NATIONAL BUREAU OF STANDARDS REPORT

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. Ventilating System for the Univac Computer

by

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U. S. DEPARTMENT OF COMMERCE
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Tests of the Ventilating System for the Univac Computer

by

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NBS

The Ventilating System of the Univac Computer

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Abstract

Tests were made of the ventilating system of the Univac Computer for the Census Bureau to evaluate the temperatures and ventilation rates of three complete units when in operation. From these results it was found that with an outside temperature of 105°F the installation would require a minimum of 20,000 cfm of ventilating air to prevent shutdowns by the temperature limit devices. The importance of other factors were evaluated and their influence on performance was analyzed. Recommendations on the design and installation of the system at Suitland, Maryland, are presented. Precautions against recirculation, duct resistance and discomfort of operating personnel were included.

After a careful consideration of the several designs factors it was recommended that the system be designed for a total of 30,000 cfm of ventilating air. The central computer was to be supplied with 22,500 cfm and the power supply with 7,500 cfm.

I. INTRODUCTION

In accordance with a request of the Census Bureau and the Electronic Computer Section of the National Bureau of Standards tests were made to determine the operating temperatures and ventilation rates of three computers manufactured by the Eckert-Mauchly Division of Remington Rand, Inc. Two units, designed as numbers 1 and 3, were located at the plant of the manufacturer in Philadelphia, Pennsylvania. The other unit, number 2, was located at the Pentagon, Arlington, Virginia. These three units are the first three commercial models of this computer produced by the manufacturer.

Some interruptions in the operation of both of the computer units in Philadelphia had occurred during this past summer as a result of excessive operating temperatures. The Heating and Air Conditioning Section of the National Bureau of Standards was requested to analyze the ventilating systems of these units to determine the cause of the interruptions and to recommend either a ventilating system

or an air conditioning system for unit number 1 when it is installed in the Census Bureau at Suitland, Maryland in the near future.

II. DESCRIPTION OF THE UNIVAC COMPUTER

The Univac computer consisted of four major elements: the central computer cabinet, the power supply, the servo-mechanism unit, and the control panel. In studying the ventilating system only the central computer cabinet and the power supply were of interest. The central computer cabinet was a large metal enclosure approximately 14 feet long, 8 feet wide, and 7 feet high enclosing a great many electronic elements which used electric energy and generated heat. Access to the inside components was provided by a door on one of the long sides and various groups of electronic elements were accessible from the outside through three doors, one above the other, on each of the 13 bays into which the cabinet was divided.

The power supply cabinet measured about 4 by 6 by 7 feet high, was accessible from the outside on three sides, and contained a door for access to the interior components on the fourth side. Each of the three bays contained rectifiers or other heat generating equipment arranged in 5 sections, one above the other. Diagrammatic sketches of the central computer cabinet and power supply are shown in Fig. 1 with the various bays numbered for convenience in identifying where certain observations were made.

THERMOSTATIC PROTECTION

A temperature-sensitive element of the bimetallic-disc type was located in the air stream at the top of each of the 13 bays in the central computer cabinet and the 3 bays in the power supply as a protective device against excessive temperature. These devices were temperature limit switches all connected in series in a control circuit so that an excessive temperature sensed by any one of the 16 elements would interrupt the power to both units until that element was cooled below the tripping temperature and manually reset. These temperature limits, also, interrupted the power to the ventilating fans for fire protection. A temperature limit of 135°F had been set as the maximum safe temperature for the equipment and it was some of these protective devices that had caused stoppages of Units 1 and 3 in Philadelphia during hot weather.

VENTILATION

Ventilation air was drawn from the outside through filters, and then forced by centrifugal blowers to a plenum under the floor beneath the central computer and power supply cabinets. Air from the plenum passed upward through the electronic equipment in the power supply cabinet and was exhausted outdoors by an overhead duct system. In the central computer cabinet the air passed upward through passages between the electron tubes and other electronic devices and the inside of the exterior doors on the 13 bays of that cabinet with a small portion of the air being diverted through the interior of the cabinet proper. The air stream passed directly over, more or less depending on the exact location of certain elements, the thermostatic limit switch at the top of each bay. The Pentagon unit, number 2, also employed an exhaust blower since both the incoming and outgoing ducts were quite long and there might be some difficulty in controlling the air conditioning of that area if a single blower were used. Units 1 and 3 used separate blowers and separate duct systems for central computer and power supply whereas unit 2 used a common supply and exhaust duct for both components.

At the Philadelphia installations both the air intake and air discharge ducts terminated in an elbow opening downward just outside the wall of the building above a parking lot. The discharge duct was directly above the intake and the distance between the two was about 10 or 12 feet. At the Pentagon installation the intake and discharge openings were at ground level about 10 or 12 feet apart facing East and North respectively.

III. TEST APPARATUS AND PROCEDURE

Temperatures were measured by means of a Brown Electronick Potentiometer Pyrometer Single Point Precision Indicator. Copper-constantan thermocouples were affixed with transparent tape around each of the 16 thermal elements. Any effect of ambient air on the temperature indication was minimized by having the junction and the adjacent 3 or 4 inches of wire firmly in contact with the metal supporting member. Additional temperature observations were made of intake and exhaust air for both components. A more detailed study was made of the temperatures within the power supply cabinet at the Pentagon installation. A total of 24 thermocouples were suspended in air one inch above selected rectifiers and transformers. A 24-point selector switch was used to connect any one thermocouple to the indicator. Temperature values were recorded usually at 15 minute intervals until a steady state condition was reached.

Air velocity measurements were made with a revolving vane anemometer at all installations. The cross sectional area of the intake duct was divided into numerous elementary areas of approximately equal size and the air velocity was measured at the center of each small area. The air velocities at each station were averaged mechanically over a period of one minute which eliminated erroneous readings due to pulsations. At the Pentagon additional readings were taken by the use of a Pitot tube and inclined gauge. All observations were made directly in the duct system inasmuch as preliminary measurements indicated that readings taken near the filter banks would be difficult to evaluate. Values reported were obtained with all inspection and access doors closed.

IV. TEST RESULTS

Table 1 shows the temperatures observed at the 16 temperature limit devices. The bays are designated in a clockwise manner, number one being to the left of the main entrance door when entering, as shown in Fig. 1. Table 2 shows the temperature of the inlet and outlet air, their difference, the maximum rise in air temperature at any location, the quantity of ventilating air to the two components, and their total. Also shown are the calculated values of heat dissipation.

An examination of Table 1 shows that the temperature rise in the several bays of the central computer differed widely. The temperature rise observed in the hottest bay was about 2-1/2 to 3 times as great as that in the coolest bay, and the average temperature rise for all 13 bays was only about half the maximum temperature rise through the hottest bay. The three hottest bays in Unit 1 were 7, 8 and 10; in Unit 2 they were 7, 8 and 9; and in Unit 3 they were 7, 8 and 9. An examination of these bays indicated that bays 7 and 8 contained a considerably greater number of electron tubes than the others. Thus there was probably more heat to be dissipated in these bays and at the same time more obstruction to the air flow.

The temperature rises in the three bays of the power supply cabinet were more nearly uniform than for the central computer.

No specific reason was established why the average temperature rise and the maximum temperature rise was greater for Unit 2 than for Unit 1 when the observed total air circulation rates were nearly the same. However, there

were some leaks in the wooden duct on the intake side of the blower of Unit 1 beyond the place where the air velocity measurements were made, whereas metal duct with tight joints was used in Unit 2. Thus the actual air circulation rate through the central computer of Unit 1 may have been appreciably greater than the observed value.

A more detailed analysis of the temperatures which existed within the power supply cabinet was made upon Unit 2. With an entering air temperature of 80°F, temperatures of 130.0°F and 127.5°F were recorded one inch above the rectifiers located in the upper level of the bottom section in bay No. 3. The highest value observed in bay No. 1 was 116.0°F. In the four sections directly above in bay No. 3 temperatures of 106.0°F, 107.0°F, 114.0°F and 104.0°F were recorded. Corresponding temperatures to the left of the entrance door in bay No. 1 were 91.0°F, 111.0°F, 101.0°F, and 103.8°F.

Some recirculation of air between outlet and inlet was observed in units 1 and 3. By a comparison of the temperatures of the intake air and air over the parking lot several feet from the intake and supply openings it was determined that the inlet air was 7 to 10 degrees warmer than the outdoor air. Of course, recirculation would adversely affect the computer performance in hot weather.

An approximation of the heat absorbed in the various units can be obtained by using the temperature rise of the air and the quantity of air circulated. The results of this computation are shown in Table 2 both as units of heat and units of electrical power. It was stated by the operating personnel that approximately 125 KW of power was used by each unit. The computed values for Units 1 and 3 were appreciably lower than this value and they were 20 to 30 KW lower than the computed value for Unit 2. The computed power consumptions for the central computer of Units 1 and 3 and for the power supply of Unit 1 were appreciably less than the corresponding values for Unit 2. These variations are attributed to the greater air leakage into the intake duct systems and the greater outward leakage around the doors or the several bays of the cabinets for Units 1 and 3 than for Unit 2. Another contributing factor for the power supply of Unit 1 was the exceptionally small intake opening which would tend to increase the air leakage even more.

V. DISCUSSION AND CONCLUSIONS

Based on Weather Bureau data for Washington, D.C., it was decided that the ventilation rate for the installation at Suitland, Maryland, should be based on a maximum outdoor temperature of 105°F. Assuming that the temperature limit devices in the computer would be set to shut the unit down at a temperature of 135°F, the maximum temperature rise that could be tolerated in any bay would be 30°F.

It is believed that the data obtained on Unit 2 were more accurate than for Units 1 and 3 because the duct leakage was less, the ducts were longer and a better measuring station could be found, and more time was available for the observations. Tables 1 and 2 show that a maximum temperature rise of 35.5°F was observed in bay No. 9 in Unit 2 for an air circulation rate of 14,550 cfm. It can be assumed that the product of the ventilating air rate and the temperature rise would be a constant.

That is $14550 \times 35.5 = 517{,}000 = K$

Then for a maximum rise of 30°F the required air circulation rate would be

$$V = \frac{517{,}000}{30} = 17000 \text{ cfm}$$

Similarly for the power supply cabinet

$$K_1 = 3850 \times 23 = 89000$$

$$V_1 = \frac{89000}{30} = 3000 \text{ cfm}$$

These ventilation rates would be the minimum which would give satisfactory operation during the hottest weather and they provide no margin of safety. A factor of safety should be incorporated in the selection of the design ventilation rates to allow for the following contingencies:

(a) Errors in correctly evaluating duct friction

(b) Excessive dirt on the filters and leaves and paper on the intake screen

(c) Recirculation between outlet and inlet due to duct location or wind direction

(d) Loss of air from cabinets due to doors or panels being left open for inspection or service.

It is recommended, therefore, that the ventilation rate for the central computer be made about one-third larger than the minimum value or 22500 cfm.

The decision about how much ventilation air should be provided for the power supply is confused by the failure of a number of selenium rectifiers in Unit 2 and the local temperature rise of 50°F observed near one of these units in Unit 2. Based on the maximum temperature observed on one of the limit switches in the power supply of Unit 2, the minimum ventilation rate would be 3000 cfm as previously shown. However, considering that the temperature rise of the air near one of the rectifiers was 50°F and that the rectifier itself could easily have been 10 or 20 degrees warmer than the downstream air, rectifier temperatures of the order of 170°F seem entirely possible for the design inlet ventilating air temperature of 105°F. The available literature[a,b] on selenium rectifiers indicates that they should be derated as much as 40 percent in output voltage and current when operated at temperatures on the order of 170°F. By doubling the ventilation rate on the power supply of Unit 2 the temperatures of the hottest rectifier could probably be reduced 20 to 25 degrees. Probably the temperature rise of this one rectifier could be reduced by a modification of the air passages inside the power supply to direct more air over it.

Considering the sensitivity of the selenium rectifiers to high temperatures it is recommended that 7500 cfm of ventilating air be provided for the power supply.

In our opinion, the cooling of the Univac computers can be done adequately at less cost and without introducing the mechanical problems of refrigeration equipment by the use of the proper quantities of ventilating air. The difficulties with the present installation stem primarily from insufficient ventilating air, inadequate duct system, and recirculation for Units 1 and 3, and from insufficient ventilating air and dirty intake screen and filters on Unit 2.

a. Metal Rectifiers, by H.K.Henisch(1949) Oxford University Press, London.

b. Selenium Rectifiers, by S.Niciejewski, Radio and Television News, Oct. 1952.

The following factors should be given careful consideration in the design of the ventilating system for the installation at Suitland:

(a) Care must be taken to prevent the heated exhaust air from reentering the air intake. Possible solutions would be to terminate the supply and exhaust ducts on opposite sides of a wing of the building or face the discharge and intake openings in opposite directions. The intake should probably be upwind from the exhaust for the prevailing summer wind direction.

(b) The intake for ventilation air should be high enough above ground level so it will not collect leaves, scrap paper, and trash. This was an important source of trouble on Unit 2 at the Pentagon.

(c) A reserve supply of air filters should be kept on hand and adequate maintenance of filters should be assured. The blowers should be selected to deliver the required ventilating air with a reasonable dirt load on the filters (say 0.5 inch water gage pressure drop across the filters).

(d) Duct restrictions and 180 degree bends should be avoided in the intake and exhaust ducts.

(e) A check test to determine the amount of air provided should be made after installation is completed and at stated intervals during use of the computers.

Consideration should be given to the installation of a 16-point temperature recorder for a continuous record of the temperatures at important locations to warn of impending shutdowns before they occur. Such an instrument would cost approximately $2,000.

A manual reset of the control circuit on the ventilating fans that would permit starting the fans to cool the Univac after it was determined that no fire existed in the equipment would shorten shutdown periods that did occur for any reason. An interlocking device should be used on this manual reset so the main control circuit would again be the primary control when the computer was in operation.

It was shown in Table 1 that several of the bays in the central computer operated at temperatures well above the average. Designers of the Univac computer should give consideration to regrouping of the electric components to attain more uniform heat generation in the several bays or provide more ventilating air for the hotter bays by baffles or scoops in the supply plenum or redesign of the air passages in these bays. Considerably less ventilating air could be used if the heat dissipation in the several bays were balanced.

Cabinet doors with less air leakage would greatly aid in promoting the comfort of the operating personnel especially if a single blower is used to force air through the ventilating system. Locating the control panel and the servomechanism unit in a room adjacent to the central computer cabinet and the power supply cabinet would greatly enhance the comfort of the operators and reduce the amount of comfort air conditioning required if that is contemplated.

Table 1

TEMPERATURES OF PROTECTIVE DEVICES
ON
UNIVAC COMPUTERS, °F

Bay No.	Central Computer Unit No. 1	2	3	Power Supply Unit No. 1	2	3
1	97.9	103.9	99.0	92.0	97.1	91.1
2	97.2	107.3	99.8	92.2	103.1	92.1
3	96.0	101.0	100.2	96.2	102.2	96.0
4	96.5	102.0	100.0			
5	98.3	102.9	98.0			
6	101.0	106.5	103.4			
7	113.3	113.0	110.0			
8	108.1	114.0	106.0			
9	102.0	115.5	104.9			
10	108.2	106.8	91.9			
11	104.0	107.1	92.0			
12	95.0	100.0	97.9			
13	96.1	95.0	99.0			
Average	104.6	105.8	100.2	93.5	100.8	93.1
Inlet Air Temp.	82.0	80.0	85.0	82.0	80.0	85.0

Table 2

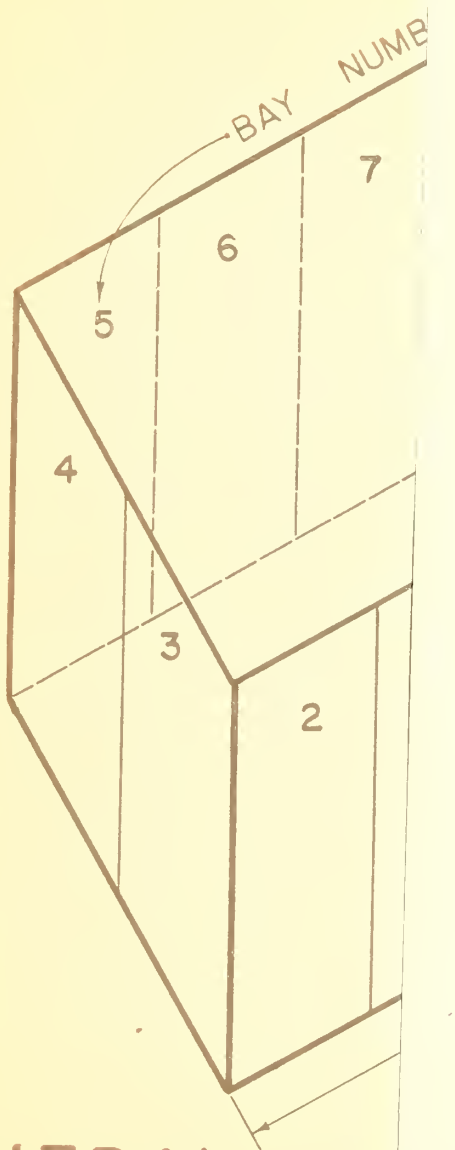
Performance of Ventilation
System on Three Univac Computers

	Central Computer Unit No.			Power Supply Unit No.		
	1	2	3	1	2	3
Inlet Air Temp °F	82.0	80.0	85.0	82.0	80.0	85.0
Outlet Air Temp °F	96.0	98.0	95.0	95.8	102.0	96.0
Outlet-Inlet Temp Diff. °F	14.0	18.0	10.0	13.8	21.9	11.0
Max. Temp. Rise for any Bay °F	31.3	35.5	25.0	14.2	23.0	11.0
Ventilating Air Rate, cfm	14,650	14,550	19,890	3435	3850	7030
Computed Heat Dissipation, BTU/hr	221,500	282,500	214,800	51,200	91,100	83,500
Equiv. Power Consumption, Watts	64,900	82,700	62,900	15,000	26,700	24,500

Totals for Both Cabinets

	Unit No.		
	1	2	3
Ventilating Air Rate, cfm	18,088	18,403	26,919
Computed Power Consumption, Watts	79,900	109,400	87,400

DIMENSIONAL



CENTRAL CO

DIMENSIONAL DIAGRAM - COMPUTER CABINETS

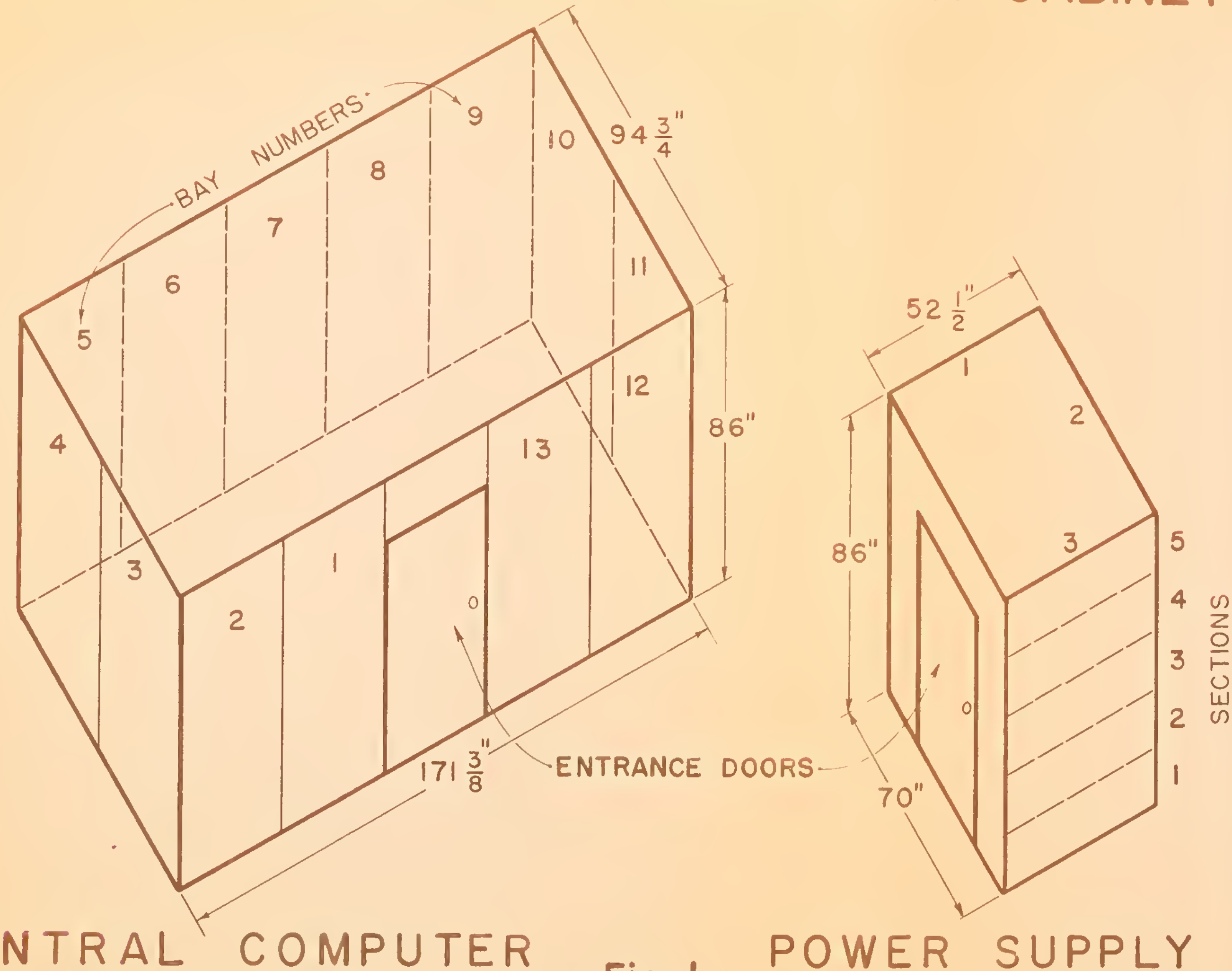


Fig. 1

THE NATIONAL BUREAU OF STANDARDS

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