7    4   15    5 2.761E-00 7.173E+01 3.691E+01 5.000E+02     822
  7    4   20    5 2.912E-00 7.566E+01 3.893E+01 5.000E+02     868
  7    4   25    5 3.016E-00 7.836E+01 4.032E+01 5.000E+02     898
  7    4   30    5 3.091E-00 8.032E+01 4.133E+01 5.000E+02     921
  7    4    5    9 1.826E-00 4.744E+01 2.441E+01 5.000E+02     544
  7    4   10    9 2.300E-00 5.976E+01 3.075E+01 5.000E+02     685
  7    4   15    9 2.564E-00 6.664E+01 3.429E+01 5.000E+02     764
  7    4   20    9 2.736E-00 7.110E+01 3.658E+01 5.000E+02     815
  7    4   25    9 2.858E-00 7.425E+01 3.820E+01 5.000E+02     851
  7    4   30    9 2.948E-00 7.660E+01 3.941E+01 5.000E+02     878
  7    4    5   13 1.661E-00 4.316E+01 2.221E+01 5.000E+02     495
  7    4   10   13 2.131E-00 5.536E+01 2.849E+01 5.000E+02     635
  7    4   15   13 2.405E-00 6.249E+01 3.215E+01 5.000E+02     717
  7    4   20   13 2.589E-00 6.728E+01 3.462E+01 5.000E+02     771
  7    4   25   13 2.722E-00 7.073E+01 3.639E+01 5.000E+02     811
  7    4   30   13 2.823E-00 7.335E+01 3.774E+01 5.000E+02     841
  7    4    5   17 1.534F-00 3.986E+01 2.051E+01 5.000E+02     457
  7    4   10   17 1.994E-00 5.181E+01 2.666E+01 5.000E+02     594
  7    4   15   17 2.272E-00 5.904E+01 3.038E+01 5.000E+02     677
  7    4   20   17 2.463E-00 6.401E+01 3.293E+01 5.000E+02     734
  7    4   25   17 2.604E-00 6.757E+01 3.482E+01 5.000E+02     776
  7    4   30   17 2.713E-00 7.049E+01 3.627E+01 5.000E+02     808
  7    4    5   21 1.432E-00 3.722E+01 1.915E+01 5.000E+02     427
  7    4   10   21 1.881E-00 4.887E+01 2.514E+01 5.000E+02     560
  7    4   15   21 2.159E-00 5.610E+01 2.886E+01 5.000E+02     643
  7    4   20   21 2.354E-00 6.117E+01 3.148E+01 5.000E+02     701
  7    4   25   21 2.500E-00 6.497E+01 3.343E+01 5.000E+02     745
  7    4   30   21 2.614E-00 6.793E+01 3.495E+01 5.000E+02     779
  7    6    5    1 5.934E-00 1.541E+02 7.933E+01 5.000E+02     786
  7    6   10    1 7.191E-00 1.868E+02 9.613E+01 5.000E+02     952
  7    6   15    1 7.828E-00 2.033E+02 1.046E+02 5.000E+02    1036
  7    6   20    1 8.217E-00 2.135E+02 1.098E+02 5.000E+02    1088
  7    6   25    1 8.481E-00 2.203E+02 1.133E+02 5.000E+02    1123
  7    6   30    1 8.671E-00 2.252E+02 1.159E+02 5.000E+02    1148
  7    6    5    5 5.225E-00 1.357E+02 6.966E+01 5.000E+02     692
  7    6   10    5 6.530E-00 1.696E+02 8.730E+01 5.000E+02     865
  7    6   15    5 7.243E-00 1.881E+02 9.683E+01 5.000E+02     959
  7    6   20    5 7.700E-00 2.000E+02 1.029E+02 5.000E+02    1019
  7    6   25    5 8.020E-00 2.083E+02 1.072E+02 5.000E+02    1062
  7    6   30    5 8.256E-00 2.145E+02 1.103E+02 5.000E+02    1093
  7    6    5    9 4.722E-00 1.226E+02 6.313E+01 5.000E+02     625
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    NO     L     I     K      Q          QCH         GE          TD          IV

     7     6    10     9  6.023E-00  1.564E+02  8.052E+01  5.000E+02      797
     7     6    15     9  6.772E-00  1.759E+02  9.054E+01  5.000E+02      897
     7     6    20     9  7.270E-00  1.888E+02  9.719E+01  5.000E+02      962
     7     6    25     9  7.626E-00  1.981E+02  1.019E+02  5.000E+02     1010
     7     6    30     9  7.895E-00  2.051E+02  1.055E+02  5.000E+02     1045
     7     6     5    13  4.341E-00  1.127E+02  5.803E+01  5.000E+02      575
     7     6    10    13  5.619E-00  1.459E+02  7.512E+01  5.000E+02      744
     7     6    15    13  6.383E-00  1.658E+02  8.533E+01  5.000E+02      845
     7     6    20    13  6.904E-00  1.793E+02  9.230E+01  5.000E+02      914
     7     6    25    13  7.286E-00  1.893E+02  9.740E+01  5.000E+02      965
     7     6    30    13  7.578E-00  1.969E+02  1.013E+02  5.000E+02     1003
     7     6     5    17  4.039E-00  1.049E+02  5.400E+01  5.000E+02      535
     7     6    10    17  5.286E-00  1.373E+02  7.067E+01  5.000E+02      700
     7     6    15    17  6.054E-00  1.572E+02  8.093E+01  5.000E+02      802
     7     6    20    17  6.589E-00  1.711E+02  8.809E+01  5.000E+02      872
     7     6    25    17  6.987E-00  1.815E+02  9.341E+01  5.000E+02      935
     7     6    30    17  7.296E-00  1.895E+02  9.755E+01  5.000E+02      966
     7     6     5    21  3.792E-00  9.854E+01  5.070E+01  5.000E+02      502
     7     6    10    21  5.006E-00  1.300E+02  6.693E+01  5.000E+02      663
     7     6    15    21  5.771E-00  1.499E+02  7.715E+01  5.000E+02      764
     7     6    20    21  6.313E-00  1.640E+02  8.440E+01  5.000E+02      836
     7     6    25    21  6.722E-00  1.746E+02  8.987E+01  5.000E+02      890
     7     6    30    21  7.044E-00  1.830E+02  9.417E+01  5.000E+02      933
     7     8     5     1  1.117E+01  2.903E+02  1.493E+02  5.000E+02      832
     7     8    10     1  1.383E+01  3.594E+02  1.849E+02  5.000E+02     1030
     7     8    15     1  1.525E+01  3.964E+02  2.039E+02  5.000E+02     1136
     7     8    20     1  1.615E+01  4.197E+02  2.159E+02  5.000E+02     1203
     7     8    25     1  1.677E+01  4.358E+02  2.242E+02  5.000E+02     1249
     7     8    30     1  1.723E+01  4.477E+02  2.303E+02  5.000E+02     1283
     7     8     5     5  1.001E+01  2.603E+02  1.339E+02  5.000E+02      746
     7     8    10     5  1.270E+01  3.299E+02  1.697E+02  5.000E+02      946
     7     8    15     5  1.421E+01  3.694E+02  1.900E+02  5.000E+02     1059
     7     8    20     5  1.521E+01  3.953E+02  2.034E+02  5.000E+02     1133
     7     8    25     5  1.592E+01  4.137E+02  2.128E+02  5.000E+02     1186
     7     8    30     5  1.645E+01  4.275E+02  2.199E+02  5.000E+02     1225
     7     8     5     9  9.162E-00  2.380E+02  1.224E+02  5.000E+02      682
     7     8    10     9  1.180E+01  3.067E+02  1.578E+02  5.000E+02      879
     7     8    15     9  1.336E+01  3.472E+02  1.787E+02  5.000E+02      995
     7     8    20     9  1.442E+01  3.747E+02  1.928E+02  5.000E+02     1074
     7     8    25     9  1.519E+01  3.946E+02  2.030E+02  5.000E+02     1131
     7     8    30     9  1.577E+01  4.098E+02  2.109E+02  5.000E+02     1175
     7     8     5    13  8.493E-00  2.206E+02  1.135E+02  5.000E+02      632
     7     8    10    13  1.107E+01  2.877E+02  1.480E+02  5.000E+02      825
     7     8    15    13  1.265E+01  3.287E+02  1.691E+02  5.000E+02      942
     7     8    20    13  1.374E+01  3.570E+02  1.837E+02  5.000E+02     1023
     7     8    25    13  1.454E+01  3.780E+02  1.945E+02  5.000E+02     1083
     7     8    30    13  1.517E+01  3.942E+02  2.028E+02  5.000E+02     1130
     7     8     5    17  7.931E-00  2.066E+02  1.063E+02  5.000E+02      592
     7     8    10    17  1.046E+01  2.719E+02  1.399E+02  5.000E+02      779
     7     8    15    17  1.204E+01  3.128E+02  1.609E+02  5.000E+02      897
     7     8    20    17  1.314E+01  3.416E+02  1.757E+02  5.000E+02      979
     7     8    25    17  1.398E+01  3.632E+02  1.869E+02  5.000E+02     1041
     7     8    30    17  1.463E+01  3.802E+02  1.956E+02  5.000E+02     1090
     7     8     5    21  7.502E-00  1.949E+02  1.003E+02  5.000E+02      559
     7     8    10    21  9.949E-00  2.584E+02  1.330E+02  5.000E+02      741
     7     8    15    21  1.151E+01  2.990E+02  1.538E+02  5.000E+02      857
     7     8    20    21  1.262E+01  3.280E+02  1.688E+02  5.000E+02      940
     7     8    25    21  1.347E+01  3.501E+02  1.801E+02  5.000E+02     1004
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  NO    L    I    K      Q          QCH         QE          TO          IV

   7    6   30   21  1.415E+01  3.676E+02  1.891E+02  5.000E+02     1054
   7   10    5    1  1.813E+01  4.711E+02  2.424E+02  5.000E+02      864
   7   10   10    1  2.282E+01  5.929E+02  3.051E+02  5.000E+02     1088
   7   10   15    1  2.542E+01  6.606E+02  3.399E+02  5.000E+02     1212
   7   10   20    1  2.711E+01  7.046E+02  3.625E+02  5.000E+02     1293
   7   10   25    1  2.831E+01  7.355E+02  3.784E+02  5.000E+02     1349
   7   10   30    1  2.919E+01  7.586E+02  3.903E+02  5.000E+02     1392
   7   10    5    5  1.648E+01  4.282E+02  2.203E+02  5.000E+02      786
   7   10   10    5  2.113E+01  5.489E+02  2.824E+02  5.000E+02     1007
   7   10   15    5  2.383E+01  6.193E+02  3.187E+02  5.000E+02     1136
   7   10   20    5  2.565E+01  6.665E+02  3.429E+02  5.000E+02     1223
   7   10   25    5  2.696E+01  7.005E+02  3.604E+02  5.000E+02     1285
   7   10   30    5  2.795E+01  7.263E+02  3.737E+02  5.000E+02     1332
   7   10    5    9  1.521E+01  3.953E+02  2.034E+02  5.000E+02      725
   7   10   10    9  1.976E+01  5.135E+02  2.642E+02  5.000E+02      942
   7   10   15    9  2.251E+01  5.849E+02  3.009E+02  5.000E+02     1073
   7   10   20    9  2.440E+01  6.339E+02  3.262E+02  5.000E+02     1163
   7   10   25    9  2.579E+01  6.703E+02  3.448E+02  5.000E+02     1229
   7   10   30    9  2.686E+01  6.978E+02  3.590E+02  5.000E+02     1285
   7   10    5   13  1.420E+01  3.689E+02  1.898E+02  5.000E+02      677
   7   10   10   13  1.863E+01  4.842E+02  2.491E+02  5.000E+02      888
   7   10   15   13  2.138E+01  5.557E+02  2.859E+02  5.000E+02     1019
   7   10   20   13  2.331E+01  6.058E+02  3.117E+02  5.000E+02     1111
   7   10   25   13  2.475E+01  6.432E+02  3.310E+02  5.000E+02     1180
   7   10   30   13  2.588E+01  6.724E+02  3.460E+02  5.000E+02     1234
   7   10    5   17  1.336E+01  3.472E+02  1.786E+02  5.000E+02      637
   7   10   10   17  1.768E+01  4.593E+02  2.363E+02  5.000E+02      843
   7   10   15   17  2.041E+01  5.304E+02  2.729E+02  5.000E+02      973
   7   10   20   17  2.236E+01  5.810E+02  2.990E+02  5.000E+02     1066
   7   10   25   17  2.384E+01  6.194E+02  3.187E+02  5.000E+02     1136
   7   10   30   17  2.500E+01  6.497E+02  3.343E+02  5.000E+02     1192
   7   10    5   21  1.266E+01  3.289E+02  1.692E+02  5.000E+02      603
   7   10   10   21  1.685E+01  4.380E+02  2.253E+02  5.000E+02      803
   7   10   15   21  1.956E+01  5.083E+02  2.615E+02  5.000E+02      933
   7   10   20   21  2.152E+01  5.591E+02  2.877E+02  5.000E+02     1026
   7   10   25   21  2.302E+01  5.980E+02  3.077E+02  5.000E+02     1097
   7   10   30   21  2.421E+01  6.290E+02  3.237E+02  5.000E+02     1154
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