PRELIMINARY EVALUATION OF AN ENERGY-CONSERVING LOCALIZED-CONTROL RESIDENTIAL KITCHEN RANGE HOOD PROTOTYPE

by

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INTRODUCTION

Of the numerous energy conservation practices encouraged for residential homes, kitchen ventilation has received very little attention. Yet a kitchen exhaust hood may have an influence on the heating and cooling load for a kitchen and surrounding space areas. A residential kitchen vented hood is involved with the room air environment in two ways. First, it is a means of controlling indoor air quality by capturing cooking contaminants generated during the cooking process. Secondly, conditioned air is captured and exhausted outside, with the result that more air must be conditioned to replace that which is lost. In a recent article published in the Manhattan Mercury [10], it emphasized as houses become more tightly sealed to conserve energy by reducing air infiltration, indoor air contaminant levels will increase. Residential kitchen exhaust hoods will become increasingly essential, as a means of removing cooking effluents in order to control indoor air quality. However, conditioning new air (heating and humidifying, or cooling and dehumidifying) to replace that exhausted in the process of removing cooking contaminants is costly for the consumer.

Maintaining indoor residential air quality is achieved by operating an efficient kitchen exhaust hood. Annis and Annis [6:727] refer to "capture efficiency" as the ability of an exhaust hood to capture a certain percentage of cooking pollutants which are generated during the cooking process. Annis and Annis [6] and DallaValle [8] claim capture efficiency of a kitchen exhaust hood is dependent on several factors which include: type of pollutant, volumetric air flow, lower edge of hood height above range surface, location of intake(s), hood depth and width.

Annis [4] demonstrated that two effective means of controlling cooking effluents are to lower the hood from the common installation height of 30-in. to 18-in. above the range surface and secondly to operate the kitchen exhaust hood at a higher volumetric air flow. The filter intake(s) would be closer to the source generating the pollutant and the high velocity air currents capture a larger percentage of the cooking effluents.

This thesis will explore whether a residential kitchen hood can be designed to have the filter intake(s) sufficiently close to the source generating the cooking pollutant that the volumetric air flow could be drastically reduced. The desired effect would be reduction of conditioned air lost.

Background Information

Cooking contaminants

Cooking generates the following air contaminants: water vapor, odor, smoke, heat and grease aerosol. The American Society of Heating, Refrigerating and Air Conditioning Engineers [1] states the rate at which a contaminant disperses is related to it's particle size, particle density and air movement. Smaller and lighter particles, or molecules, such as water vapor and odor (approximately 0.0004 μ in diameter) and smoke 0.1 to 0.3 μ in diameter) diffuse quickly by Brownian movement while larger heavier particles like grease aerosol (1.0 μ in diameter) depend upon air currents. Cooking effluents that are not captured by an exhaust hood escape into the kitchen environment and spread throughout the dwelling causing damage and discomfort to the occupants. Grease and smoke pollutants are a nuisance and cause severe damage to furniture, walls and furnishings such as drapes. Heat and moisture result from gas combustion or electrical resistence heating of a range and by cooking foods. This heat and water vapor are limited to the kitchen environment, depending on floor plan design and openness, and do very little to maintain the entire dwelling at design conditions during the winter months. However, such heat and moisture gains during the summer months increase the amount of energy required to maintain a comfortable environment in the home. Indoor winter and summer design conditions (dry-bulb and wet-bulb temperatures) of a dwelling vary depending upon the home's geographical location.

Function of a vented hood

The function of a residential kitchen vented hood is to capture cooking effluents. A vented hood draws cooking effluents into its blower by induced air currents and discharges the contaminated air outside. The resultant negative pressure causes make-up air to be introduced into the kitchen to replace that which is captured and exhausted with the cooking contaminants. An expanded loose mesh aluminum filter is positioned at each filter intake to prevent lint and grease aerosol from collecting in the fan and ductwork, thus reducing the danger of fire. A certain percentage of cooking effluents is captured and removed permanently from the environment.

Minimizing energy loss from exhaust hoods

Maynard [11] notes space heating accounts for 63.5% of the total energy operational costs for a typical home. Energy expenditures to condition the air in a dwelling can be reduced by intelligent operation of the kitchen exhaust hood. The Department of Energy and Consumer Research Magazine [9, 12] have identified kitchen ventilation as a source of energy loss, since expensive conditioned air is exhausted, and they recommend that a kitchen exhaust fan operate no longer that absolutely necessary. Another source, Handbook of Energy Conservation For Mechanical Systems in Buildings [14], suggests reducing the air quantities exhausted from the kitchen when feasible and implementing a filter maintenance program to ensure peak efficiency.

Research

The only studies investigating residential range exhaust hood evaluations have been those conducted at Kansas State University [2, 3, 4]. In 1962, Annis and Annis [2] evaluated a number of vented and recirculating hoods for performance characteristics. Findings most important to the present investigators study were the air flow measurements and removal effectiveness values for water vapor, smoke and grease aerosol cooking pollutants. This early study reported the kitchen vented hoods tested were superior to the recirculating hoods by performing at higher volumetric air flows and having higher removal effectiveness values for the three pollutants generated.

Annis and Annis were requested to compare the performance of a vented hood and two types of recirculating hoods (activated carbon and electro-static) by the Federal Housing Administration in 1964 [3]. The investigators duplicated and refined their earlier procedures for air flow and removal effectiveness evaluation, with the goal of developing standard test procedures. They reported the vented hood when operated at 100 cubic feet per minute (cfm) had a far higher removal effectiveness value compared to the activated carbon or electro-static recirculating hoods which were operated at 189 cfm and 40 cfm respectively.

Annis [4] reported that energy losses can be reduced while maintaining the equivalent removal effectiveness by locating the filter intake(s) 18-in. above the range surface and operating the hood at a low air flow rate of 83 cfm, a two-thirds reduction from the typical 250 cfm air flow. Calculations indicated cooling energy demands for a Manhattan, Kansas home were reduced 35% annually when the vented hood was operated at 83 cfm.

New improved vented hood design

Recently, a down-draft cooktop with a retractable ventilation unit positioned at the rear of the range cooking surface was introduced by Thermador/Waste King [16]. This innovative design, Cook'n'Vent, model CV-336 ventilator, employs the concept of locating the filter intake close to the source of pollution, but it is designed perpendicular to the range surface and is quite a distance from the two front elements. Tappan [15] also has a down-draft ventilation system for the range available in the market. The modular cooktop, Converta-Cook models 13-1581 and 13-281, are designed with the retractable down-draft unit placed in the center of the range and perpendicular to the cooking surface. A variety of modules (such as open coil, grill, griddle or rotisseries) can be inserted on one or both sides of this vent.

Objectives

An alternative to the currently marketed kitchen vented hoods today would be localized effluent control that captures cooking pollutants at their point of origin. A hood can be lowered only so far without interferring with normal cooking tasks. An extended duct with the filter intake(s) section lowered parallel to the range surface could act as a cooking utensil's lid (for some cooking tasks) and allow the food preparer to lower or raise the duct to facilitate cooking tasks such as inspection, stirring and addition of ingredients. A localized-control vented hood would have the advantage of placing the hood intake within inches of the cooking utensil, resulting in a reduction of volumetric air flow rate required to capture the contaminants.

It is the purpose of this study to evaluate the effect a localized-control vented hood has upon the amount of cooking contaminant captured and the impact it has on the conditioned air in the kitchen space. Specific objectives for this study are the following:

1. Measure the capture effectiveness of a conventional vented hood operated at three heights and three volumetric air flows

2. Investigate the improved effectiveness and/or reduced air flow requirements of a localized-control vented hood

EXPERIMENTAL ENVIRONMENT, EQUIPMENT AND PROCEDURE

Testing was conducted in Justin 328, Household Equipment Laboratory, Kansas State University, Manhattan, Kansas. This large equipment laboratory facility was designed with four distinct areas. All testing was conducted in the area designated as number one on the floor plan in Figure 1.

Test Environment

The test chamber was 9 ft-9-in. by 14 ft by 8 ft-1 1/2-in. high. This 136.5 sq ft space meets the minimum standard for a four bedroom house established by Housing and Urban Development [17]. All interior walls were constructed of 4-in. metal stud, 16-in. on center, 3/4-in. metal lath, smooth finish gypsum plaster, 4-in. rubber baseboard and two coats of water base latex paint. The ceiling had a white sand finish plaster and the floor 9 by 9 by 1/8-in. vinyl asbestos tile. No structural changes, nor painting had occurred to this test chamber area since the original building construction.

The west wall of the test chamber had a north and south entry leading from the open laboratory into the testing chamber. To maintain a stable environment in the test chamber, 2 by 2-in. wooden frames were constructed to fit the northwest and southwest openings. Warp Flex-O-Pane, 5 gauge, was stapled onto the southwest wall creating a portable wall whereas Warp Flex-O-Glass, 4 gauge, was used for the northwest wall section, creating a door which allowed the researcher to enter during data collection periods. Felt strips, 3/4-in. wide, were glued around

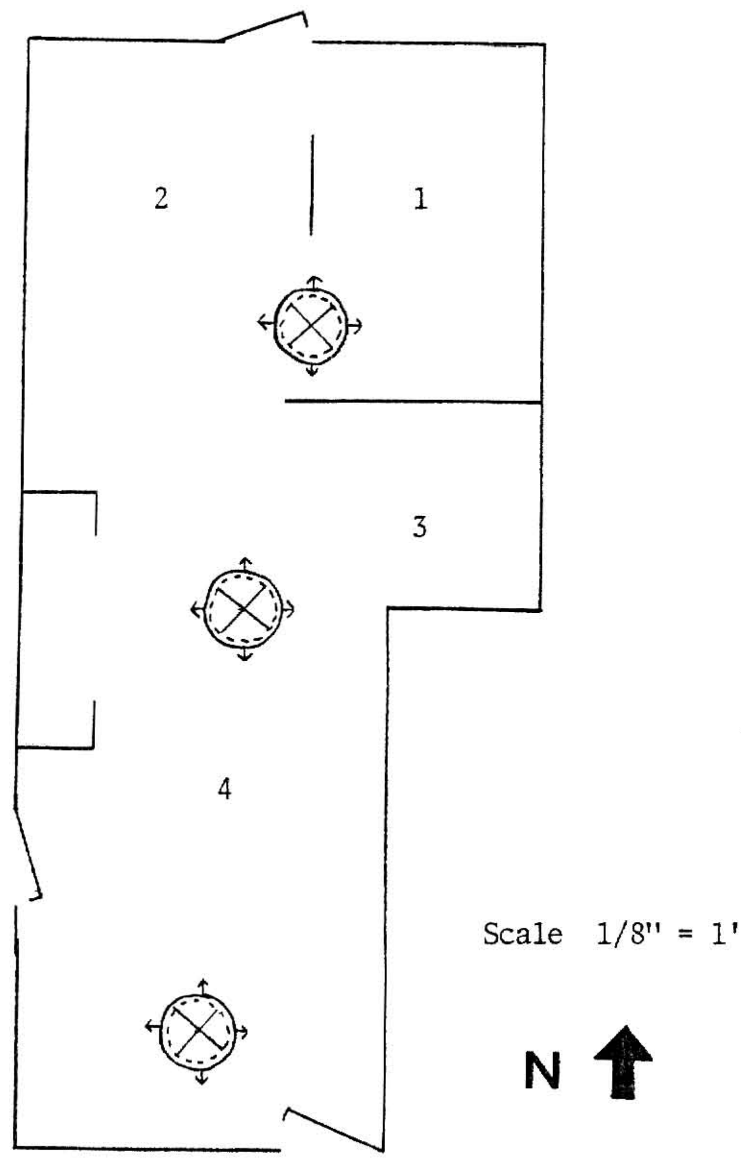

Figure 1. Floor plan of household equipment laboratory

the exterior edges of the frames, flush with the permanently constructed wall and floor to restrict air infiltration.

Three circular 30-in. ceiling diffusers supply conditioned air for Justin 328, one of which was centered over the southwest plastic wall. This diffuser was removed and the hole covered by a piece of poster board so that air from this diffuser would neither dilute the cooking contaminant nor create unnatural air movements.

Pilot tests revealed the test chamber air to be stratified due to lack of air movement. This situation was corrected by introducing make-up air when the hoods were operating through a triangular opening of the southwest plastic test chamber wall which was held in position by masking tape, see Plate I-A for a picture of this arrangement.

Test Equipment

Test equipment included two designs of one kitchen vented hood. For the purpose of this study "conventional vented hood" will denote the vented hood was tested as designed by the manufacturer and the "modified vented hood" will denote the same exact design as the conventional vented hood with the exception of the intake configuration design. Other equipment necessary for this study were an electric element, psychrometers, electrical instruments and accessories. All equipment was located and operated in the test chamber, with the exception of the balance, unless otherwise specified in the sequence of operations. Figure 2 illustrates the location of all testing equipment in the test chamber (Range No. 2 was not used for this study).

Plate I-A Southwest plastic test chamber wall

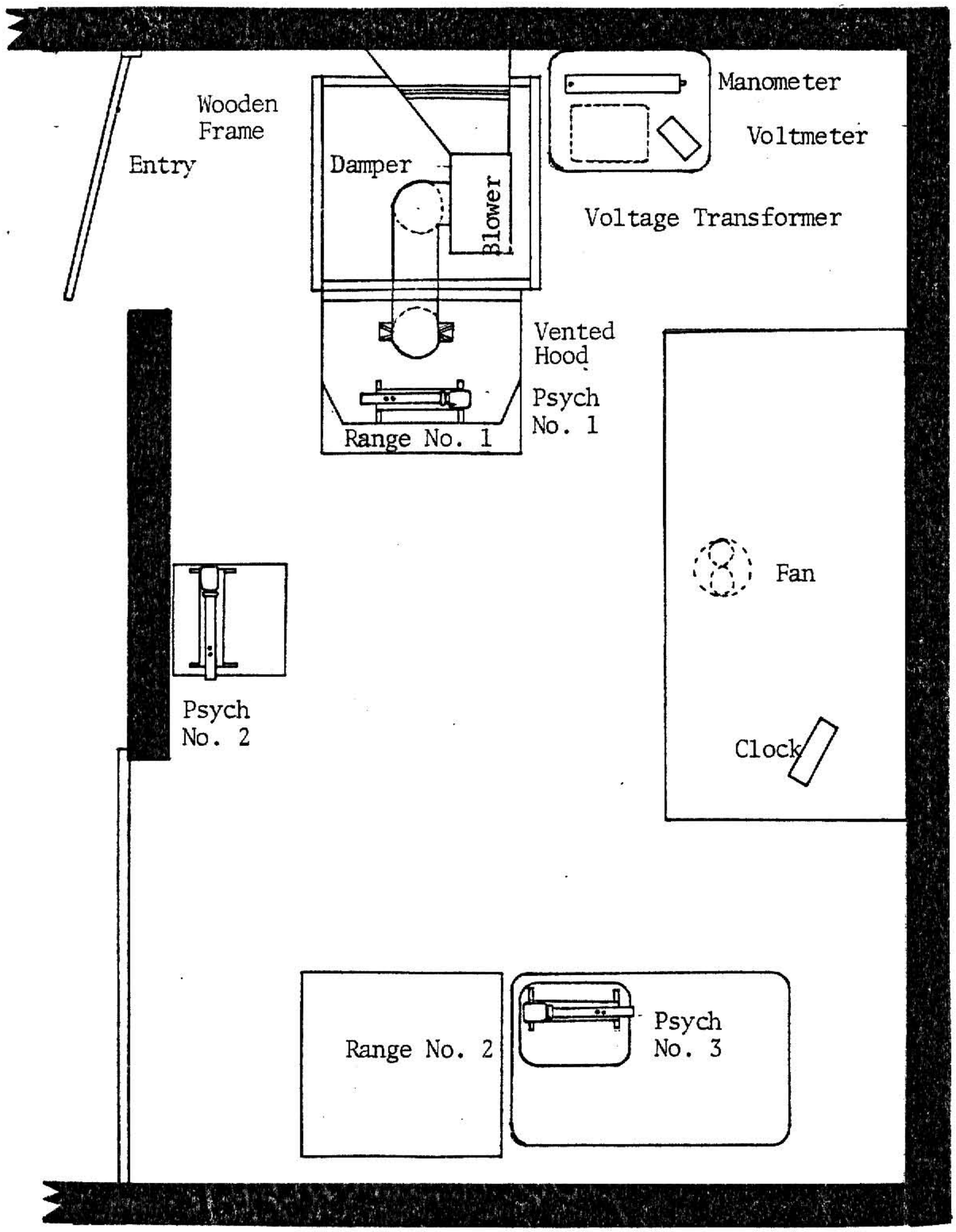

Figure 2. Arrangement of test equipment

Conventional vented hood

Evaluating the performance of a conventional vented hood for all tests had the distinct advantage over a recirculating hood of permanently removing all captured cooking contaminants by exhausting outside. A recirculating hood permanently removes a certain percentage of cooking contaminants which are captured, and returns the remainder to the living space. Removal effectiveness of a recirculating hood is dependent upon the types and condition of the filter(s) and the cooking contaminant generated. A recirculating hood cannot permanently remove heat and moisture, whereas a vented hood can remove these pollutants. Recently Consumer Reports [7] stated "Recirculating hood fans are of almost no value, except to reduce airborne grease."

The conventional vented hood used for testing was a Broan model 15000. It had a double vertical centrifugal fan (5.2-in. diameter and 2.2-in. depth) with an open motor rated at 1.2 amps. This hood was equipped with a top and back discharge (3-1/4 by 10-in.), a back-draft damper, and measured 18-in. in depth (front to back), 7.5-in. in height (bottom to top of rim) and 36-in. wide. This Broan model had two vertical intakes (9-1/2 by 8-in.) positioned 10-in. apart and located over the inner sides of the back elements. Each intake had a filter, 0.4-in. thick, of loose mesh aluminum. Annis [4] has reported this intake configuration as a superior design compared to horizontal designs available in the marketplace today.

Attached to the conventional vented hood's top discharge was a 3-1/4-in. by 10-in. rectangular to 6-in. transition piece, followed by a 6-in. to 8-in. diameter transition section. An 8-in. diameter poster board tube connected the 8-in. transition to an 8-in. diamter, five piece adjustable elbow for the conventional vented hood tested at 18-in. and 22-in.

heights. A band clamp joined the section for the conventional vented hood tested at 30-in. Joined to the five piece adjustable elbow was a 6 ft long, 8-in. diameter round pipe which had a flow nozzle and two 4-tap piezometer rings circling it 4-in. from the face of the nozzle. A four piece adjustable elbow connected the 6 ft long pipe to the auxiliary blower, which discharged into the building's ventilation system.

Modified vented hood

The innovative localized-control vented hood was designed by Assistant Professor Patty J. Annis, Kansas State University, and Dr. Jason C. Annis, mechanical engineer and air contaminant consultant, Manhattan, Kansas. The manufacturered filters were removed from the conventional vented hood and fabricated intake ducts were inserted for all modified vented hood tests. Other than the insertion of the fabricated intake ducts, all duct transition pieces were the same as the conventional vented hood.

A rectangular frame 9-7/16 by 8-in. with a 4-in. diameter hole was custom fabricated using 28 gauge galvanized steel. A four piece adjustable elbow, constructed from 30 gauge galvanized steel, fit into the frame's 4-in. diameter hole by means of dove tailing and was crimped at the other end. A galvanized 4-in. round pipe with a snap lock was attached to the crimped edge of the four piece adjustable elbow by 1/8-in. steel blind rivets. A 28 gauge galvanized steel custom fabricated 6-in. extension piece, 4-in. in diameter, was joined to a 4-in. diameter expanding to 8-in. diameter cone shape using 1/8-in. steel blind rivets. This extension with the cone shape configuration slid on the 4-in. diameter round snap lock pipe and was easily adjusted for various heights. Duct tape was used to seal every seam on the modified vented hood intake configuration and also held the cone shape attachment securely in place for each desired testing height. A 4-in. diameter piece of loose mesh aluminum filter was positioned at the intersection of the cone shape and extension piece. Another cone shape, 4-in. in diameter expanding to 12-in. diameter cone shape was also custom fabricated and assembled, however this larger modified intake configuration was sealed at the bottom of the 4-in. round snap lock pipe and was not used for this study. Plate II-B illustrates the four piece adjustable elbow attached to the custom fabricated frame and round snap lock pipe while Plate II-C is a view of the modified vented hood intake configurations. Specifications for the modified intake configuration used for this study can be found in Appendix A.

Range

A 30-in. Roper gas range, model 1353004, identified as Range No. 1 in Figure 2, was used for all tests. However, no gas burner was used for testing; instead, the range was equipped with an electric element positioned at the right rear burner space. The researcher elected to incorporate an electric element to avoid calculating water vapor given off during the gas combustion process of a burner. The electric element was a 6-in. diameter Tuttle & Kift, No. 75168, rated at 118 volts and 1250 watts.

Psychrometers

A psychrometer is one type of hygrometer which measures humidity. Various air properties for a given space are determined from two measured temperatures, wet bulb (t_{wb}) and dry bulb (t_{db}): humidity ratio (W), dew point and relative humidity. This study recorded the t_{wb} and t_{db} periodically during each run to determine the increase in room humidity ratio W (pounds of water vapor per pound of dry air in a given air mixture).

All three portable psychrometers for this study had matching

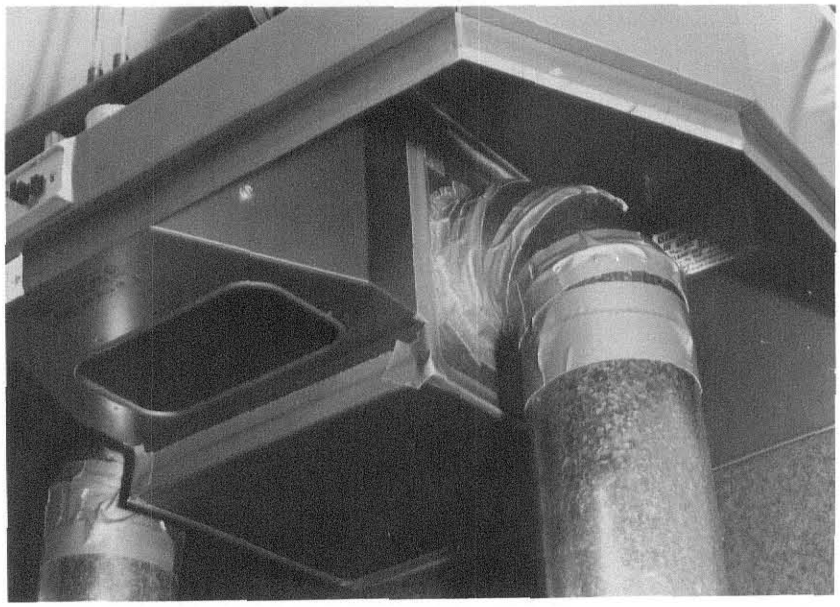

Plate II-B Close-up of modified intake configuration

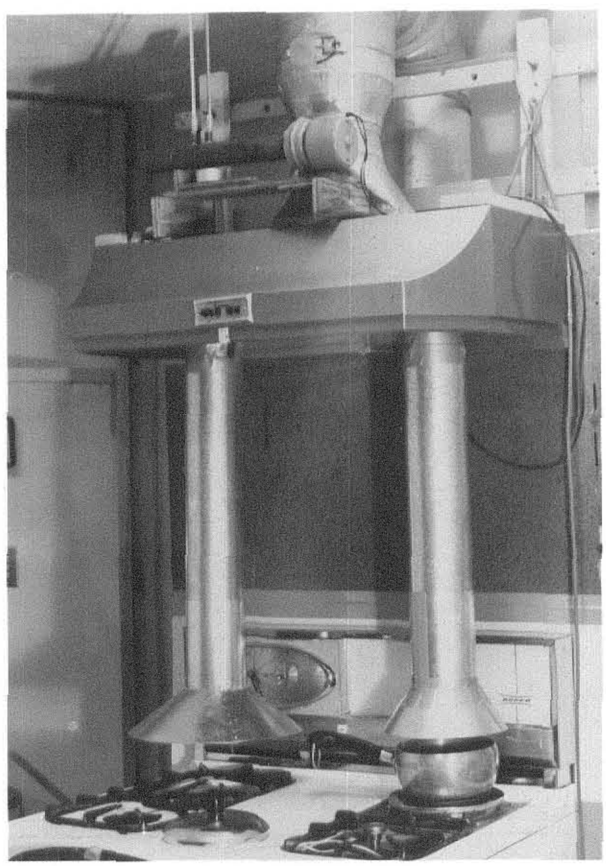

Plate II-C Modified vented hood intake configuration thermometers with a range of 20° to 120° F in 0.5° F increments. The t_{db} measured the normal air temperature while the t_{wb} had a sock on the end of the bulb which was immersed in a reservoir of distilled water. Plate III-D illustrates the thermometers mounted in a 1-3/8-in. diameter tube, 12-in. long. Each motor had a blower drawing 13 cfm through the tubing, resulting in an air flow of 903 fpm, which is slightly above the 900 minimum recommendation for psychrometers.

Psychrometers, positioned at three locations and three heights, allowed the researcher to have a fairly representative air property sample of the entire test chamber. Psychrometer No. 1, located on top of the range hood, had a Dayton, model 2C782 blower. The bottom of the 12-in. long tube was 79-in. from the floor. Psychrometer No. 2, located on a small table in front of and to the left of the range had a Dayton, model 2C782 blower. The bottom of the 12-in. long tube was positioned 32-1/2-in. from the floor. Psychrometer No. 3, using a Fasco, No. 507-45 blower, was located by the south wall opposite the range. This psychrometer was positioned on a wire basket which was placed on a table, and the bottom of the 12-in. long tube being 44-1/2-in. from the floor.

Flow nozzle and manometer

An ASME long-radius flow nozzle, 3-1/8-in., discharged into a section of 8-in. round duct which was fastened air tight to an auxiliary blower. Two 4-tap piezometer rings circling the 8-in. duct were positioned 4-in. from the face of the nozzle. Clear plastic tubing, 3/16-in. in diameter, joined the pressure taps to an inclined manometer. Two different manometers were used for this study. All evaluation tests for the conventional vented hood employed an Ellison Inclined Draft Gage which had a range of 0.0 to 2.0-in. and gradations equal to 1/100-in. of water pressure. Another manometer, Meriam, type GP, model GP-1, had a range of 0.0 to 0.5-in. which allowed greater accuracy for the modified vented hood tested at lowered air flow rates. This manometer also had gradations equal to 1/100-in. of water pressure. Plate III-E illustrates the Meriam manometer positioned on the cart (and arrangement of electrical equipment).

Auxiliary blower/damper

Air flow for the conventional and modified vented hood tests was controlled by the damper on the auxiliary blower. The auxiliary blower had an 8-in. diameter opening to which a 90^{o} adjustable elbow was sealed to, and then was connected into the building's ventilation system at the north wall return duct. Connected by belt drive to the auxiliary blower was a Craftsman, 1/2 horsepower, model 113.12120 motor. The auxiliary blower was operated when the conventional vented hood was operated at 200 cfm or 300 cfm and when the modified vented hood was operated at 100 cfm.

Voltage transformer

A Variac Autotransformer, type W20M, regulated the amount of voltage delivered to the electric element, eliminating any resistence variance due to the building load. This voltage transformer, located on the bottom of the cart in Plate III-E, had a range of 0 to 140 volts which was regulated by a dial.

Voltmeter

The voltage at the element was measured by a voltmeter, manufactured by Jewel Electrical Instrument Co., which had dial ranges of 150 and 300 volts. The voltmeter is to the right of the manometer in

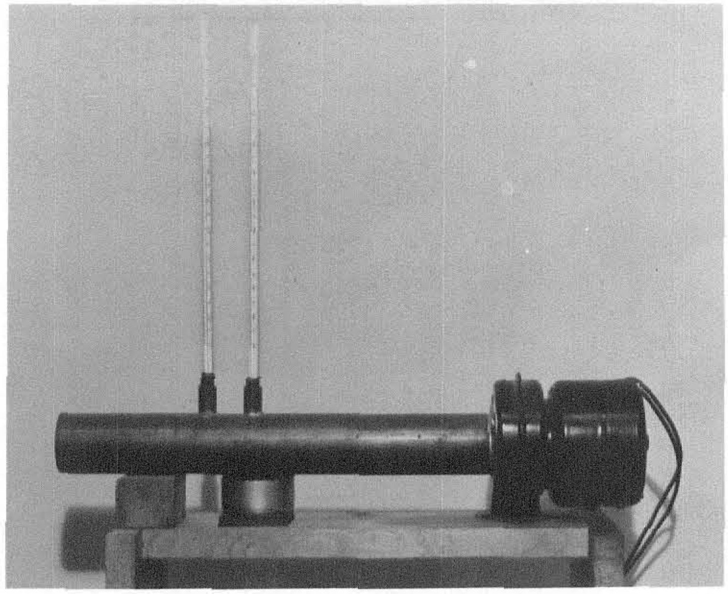

Plate III-D Psychrometer

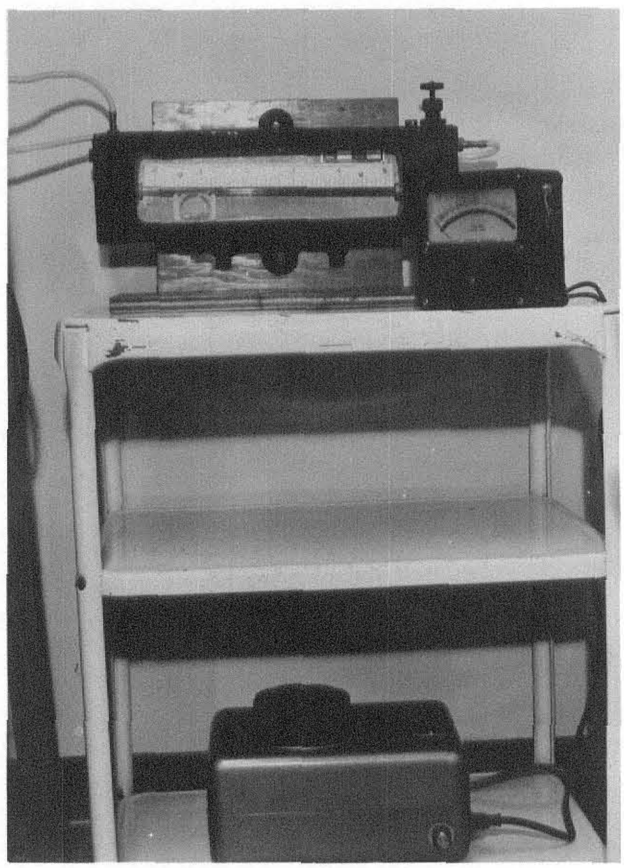

Plate III-E Manometer and electrical equipment

Plate III-E.

Fan

When the conventional vented hood was not operating during a run, air in the test chamber was stagnant because the test chamber had been sealed. Thus a fan, General Electric, No. S16275, 220 volts, was positioned on the floor, oscillating at low speed in the direction of psychrometers No. 2 and 3. This fan was also operated for all modified vented hood runs. The filter intake on the modified vented hood was considerably closer to the cooking utensil than the filter intake on the conventional vented hood. This means that air movement in the test chamber was more restricted during tests of the modified vented hood than during the conventional vented hood tests. Thus, the fan oscillated at a low speed for all modified vented hood runs providing a representative air sample for data collection. This fan failed before all the modified vented hood runs were completed. It was replaced with a Sears fan, model 453-800002, 120 volts, which was similarly positioned and set to oscillate at 90° and at a low speed (approximately equivalent to the General Electric low speed setting).

Cooking utensil

A 1-1/2 qt Wearever Aluminum saucepan (model 2102) with a 6-in. diameter opening was the utensil used when generating the cooking contaminant. This saucepan is representative of saucepans available in the marketplace today and had been used in a previous study conducted by Annis [4].

Accessories

Balance. An Ohaus Harvard Trip Balance, No. 4003, was used to weigh all water. It has a capacity of five pounds (two kilograms) and was sufficient for testing needs.

Clock. A GraLab, model 171, was used for the intervals of psychrometer readings. This clock had a second hand.

Ammeter. A clamp-on split armature ammeter was used to measure the current of electricity going into the electric element. The clamp-on split ammeter was a Amprobe instrument, model Y550.

Air velocity meter. A Hastings directional probe air velocity meter, B-22, probe type S-22A, was used to identify undesired air infiltration around the portable plastic walls and duct work. The air velocity meter had ranges of 0 to 500 fpm and 500 to 10,000 fpm. Taped duct work and the blower damper were periodically examined for air leakage due to time and movement of duct work. Any detectable air leaks were re-taped securely.

Cooking Contaminant Generated

Annis and Annis [6] identify five cooking contaminants as indoor sources of pollution: water vapor, odor, smoke, heat and grease aerosol. A complete evaluation of a conventional versus a localized-control vented hood requires a removal effectiveness test for each of the cooking contaminants listed. This study attempts to evaluate the contaminant water vapor only. Water vapor molecules and smoke particles are relatively small in size, both remaining suspended in air much longer than grease aerosol. It is hypothesized that water vapor disperses more rapidly than smoke, a hypothesis supported by previous research conducted by Annis and Annis [6].

Distilled water, weighing 794.7 grams, with a temperature range of 72.5^{o} to 78.5^{o} F was used for all runs when boiling water. Initial and final water weight was determined in area two, illustrated in Figure 1.

Procedure

Experimental procedure

Annis and Annis [2] developed an experimental procedure for water vapor removal effectiveness by boiling water and eggs. An electric hot plate was used to boil the eggs (total initial weight of water and eggs was 1231.1 grams) and three psychrometers were positioned in the test chamber to measure the change in room humidity ratio ($\triangle$ W). Consistency of the runs was verified by recording the final weight of the water and eggs.

In 1964, a standard for measuring water vapor removal effectiveness for a kitchen range exhaust hood was developed for the Federal Housing and Administration by Annis and Annis [3]. This investigation involved the use of water, only, with carefully controlled boiling rates. Removal effectiveness was determined by a series of runs with the exhaust hood operating and the exhaust hood not operating (referred to as "on" and "off" runs respectively).

Procedural development

Each vented hood was mounted at various heights on a wooden frame which was positioned behind the range. The height and volumetric air flow rates for the conventional and modified vented hoods were identified by referring to specification sheets and previous research reported by Annis [4].

Conventional vented hood. Current specification sheets for conventional vented hoods list air flows of 100 cfm to 350 cfm. To represent the air flows of conventional vented hoods available in the marketplace and to compare with previous research reported [4], 100 cfm, 200 cfm and 300 cfm were the volumetric air flow rates selected for this study.

Three heights measured from the range surface to the bottom rim of the hood were selected for testing: 18-in., 22-in. and 30-in. These heights, previously tested by Annis [4] were suggested as possible installation heights by manufacturers and are in accordance with the Housing and Urban Development requirement "...the bottom of the hood rim shall be not more than 30-in. above the range top" [17:*6-15-3].

Modified vented hood. In a previous study conducted by Annis [4], an exhaust hood positioned 18-in. from the range surface could have a 250 cfm air flow rate reduced to 83 cfm and still operate as effectively. To evaluate the modified vented hood, the present researcher selected 67 cfm and 100 cfm volumetric air flow rates representing a two-thirds reduction in air flow from the conventional vented hood operated at 200 cfm and 300 cfm respectively. A two-thirds reduction from 100 cfm to 34 cfm was not feasible with the auxiliary blower leading into the building's ventilation system.

Two heights measured from the top of the saucepan to the bottom of the 8-in. diameter cone shape were 1-1/8-in. and 6-in. The 1-1/8-in. height allowed the researcher to visually inspect the contents of the saucepan. The 6-in. height would allow a food preparer to perform the tasks of stirring food contents with a 12-in. long spoon and/or remove a utensil's lid for inspection.

There were three different tests conducted for the conventional vented hood and four for the modified vented hood. For purposes of this study, "test" will denote the selected hood and the conditions employed, while "run" will denote one data sample collected during a test series. If any run was conducted with the hood operating at any volumetric air flow rate the hood was considered "on" and if a run was conducted with the hood not operating, it was considered an "off" run.

Conditioning of the test chamber before any run was extremely important and a series of precautions were developed through pilot testing. The researcher was only in the test chamber to activate the equipment 90 to 60 minutes before beginning a run, to record psychrometric temperatures every 15 minutes until the test chamber reached a stable condition, and during the actual 28 minute run. All activity in the large household equipment laboratory was kept to a minimum and general use of the laboratory prohibited.

Tests conducted to determine the hood's removal effectiveness values were the following:

Test 1. Conventional vented hood "off" researcher in test chamber and water boiling (determine increase in humidity ratio without hood operating and to alert the researcher of air leaks in the test chamber)

Test 2. Conventional vented hood "on" researcher in test chamber and water boiling (determine the removal effectiveness of the hood)

Test 3. Modified vented hood "on" researcher in test chamber and water boiling (determine the removal effectiveness of the hood)

Other tests were performed to provide additional information concerning the amount of moisture given off by the researcher and air distribution in the test chamber. These tests included the following:

Test 4. Conventional vented hood "on" researcher in test chamber and no water boiling (determine the amount of moisture given off by the researcher)

Test 5. Modified vented hood "on" researcher in test chamber and and no water boiling (determine the amount of moisture given off by the researcher)

Test 6. Modified vented hood "on" researcher not in test chamber and water boiling (determine the amount of moisture given off by the researcher)

Test 7. Modified vented hood "on" researcher not in test chamber and no water boiling (determine effect of air changes in the test chamber)

A detailed operations and sequence of all the tests listed above are contained in Appendix B. An example of a data sheet used for recording t_{wb} and t_{db} with calculated Δ W average is illustrated in Appendix C.

RESULTS AND DISCUSSION

For this study, 217 runs were performed (March to September 1981). There were 106 completed runs for the conventional vented hood tests and 111 runs for the modified vented hood tests. Data for 22 of the conventional vented hood runs and 42 runs of the modified vented hood runs had to be discarded as a result of procedural development, equipment failure, or an unusual increase or decrease in the humidity ratio indicated by an individual psychrometer. Tables 1 through 14 list all the valid runs for determining removal effectiveness of hoods, while Table 15 lists runs which were discarded and their justification.

Experimental accuracy

Reproducibility of runs varied because of several factors. Test room hood make-up air was drawn from the adjoining laboratory space, which was being heated or cooled by the building's forced-air system. The building's system blended varying amounts of outside ventilation air, so changes in outside air properties would slowly be reflected in the test room air.

Other potential sources of error were equipment calibration, and human error in reading the balance, manometer and most importantly, the psychrometers. The psychormeters were marked in 0.5° F divisions, which the researcher read to the nearest 0.1° F. If the data recorder, who was seated outside the test chamber immediately identified any unusual increase or decrease for any t_{wb} or t_{db} reading, the researcher was asked to verify the reading. Appendix D illustrates the importance of precise t_{wb} and t_{db} readings given a $\pm 0.1^{\circ}$ F reading error.

The researcher did not remain in the test chamber constantly during pre-test because, as Rizzi [13] cites, the human body has sensible and latent heat losses. If the researcher remained in the test chamber constantly, these heat losses could have inhibited the stabilization period for the test chamber. Since the body is usually at a higher temperature than it's surroundings, a person frequently has a heat radiation loss while latent heat is given off by breathing and evaporation. The researcher was seated at rest during each run and had a heat loss of approximately 225 Btu/hr sensible heat and 105 Btu/hr of latent heat according to Rizzi [13]. Other heat gains in the test chamber were minute (electrical element and warm air from the blower and psychrometer motors).

Table 1. Test 1 results (conventional vented hood "off" installed at 18-in., 22-in. and 30-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
41	Conventional	0	18	240.3	.00397
67	Conventional	0	18	224.8	.00384
73	Conventional	0	18	209.9	.00340
21	Conventional	0	22	229.8	.00431
29	Conventional	0	22	227.0	.00416
74	Conventional	0	30	212.1	.00370
80	Conventional	0	30	217.5	.00452
93	Conventional	0	30	192.1	.00413

$\overline{X} = 0.004004$

$s = 0.000356$

Table 2. Test 2 results (conventional vented hood operated at 100 cubic feet per minute and installed at 18-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
42	Conventional	100	18	220.4	.00045
43	Conventional	100	18	223.4	.00052
44	Conventional	100	18	226.2	.00035
45	Conventional	100	18	222.3	.00042
46	Conventional	100	18	220.2	.00055
47	Conventional	100	18	220.2	.00044
53	Conventional	100	18	227.1	.00023
58	Conventional	100	18	221.8	.00050
59	Conventional	100	18	215.8	.00050
62	Conventional	100	18	229.2	.00033
69	Conventional	100	18	218.1	.00044
70	Conventional	100	18	222.5	.00046
71	Conventional	100	18	219.6	.00035

$\bar{X} = 0.000426$

$s = 0.000090$

Table 3. Test 2 results (conventional vented hood operated at 100 cubic feet per minute and installed at 22-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
12	Conventional	100	22	226.7	.00054
13	Conventional	100	22	230.5	.00052
15	Conventional	100	22	231.0	.00041
16	Conventional	100	22	218.5	.00049
30	Conventional	100	22	221.8	.00042

$\overline{X} = 0.000476$

$s = 0.000059$

Table 4. Test 2 results (conventional vented hood operated at 100 cubic feet per minute and installed at 30-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
75	Conventional	100	30	213.4	.00060
82	Conventional	100	30	229.5	.00066
87	Conventional	100	30	217.4	.00053
89	Conventional	100	30	220.8	.00058
92	Conventional	100	30	212.9	.00038
95	Conventional	100	30	216.5	.00046

$\overline{X} = 0.000535$

$s = 0.000102$

Table 5. Test 2 results (conventional vented hood operated at 200 cubic feet per minute and installed at 18-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
51	Conventional	200	18	217.6	.00021
52	Conventional	200	18	213.7	.00023
54	Conventional	200	18	214.9	.00013
55	Conventional	200	18	225.3	.00014
56	Conventional	200	18	224.5	.00010
57	Conventional	200	18	213.4	.00022

$\overline{X} = 0.000172$

$s = 0.000055$

Table 6. Test 2 results (conventional vented hood operated at 200 cubic feet per minute and installed at 22-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
17	Conventional	200	22	212.2	.00032
18	Conventional	200	22	235.7	.00018
19	Conventional	200	22	223.4	.00025
20	Conventional	200	22	217.3	.00016
31	Conventional	200	22	235.6	.00019
39	Conventional	200	22	219.8	.00035

$\overline{X} = 0.000242$

$s = 0.000079$

Table 7. Test 2 results (conventional vented hood operated at 200 cubic feet per minute and installed at 30-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
76	Conventional	200	30	202.2	.00025
81	Conventional	200	30	218.1	.00031
83	Conventional	200	30	229.0	.00030
85	Conventional	200	30	213.8	.00021
86	Conventional	200	30	222.4	.00033

$\overline{X} = 0.000280$

$s = 0.000049$

Table 8. Test 2 results (conventional vented hood operated at 300 cubic feet per minute and installed at 18-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
60	Conventional	300	18	221.3	-.00010
63	Conventional	300	18	224.9	.00010
64	Conventional	300	18	216.1	.00009
65	Conventional	300	18	206.1	.00007
66	Conventional	300	18	225.0	.00009
68	Conventional	300	18	220.2	.00004
72	Conventional	300	18	214.4	.00019

$\bar{X} = 0.000069$

$s = 0.000045$

Table 9. Test 2 results (conventional vented hood operated at 300 cubic feet per minute and installed at 22-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
28	Conventional	300	22	227.9	.00000
32	Conventional	300	22	226.2	-.00001
33	Conventional	300	22	211.1	.00007
34	Conventional	300	22	223.9	.00008
35	Conventional	300	22	232.7	.00006
36	Conventional	300	22	234.8	.00000
37	Conventional	300	22	226.5	.00009
38	Conventional	300	22	220.3	.00001
40	Conventional	300	22	224.5	.00007

$\overline{X} = 0.000041$

$s = 0.000037$

Table 10. Test 2 results (conventional vented hood operated at 300 cubic feet per minute and installed at 30-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
77	Conventional	300	30	218.1	.00021
78	Conventional	300	30	217.1	.00005
79	Conventional	300	30	214.6	.00005
84	Conventional	300	30	235.1	.00010
88	Conventional	300	30	218.4	.00021
90	Conventional	300	30	223.9	.00011
91	Conventional	300	30	215.9	.00011
94	Conventional	300	30	216.2	.00010

$\bar{X} = 0.000118$

$s = 0.000062$

Table 11. Test 3 results (modified vented hood operated at 67 cubic feet per minute and installed at 1-1/8-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
139	Modified	67	1-1/8	216.4	.00016
140	Modified	67	1-1/8	245.6	.00003
142	Modified	67	1-1/8	226.5	.00019
143	Modified	67	1-1/8	229.5	.00018
144	Modified	67	1-1/8	220.3	.00007
149	Modified	67	1-1/8	218.4	.00021

$\overline{X} = 0.000140$

$s = 0.000073$

Table 12. Test 3 results (modified vented hood operated at 67 cubic feet per minute and installed at 6-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
191	Modified	67	6	223.2	.00022
192	Modified	67	6	229.8	.00021
193	Modified	67	6	225.4	.00020
194	Modified	67	6	231.0	.00005
199	Modified	67	6	234.3	.00009
200	Modified	67	6	225.5	.00020
203	Modified	67	6	221.2	.00007
204	Modified	67	6	221.4	.00011
205	Modified	67	6	219.8	.00023
206	Modified	67	6	223.8	.00022

$\overline{X} = 0.000160$

$s = 0.000071$

Table 13. Test 3 results (modified vented hood operated at 100 cubic feet per minute and installed at 1-1/8-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
137	Modified	100	1-1/8	225.4	.00020
138	Modified	100	1-1/8	225.1	.00015
141	Modified	100	1-1/8	219.2	.00013
145	Modified	100	1-1/8	228.6	.00010
146	Modified	100	1-1/8	212.2	.00012
147	Modified	100	1-1/8	217.5	.00008

$\bar{X} = 0.000130$

$s = 0.000042$

Table 14. Test 3 results (modified vented hood operated at 100 cubic feet per minute and installed at 6-in. with researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
195	Modified	100	6	238.8	.00015
196	Modified	100	6	219.8	.00005
197	Modified	100	6	220.7	.00022
198	Modified	100	6	222.8	.00017
201	Modified	100	6	216.9	.00016
202	Modified	100	6	217.6	.00015

$\overline{X} = 0.000150$

$s = 0.000056$

Table 15. List of test runs discarded, with justification.

Run no.	Justification
1 - 11	Procedural development and arranging equipment
14	Final $\triangle$ W for Psych. Nos. 1, 2 and 3 low
22	Final $\triangle$ W for Psych. Nos. 1, 2 and 3 low
23	Final $\triangle$ W for Psych. No. 1 low, Psych. No. 2 high
24	Final $\triangle$ W for Psych. Nos. 1, 2 and 3 high
25	Final $\triangle$ W for Psych. Nos. 1 and 2 low
26	Final $\triangle$ W for Psych. No. 1 low
27	Final $\triangle$ W for Psych. No. 1 low
48	Final $\triangle$ W for Psych. Nos. 1, 2 and 3 high
49	Final $\triangle$ W for Psych. No. 3 high
50	Final $\triangle$ W for Psych. Nos. 1 and 3 high
61	Equipment failure
96 - 136	Procedural development
148	Final $\triangle$ W for Psych. No. 3 high

Data Analysis

Only data from Tests 1, 2 and 3 were used to determine the hood's removal effectiveness values for the statistical analysis. Data from Tests 4, 5, 6 and 7 are not incorporated into the statistical analysis, but provided the researcher with valuable information concerning the test chamber. Evaluation of the moisture given off by the researcher and the influence of air distribution is found at the end of this chapter.

Removal effectiveness

The first objective of this study was to measure the removal effectiveness of a conventional vented hood and, in turn, a modified vented hood. Using equations (1) and (2) below, based upon a previous study [2], the residuum ratio could be calculated and used to derive the removal effectiveness:

$$\text{Residuum ratio: } \frac{(\Delta W)_{on}}{(\Delta W)_{off}} \qquad \text{(Eq. 1)}$$

where: residuum ratio = fraction of water vapor not captured by hood

$(\Delta W)_{on}$ = the increase in humidity ratio of room air with hood operating (on), lb_m water/lb_m dry air

$(\Delta W)_{off}$ = the increase in humidity ratio of room air with hood not operating (off), lb_m water/lb_m dry air

$$\text{Removal effectiveness, \%} = (1 - \text{residuum ratio}) \times 100 \qquad \text{(Eq. 2)}$$

The hood's removal effectiveness increased as the cfm increased while the hoods were positioned at all heights. Table 16 illustrates a similar increase in effectiveness when the air flow was held constant but the hood height is increased, except for the air flow 300 cfm at the 22-in. height.

The modified vented hood removal effectiveness, when operated at any air flow at any height, results indicate it performed better than the conventional vented hood operated at 100 cfm and 200 cfm at any of the three heights tested. The removal effectiveness for the modified vented hood ranged from 96.0% to 96.8% compared to the conventional vented hood range of 86.6% to 95.7%.

A $(1 - \alpha)100$ confidence interval for μ is an interval running between two numbers referred to as a lower and upper boundry resulting in a $(1 - \alpha)100$ chance that μ is between the lower and upper boundry numbers. A 95% confidence interval was selected for the hood's removal effectiveness. Figure 3 illustrates a conventional vented hood operated at 300 cfm, at any height, and a modified vented hood operated at 67 cfm at a height of 1-1/8-in. and 100 cfm at a height of 1-1/8-in. or 6-in. all have lower and upper boundries of removal effectiveness greater than 95.0%.

Regression analysis

A linear regression was performed to measure the strength of the relationship between the variables air flow and increase in room humidity ratio for the conventional and modified vented hoods. The analysis investigated the extent to which hood air flow controlled the increase in humidity ratio of the air in the test chamber.

Table 16. Water vapor removal effectiveness for selected hoods at various air flows and heights.

	Water vapor removal effectiveness - percentages				
Air flow-cfm	Conventional vented hood height - in.			Modified vented hood height - in.	
	18	22	30	1-1/8	6
67	-	-	-	96.5	96.0
100	89.4	88.1	86.6	96.8	96.3
200	95.7	94.0	93.0	-	-
300	98.3	99.0	97.5	-	-

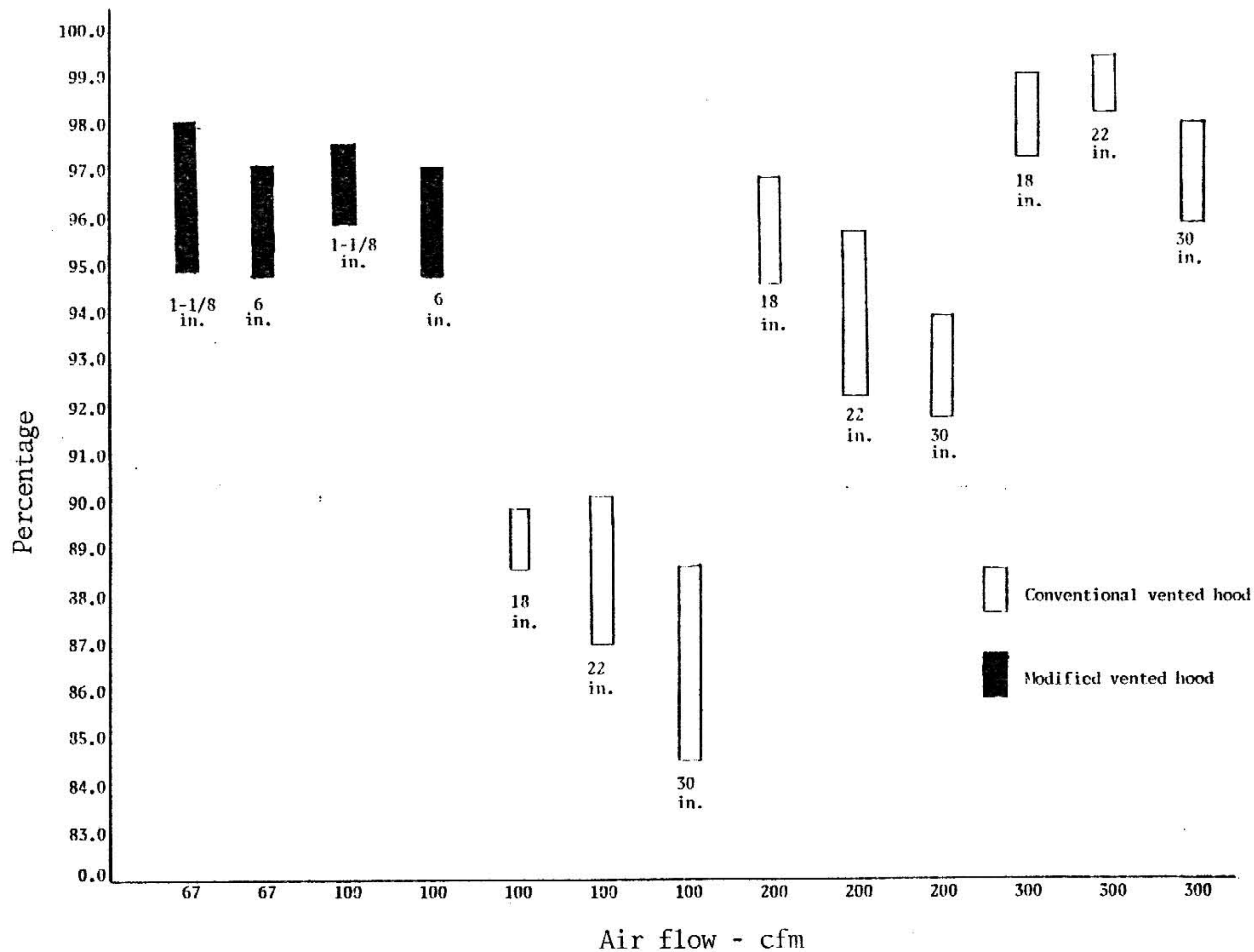

Figure 3. Ninety-five percent confidence interval boundries of water vapor removal effectiveness for selected hoods at various air flows and heights.

The strength of relationship between two variables, X and Y, is determined by the amount of effect any change in X has on Y. A positive correlation results when as X increases, Y tends to increase and a negative correlation when X increases and Y tends to decrease. The linear correlation coefficient, $\hat{r}$, always has a value between ± 1.0, perfect positive and negative correlation, respectively. When $\hat{r}$ equals 0, there is said to be no linear correlation. A high correlation exists between two variables when the coefficient is close to ± 1.0 and low when it is close to zero.

Once all data points have been plotted on a graph, it is desirable to compute a straight line through the data points describing the relationship between X and Y variables. This line is referred to as the line of best fit, or least squares line and is determined by it's slope and Y intercept (a). The line of best fit for linear regression is achieved by equation (3) below:

$$y = a + bx \qquad \text{(Eq. 3)}$$

where: y = value on the Y axis

x = value on the X axis

a = point where the line crosses the Y axis or known as the Y intercept

b = indicates the amount by which the line rises for each unit increase in X or known as the slope of the line

The selected hood operated at various air flows and heights (variable X) and the increase in room humidity ratio (variable Y) linear regression relationship was computed by Annis [5] and is presented in Figure 4. For a perfect linear regression relationship to exist for variables X and Y, the line of best fit would intercept the Y axis at 0.00400, that is if the Y axis were to be extended. It was apparent the linear correlation coefficients were very close to +1.0, but intercepting the Y axis far below 0.00400. Thus an exponential regression relationship was computed, resulting in curve lines which would approach the Y axis at 0.00400, providing a better correlation relationship. The exponential regression coefficient values were obtained by Annis [5] using equation (4) below:

$$y = be^{mx} \qquad \text{(Eq. 4)}$$

where: y = value on Y axis

m & b = constant

e = natural logarithm base

x = value on the X axis

The linear and exponential correlation coefficient, $\hat{r}$, values are listed in Table 17. Since two points determine a line, the modified vented hood has no $\hat{r}$ values. The researcher used the computed exponential regression correlation coefficients of the conventional vented hood to compare to the modified vented hood linear lines. As stated earlier, these exponential regression lines would approach the Y axis at 0.00400. The exponential coefficients for the conventional vented hood had extremely high correlation coefficient $\hat{r}$ values of 18-in. = +1.0, 22-in. = +.968 and 30-in. = +.997.

Figure 4 is the plotted linear and exponential regression lines from Annis [5] for both hoods which observations regarding objective two can be stated. In general, the modified vented hood appears to be capable

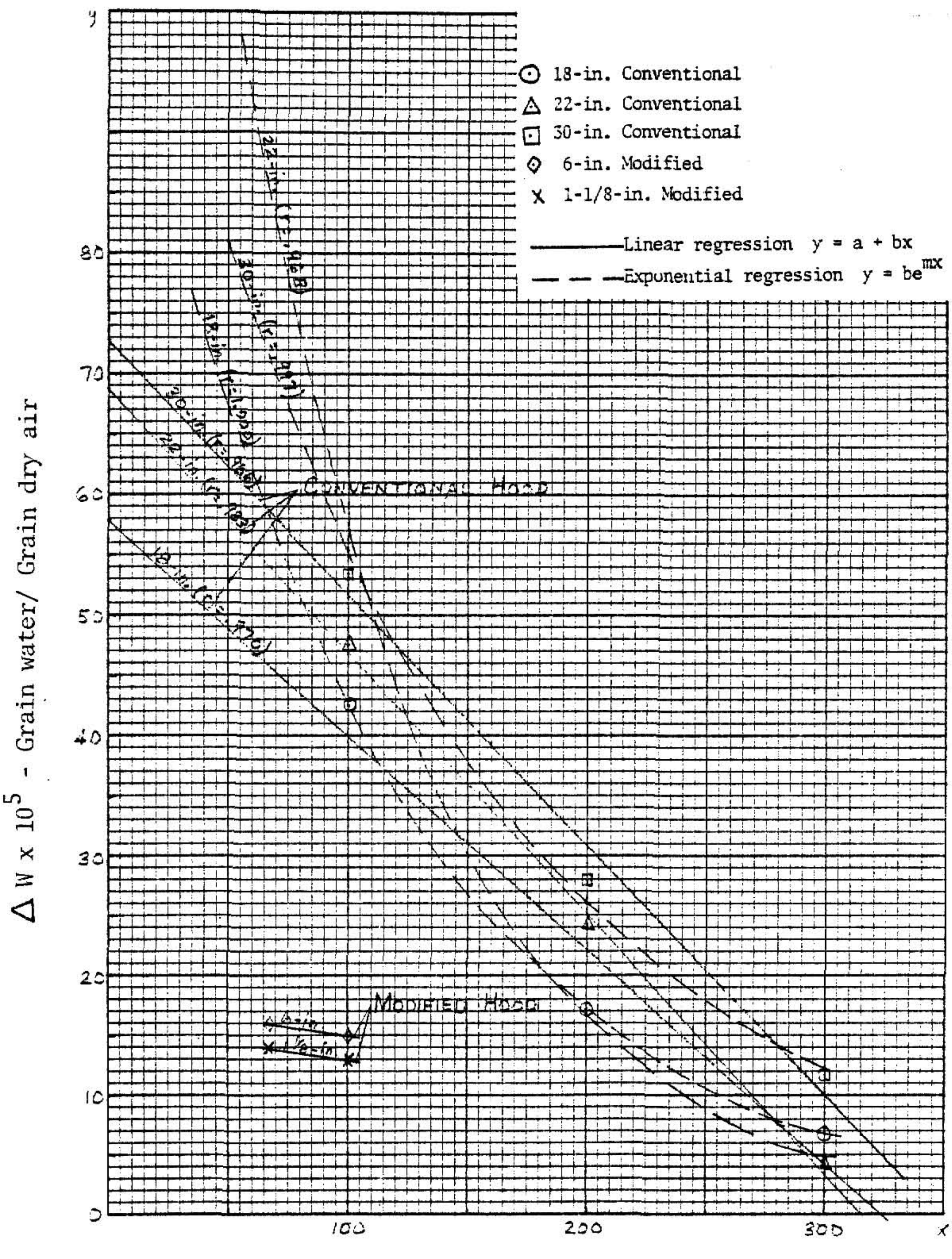

Figure 4. Increase in room humidity ratio for selected hoods at various air flows and heights.

Table 17. Linear and exponential regression correlation coefficients for selected hoods are various air flows and heights.[1]

Vented hood type	Height-in.	Linear regression correlation coefficient $\hat{r}$	Exponential regression correlation coefficient $\hat{r}$
Modified	1-1/8	-[2]	-[2]
Modified	6	-[2]	-[2]
Conventional	18	+.970	+1.000
Conventional	22	.983	.968
Conventional	30	.966	.997

[1]Statistical analysis conducted by Annis [5]

[2]Two points determine the line, therefore no $\hat{r}$

of operating at a drastically lower air flow rate when positioned close to the source of pollutant. The modified vented hood has slight increases in room humidity ratios compared to the conventional vented hood operated at 100 cfm or 200 cfm when positioned at any height.

Table 18 list required air flows for each selected hood when the increase in room humidity ratios are equivalent. The increase in room humidity ratios were identified, using Figure 4, for the modified vented hood when operated at 67 cfm and 100 cfm positioned at 1-1/8-in. and 6-in. heights. An air flow for the conventional vented hood was determined by following the identified increase in room humidity ratio until it intercepted the exponential regression line for the conventional vented hood when positioned at 18-in., 22-in. and 30-in. The modified vented hood could be operated at a reduced air flow rate and still achieve the same equivalent removal effectiveness as a conventional vented hood. Table 18 lists an air flow reduction percentage for each pair of air flows given. This air flow reduction percentage was determined by dividing the given conventional vented hood's air flow listed in the table by it's paired modified vented hood air flow, then multiplied by 100. This figure was then subtracted from 100% to determine the air flow reduction percentage a modified vented hood could be operated at and still achieve the same removal effectiveness as a conventional vented hood.

The greatest difference in required air flows necessary to achieve the same removal effectiveness is observed when the conventional vented hood is positioned at 30-in. The conventional vented hood requires an air flow of 265 cfm to 292 cfm, when positioned at 30-in. while the modified vented hood only requires 67 cfm and 100 cfm when positioned at either height of 1-1/8-in. or 6-in. Thus, these air flow requirements indicate a modified vented hood can be operated at 63.5% to 76.1% of the conventional vented hood's air flow and be as effective in controlling the water vapor pollutant.

With the conventional vented hood positioned at 22-in., this hood is required to operate at 204 cfm to 220 cfm in order to perform as effectively as the modified vented hood operated at 67 cfm or 100 cfm when it is positioned at 1-1/8-in. or 6-in. At the least, a modified vented hood can be operated at a 52.4% reduced air flow rate of the conventional vented hood, positioned at 22-in. and still have equivalent removal effectiveness.

The conventional vented hood requires an air flow of 223 cfm when positioned at 18-in. whereas the modified vented hood can be operated at a reduced air flow rate of 67 cfm positioned at 1-1/8-in. in order for both hoods to have the same removal effectiveness values. The difference in

Table 18. Comparison of air flow requirements for selected hoods when increase in room humidity ratios are equivalent.

Conventional vented hood		Modified vented hood		Percent air flow reduction
Air flow-[1] cfm	height-in.	Air flow-cfm	height-in.	
223	18	67	1-1/8	70.0
208	18	67	6	67.8
229	18	100	1-1/8	56.3
215	18	100	6	53.5
215	22	67	1-1/8	68.8
204	22	67	6	67.2
220	22	100	1-1/8	54.5
210	22	100	6	52.4
280	30	67	1-1/8	76.1
265	30	67	6	74.7
292	30	100	1-1/8	65.8
274	30	100	6	63.5

[1]Values from exponential regression line

in these two air flow requirements results in a 70.0% air flow reduction for the modified vented hood.

Table 18 indicates the required air flow rates differ slightly when the conventional vented hood is positioned at 22-in. and lowered to 18-in. When the conventional vented hood is positioned at 22-in. the required air flows range from 204 cfm to 220 cfm, but when the hood is lowered to 18-in. the ranges are only slightly higher, 208 cfm to 229 cfm. Table 18 also reveals a modified vented hood can be operated at an air flow reduction of 52.4% to as high as 76.1%, given the testing conditions of this study, and still be as effective in controlling the cooking pollutant water vapor.

Figure 4 can also be used to compare the increase in room humidity ratio when the selected hoods are operated at the same air flow. Table 19 presents the increase in room humidity ratio for the selected hoods when positioned at various heights and operated at either 67 cfm or 100 cfm. The increase in room humidity ratio rises sharply when the hoods operate at 67 cfm and the height is increased from 6-in. to 18-in, 0.00016 and 0.00058 lb water vapor/lb dry air, respectively. The greatest increase in room humidity ratio occurs when the conventional vented hood is operated at 67 cfm and is positioned at 18-in., 22-in. and 30-in., the resulting increase in room humidity ratio being 0.00058, 0.00085 and 0.00071 lb water vapor/lb dry air, respectively. In contrast when a modified vented hood is operated at 67 cfm and the hood is very close to the source of pollution the increase in room humidity ratio is drastically less. With the hood positioned at 1-1/8-in. and 6-in. the increase in room humidity ratio is only 0.00014 and 0.00016 lb water vapor/lb dry air, respectively.

When the selected hoods are operated at 100 cfm and positioned at the various heights, the resulting increase in room humidity ratios are slightly less than when operated at 67 cfm. Similar characteristics exists when the various heights are compared at the 67 cfm air flow and 100 cfm. Once again, with the hoods operated at 100 cfm, the greatest increase in room humidity ratio is observed when the height is increased from 6-in. to 18-in., 0.00015 and 0.00042 lb water vapor/lb dry air, respectively. With the hood positioned very close to the source of pollution, the increase in room humidity ratio was drastically less at the lowered heights of 1-1/8-in. and 6-in., 0.00013 and 0.00015 lb water vapor/lb dry air, respectively, compared to the 18-in., 22-in. and 30-in., 0.00042, 0.00057 and 0.00055 lb water vapor/lb dry air, respectively, when the hood was operated at 100 cfm but with the intake positioned at different heights.

Table 19 indicates the increase in room humidity ratios are very close when the modified vented hood is operated at 67 cfm and positioned at 1-1/8-in. or 6-in. resulting in 0.00014 and 0.00016 lb water vapor/lb dry air, respectively. The increases in room humidity ratios are extremely close when the modified vented hood is operated at 100 cfm and positioned at 1-1/8-in. or 6-in. The resutling increase in room humidity ratios when the hood is operated at 100 cfm and positioned at 1-1/8-in. and 6-in. are 0.00013 and 0.00015 lb water vapor/lb dry air, respectively. Thus, the increase in room humidity ratio differs minutely when the modified vented hood is operated at 67 cfm or 100 cfm when the intake is positioned at 1-1/8-in. or 6-in. height.

Table 19. Comaprison of increase in room humidity ratio for selected hoods operated at equivalent air flows, various heights.

Vented hood type	Air flow-cfm	Height-in.	Increase in room humidity ratio, W-lb water vapor/lb dry air
Modified	67	1-1/8	.00014
Modified	67	6	.00016
Conventional	67	18	.00058[1]
Conventional	67	22	.00085[1]
Conventional	67	30	.00071[1]
Modified	100	1-1/8	.00013
Modified	100	6	.00015
Conventional	100	18	.00042[1]
Conventional	100	22	.00075[1]
Conventional	100	30	.00055[1]

[1]Values from exponential regression line

Evaluation of Water Vapor Given Off by Researcher in Test Chamber

A series of tests were conducted in an attempt to determine the amount of moisture given off by the researcher. Results of these runs are contained in Tables 20 through 23. The increase in room humidity ratio means was 0.00012 lb water vapor/lb dry air when only the researcher was present in the test chamber with no water boiling while the hood's were operated at 67 cfm, 100 cfm and 200 cfm and only 0.00015 lb water vapor/lb dry air when operated at 300 cfm.

The increase in room humidity ratio due to the moisture given off by the researcher can be subtracted from the increase in room humidity ratio when the researcher is in the test chamber with water boiling, this value being the true increase in room humidity ratio resulting from the cooking pollutant. This was not feasible for this study for two reasons. First the data obtained for the moisture given off by the researcher had a high coefficient of variation. A linear regression analysis was conducted by Annis [5]. However, at such low levels of humidity ratio, minimum errors of measurement caused relatively great data scatter (see Appendix E). Secondly, in a realistic cooking situation a person would be present during part of the cooking task(s), if not for the entire time. The hood "off" data included contributions of moisture from a person in the test chamber.

Impact of Air Distribution

Runs were conducted to determine the test chambers air activity. This was achieved by operating the hood at a desired air flow without the researcher in the test chamber with and without water boiling.

Tables 24 through 26 contain the data. When the researcher was not present in the test chamber and there was no water being boiled, the mean increase in room humidity ratio was 0.00003 lb water vapor/lb dry air.

Table 20. Test 4 results (conventional vented hood operated at 200 cubic feet per minute and installed at 30-in. with researcher in test chamber and no water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
207	Conventional	200	30		.00009
208	Conventional	200	30		.00013
209	Conventional	200	30		.00013
210	Conventional	200	30		.00013
211	Conventional	200	30		.00011

$\overline{X} = 0.000118$

$s = 0.000018$

Table 21. Test 4 results (conventional vented hood operated at 300 cubic feet per minute and installed at 30-in. with researcher in test chamber and no water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
212	Conventional	300	30		.00006
213	Conventional	300	30		.00008
214	Conventional	300	30		-.00001
215	Conventional	300	30		.00005
216	Conventional	300	30		.00012
217	Conventional	300	30		-.00002

$\overline{X} = 0.000046$

$s = 0.000040$

Table 22. Test 5 results (modified vented hood operated at 67 cubic feet per minute and installed at 1-1/8-in. with researcher in test chamber and no water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
159	Modified	67	1-1/8		.00015
160	Modified	67	1-1/8		.00011
163	Modified	67	1-1/8		.00014
185	Modified	67	1-1/8		.00009
186	Modified	67	1-1/8		.00012
187	Modified	67	1-1/8		.00010

$\bar{X} = 0.000118$

$s = 0.000023$

Table 23. Test 5 results (modified vented hood operated at 100 cubic feet per minute and installed at 1-1/8-in. with researcher in test chamber and no water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
161	Modified	100	1-1/8		.00013
162	Modified	100	1-1/8		.00009
164	Modified	100	1-1/8		.00012
188	Modified	100	1-1/8		.00009
189	Modified	100	1-1/8		.00014
190	Modified	100	1-1/8		.00016

$\overline{X} = 0.000121$

$s = 0.000028$

Table 24. Test 6 results (modified vented hood operated at 67 cubic feet per minute and installed at 1-1/8-in. without researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
150	Modified	67	1-1/8	228.4	.00002
152	Modified	67	1-1/8	242.5	.00010
158	Modified	67	1-1/8	226.4	.00011
167	Modified	67	1-1/8	229.9	.00007
168	Modified	67	1-1/8	231.3	.00012
169	Modified	67	1-1/8	246.1	.00011
170	Modified	67	1-1/8	220.4	.00003
173	Modified	67	1-1/8	250.7	.00008
174	Modified	67	1-1/8	222.9	.00011
183	Modified	67	1-1/8	259.9	.00016
184	Modified	67	1-1/8	216.9	.00003

$\overline{X} = 0.000086$

$s = 0.000044$

Table 25. Test 6 results (modified vented hood operated at 100 cubic feet per minute and installed at 1-1/8-in. without researcher in test chamber and water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
153	Modified	100	1-1/8	226.5	.00008
154	Modified	100	1-1/8	229.5	.00005
155	Modified	100	1-1/8	226.2	.00013
156	Modified	100	1-1/8	220.2	.00018
157	Modified	100	1-1/8	210.3	.00011
171	Modified	100	1-1/8	226.4	.00003
172	Modified	100	1-1/8	232.9	.00007
175	Modified	100	1-1/8	232.2	.00001
176	Modified	100	1-1/8	232.8	.00008
177	Modified	100	1-1/8	235.6	.00009
178	Modified	100	1-1/8	238.0	-.00007
179	Modified	100	1-1/8	239.3	-.00002

$\overline{X} = 0.000062$

$s = 0.000048$

Table 26. Test 7 results (modified vented hood operated at 67 cubic feet per minute and installed at 1-1/8-in. without researcher in test chamber and no water boiling).

Run no.	Vented hood type	Air flow-cfm	Height-in.	Water evaporated-gm	Increase in humidity ratio, W-lb water vapor/lb dry air
151	Modified	67	1-1/8		.00000
165	Modified	67	1-1/8		.00003
166	Modified	67	1-1/8		-.00001
180	Modified	67	1-1/8		.00004
181	Modified	67	1-1/8		.00003
182	Modified	67	1-1/8		.00010

$\overline{X} = 0.000032$

$s = 0.000035$

CONCLUSIONS AND RECOMMENDATIONS

This study thus conducted established some important connotations. A kitchen range vented hood when operated at different air flows and positioned at various heights has an effect upon the increase in room air humidity ratio when the cooking pollutant water vapor is generated. Specifically, this study indicates the localized-control vented hood, employed by the modified vented hood design tested, demonstrated this type of hood design could perform as effectively as a conventional vented hood when the cooking pollutant water vapor was generated.

The increase in room humidity ratio varied among the two types of hoods tested. This variance was a result of the air flow the hood was operated at and the height the intake was from the cooking pollutant. The increase in room humidity ratio was kept to a minimum when the modified vented hood was operated at reduced air flow rates of 67 cfm and 100 cfm with the intake positioned 1-1/8-in. or 6-in. from the point of cooking pollutant origin. With the intake being within inches of the pollutant, the hood was able to be operated at a drastically reduced air flow than the conventional vented hood positioned at 18-in., 22-in. or 30-in. from the cooking pollutant. The impact the hood's intake position has upon the air flow requirement is evident when the modified vented hood can be operated at a minimum of 52.4% air flow reduction of the conventional vented hood and still achieve the same equivalent removal effectiveness. In fact, in 66.6% of the comparisons when the selected hoods had equivalent increases in room humidity ratios, but the heights of the two types of hoods varied the modified vented hood could be operated at least

63.5% to 76.1% reduced air flow rate of the conventional vented hood and still achieve the equivalent removal effectiveness.

The results of reduced air flow requirements of the modified vented hood support previous research conducted by Annis [4]. In this earlier investigation a conventional vented hood air flow could be reduced 66.8% (from 250 cfm to 83 cfm) when the hood's intake position was lowered from 30-in. to 18-in. and maintain equivalent removal effectiveness. The present study proved a localized-control vented hood could be operated at a 52.4% to 76.1% air flow reduction when the intake is positioned 1-1/8-in. or 6-in. from the cooking pollutant compared to the conventional vented hood positioned at 18-in, 22-in. or 30-in.

When the hoods are operated at the same equivalent air flows but the heights vary, the increase in room humidity ratio is drastically effected. When the selected hoods were operated at 67 cfm and 100 cfm and positioned at 1-1/8-in. and 6-in., the increase in room humidity ratio ranged from 0.00013 lb water vapor/lb dry air to 0.00016. With the intake so close to the cooking source, more of the water vapor was captured by induced air currents and less escaped into the environment. In fact, the difference in the increase in room humidity ratios 0.00013 lb water vapor/lb dry air to 0.00016 is so minute that there appears to be no advantage whether the modified vented hood is operated at 67 cfm or 100 cfm, or positioned at 1-1/8-in. or 6-in. These humidity ratios translate into removal effectiveness values of 96.0% to 96.8%.

The results of this study are actually two-fold. The first, which has been addressed, is the ability of a localized-control vented hood (such as the modified vented hood tested) can be operated at a greatly reduced air flow rate with the intake positioned within inches of the cooking pollutant and be as effective in controlling the pollutant as a conventional vented hood. The second impact this innovative hood design has is related to energy conservation. A hood with the ability to operate at a reduced air flow rate while the intake is localized over the cooking pollutant implies less conditioned air will be captured and exhausted. The impact a modified vented hood has when operated at 100 cfm and positioned at 6-in. compared to a conventional vented hood operated at 210 cfm and positioned at 22-in. is 52.4% reduction of hood make-up air energy loss. This can be interpreted to mean the modified vented hood is more energy effective because less conditioned air is removed and exhausted. The greatest energy savings occurs when the modified vented hood is operated at 67 cfm positioned at 1-1/8-in. while the conventional vented hood is operated at a greatly increased air flow of 280 cfm when positioned at 30-in. in order for both hoods to have equivalent removal effectiveness values. The modified vented hood can be operated at a 76.1% air flow reduction.

To further demonstrate the effect the hood's air flow has upon the heating and cooling load demands for a home in Manhattan, Kansas, (see Appendix F) the impact of a conventional vented hood operated at 280 cfm, positioned at 30-in. has the same effectiveness as a modified vented hood operated at 67 cfm, positioned at 1-1/8-in. The Btu/hr added to the cooling load as a result of the hood operating during the summer months, where the greatest savings can occur, and the winter can be calculated. When the conventional vented hood is operated under the conditions stated above, 14,969 Btu/hr is added to the cooling load, whereas the modified vented hood only adds 3,587 Btu/hr. During the winter, 32,265 Btu/hr are added to the heating load while the modified vented hood adds only

7,732 Btu/hr. The modified vented hood adds sufficiently fewer Btu/hr to either the cooling or heating loads for a Manhattan, Kansas home.

The results obtained from this study indicate the localized-control vented hood controls the cooking pollutant water vapor superbly and is energy effective and merits further investigation. Recommended areas for future investigations are:

1. Additional research is needed to determine the localized-control vented hood effectiveness when grease aerosol is generated
2. Ultimately the duct extension should be designed to be retractable for ease of cooking tasks and appearance when the hood is not in use
3. Investigate the removal effectiveness and required air flows of a localized-control vented hood when cooking large quantities of food or special tasks (i.e. canning)
4. Conduct a consumer acceptance study on the appearance of the localized-control vented hood for marketing purposes

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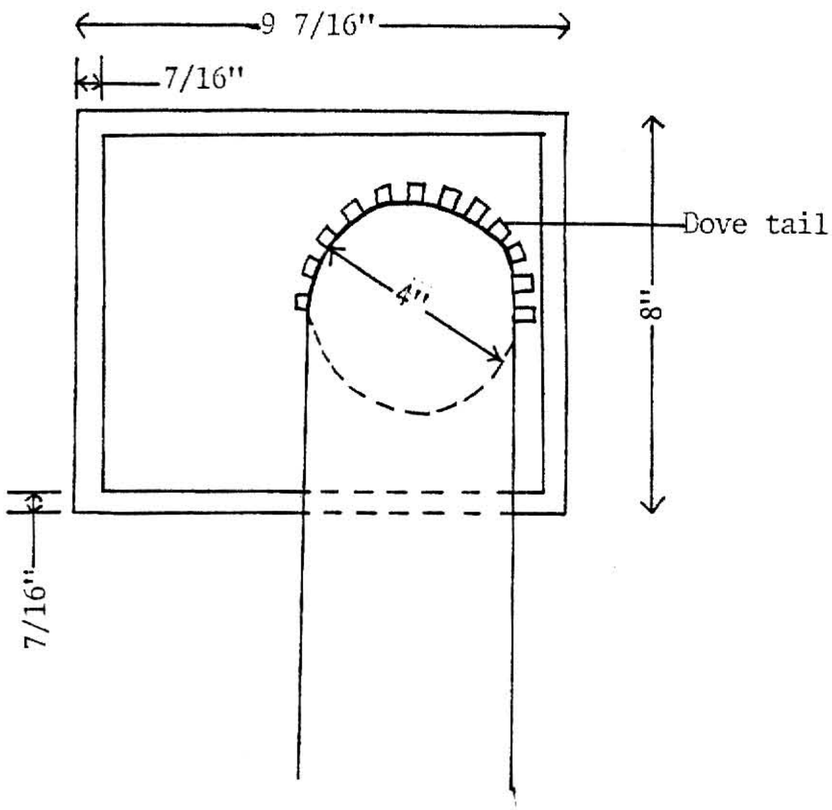
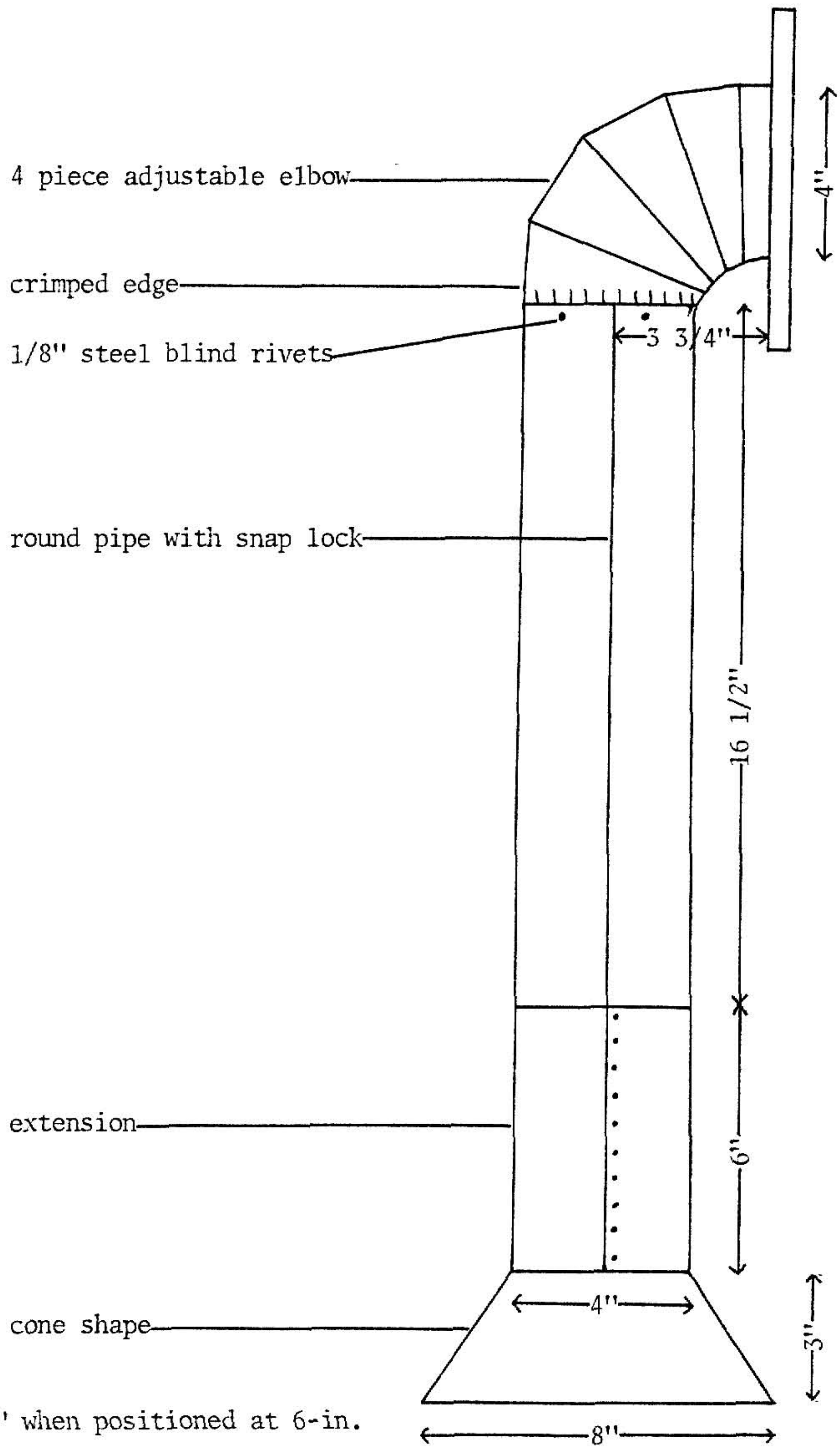
APPENDICIES

Appendix A. Modified vented intake configuration specifications.

Custom fabricated frame



Appendix A. Modified vented intake configuration specifications (concluded)



*10 1/2" when positioned at 6-in.

Appendix B. Tests procedures

The following are detailed operations and sequence of the conventional and modified vented hood tests conducted for this study.

REMOVAL EFFECTIVENESS TESTS

Test 1. Conventional vented hood "off" with researcher in test chamber and water boiling.

Step	Time (min.)	Operation
1	-90 to -60	Fill all psychrometers with distilled water to their reservoir rim. Zero manometer. Door and southwest plastic wall partition open. Remove exhaust fan from hood compartment.
2	-60	Begin to record t_{wb} and t_{db} temperatures every 15 minutes. Do not begin a run until psychrometers t_{wb} and t_{db} do not change more than 0.1^{o} F for two consecutive readings.
3	-30 to 0	Weigh water (water plus saucepan should total 1221.1 grams)
4	-5:00	Start fan sitting on floor. Seal hood duct top discharge with poster board. Seal southwest plastic wall corner.
5	-0:30	Place saucepan on element. Read psychrometers, assistant records.
6	0:00	Assistant closes door, researcher adjusts voltage to 119.
7	2:00	Researcher checks voltage, adjust if necessary. Read amperage, assistant records.
8	6:30	Reduce voltage to 77. Read amperage, assistant records.
9	6:30 to 10:00	Record time water boiled.
10	10:00	Researcher reads psychrometers, assistant records.
11	20:00	Researcher reads psychrometers, assistant records.
12	27:30	Researcher reads psychrometers, assistant records.

Appendix B. Tests procedures (continued)

Step	Time (min.)	Operation
13	28:00	Place lid on saucepan, remove from element. Turn element off. Open door.
14	28:30	Weigh water, record.
15	30:00	Remove taped poster board from hood duct top discharge. Replace fan in hood compartment.
16	33:00	Secure southwest plastic wall corner in open position.

Test 2. Conventional vented hood "on" with researcher in test chamber and water boiling.

Step	Time (min.)	Operation
1	-90 to -60	Fill all psychrometers with distilled water to their reservoir rim. Zero manometer. Door and southwest plastic wall corner open. Turn on hood and/or blower, adjust damper for desired air flow.
2 - 3		Same as Test 1.
4		Omit
5 - 14		Same as Test 1.
15 - 16		Omit

Test 3. Modified vented hood "on" with researcher in test chamber and water boiling.

Step	Time (min.)	Operation
1	-90 to -60	Fill all psychrometers with distilled water to their reservoir rim. Zero manometer. Door and southwest plastic wall corner open. Turn on hood and/or blower, adjust damper for desired air flow. Start floor fan.
2	-60	Begin to record t_{wb} and t_{db} temperatures every 15 minutes. Do not begin a run until psychrometers t_{wb} and t_{db} do not change more than 1.0^{o} F for two consecutive readings.
3	-30 to 0	Weigh water (water plus saucepan should total 1221.1 grams).

Appendix B. Tests procedures (continued)

Step	Time (min.)	Operation
4	-0:30	Researcher reads psychrometers, assistant records.
5	0:00	Assitant closes door, researcher adjusts voltage to 119.
6	2:00	Researcher checks voltage, adjust if necessary. Read amperage, assistant records.
7	6:30	Reduce voltage to 77. Read amperage, assistant records.
8	10:00	Researcher reads psychrometers, assistant records.
9	20:00	Researcher reads psychrometers, assistant records.
10	27:30	Researcher reads psychrometers, assistant records.
11	28:00	Place lid on suacepan, remove from element. Turn element off. Open door.
12	28:30	Weigh water, record.

MOISTURE GIVEN OFF BY RESEARCHER IN TEST CHAMBER AND AIR DISTRIBUTION TESTS

Test 4. Conventional vented hood "on" with researcher in test chamber and no water boiling.

Step	Time (min.)	Operation
1	-90 to -60	Fill all psychrometers with distilled water to their reservoir rim. Zero manometer. Door and southwest plastic wall corner open. Turn on hood and/or blower, adjust damper for desired air flow.
2	-60	Begin to record t_{wb} and t_{db} temperatures every 15 minutes. Do not begin a run until psychrometers t_{wb} and t_{db} do not change more than 0.1^{o} F for two consecutive readings.
3	-0:30	Researcher reads psychrometers, assistant records.
4	0:00	Assistant closes door.
5	10:00	Researcher reads psychrometers, assistant records.
6	20:00	Researcher reads psychrometers, assistant records.

Appendix B. Tests procedures (continued)

Step	Time (min.)	Operation
7	27:30	Researcher reads psychrometers, assistant records.
8	28:00	Open door.

Test 5. Modified vented hood "on" with researcher in test chamber and no water boiling.

Step	Time (min.)	Operation
1	-90 to -60	Fill all psychrometers with distilled water to their reservoir rim. Zero manometer. Door and southwest plastic wall corner open. Turn on hood and/or blower, adjust damper for desired air flow. Start floor fan.
2 - 8		Same as Test 4.

Test 6. Modified vented hood "on" without researcher in test chamber and water boiling.

Step	Time(min.)	Operation
1	-90 to -60	Remove voltage transformer, voltmeter and clock out of test chamber, locate outside northwest entry doorway. Fill all psychrometers with distilled water to their reservoir rim. Door and southwest plastic wall corner open. Turn hood on and/or blower, adjust damper for desired air flow. Start floor fan.
2	-60	Begin to record t_{wb} and t_{db} temperatures every 15 minutes. Do not begin a run until psychrometers t_{wb} and t_{db} do not change more than 0.1^{o} F for two consecutive readings.
3	-30 to 0	Weigh water (water plus saucepan should total 1221.1 grams)
4	-0:30	Researcher reads psychrometers, assistant records.
5	0:00	Researcher exits test chamber and closes door. Researcher adjusts voltage to 120 volts (because of extension cord used in this situation)
6	2:00	Researcher checks voltage, adjust if necessary. Read amperage, assistant records.

Appendix B. Tests procedures (concluded)

Step	Time (min.)	Operation
7	6:30	Reduce voltage to 79. Read amperage, assistant records.
8	27:30	Researcher enters test chamber and closes door. Researcher reads psychrometers, assistant records.
9	28:00	Place lid on suacepan, remove from element. Turn element off. Open door.
10	28:30	Weigh water, record.

Test 7. Modified vented hood "on" without researcher in test chamber and no water boiling.

Step	Time (min.)	Operation
1	-90 to -60	Remove voltage transformer, voltmeter and clock out of test chamber, locate outside northwest entry doorway. Fill all psychrometers with distilled water to their reservoir rim. Door and southwest plastic wall corner open. Turn hood on and/or blower, adjust damper to desired air flow. Start floor fan.
2	-60	Begin to record t_{wb} and t_{db} temperatures every 15 minutes. Do not begin a run until psychrometers t_{wb} and t_{db} do not change more than 0.1^{o} F for two consecutive readings.
3	-0:30	Researcher reads psychrometers, assistant records.
4	0:00	Researcher exits test chamber and closes door.
5	27:30	Researcher enters test chamber and closes door. Researcher reads psychrometers, assistant records.
6	28:00	Open door.

Appendix C. Example of data sheet

DATA SHEET

RANGE HOOD WATER VAPOR REMOVAL TEST RESULTS

Date 4 - 20 - 81 Run No. 45 Hood ON

Design Conventional Height 18" in. Air Flow 100 CFM

Person in test chamber B. Frailey Room stablized 1 hr.

Water evaporation data:		
Aluminum Wearever pan + lid	556.4	gm
Water weight	794.7	gm
Total weight before run	1351.1	gm
Total weight after run	1128.8	gm
△ weight	222.3	gm

Time min:sec	Psychro-meter	t_{wb}	t_{db}	W	W △	△ W_{avg}
0	1	60.8	74.9	.00813		
	2	61.3	74.9	.00845		
	3	61.0	75.2	.00819		
10	1	61.8	75.7	.00859	.00046	
	2	61.8	75.3	.00868	.00023	.00026
	3	61.4	75.9	.00829	.00010	
20	1	62.0	75.8	.00870	.00057	
	2	61.9	75.4	.00872	.00027	.00036
	3	61.7	76.1	.00844	.00025	
27:30	1	62.1	75.9	.00874	.00061	
	2	62.2	75.8	.00883	.00038	.00042
	3	61.8	76.2	.00847	.00028	

Read from 27:30 to 28:00

Time to boil water 8:45 min.

Bar Press 29.28

Energy Input to Element

Time	Watts	Volts	Amps
0			
6:30			

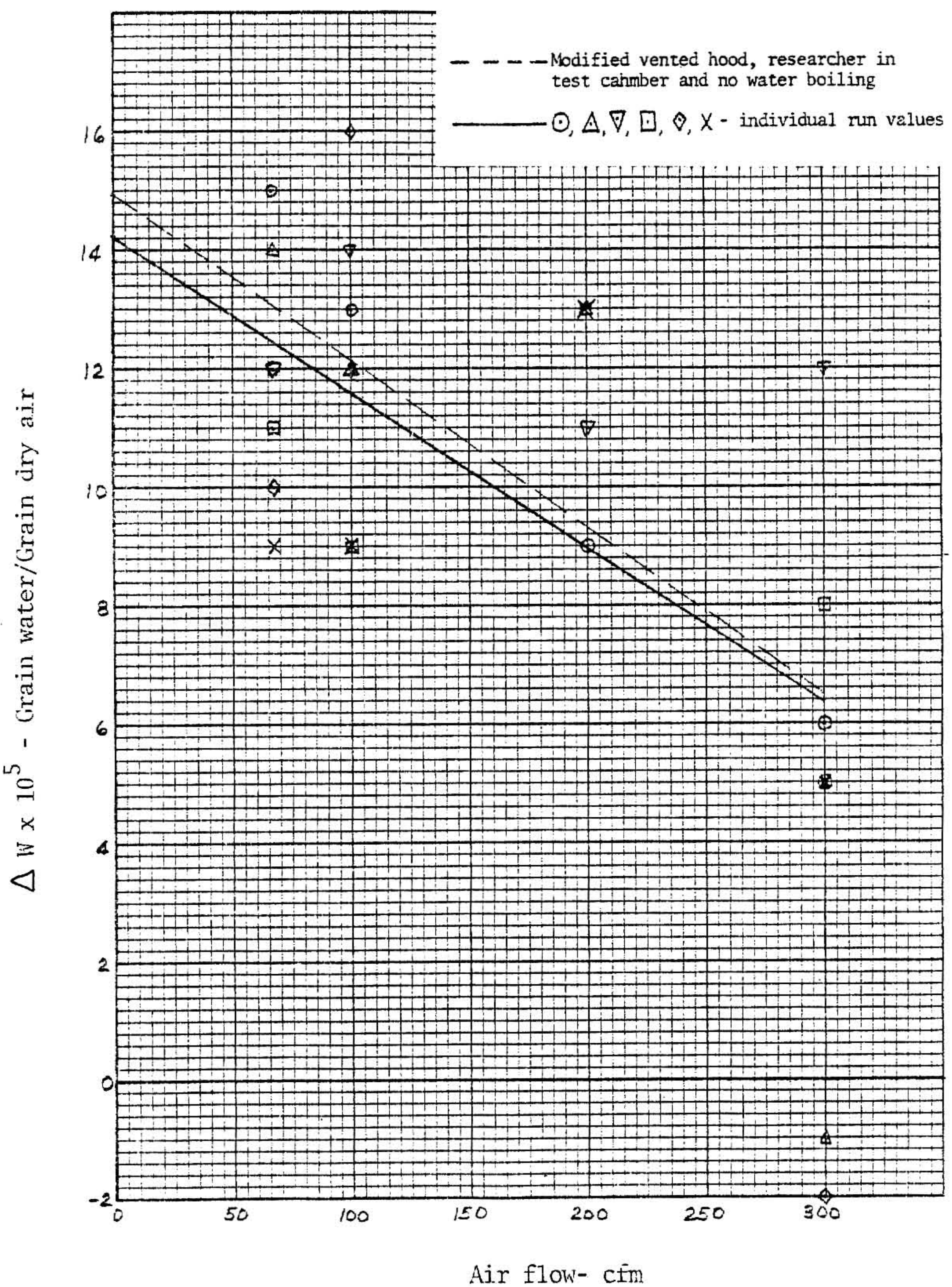
Appendix D. Example of $\pm 0.1^{o}$ F reading error of a psychrometer.[1]

Time	Error	Psych.	Actual			Maximum			Minimum		
			t_{wb}	t_{db}	W	t_{wb}	t_{db}	W	t_{wb}	t_{db}	W
1:00	$\pm 0.1^{o}$ F	1	60.8	74.9	.00813	60.7	75.0	.00804	60.7	74.8	.00809
27:30	$\pm 0.1^{o}$ F	1	62.1	75.9	.00874	62.2	75.8	.00838	62.0	76.0	.00865
					W = .00061			W = .00079			W = .00056

[1]Therefore with run No. 45 as an *example*, with a $\pm 0.1^{o}$ F reading error the range becomes:

.00079 - .00056 = .00023 lb water vapor/lb dry air

Appendix E. Linear regression analysis of moisture given off by researcher.



Appendix F. Design conditions for a Manhattan, Kansas home.[1]

Season	Condition	Dry Bulb	Wet Bulb	Relative Humidity	Enthalpy
Summer	Inside	75.0° F	-	40.0%	26.21
Summer	Outside	99.0° F	75.0° F	-	38.37
Winter	Inside	75.0° F	-	40.0%	26.21
Winter	Outside	-1.0° F	-	70.0%	0.00

[1] Source: Annis, Patty J. Energy Conservation Through Optimal Kitchen Range and Hood Design. Proceedings of Major Home Appliance Technology for Energy Conservation Conference, Purdue University, February 27 - March 1, 1978, pp. 29 - 30.

PRELIMINARY EVALUATION OF AN ENERGY-CONSERVING LOCALIZED-CONTROL RESIDENTIAL KITCHEN RANGE HOOD PROTOTYPE

by

BONNIE FRAILEY TEMME

B. A., San Diego State University, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Family Economics

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1982

The purpose of this study was to evaluate the effect a localized vented hood has upon the control of the cooking contaminant water vapor. To provide a data base for comparison a conventional vented hood was tested at three heights (18, 22 and 30-in.) and three volumetric air flows (100, 200 and 300 cfm). The localized vented hood was operated at heights of 1-1/8 and 6-in. above the cooking utensil and two volumetric air flow rates (67 and 100 cfm).

The localized-control vented hood's removal effectiveness operating at the test air flows and heights was better than the conventional vented hood when operated at 100 and 200 cfm at the heights tested. The removal effectiveness for the localized-control vented hood ranged from 96.0% to 96.8%, whereas the conventional vented hood had a range of 86.6% to 95.7%

Exponential regression analyses was performed to measure the effect of design, air flow and height on the increase in air humidity ratio in the test chamber. The modified vented hood can be operated at a minimum of 52.4% air flow reduction of the conventional vented hood and still achieve the same equivalent removal effectiveness. In 66.6% of the comparisons when the selected hoods had equivalent increases in room humidity ratios, but the heights of the two types of hoods varied, the modified vented hood could be operated at least 63.5% to 76.1% reduced air flow rate of the conventional vented hood and still achieve the equivalent removal effectiveness.

A comparsion of increase in room humidity ratio for each hood operated at equivalent air flows when positioned at various heights was performed. As the intake height increased from the cooking utensil, a definite increase in room humidity ratio was apparent. The localized-control vented hood when operated at the test air flows and test heights caused increases in room humidity ratios of 0.00013 to 0.00016 lb water vapor/lb dry air. The conventional vented hood had significantly higher increases in humidity ratios, ranging from 0.00042 to 0.00085 lb water vapor/lb dry air when operated at 67 or 100 cfm at heights of 18, 22 and 30-in.

The results of this study indicate the localized-control vented hood has, in most comparisons, a higher removal effectiveness value than the conventional vented hood, reducing indoor pollutant levels when water vapor is generated. The localized-control vented hood when operated at the design reduced air flow rates and intake height can control the cooking pollutant water vapor more effectively while being energy efficient because less conditioned air is captured and exhaustd. The localized-control vented hood adds sufficiently fewer Btu/hr to either the cooling or heating loads.

Recommended areas for future investigations include determination of the localized-control vented hood's removal effectiveness when grease aerosol is generated and further modification of the localized-control vented hood to incorporate a flexible connecting duct.