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# EVALUATION OF RACK-TYPE CONVECTION OVEN AND PROOF BOX

by

Edward G. Adams



August 1971

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EVALUATION OF  
RACK-TYPE CONVECTION OVEN AND PROOF BOX.

by

EDWARD Q. ADAMS  
Engineering Evaluation Office

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1J664713D548

August 1971

General Equipment & Packaging Laboratory

U. S. ARMY NATICK LABORATORIES

Natick, Massachusetts 01760

## FOREWORD

The U. S. Navy Subsistence Office, through the Department of Defense Service & Facilities Planning Board, requested the U. S. Army Natick Laboratories to evaluate a commercial, gas-fired rack-type convection oven and a commercial, electrically heated proof box. The objectives of the evaluation are to determine the capability of the oven for roasting large quantities of meat products and for baking large quantities of bread and pastry products. The proof box is evaluated to determine its capability to proof large quantities of dough products.

The U. S. Army Natick Laboratories acknowledge the cooperation of the Despatch Oven Company for providing the oven and proof box for the evaluation. Acknowledgment is accorded to Mr. James K. Prifti, Mr. James E. Lindsey, CW2 Robert T. Wilson and SSG Richard L. Morgan, General Equipment & Packaging Laboratory, and to Mrs. Frances H. Lee and SSG Andrew P. Jackson, Food Laboratory, for their support during various phases of the evaluation.

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| Convection              | 9      |    |        |    |        |    |
| Ovens                   | 9      |    |        |    |        |    |
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## ABSTRACT

This report covers the evaluation of a commercial, gas-fired, rack-type convection oven and a commercial electrically heated proof box. The evaluation of the oven is to determine its capability for roasting large amounts of meat products and for baking large amounts of bread and bakery products, and its suitability for military use. The evaluation of the proof box is to determine its capability to proof large amounts of dough products and its suitability for military use. The three major areas evaluated are 1) the engineering aspects, 2) the food preparation capabilities, and 3) the operational, human engineering and safety aspects.

The oven has the following deficiencies:

- a. The heat distribution pattern is not uniform with the rack fully loaded with meat or bakery products.
- b. The rod-and-shaft which keeps the rack in motion during the baking or roasting cycle is a serious safety hazard.
- c. The lighting system is not adequate.
- d. The mass of the rack increases the preparation time for both meat and bakery products.

The proof box is satisfactory to proof large amounts of dough products.

## EVALUATION OF RACK-TYPE CONVECTION OVEN AND PROOF BOX

### INTRODUCTION

The evaluation of the oven is to determine its capability to roast large amounts of meat products and to bake large amounts of dough and bakery products, and its suitability for military use. The evaluation of the proof box is to determine its capability to proof large amounts of dough products and its suitability for military use. The three major areas evaluated are 1) the engineering aspects, 2) the food preparation capability, and 3) the operational, human engineering, and safety aspects.

### DESCRIPTION OF EQUIPMENT

#### 1. Rack-Type Convection Oven:

The gas-heated, rack-type convection oven used in this evaluation was the "Revers-A-Flow" model manufactured by the Despatch Oven Company, 619 S.E. Eighth Street, Minneapolis, Minnesota. See Table I for descriptive material.

All operations of the convection oven are controlled by a side-mounted control console which consists of the following controls:

- a. Dial-type temperature indicator (degrees Fahrenheit).
- b. Steam injection control.
- c. Interval timer (minutes).
- d. Airflow reversing timer (seconds).
- e. Interior light switch.
- f. Main burner button.
- g. Recirculating fan button.
- h. Exhaust fan button.
- i. Combustion air blower switch.

The convection oven and control console are shown in Figure 1.

The oven has an indirect gas-fired heater located in the rear. (see Figure 2). The heat chamber contains tubes for indirectly

TABLE I

## Descriptive Data on Convection Oven and Proof Box

| CHARACTERISTICS                      | IDENTIFICATION  |               |
|--------------------------------------|-----------------|---------------|
|                                      | CONVECTION OVEN | PROOF BOX     |
| Number of Sections (Compartments)    | 1               | 2             |
| Number of Racks (8 shelves per rack) | 1               | 2             |
| Compartment Width                    | 2' 10"          | 2' 10"        |
| Compartment Depth                    | 7' 1"           | 7' 1"         |
| Compartment Height                   | 6' 3"           | 6' 4"         |
| Overall Outside Dimensions:          |                 |               |
| Width                                | 6' 10"          | 7' 1"         |
| Depth                                | 11' 9"          | 7' 6"         |
| Height                               | 6' 11"          | 8' 0"         |
| Control Temperature - Range          | to 550°F        | 70°F to 120°F |
| Unit Weight (Approximate)            | 5,200 lbs       | 1,600 lbs     |
| Electrical Rating:                   |                 |               |
| Line                                 | 240V, 3-Phase   | 240V, 1-Phase |
| Control                              | 120V, 1-Phase   | 120V, 1-Phase |
| Motor                                | 20 Amps @ 240V  | 2.9 Amps      |
|                                      | 60 Hz AC        | 60 Hz AC      |
| Heater                               | --              | 43 Amps       |
| Fuel                                 | Natural Gas     | --            |

heating the air. Hot air supplied by the heater is introduced into the oven through a reversible damper that alternately supplies heated air to one side and then to the other side of the oven. The duration of the airflow from each side of the oven is adjustable independently from the control so that the air can be uniformly distributed throughout the oven. Airflow direction is shown in Figure 3.

The oven used for this evaluation is provided with a single, one-piece rack. Two half-racks can also be used with the oven. The rack positioned in the oven is shown in Figure 4. The oven is also equipped with a rod and shaft to provide motion to the rack involved to obtain an even flow of heat over all the products being cooked. The oven interior is shown in Figure 5.

## 2. Proof Box:

The proof box used in this evaluation (See Figure 6) is an electric-heated, rack-type, two-compartment proof box, Model BPA 3-25R, manufactured by the Despatch Oven Company, 619 S.E. Eighth Street, Minneapolis, Minnesota. See Table I for descriptive material. The interior of the box is shown in Figure 7. Wet and dry bulb temperatures of the box are controlled by separate adjustable thermostats on the control panel located on top of the box. The unit is provided with a forced air circulation system to insure even distribution of heat and humidity. The water flow is automatically regulated by a float valve.

## PROCEDURES AND RESULTS

### 1. Evaluation of Engineering Aspects - Convection Oven:

This evaluation of the convection oven to determine the temperature distribution pattern with and without load, the effect of door opening on the oven temperature distribution, the oven heat-up time, the oven heating capacity and the oven maintaining rate are based upon tests specified in USA Standard Z21.28-1967, Commercial Gas Baking and Roasting Oven, and the approved test plan prepared by the U. S. Army Natick Laboratories. The fuel for all tests is natural gas, 1,000 Btu at 6" to 8' water column. However, the gas pressure was reduced to the manufacturer's recommended operating pressure of 2-1/2" at the gas regulator.

#### a. Temperature Distribution Pattern without Load:

(1) Procedure: Twenty-seven iron constantan thermocouples were positioned in the oven as shown in Figure 8 and the readings were taken with two recording potentiometers. In addition, a kilowatt meter and a kilowatt-hour meter were installed to obtain the power requirements. A gas meter was installed in the gas line to

obtain usage data. With the oven thermocouple readings at room ambient,  $\pm 2$  degrees F, the oven door was closed, the burner fired with the control set at 200 degrees F and operated for one hour prior to taking temperature readings. The temperature readings were then taken at five-minute intervals for a period of thirty minutes. The above procedure was repeated at intervals of 50 degrees F to a maximum of 500 degrees F.

(2) Results: Table II shows the temperature distribution pattern of the oven at various control settings. The average temperature is rounded off to the nearest degree.

TABLE II

Temperature Distribution Pattern for the Convection Oven

| CONTROL<br>SETTING*<br>(°F) | AVERAGE<br>TEMPERATURE<br>(°F) | MINIMUM<br>TEMPERATURE<br>(°F) | MAXIMUM<br>TEMPERATURE<br>(°F) | TEMPERATURE<br>RANGE<br>(°F) |
|-----------------------------|--------------------------------|--------------------------------|--------------------------------|------------------------------|
| 200                         | 216                            | 215                            | 217                            | 2                            |
| 250                         | 258                            | 254                            | 260                            | 6                            |
| 300                         | 299                            | 295                            | 303                            | 8                            |
| 350                         | 348                            | 344                            | 352                            | 8                            |
| 400                         | 392                            | 388                            | 396                            | 8                            |
| 450                         | 439                            | 434                            | 443                            | 9                            |
| 500                         | 484                            | 473                            | 492                            | 19                           |

\*The control settings were not calibrated during this evaluation.

b. Effect of Door Opening:

(1) Procedure: To determine the effect of door opening on the oven temperature distribution, the oven control was set at 400 degrees F and the burner fired with the door closed. The oven was operated for thirty minutes with the door closed and a record made of the temperature readings at the rear wall and the door opening areas at the end of the thirty-minute period. The door was opened for thirty seconds and closed. A record was made of the effect of the door opening on the temperatures in the two areas. The door was kept closed for 15 minutes and the door-opening procedure repeated three additional times. A record was made of the time for the temperature in the two areas to recover to the original temperature before the door was opened.

(2) Results: Table III shows the average results of four test runs made for this evaluation. The temperature readings are averages and are rounded off to the nearest degree.

TABLE III

## Door Opening Effect on Oven Temperature

| AREA         | BEFORE DOOR<br>OPENING<br>(°F) | AFTER DOOR<br>OPENING<br>(°F) | TEMPERATURE<br>DROP<br>(°F) | RECOVERY<br>TIME<br>(Min) |
|--------------|--------------------------------|-------------------------------|-----------------------------|---------------------------|
| Rear Wall    | 395                            | 371                           | 24                          | 8                         |
| Door Opening | 388                            | 366                           | 22                          | 8                         |

c. Oven Heat-Up Time:

(1) Procedure: To determine the oven heat-up time, the oven door is open until the average oven temperature is approximately that of the room ambient temperature. The control is set at 200 degrees F, the door closed and the burner fired. The oven is allowed to operate until the oven temperature is 200 degrees F. A record is made of the time for the oven to heat up to the control setting of 200 degrees F. The above procedure is repeated for control settings of 300 degrees F, 400 degrees F, and 500 degrees F, respectively. The starting oven temperature in each instance is approximately that of the room ambient temperature.

(2) Results: Table IV shows the oven heat-up time from room temperature for control settings of 200 degrees F, 300 degrees F, 400 degrees F, and 500 degrees F, respectively.

TABLE IV

## Oven Heat-Up Time

| OVEN TEMPERATURE<br>(°F) | TIME TO REACH OVEN<br>TEMPERATURE<br>(Min) |
|--------------------------|--------------------------------------------|
| 200                      | 15                                         |
| 300                      | 28                                         |
| 400                      | 42                                         |
| 500                      | 55                                         |

d. Oven Heating Capacity:

(1) Procedure: To determine the oven heating capacity, the oven door is closed with the average oven temperature at the room ambient temperature and the burner ignited. The thermostat dial is set at the maximum position and the burner operated until the oven temperature reaches 400 degrees F. A record is made of

the time for the oven temperature to reach 400 degrees F. The oven heating capacity, or average heating rate, is computed using the following formula:

$$\text{Average Heating Rate} = \frac{400^{\circ}\text{F}-\text{Room Temperature}}{\text{Recorded Heating Time}}$$

The average heating rate is satisfactory if it is not less than 7 degrees F per minute.

(2) Results: The recorded time for the oven to reach 400 degrees F was 43 minutes. The average heating rate is 7.6 degrees F per minute. The calculations are as follows:

$$\begin{aligned}\text{Average Heating Rate} &= \frac{400^{\circ}\text{F}-\text{Room Temperature}}{\text{Observed Heating Time}} \\ &= \frac{400-73}{43} \\ &= \frac{327}{43} \\ &= 7.6^{\circ}\text{F per minute}\end{aligned}$$

e. Oven Maintaining Rate:

(1) Procedure: To determine the oven maintaining rate, the oven temperature is brought to and maintained at 330 degrees F above room temperature. The oven is operated for one hour at the established temperature. The gas consumption during the one-hour period is measured. The oven temperature is considered to be constant if the averages of the oven temperature readings do not vary more than 10 degrees F during the one-hour period. The oven maintaining rate is determined by the following formula:

$$\text{Oven Maintaining Rate} = \frac{HFQK}{V}$$

where:

H = Gross heating value of gas  
in Btu/cu ft

Q = Volume of gas burned in  
cubic feet

K = 1.0 for direct-fired ovens,  
0.875 for indirect-fired  
ovens

V = Oven volume in cubic feet

F = Correction factor for gas  
volume

The oven maintaining rate is satisfactory if the oven does not require more than 2,200 Btu per hour per cubic foot of oven volume to maintain the oven temperature at 330 degrees F above room ambient temperature.

(2) Results: The oven requires 266 Btu per hour per cubic foot of oven volume to maintain the oven temperature at 330 degrees F above the room temperature with the average oven temperature varying less than 10 degrees F. The calculations are as follows:

$$\begin{aligned}\text{Oven Maintaining Rate} &= \frac{HFQK}{V} \\ &= \frac{1000 \times 38 \times .875}{125} \\ &= \frac{33250}{125} \\ &= 266 \text{ Btu per hour per cubic} \\ &\quad \text{foot of oven volume}\end{aligned}$$

The volume of the gas burned, 38 cubic feet, is the average of three separate one-hour periods of operation.

f. Temperature Distribution Pattern with Load:

(1) Method: The evaluation of the temperature distribution pattern of the oven with load is based upon the results from baking dough and pastry products, and from roasting meat products. Specifically, the shade of the browning of the dough and pastry products is examined visually to see if the shade varies with the location of the product in the oven. Also, the uniformity of the degree of roasting of meat products is analyzed to see if the location of the meat product in the oven has any effect.

(2) Results: The temperature distribution pattern of the oven with load is not uniform. Dough and pastry products on the upper three shelves are browned more than are products on the lower five shelves. Also, meat products on the upper shelves are roasted to a greater degree than are meat products on the lower shelves.

2. Evaluation of Engineering Aspects - Proof Box:

The evaluation of the proof box to determine the average temperature and relative humidity during operation and the amount of power used per hour is based upon the approved test plan prepared by the U. S. Army Natick Laboratories.

a. Average Temperature, Relative Humidity, and Power Usage:

(1) Procedure: Ten copper constantan thermocouples were positioned in the two compartments of the proof box as shown in Figure 9, eight approximately six inches from the corners and the other two at the center line of the proof box area. The readings were taken with a recording potentiometer. A humidigraph was used to record the dry and wet bulb readings and to determine the relative humidity. The controls were set at 100 degrees F dry bulb reading and 95 degrees F wet bulb reading, and the proof box operated until both readings stabilized. A record was made of the power used in one hour at stabilized temperatures. The above test was repeated after the temperature of the proof box was allowed to reach room ambient temperature. A third test was made with the dry bulb set at 96 degrees F and the wet bulb set at 92 degrees F. These latter settings are used to proof dough and bakery products. A record was made of the power used during the last two tests.

(2) Results: Table V shows the results of the three operational evaluations of the proof box without any load.

TABLE V

Average Temperature and Relative Humidity

| <u>CONTROL SETTING</u>  |                         | <u>HUMIDIGRAPH READINGS</u> |                         | <u>RELATIVE HUMIDITY</u><br>(%) | <u>AVERAGE BOX TEMPERATURE</u><br>(°F) |
|-------------------------|-------------------------|-----------------------------|-------------------------|---------------------------------|----------------------------------------|
| <u>WET BULB</u><br>(°F) | <u>DRY BULB</u><br>(°F) | <u>WET BULB</u><br>(°F)     | <u>DRY BULB</u><br>(°F) |                                 |                                        |
| 95                      | 100                     | 94                          | 100                     | 80                              | 101                                    |
| 96                      | 100                     | 94                          | 99                      | 83                              | 100                                    |
| 92                      | 96                      | 92                          | 96                      | 86                              | 97                                     |

The proof box used seven kilowatts of power for each hour of operation, or a total of seven kilowatt hours per test.

3. Evaluation of Food Preparation Capability - Convection Oven and Proof Box:

The capability of the convection oven to bake dough and pastry products was determined by the making of white pan bread, French bread, frankfurter and hamburg rolls, sheet cake, piecrust and apple pie. The capability of the convection oven to roast meat products was determined by the roasting of turkey roll, pork loin and roast beef. The proof box was used to proof the dough products. An Amflow Model 300 Continuous Mixer was used in the preparation of the white pan bread, the hamburg rolls and the frankfurter rolls. An experienced

Army baker and food technologist prepared the foods. The oven was preheated to the selected temperature for each product prior to use. The oven was fully loaded with products. The utensils were the Army standard stock pans as follows:

TABLE VI

Standard Federal Stock Pans used in Food Preparation Evaluation

| TYPE OF UTENSIL            | FEDERAL STOCK NUMBER | DIMENSIONS (Inches) |        |        |
|----------------------------|----------------------|---------------------|--------|--------|
|                            |                      | LENGTH              | WIDTH  | HEIGHT |
| Baking Pans*               | 7330-272-2586        | 25-3/4              | 17-3/4 | 1-1/4  |
| Baking and Roasting Pans** | 7330-634-4491        | 24                  | 18     | 4-1/2  |
| Bread Pan***               | 7330-255-5995        | 10-3/4              | 4-5/8  | 2-3/4  |

\*Referred to in this evaluation as sheet pan.

\*\*Referred to in this evaluation as roast pan.

\*\*\*Pans used were of the four-loaf strap type; the dimensions are of the individual pans.

Meat products were weighed prior to and after preparation to determine loss in weight of each product. Thermocouples and meat thermometers were used to measure internal meat temperatures during roasting. A comparison of the Armed Forces' and manufacturer's recommended preparation times and the actual times is included in the results. However, the manufacturer's recommended times and temperatures were not available for all products prepared during the evaluation. As recommended by the manufacturer, the oven steam injection system was used during the baking of dough products. A food acceptance panel was used to evaluate each of the prepared products. Table VII lists the food products and the conditions under which each product was prepared.

TABLE VII

List of Food Products and Conditions

| TYPE OF PAN             | NUMBER OF PANS PER RACK | QUANTITY OF PRODUCT | AVERAGE                |              | PROOF TIME (Min) | RELATIVE HUMIDITY (%) | OVEN TEMP (°F) | TIME TO COOK (Min) | STEAM (Min) |
|-------------------------|-------------------------|---------------------|------------------------|--------------|------------------|-----------------------|----------------|--------------------|-------------|
|                         |                         |                     | WEIGHT OF PRODUCT (Oz) | PER PAN (Lb) |                  |                       |                |                    |             |
| <u>Baked Products</u>   |                         |                     |                        |              |                  |                       |                |                    |             |
| White Pan Bread         | 30                      | 120                 | 20                     | 5.0          | 50               | 85                    | 425            | 50                 | 5           |
| French Bread            | 24                      | 72                  | 19                     | 3.56         | 60               | 86                    | 425            | 35                 | 5           |
| Frankfurter Rolls       | 24                      | 884                 | 2.5                    | 5.6          | 20               | 86                    | 410            | 35                 | 5           |
| Hamburg Rolls           | 24                      | 840                 | 2.5                    | 5.47         | 30               | 86                    | 435            | 28                 | 5           |
| Sheet Cake              | 24                      | 24                  | 120                    | 7.5          | None             | None                  | 325            | 45-60              | None        |
| Piecrust                | 118                     | 118                 | 6                      | 0.375        | None             | None                  | 450            | 20                 | None        |
| Apple Pie               | 120                     | 120                 | 38                     | 2.375        | None             | None                  | 425            | 60                 | None        |
| <u>Roasted Products</u> |                         |                     |                        |              |                  |                       |                |                    |             |
| Turkey Rolls            | 12                      | 36                  | 11.43*                 |              |                  |                       | 250            | 300                |             |
| Pork Loin               | 12                      | 24                  | 12.94*                 |              |                  |                       | 325            | 180                |             |
| Roast Beef              | 12                      | 30                  | 9.97*                  |              |                  |                       | 325            | 210                |             |

\*Average weight of roasted products computed in pounds.

a. Baking of White Pan Bread:

(1) Details: Table VIII lists the details for three separate bakings of white pan bread. The first two bakings were exploratory to determine baking conditions for other products and to determine results in different sections of the oven. The third baking was done with a fully loaded oven.

TABLE VIII  
Baking of White Pan Bread

|                                                               | RUN NUMBER |        |        |
|---------------------------------------------------------------|------------|--------|--------|
|                                                               | 1          | 2      | 3      |
| Armed Forces Recommended Oven Temperature ( <sup>o</sup> F)   | ---        | ---    | 375    |
| Manufacturer's Recommended Oven Temperature ( <sup>o</sup> F) | ---        | ---    | 380    |
| Actual Oven Temperature ( <sup>o</sup> F)                     | 435        | 435    | 435    |
| Heat Requirement (Btu/hr)                                     | 57,000     | 60,000 | 42,000 |
| Power Requirement (kw-hr)                                     | 3          | 3      | 6      |
| Number of Loaves                                              | 19         | 32     | 120    |
| Armed Forces Recommended Bake Time (Min)                      | ---        | ---    | 30-35  |
| Manufacturer's Recommended Bake Time (Min)                    | ---        | ---    | 30-35  |
| Actual Bake Time (Min)                                        | 21         | 23     | 50     |

(2) Results: The loaves from the first two runs on the lower shelves and near the door were not baked in the center. Product from these runs was not rated by the acceptance panel. The acceptance panel rated the odor, flavor, texture and color of the product from the third run as good. The product on the top three shelves rated as best. However, all of the rated product was scored as satisfactory.

b. Baking of French Bread:

(1) Details: Table IX lists the details for one baking of French bread. The oven was fully loaded and the baking was done with steam as recommended by the oven manufacturer.

TABLE IX

Baking of French Bread

---

|                                                |        |
|------------------------------------------------|--------|
| Armed Forces Recommended Oven Temperature (°F) | 450    |
| Actual Oven Temperature (°F)                   | 425    |
| Heat Requirement (Btu/hr)                      | 50,000 |
| Power Requirement (kw-hr)                      | 4      |
| Number of Loaves                               | 72     |
| Armed Forces Recommended Bake Time (Min)       | 30     |
| Actual Bake Time (Min)                         | 35     |

(2) Results: The acceptance panel rated the product excellent in all respects.

c. Baking of Frankfurter Rolls:

(1) Details: Table X lists the details for one baking of frankfurter rolls. The oven was fully loaded.

TABLE X

Baking of Frankfur      Rolls

---

|                                                             |        |
|-------------------------------------------------------------|--------|
| Armed Forces Recommended Oven Temperature ( <sup>o</sup> F) | 400    |
| Actual Oven Temperature ( <sup>o</sup> F)                   | 410    |
| Heat Requirement (Btu/hr)                                   | 39,400 |
| Power Requirement (kw-hr)                                   | 3      |
| Number of Rolls                                             | 884    |
| Armed Forces Recommended Bake Time (Min)                    | 13-20  |
| Actual Bake Time (Min)                                      | 35     |

(2) Results: The acceptance panel rated the flavor as good, with texture, odor and color as fair.

d. Baking of Hamburg Rolls:

(1) Details: Table XI lists the details for one baking of hamburg rolls. The baking was done with the oven fully loaded.

TABLE XI

Baking of Hamburg Rolls

|                                                |        |
|------------------------------------------------|--------|
| Armed Forces Recommended Oven Temperature (°F) | 400    |
| Actual Oven Temperature (°F)                   | 435    |
| Heat Requirement (Btu/hr)                      | 47,000 |
| Power Requirement (kw-hr)                      | 3      |
| Number of Rolls                                | 840    |
| Armed Forces Recommended Bake Time (Min)       | 15-20  |
| Actual Bake Time (Min)                         | 28     |

(2) Results: The acceptance panel rated the product on the top three shelves as satisfactory and the product on the bottom five shelves as edible but doughy. The odor, flavor and texture of the product from the top three shelves was rated as good. The odor, flavor and texture of the product on the bottom five shelves rated as poor.

e. Baking of Sheet Cakes:

(1) Details: Table XII lists the details for two bakings of sheet cakes. The initial baking evaluated the heat distribution pattern of the oven with load in accordance with the method specified in paragraph 2.15, USA Standard for Commercial Gas Baking and Roasting Oven, Z21.28-1967, as well as the baking capability. The oven was fully loaded for both bakings.

TABLE XII

Baking of Sheet Cakes

|                                                  | RUN NUMBER |        |
|--------------------------------------------------|------------|--------|
|                                                  | 1          | 2      |
| Armed Forces Recommended Oven Temperature (°F)   | 375        | 375    |
| Manufacturer's Recommended Oven Temperature (°F) | 325        | 325    |
| Actual Oven Temperature (°F)                     | 325        | 325    |
| Heat Requirement (Btu/hr)                        | 30,000     | 23,000 |
| Power Requirement (kw-hr)                        | 4          | 6      |
| Number of Cakes                                  | 24         | 24     |
| Armed Forces Recommended Bake Time (Min)         | 25-30      | 25-30  |
| Manufacturer's Recommended Bake Time (Min)       | 50-56      | 50-56  |
| Actual Bake Time (Min)                           | 45         | 60     |

(2) Results: The cakes on the top three shelves were darker in color indicating that the heat distribution pattern of the oven with load was not uniform. The taste panel rated the overall quality of the cakes as good.

f. Baking of Piecrusts:

(1) Details: Table XIII lists the details for one baking of piecrusts. The oven was fully loaded with the product.

TABLE XIII

Baking of Piecrust

---

|                                                |        |
|------------------------------------------------|--------|
| Armed Forces Recommended Oven Temperature (°F) | 450    |
| Actual Oven Temperature (°F)                   | 450    |
| Heat Requirement (Btu/hr)                      | 60,000 |
| Power Requirement (kw-hr)                      | 3      |
| Number of Piecrusts                            | 118    |
| Armed Forces Recommended Bake Time (Min)       | 10     |
| Actual Bake Time (Min)                         | 20     |

(2) Results: The crusts on the lower shelves were of a lighter color. The acceptance panel rated the product as good overall.

g. Baking of Apple Pie:

(1) Details: Table XIV lists the details for one baking of apple pie. The oven was fully loaded. The pies on the upper three shelves were removed after fifty minutes; the pies on the lower five shelves were baked an additional ten minutes.

TABLE XIV

Baking of Apple Pie

|                                                  |        |
|--------------------------------------------------|--------|
| Armed Forces Recommended Oven Temperature (°F)   | 425    |
| Manufacturer's Recommended Oven Temperature (°F) | 390    |
| Actual Oven Temperature (°F)                     | 425    |
| Heat Requirement (Btu/hr)                        | 36,000 |
| Power Requirement (kw-hr)                        | 6      |
| Number of Pies                                   | 120    |
| Armed Forces Recommended Bake Time (Min)         | 30-35  |
| Manufacturer's Recommended Bake Time (Min)       | 35-40  |
| Actual Bake Time (Min)                           | 60     |

(2) Results: The pies on the upper three shelves were baked completely in fifty minutes. The pies on the lower five shelves were baked an additional ten minutes. The acceptance panel rated all pies after completely baked as good.

h. Roasting Turkey Roll:

(1) Details: Table XV lists the details for roasting one fully loaded oven of turkey roll. The Food Laboratory, U. S. Army Natick Laboratories, is conducting a study of the effectiveness of low temperature cooking of selected meat products. Also, manufacturers of convection ovens recommend that meat products be prepared at a temperature which is fifty degrees lower than that used in deck or revolving tray ovens. This test evaluated the effectiveness of low temperature roasting of turkey roll and the capability of the convection oven to roast a meat product at a lower temperature than that recommended by the Armed Forces.

TABLE XV

Roasting Turkey Roll

|                                                |           |
|------------------------------------------------|-----------|
| Armed Forces Recommended Oven Temperature (°F) | 350       |
| Actual Oven Temperature (°F)                   | 250       |
| Heat Requirement (Btu/hr)                      | 27,600    |
| Power Requirement (kw-hr)                      | 28        |
| Number of Turkey Rolls/Total Pounds In         | 36/411.62 |
| Total Pounds Out                               | 362.62    |
| Total Weight Loss (Lbs)                        | 49.0      |
| Armed Forces Recommended Roasting Time (Min)   | 210-240   |
| Actual Roasting Time (Min)                     | 300       |
| Internal Meat Temperature Range (°F)           | 135-175   |

(2) Results: Six turkey rolls were completely cooked based upon the internal temperature of a nominal 175 degrees F. The acceptance panel rated the completely cooked turkey roll as good.

The data on the effectiveness of lower temperature roasting of meat products is insufficient to make any positive statement.

The average percent of loss of weight from cooking is 11.9 percent.

i. Roasting Pork Roasts

(1) Details: Table XVI lists the details for roasting one fully loaded oven of pork roasts. The product is considered to be completely prepared if the internal temperature is a nominal 170 degrees F. Meat thermometers were used to determine the internal temperature of the individual roasts.

TABLE XVI

Roasting Pork Roasts

---

|                                                |           |
|------------------------------------------------|-----------|
| Armed Forces Recommended Oven Temperature (°F) | 325       |
| Actual Oven Temperature (°F)                   | 325       |
| Heat Requirement (Btu/hr)                      | 25,000    |
| Power Requirement (kw-hr)                      | 17        |
| Number of Roasts/Total Pounds In               | 24/310.62 |
| Total Pounds Out                               | 263.87    |
| Total Weight Loss (Lbs)                        | 46.75     |
| Armed Forces Recommended Roasting Time (Min)   | 120-240   |
| Actual Roasting Time (Min)                     | 180       |
| Internal Meat Temperature Range (°F)           | 155-180   |

(2) Results: The pork roasts on the upper two shelves of the rack were completely cooked in 180 minutes. Only two of the eight roasts on the lower two shelves were completely cooked.

The acceptance panel rated the roasts from the upper two shelves as good. The roasts on the lower two shelves were rated as fair.

The average percent of loss in weight due to cooking is fifteen percent.

j. Roasting Beef Roast:

(1) Details: Table XVII lists the details for roasting one fully loaded oven of beef roasts. Meat thermometers were inserted into the roasts and the roasts were considered to be completely prepared if the internal temperature was a nominal 175 degrees F.

TABLE XVII

Roasting Beef Roasts

|                                                |           |
|------------------------------------------------|-----------|
| Armed Forces Recommended Oven Temperature (°F) | 325       |
| Actual Oven Temperature (°F)                   | 325       |
| Heat Requirement (Btu/hr)                      | 22,000    |
| Power Requirement (kw-hr)                      | 14        |
| Number of Roasts/Total Pounds In               | 30/299.25 |
| Total Pounds Out                               | 246.41    |
| Total Weight Loss (Lbs)                        | 52.94     |
| Armed Forces Recommended Roasting Time (Min)   | 120-240   |
| Actual Roasting Time (Min)                     | 210       |
| Internal Meat Temperature Range (°F)           | 150-175   |

(2) Results: The roasts, after 210 minutes at 325 degrees F, ranged from medium to rare. The taste panel rated the product as good to excellent, overall.

The average percent of loss in weight due to cooking was 17.7 percent.

4. Evaluation of Operational Human Engineering and Safety Aspects - Convection Oven and Proof Box:

a. Procedure:

A record was made of any difficulties or problems encountered during installation and operation of the convection oven and proof box. Particular attention was given to the human engineering and safety aspects of both items.

b. Results:

(1) The convection oven was assembled when received. The availability and location of electrical power, water, gas, and an exhaust system determine the time to make the oven ready for operation. A ten-foot clearance is required for opening the door and for moving the rack in and out of the oven. A high-temperature insulated concrete floor or a three-inch-thick concrete slab, or equal, with approximately a twelve-inch outline around the oven is adequate for the oven service area.

(2) The proof box was received disassembled and was assembled in two hours. The assembly instructions are definitive and precise. The availability and location of electrical power and drains affect the time required to make the proof box ready for use. A ten-foot clearance is required for opening the door and for moving the rack in and out of the unit. The proof box was mounted on the cement floor without any extra protection.

(3) The motors on the convection oven are designed for 240 volts, 3-phase power, whereas military requirements call for 208 volts, 3-phase power.

(4) Products located near the oven door during baking and roasting were the slowest to cook. During the baking, the dough products in this area were lighter in color and in general were doughy.

(5) It was difficult to observe the food products in the rear of the oven during baking and roasting although the oven had interior lights located at the door. The complete rack had to be removed to check food products.

(6) The attaching of the rod and shaft to the rack in a hot oven is a serious safety and human engineering problem. The operator must reach into the hot oven chamber, pick up a hot rod and attach it to the rack. He must detach the rod before he can remove the rack from the oven. The operator, in order to reach the rod, must place his body close to the oven wall. Elbow length

insulated gloves protect the hands and arms of the operator. It is difficult to protect the shoulders and body of the operator. The operator was burned several times during the operational evaluation. The preparation of the various food products was done without the use of the rod and shaft to eliminate the possibility of further injury to the operator.

(7) There is a difference between the Armed Forces recommended preparation times and the actual times; also, between the Armed Forces recommended preparation times and the manufacturer's recommended times. The significant difference between the convection oven and the conventional deck or revolving tray oven is that for the former the rack upon which the products are placed is at room temperature when placed in the oven. For both the deck and revolving tray oven the racks and trays are at oven temperature. The rack used in the convection oven weighs a nominal 600 pounds and is made of angular steel bars welded together. A rack at room temperature will absorb some of the heat of the oven when the rack enters the heated area. The amount of heat which will be absorbed depends upon the weight of the mass, the specific heat of the metal and the amount of increase in temperature. Specifically, 19,000 Btu will be absorbed by the rack used in these tests when heated from 80 degrees F to a nominal 350 degrees F. As a result, the actual preparation time in the convection oven is greater than the Armed Forces recommended time.

#### SUMMARY OF RESULTS

1. The oven heat-up rate exceeds the minimum standard average rate of 7 degrees F per minute from ambient to an oven temperature of 400 degrees F specified in USA Standard Z21.28-1967.
2. The oven maintaining rate is less than the maximum standard of 2,200 Btu per hour per cubic foot of oven space specified in USA Standard Z21.28-1967.
3. The oven temperature distribution pattern of the convection oven with load does not conform to the provisions of USA Standard Z21.28-1967 based upon the fact that the color of the sheet cakes in the upper three shelves is darker than the color of the sheet cakes on the lower five shelves.
4. The time for the oven temperature to recover to the original temperature after a door opening is eight minutes.
5. The bakery products on the top three shelves are uniformly properly prepared. Products on the lower five shelves are doughy and lighter in color.

6. The interior lights located at the door are ineffective for observing all of the products on the rack. The products on the end of the rack facing the rear wall cannot be seen unless the rack is removed from the oven.
7. The rod and shaft are a serious safety hazard to the operator. The use of insulated gloves is insufficient to overcome this hazard.
8. The heavy mass of metal in the rack increases the actual preparation time. In some instances, the preparation time is double that of the Armed Forces recommended time.
9. Meat products on the upper two shelves are completely prepared in less time than those on the two lower shelves.
10. The weight of the individual meat product items within a single load must not vary more than plus or minus two pounds based on a nominal weight of twelve pounds in order to obtain uniformity of the individual item.

#### RECOMMENDATIONS

It is recommended that the following changes be made to improve the effectiveness and efficiency of the convection oven:

1. The airflow system be improved to result in a uniform heat distribution pattern in the oven with load.
2. The rod and shaft be improved or eliminated. It is a serious safety hazard to the operator.
3. The lighting system be improved. It is inadequate for complete examination of all of the products on the rack.
4. The mass of the rack be reduced. The heavy mass of metal of the rack absorbs some of the heat of the oven which increases the actual preparation time.



Figure 1. The Rack-Type Convection Oven  
and Control Console

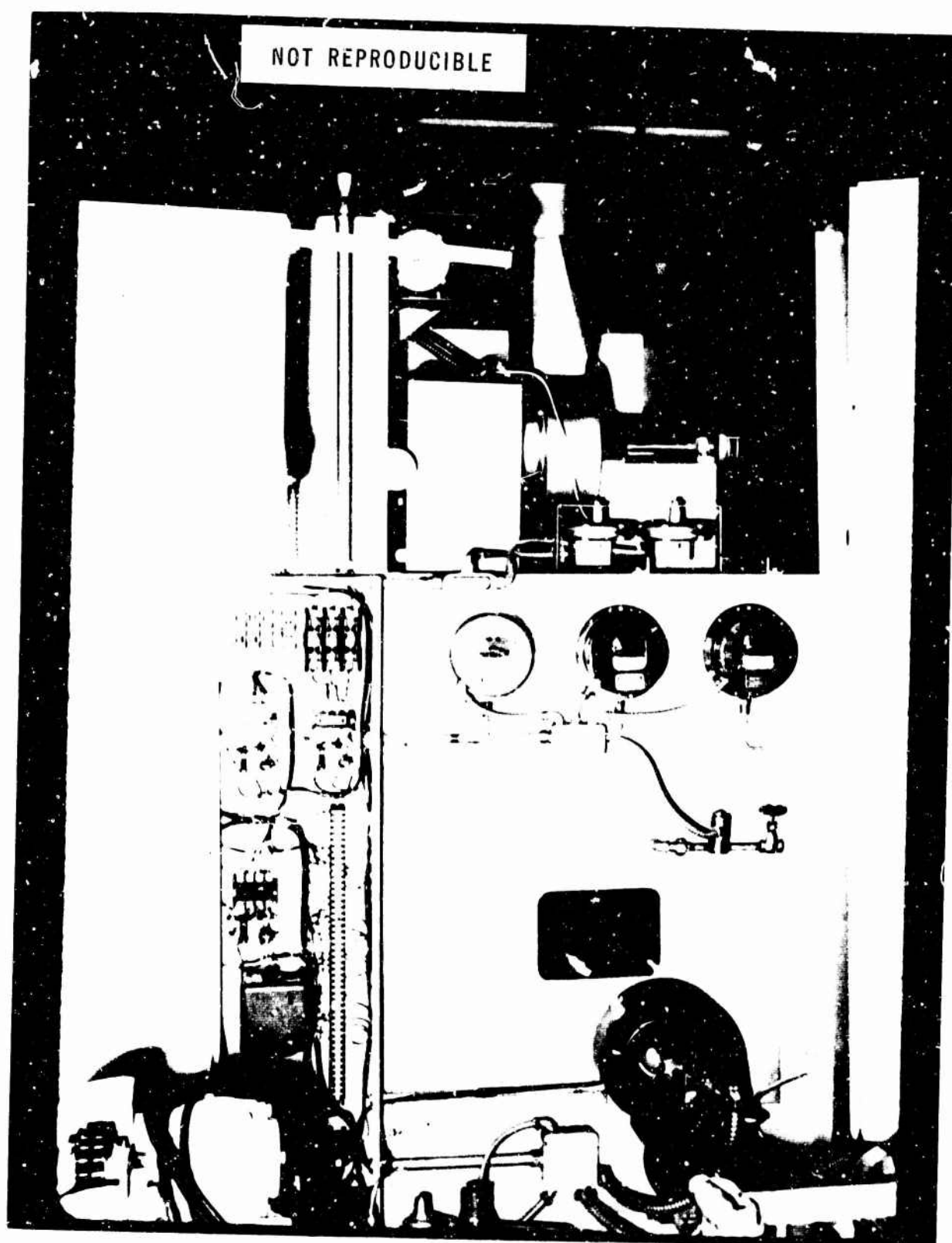


Figure 2. The Oven Heater

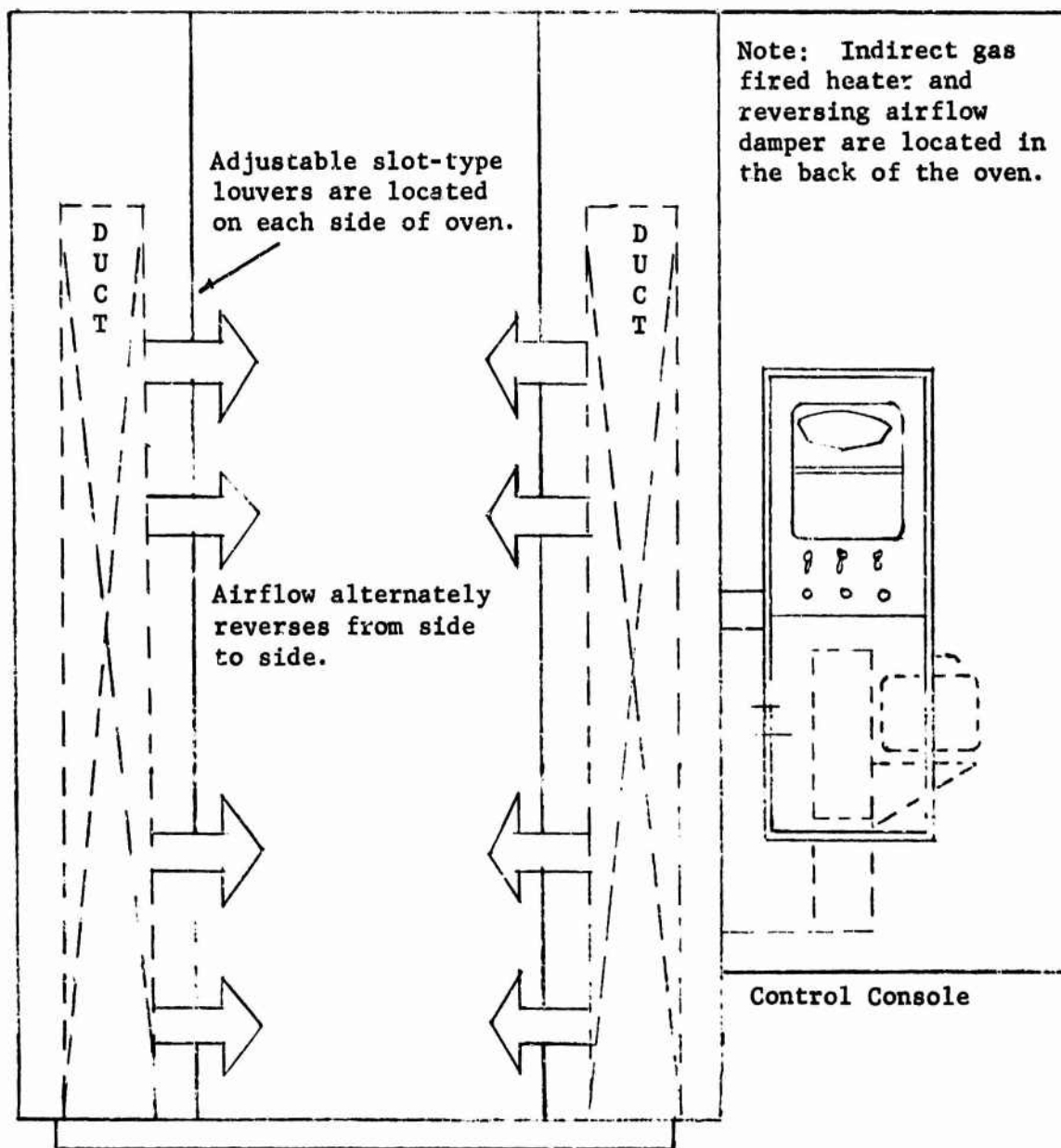


Figure 3. Sketch of Airflow Direction in the Convection Oven.

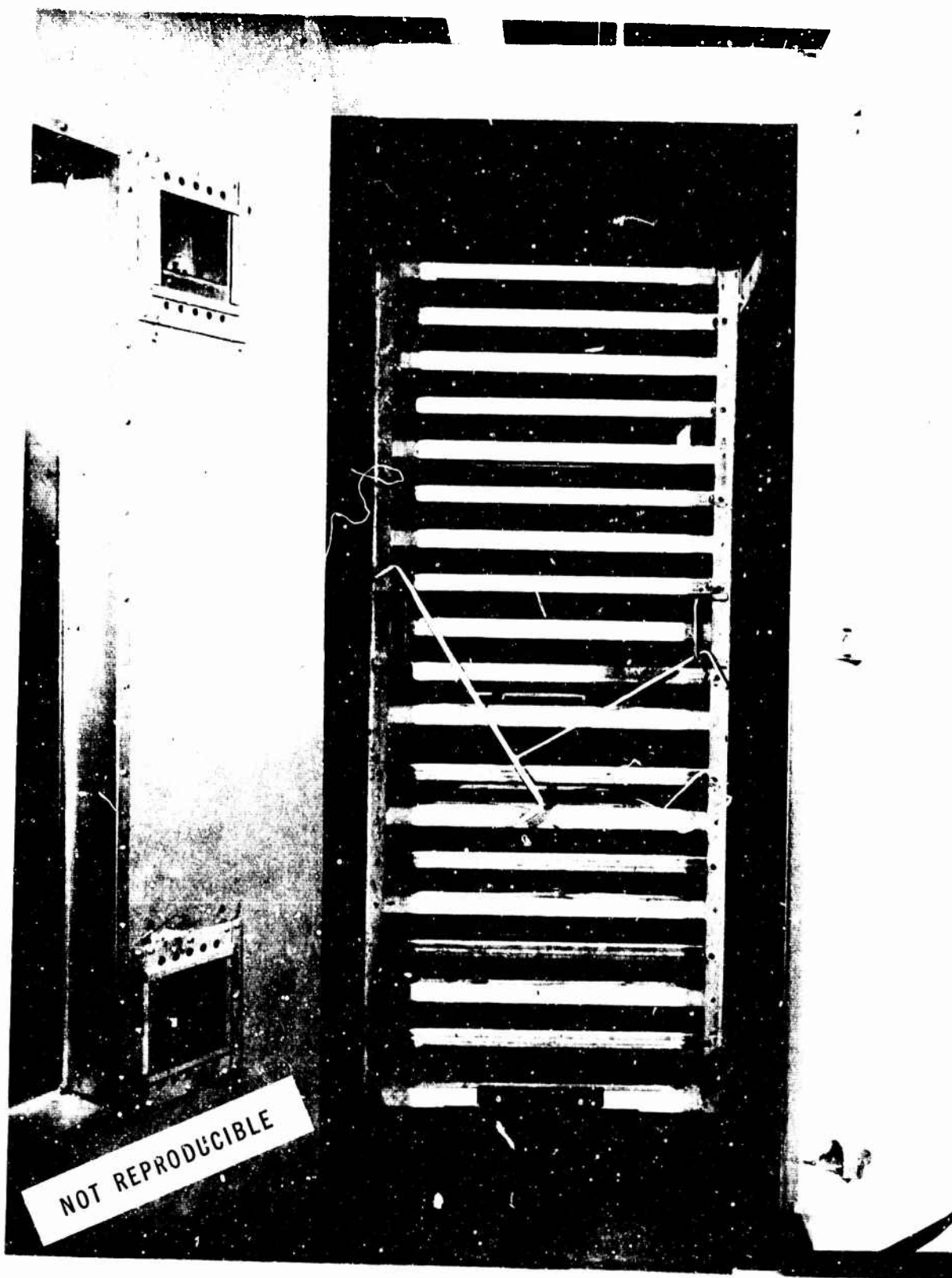


Figure 4. The Oven Rack in Position



Figure 5. Interior of Oven with Thermocouples  
for Temperature Studies

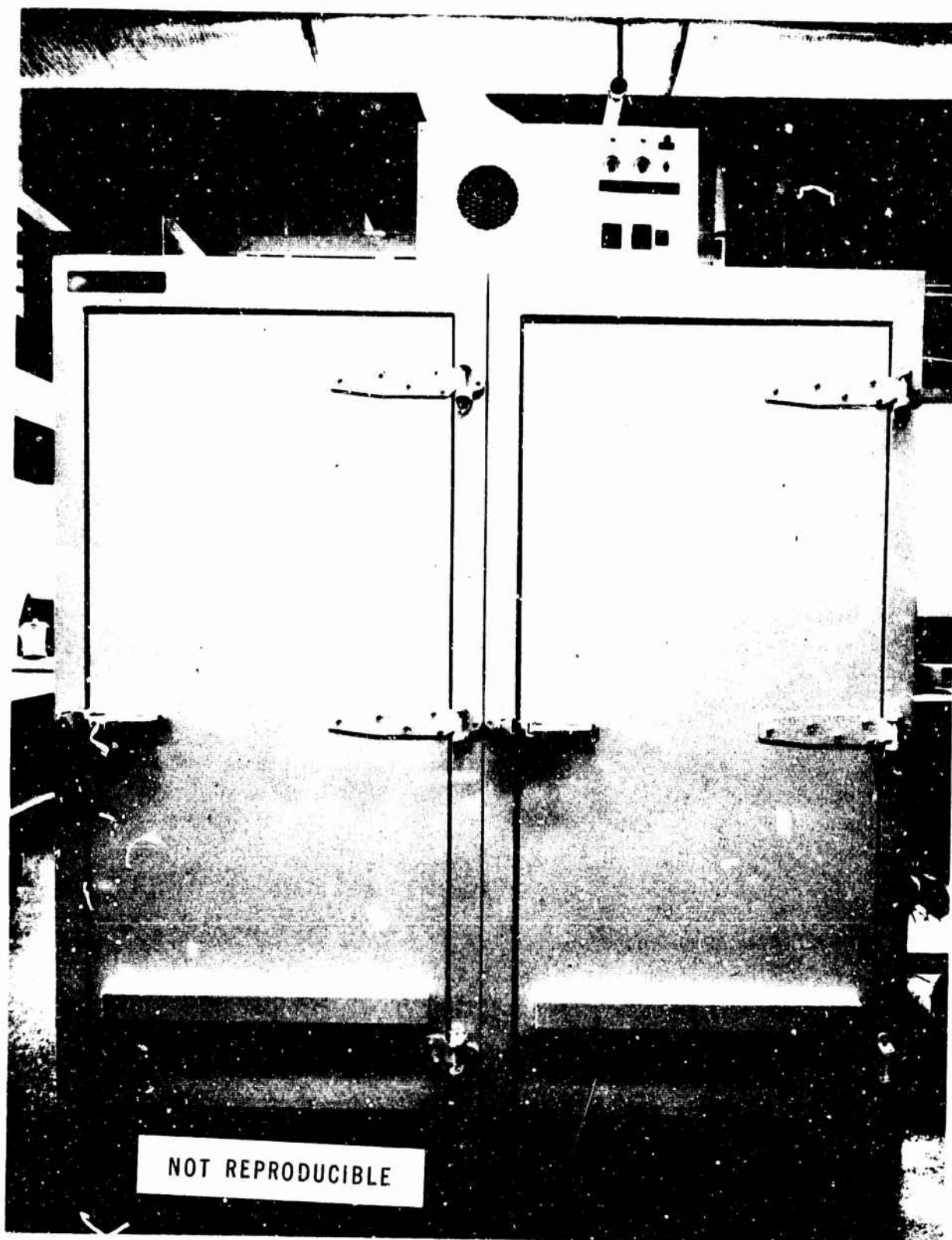


Figure 6. Two-Compartment Proof  
Box and Control Panel

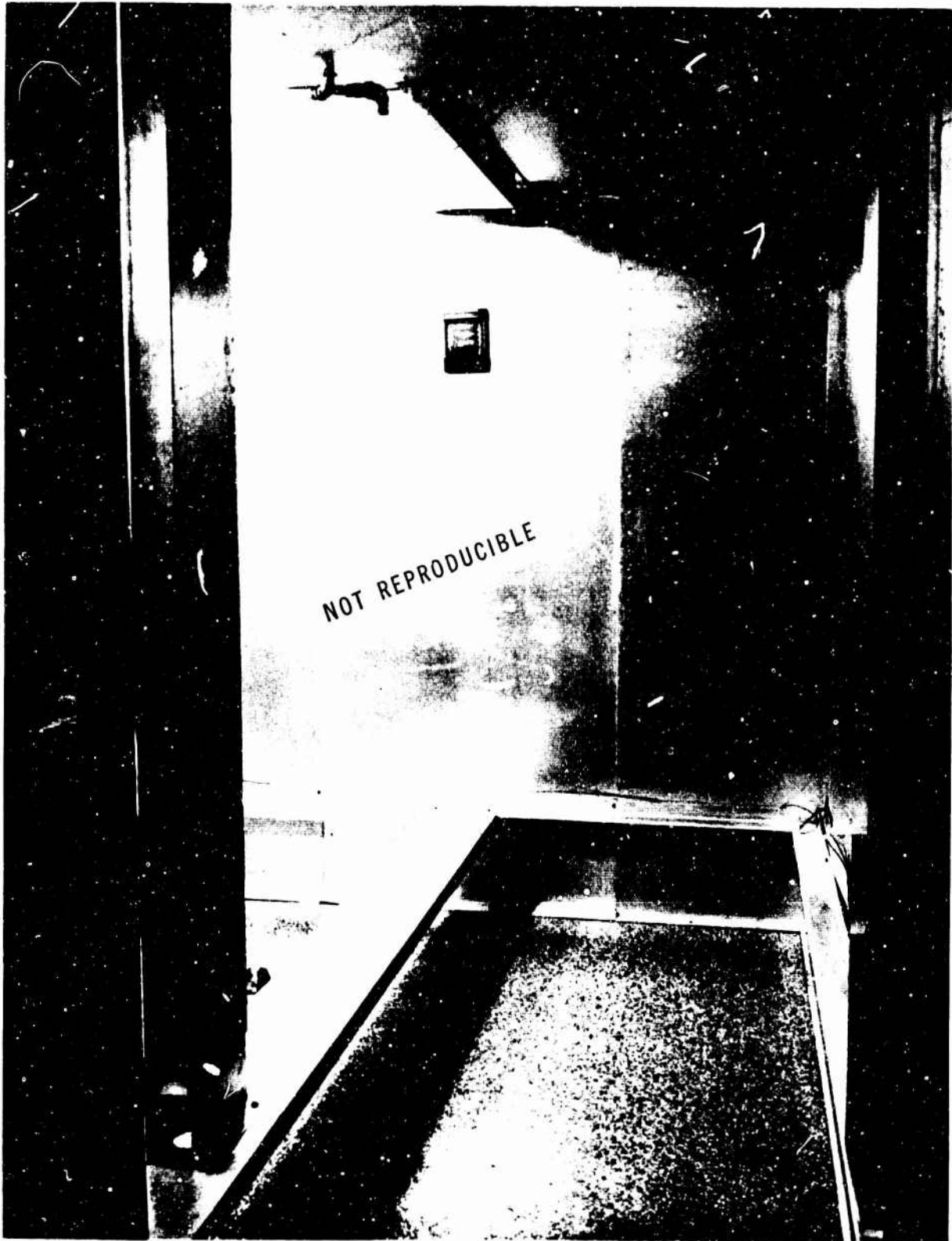


Figure 7. Interior of Proof Box

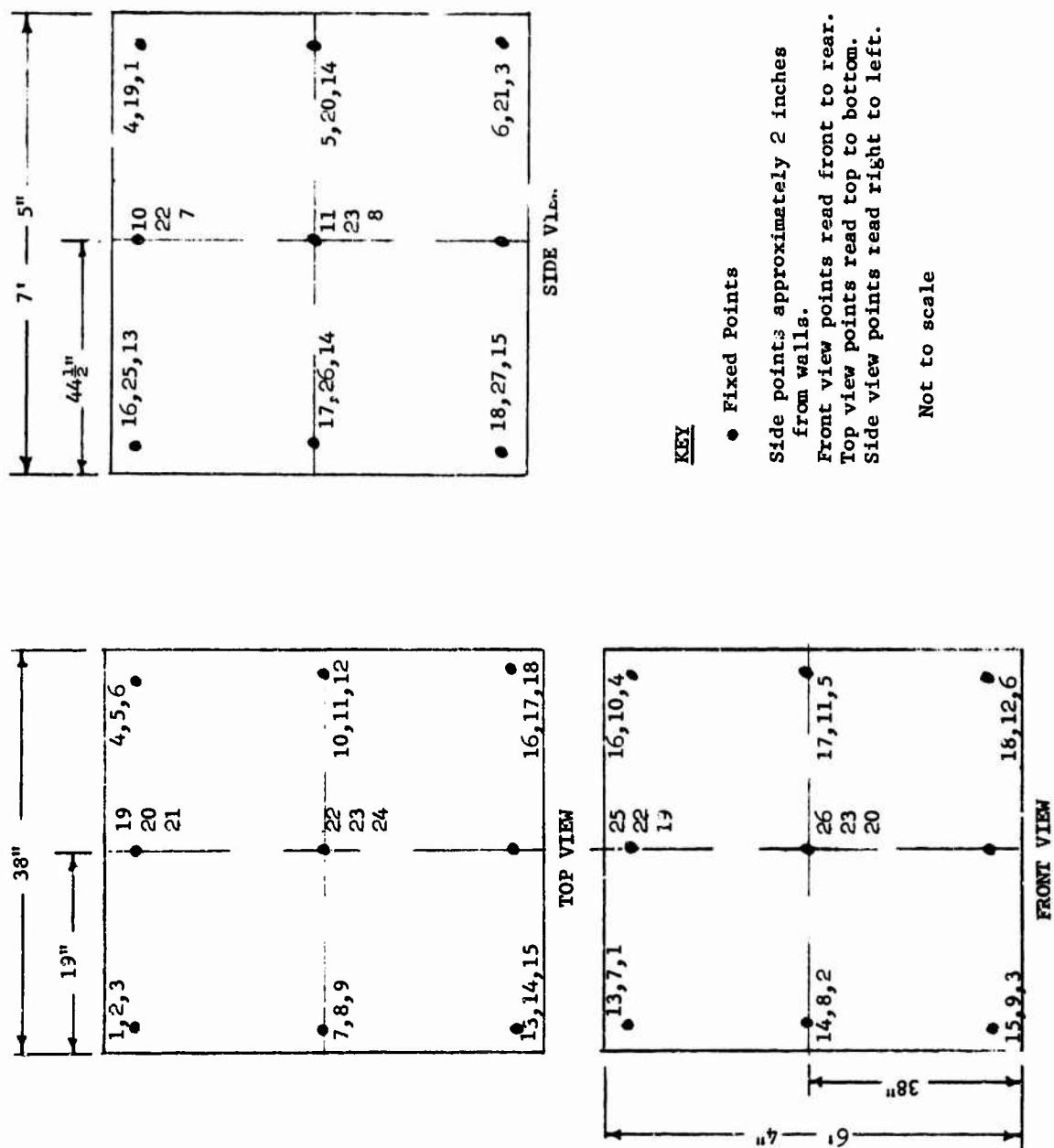


Figure 8. Thermocouple Layout for Determining Temperature Characteristics of Convection Baking Oven.

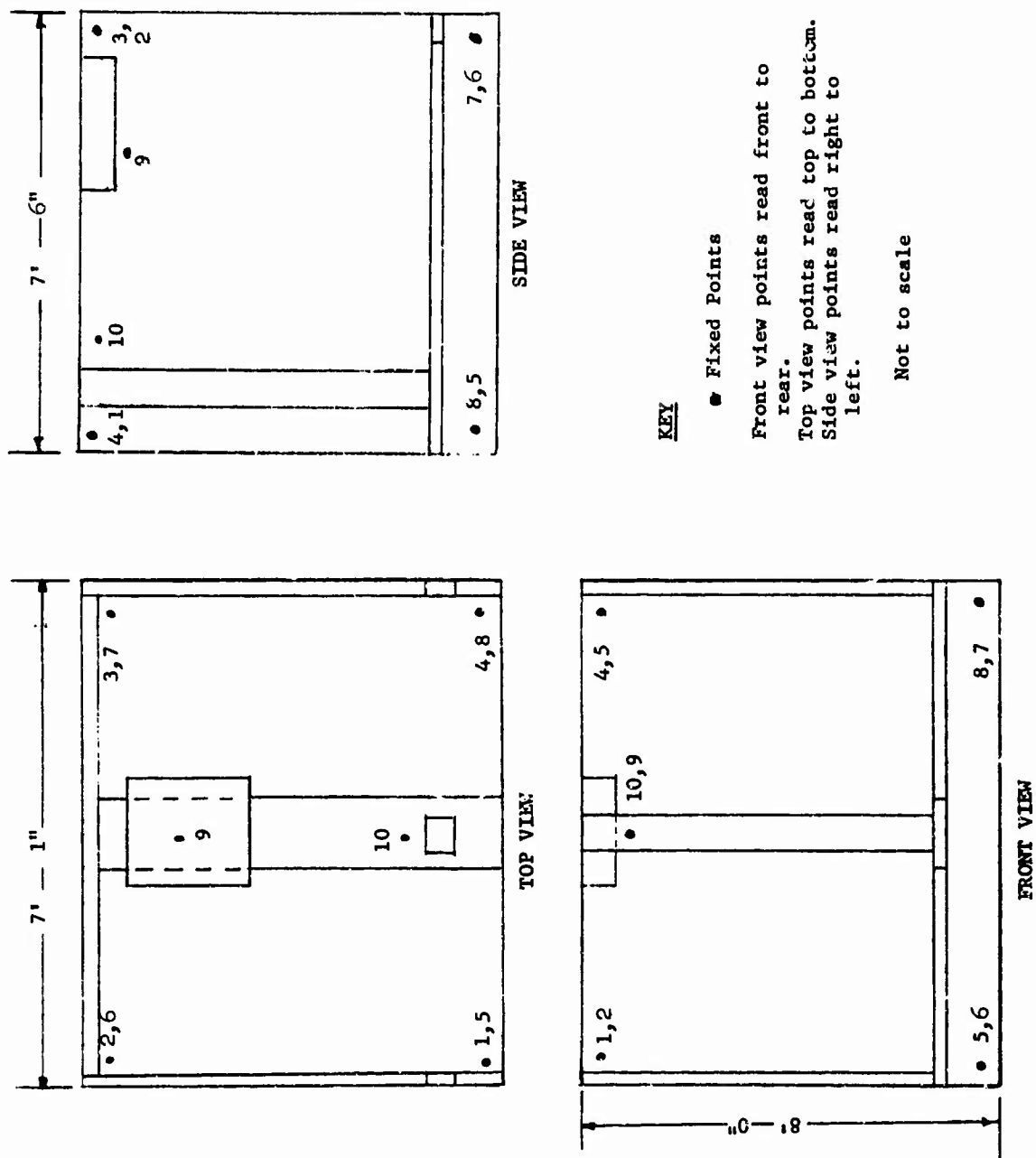


Figure 9. Thermocouple Layout of Determining Temperature Characteristics of Proof Box.