Stack design for small air flow
by Nelson Alejandro Quintero

A thesis submitted to the Graduate Faculty in partial fulfillment of the the requirements for the degree of MASTER OF SCIENCE in Mechanical Engineering
Montana State University

Abstract:
This paper is based on the study of stack design to induce small air inflow rates. The data for the study were obtained by testing six and eight inch diameter double walled stacks of five, ten, and fifteen foot lengths. The testing was conducted in conjunction with the study of the feasibility of ventilating a family size fall-out shelter by means of natural draft ventilation. This made it necessary to expand the testing to include stacks containing elbows, horizontal lengths and stack caps.

The inclusion of these fittings made it possible to investigate the effect of adding restrictions to the system. Such restrictions will provide the designer of a family fallout shelter with a more feasible stack design.

An empirical equation was developed to solve for the amount of available draft provided by the system. The values obtained by solving this equation were in close agreement, throughout the testing, with the measured values. This established the validity of this empirical equation for the conditions existing in the laboratory. After establishing the validity of the equation a computer program was written to solve the equation for stacks of five, ten, fifteen, twenty, twenty-five, and thirty feet height and four, six, eight, and ten inch diameter. The results of the computer program are given in the form of graphs in Chapter 13. The maximum value of draft obtained was 400 ACFM.

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CHAPTER 1

INTRODUCTION

The purpose of this paper is to provide the reader with the basic theory of stack design and with a set of graphs and tables which will permit him to obtain the amount of air, in actual cubic feet per minute, available under a specific set of conditions.

Since tests could not be performed on every combination of stack length and diameter available, it was decided to develop an empirical equation which would solve the problem and to conduct testing on six and eight inch diameter stacks of different lengths in order to check the validity of the empirical equation. The values obtained by making measurements in the laboratory closely agreed with the values obtained by solving the empirical equation. This indicated that this empirical equation will give accurate results when the system used is the same as the one used in the experiments.

After establishing the validity of the empirical draft equation a computer program was written to solve the empirical equation for various sizes of stack lengths and diameters. The results of the computer program are given in the form of graphs in Chapter 13.

Because the sole presentation of the graphs would not satisfy the interested reader, as they would not provide him with the information of how these graphs were obtained, a detailed presentation is given of the experimental procedure followed by a brief discussion on the basic theory of stack design. This discussion will give the reader enough information to accurately interpret the results presented in this paper.

CHAPTER 2

BASIC EQUIPMENT

The experimental part of this study was conducted in an air-tight room situated underneath the Mechanical Engineering Power Laboratory in Ryon Laboratory, Montana State University. The inside dimensions of the room are twenty-eight feet long, six feet wide and six feet high.

The basic equipment used in performing the testing was:

1. Stack
2. Temperature measuring apparatus
3. Air measuring apparatus
4. Fuel measuring and burning apparatus
5. Pressure measuring apparatus

The chimney was built of double walled tube sections, the inside wall of these tubes is made of aluminum and the outside wall of galvanized steel; the tube sections are five feet long and of six and eight inch diameter. By joining the tube sections, stacks of different lengths can be easily built.

The temperature measuring equipment consists of thirty gage iron-constantan thermocouples connected to temperature recording and indicating potentiometers.

The air flow measurement was approached in various ways. The original method was to use thermistors. The results obtained by this method were so irregular, would change from day to day, that it was decided to abandon this method. It was then decided to use a windmill type anemometer; this method provided an easier and more accurate way of measuring the air inflow.

The fuel measuring apparatus consists of a balance scale and stop watch with which the time to burn a fixed amount of fuel was measured. The fuel rate was obtained by dividing the amount of fuel burned by the time necessary to burn it.

The pressure drop measurements were taken with a micromanometer, plastic hoses connected the different tap points to the micromanometer. This set-up provided a satisfactory method of measuring pressure drops as small as .001 inch of water.

One of the three following types of fuel burners were used during the testing: (1) Space heater, see Figure 2; (2) Kerosene burner, see Figure 6; (3) Natural gas heater. The type of burner used depended on the desired value of mean temperature in the stack.

CHAPTER 3

CHIMNEY CONSTRUCTION

It was decided to construct the stack using double walled tubes because of its good insulation properties, the double wall allows the existence of an air film between the walls and thus reduces the heat transfer to the surrounding medium. The reduction in heat transfer to the surrounding medium results in higher mean temperatures in the stack with the same fuel consumption.

Testing was conducted on stacks of two different configurations; straight vertical stacks and stacks containing two 90° elbows in the lower part. The straight stack was used to reduce variables to a minimum. Adding the two 90° elbows at the lower part allowed investigation of the performance of the stack under conditions simulating the probable installation where turns in the duct work must be present to minimize radiation streaming. Stacks of six and eight inch diameter were tested at vertical heights of five, ten, and fifteen feet.

Pressure taps and thermocouples were placed along the vertical height of the stack. See Figure 1. The exact position of the taps and thermocouples will be described in the sections on pressure and temperature measurements.

The entrance to the stack consists of a bottomless rectangular hood, see Figure 3. The dimensions of the hood are: height, 13 inches; width, 10 inches; and length, 17 inches.

The burners were positioned under the hood, see Figure 2, in such a way that the hot gases would go up the stack with a minimum loss of heat from the hot gases to the surrounding medium.

The chimney was situated on the end of the testing room opposite to the air entrance opening. See Figure 4. This allowed the air surrounding the chimney entrance to be undisturbed.

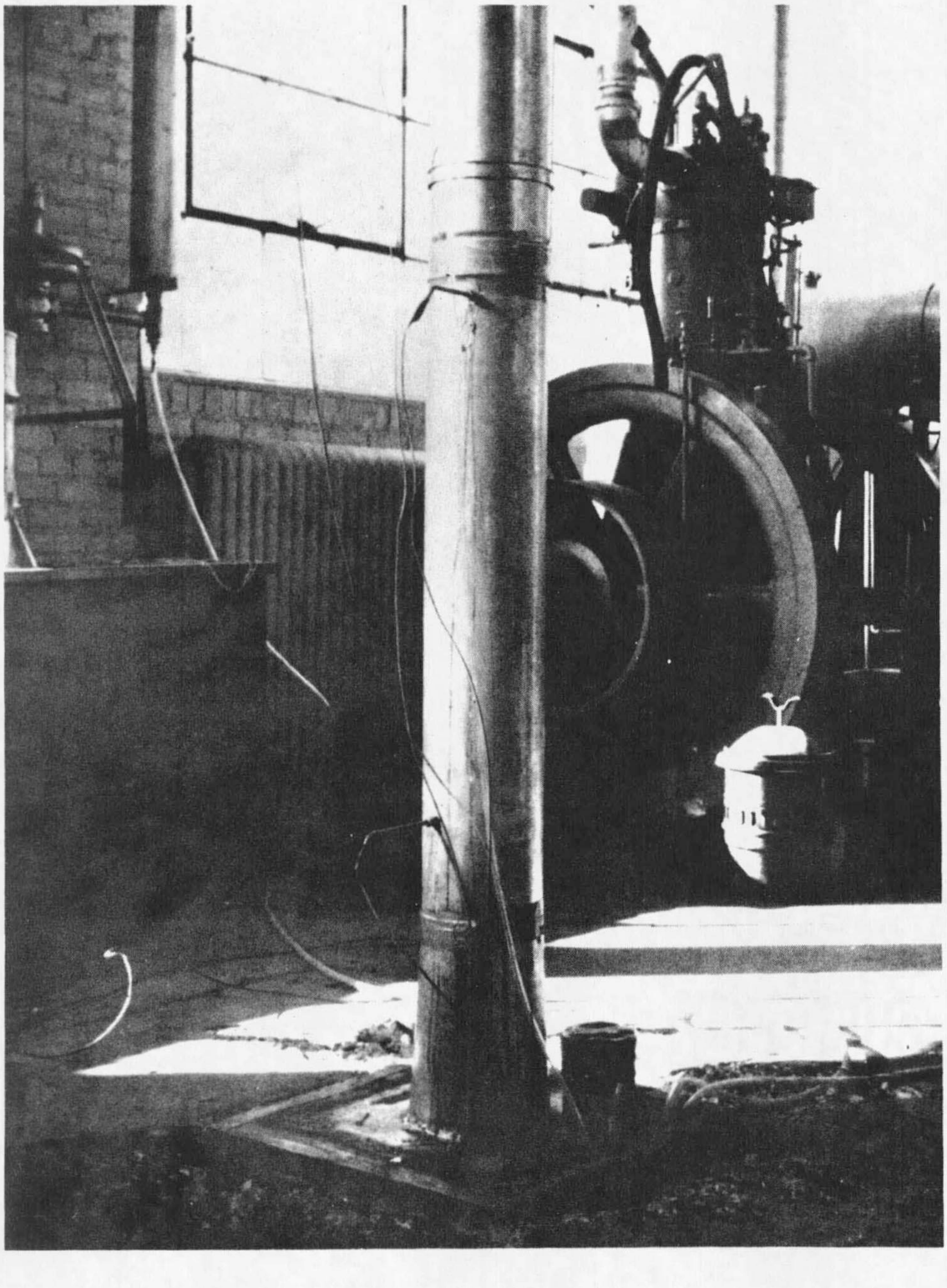

Figure 1 UPPER PORTION OF STACK