AN INVESTIGATION OF OVEN DOOR SURFACE TEMPERATURES OF HOUSEHOLD GAS AND ELECTRIC RANGES

by

CHRISTINE M. GEE

B.S. Kansas State University, 1972

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

1979

Approved by:

Patty J. Annis
Major Professor

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

FIGURE PAGE

LIST OF APPENDICES

INTRODUCTION

The home has been recognized as a potentially hazardous place since early in time. The Book of Accidents, published for children in 1830, warned young readers of dangers in and around the home. One chapter noted that carelessness around cooking liquids might cause scalds [1] while another warned of the dangers of open fires [2].

Today, as then, burns are among the leading injuries in the home. According to the Department of Health, Education and Welfare estimates to the National Commission on Product Safety in 1968, approximately 100,000 persons suffer burn injuries from gas and electric cooking ranges each year [3]. From July 1969 to 1975 the National Electronic Injury Surveillance System (NEISS) and its predecessors, the National Injury Surveillance System (NISS) and the Hospital Emergency Room Injury Reporting System (HERIRS) have accumulated reports on more than 600 injuries associated with cooking ranges. While a variety of injuries related to ranges were reported, burn injuries were the most frequent [4].

Many, if not most, of these injuries happen to children. Range manufacturers have maintained that it is the parents' responsibility to educate their children as to the burn dangers of a hot range. However, parents are aware that children old enough to touch hot range surfaces cannot be counted upon to comprehend the danger or remember the warnings. To a child under six, the world is not a dangerous place but an interesting one. He is likely to be unaware of potential dangers because his senses, his intuition and his scope of knowledge are still in the early stages of development. The child must be protected from dangers through close supervision or by the development of safe products for the home.

The young child who can pull himself up to a standing position and one who needs to grasp objects for support as he walks are particularly vulnerable to severe hazards. The oven door viewing window, being inset, provides a ledge to which the child can cling. Being curious, the child may desire to peer into the window to see what is inside or be attracted by the reflection in the glass, unaware of the potential danger of the hot oven door.

The severity of the child's burn may be increased because of longer contact time. The child, with an instinctive fear of falling, may be hesitant to release his support. He may be aware of the pain caused by the hot surface but not be certain how to make it stop. He may have a slower reaction time and probably a thinner skin thickness, both of which would contribute to a child being burned more severely than an adult under the same circumstances. These factors will be further discussed in the review of literature.

The National Commission on Product Safety sought to identify problem areas and find solutions to ensure a safe environment. Although manufacturers have established standards for appliance safety, the exterior surface temperatures reached by household gas and electric ranges remains an area of concern.

The purpose of this study is to determine if ranges in normal use in homes today are reaching surface temperatures that could cause burns to humans. The study will seek to answer the following questions; 1) Are ranges meeting the guidelines established by industry safety standards? 2) Are newer ranges safer than those manufactured several years ago? 3) Are companies complying with standards better than they have in the past? 4) Does quality control, with respect to surface temperatures and hot spots, appear to be improving? 5) Are the present standards adequate to protect both adults and young children?

REVIEW OF LITERATURE

Applicable literature was searched in regard to appliance design, results of touching hot surfaces made of various materials, variables relating to the severity of burns, children's skin thickness and responses to pain, recorded burn cases and appliance standards. Prior to 1975, very little information related directly to the problem of surface temperatures of ranges was available.

Burn classifications

Some understanding of the skin structure and the classification of burns by degree is necessary before discussion of other factors related to burns. W.A. Bullerick and D.E. Adams [5], in a Calspan Technical Report, describe skin as consisting of about a 80-100 micrometer epidermis layer over about a 2000 micrometer layer of dermis, which in turn is over a much thicker fatty layer. Concerning burn classification, they describe a first degree burn of the mild type as having transient dilation of near surface blood vessels, i.e. a slight reddening. More severe first degree burns were indicated by prolonged hypermia (reddening due to increased amount of blood), while the most severe first degree burns resulted in some exfoliation of the epidermis after a few days. Blistering followed by epidermis which could be removed by friction in a few days and by an encrustation within a week was an indication of at least a second degree burn. Whether a burn was second or third degree depended on the depth of penetration into the dermal layer. A third degree burn is said to have occurred after a significant portion, 50 to 75 percent, of the dermis is irreversibly damaged. Reversible injuries are burns of the first degree type and non-reversible injuries are burns of the second or third degree type.

Thermal injury

There are three different responses to be considered when human skin comes into contact with a hot surface. These are: 1) the sensation of warmth or coolness 2) the sensation of pain, and 3) the occurance of a burn. A study done by the Human Factors Section of the Kodak Company's Health and Safety Laboratory [6] investigated the physiological and psychological processes underlying these responses. The same group formulated guidelines [7] to control the hot surface problem.

Pain is felt when the appropriate sensory nerve endings in the skin are raised to a specific threshold temperature. Kodak researchers [7] established a number of factors that must be taken into consideration in the evaluation of pain. "The most important variables are the temperature of the material being touched and its thermal properties. Other important variables include duration of contact time, initial skin temperature and epidermal thickness (callusing)." They also indicated that reaction time when touching a hot surface is normally 0.2 to 1.0 seconds. By using a high initial skin temperature of 94°F, a conservative epidermal thickness of 115 micrometers and a 5th percentile threshold where only one in 20 contacts with a hot surface can be expected to elicit pain, the pain threshold (the temperature within the skin at the depth of the receptors) was calculated to be 108°F. With this information it was possible for Kodak investigators [7] to compute the temperature of a hot surface that will raise 115 micrometer deep skin temperature to 108°F within one second contact time. The thermal properties of the various materials affect this calculation (metal is much better conductor of heat than glass, etc.)

Table 1 shows the pain and burn threshold temperature for various materials. The conclusion reached by the Kodak researchers regarding pain was that "no surface, regardless of its composition, that might be frequently or continuously touched, should exceed 108°F" [7].

Table 1. Material surface temperature limits.

Material	Surfaces intended to be touched		Surfaces that may be accidently touched	
	Normal Design Temperature		One second pain threshold (5th percentile)	One second 1st degree burn threshold (1st percentile)
	Comfort	Upper limit (unlimited time)		
Aluminum	70° - 95°F	108°F	112°F	141°F
Steel	70° - 95°F	108°F	113°F	143°F
Pyrex glass	70° - 95°F	108°F	129°F	180°F
Phenolics (avg)	70° - 95°F	108°F	141°F	210°F
ABS Resins	70° - 95°F	108°F	166°F	268°F

Source: [7]

Taking these calculations one step further, researchers at Kodak also investigated accidental contact with a hot surface which might result in a burn. The report used the least severe, first degree burn as the basis for the calculations. The assumptions made in these calculations were a contact time of 1.0 seconds, a very high skin temperature of 97°F, a dermal-epidermal interface level of 80 micrometers and a 1st percentile threshold to ensure a higher degree of protection. The burn threshold 80 micrometers below the skin surface was calculated as 133°F for this set of conditions. The critical material temperatures that will result in this threshold being exceeded was calculated for materials whose thermal peoperties were known and results are shown in Table 1.

An important pioneer study of skin burns was that of Mortiz and Henriques [8] in 1947. In experiments on pigs and later on humans to determine time and temperature relationships of contact with a hot surface, the investigators established a threshold curve at which burns to human skin occur. After reviewing their own and other research they concluded that 111°F is a critical temperature. Long exposure at this temperature will produce burns, but a lower temperatures burns will not be produced regardless of exposure time.

Wu [9] stated that there are three principle factors involved in the cause of thermal injury by heat conduction. They are temperature, time and type of material used in the heated surface touching the body. He concluded that a "metal (aluminum) surface with a temperature of 167°F or greater can be expected to burn human tissue with one second". Wu advised, however, that care should be exercised in the use of this value in actual application as a safety factor should be considered.

A September 1970 Consumer Reports [10] article on product safety stated that "in order to avoid burns to small children, it would likely be necessary to limit metal temperature to maximum of 120°- 130°F".

Burn injuries and their causes have been recorded in a few studies in past years. Waller and Manheimer [11] published a study in 1964 in which 508 non-fatal burns to children were analyzed to determine causes, age relationships, sex relationwhips, severity of burns and part of the body most commonly involved. The researchers evaluated medical records of children treated between April 1946 and June 1960 at the Kaiser Foundation Hospital in Oakland, California. It was found that the "non-fatal burn injury rates vary widely according to age. The risk of injury by burn during the first two years of life is 29.3 per thousand but it rapidly decreases after this time. For children under two, burns account for 13.5% of all non-fatal injuries, whereas after the age of three they account for less than 2% of all injuries." Table 2 shows the burn rate for each year from age 0 through 15 as reported in this study.

Table 2. Burn rates per thousand per year for ages birth through 15 years (2 year age period).

Age	No. of burns	No. of children	Rate per 1,000/year
0 to 1	206	3,511	29.3
2 to 3	116	4,608	12.6
4 to 5	63	6,033	5.2
6 to 7	46	6,070	3.8
8 to 9	47	5,714	4.1
10 to 11	48	4,902	4.9
12 to 13	27	3,427	3.9
14 to 15	13	2,075	3.1

Source: [11]

Waller and Manheimer also note that "Stoves caused 8% of the burns investigated" and these tended to be the most severe, with 21% being of the third degree type. Table 3 shows the degree of burn injury for all burn causes encountered in their research.

Table 3. Degree of burn injury by cause.

Degree of burn injury	Floor heaters %	Other heaters %	Scalds %	Stoves %	Elec. App. %	Misc. %	Unknown %	Total %
First degree	7	9	7	7	17	21	12	11
Second degree	81	70	84	69	68	52	65	71
Third degree	7	17	7	21	12	19	12	12
Unknown	5	4	2	3	3	8	11	6
Total %	100	100	100	100	100	100	100	100
Total no. of burns	97	23	123	42	34	85	104	508

Source: [11]

"As one might expect," they continue, "the child's lack of coordination plays an important role in burns to children under the age of five." Table 4 would indicate that a younger child is more likely to be injured by a stove, with those in the early walking stages encountering the greatest risk.

Table 4. Distribution of burns for first 5 years of life by cause.

Age in months	Floor heaters (%)	Scalds (%)	Stoves (%)	Electrical Appliances (%)	Misc. (%)	Unkown (%)	Total (%)
0-11	9	26	27	14	21	19	18
12-23	69	45	36	34	11	45	47
24-35	18	12	14	33	16	13	16
36-47	3	11	15	13	27	18	13
48-59	1	6	8	6	25	5	6
Total	100	100	100	100	100	100	100

Source: [11]

The causes of these burns were also catagorized for this study. Burns from stoves are most likely to injure the hands and arms. Second degree burns were most common in the group of stove injuries, followed by third degree burns.

The U.S. Consumer Product Safety Commission [12], stated that based on an analysis of over 3,000 cases of burns to the hands of children in the six NEISS product categories associated with ovens received in FY 1974, they could "reasonably assure that thermal burns to the hands of children under four years of age (particularly to those under two years of age) were associated with either side panels or oven doors." The Commission did several indepth investigations of burns resulting from contact with a range surface while it was in operation. [4] In eight of the cases, outside temperature readings on the oven door were taken and ranged from 130°F to 220°F. All of the burns occurred to the hand or forearm, with first and second degree burns being the diagnoses.

For the indepth investigation, no injuries that were a result of contact with flame, burners or burner areas, or the interior surfaces of the oven or broiler were included. The incidence of burns peaked during the late afternoon and early evening hours, those of maximum cooking activity. Small children can be expected to follow their mother closely at that time, as they are often tired and hungry, and will therefore more likely be in the kitchen while cooking is in progress and shortly thereafter. In 13 of the 16 indepth studies the victim was in the toddler stage, the mean and median age for these 13 cases being 11 months. Typically, the burn was to the palms and fingers. Following are descriptions of the cases used for the indepth review: [4]

Case 1. An 11 month-old girl suffered 1° and 2° burns to the right palm when she reached out to support her unstable "toddle" and contacted the front of a hot oven door.

Case 2. A one year-old girl received 1° and 2° burns on the fingers and palms of both hands when she leaned against the oven door of a range several minutes after it had been turned off from one hour at 350°F.

Case 3. An eight month-old little boy tried to pull himself up by grabbing the edge of the oven door on a gas range which had been set at 500° for about 30 minutes. He suffered 2° burns to his left palm and to his right palm and finger.

Case 4. An 11 month-old girl received 1° and 2° burns to both hands when she supported herself, while walking, against the oven door of a gas range which had been set at 350° for about one hour.

Case 5. A one year-old boy fell against an oven door when he lost his balance, receiving a 2° burn to his left palm.

Case 6. A 65 year-old woman suffered 2° burns to her left forearm when she contacted the glass in her oven door as she tried to push it closed with her arm.

Case 7. A 13 month-old girl, walking from one supporting structure to another, received a 2° burn to the right palm when she tried to support herself against a hot oven door.

Case 8. A nine month-old boy received 2° burns to his right palm and fingertips when he reached up to touch a hot oven door while crawling on the kitchen floor.

Case 9. A 10 month-old boy, trying to stand up, lost his balance and fell against a gas oven floor receiving 2° burns to both palms. The oven had been turned on and set at 450° less than 10 minutes earlier.

Case 10: An 11 month-old boy leaned against the hot oven door of a gas range and suffered 1° and 2° burns to his right palm and forehead.

Case 11: An eight month-old boy, crawling in the kitchen, suffered 2° burns to his hand when he touched the top edge of the broiler door on a gas range which had been turned off about two hours earlier.

Case 12: A 72 year-old woman who suffered a dizzy spell and fell against the side of her hot stove received 2° burns to her right forearm.

Case 13: A 14 month-old boy, pulling himself to a standing position by grabbing the oven door of an electric range, set at 450°, received burns to both palms when he contacted the glass window of the oven door.

Case 14: A 13 month-old girl suffered 1° and 2° burns to the palms and fingers of both hands from an oven door when she pulled herself to a standing position.

Case 15: A 10 month-old girl suffered 2° burns to both palms when she touched the glass window of an oven door.

Case 16: A 15 year-old girl contacted the oven door of an electric range when she climbed on a stool to reach above the stove, receiving 2° burns to her left knee.

About half of the children involved in these cases had crawled over to the cooking range and stood or pulled themselves into a standing position or placed their hands against the range for balance. Contact with the hot oven door was typically rather brief as parents responded quickly to their cries of distress. In three cases the parent had left the kitchen, only to return to the child's cry, and found them with their hands still in contact with the hot oven door. The Commission stated that "since none of these children were known to suffer from reduced sensitivity to heat sensation, it is assumed that they were unable to coordinate their movements well enough to react quickly once their pain threshold was reached". [4]

NEISS News [13], a publication of the U.S. Consumer Product Safety Commission, reported that "Direct contact with the range exterior or inside the oven door injured children under two most often. Most of these injuries were to hands." It cited examples of injuries to children which indicated that they may have a relatively long response time in withdrawing from a hot surface. One 15-month old girl pressed her hand for several seconds against an oven glass door which had reached a temperature of 200° F. Another case involved an eight month old boy who kept slapping an open oven door until stopped by his mother.

Other cases of burn injuries have been reported in the press. In the July 4, 1973 Wichita Eagle Newspaper [14], a mother wrote in to report that her "nine month old daughter incurred second and third degree burns on her right hand as a result of touching the outside of the oven when it was set at 450° F". She had written to ask why all ovens are not insulated like the self cleaning type and to alert other parents of the possible danger.

Range design

While insulation on the self cleaning type ranges is certainly better than on other types, it is by no means perfect. Consumer Reports [15] evaluated self cleaning ranges in July 1972 and reported that "during the cleaning cycle, one model never became hotter than 160° F on the outside, but most of the others had hot spots on the front of the oven door or the front of the cooktop that got up to around 180°- 200° F". A model that reached the highest inside temperature produced temperatures of 250° F just above the door handle while in operation. Metal parts on the underside of the ovens become very hot during the cleaning cycle as well. Here, temperatures of

250°- 320° F were reached by the tested ranges.

Range manufacturers do try to prevent excessive heat loss from ovens by design and insulation techniques. Usually the frame of a range is made of steel or iron which is riveted or held together by screws. Panels of sheet metal are attached to the frame. The material used for insulation is usually rock wool or Fiberglas [16].

Some manufacturers make use of insulation and a design feature called an air wash. There are two panels on the door front with openings at the top and bottom. Air enters at the bottom and moves up in a chimney effect and out the top. The outside panel is kept cool by the moving air. Some manufacturers use this design with a black glass as the outside panel while others use a porcelain enamel on steel material. Kenneth Brown, President of Brown Stove Works in Cleveland, Tennesee, stated in an interview with Home Furnishings Daily in August, 1975, that they had been working for a year to reduce the outside window area temperature of their ranges. He explained that they would be using three panes of glass instead of two to meet the new standard requirements. The improved insulation and design used in the newer ranges to conform to the lowered exterior temperature safety requirements also conserves energy because the oven heat is retained better.

Consumer's Research (May 1976) [17], measured the exterior temperature of several ranges after two hours operation at 450°F. Their report concluded that a major area of heat loss was the oven door, particularly a door with a window. The window "not only presents a burn hazard, particularly to small children who might touch the exterior surface of the glass in the window, but also makes for inefficient operation". Their researchers emphasized that determining at just what temperature a particular part of a range might constitute a burn hazard is a complex problem. They stated that factors to be considered are the material involved, the nature of its surface, its heat conductivity and the contact interval of the temperature sensor with the hot surface. Materials and finishes vary as to the hazard they present. A part made of steel is much more hazardous at the same temperature than one made of plastic.

The article [17] made reference to the new standard which set a temperature of 400° F as representative of the maximum temperature at which a home range oven will be operated for a prolonged time, but took exception to this as a standard temperature. "Unfortunately, the 400°F figure doesn't represent the maximum oven temperature that may be used (in fast-baking a turkey, for example) and therefore outer shells of ovens which pass the standards of testing organizations and carry their seals may still present a burn hazard under certain conditions of operation."

Children's physiological and psychological characteristics

The Calspan Corporation [18], made an investigation for the Consumer Product Safety Commission to identify and classify potential hazards associated with the use of ranges and other home heating appliances. It looked at the burn problem in general and burns of children, specifically. Researchers found a scarcity of literature studying causes and factors leading to burns of children and, also, no general agreement as to the thermal sensory mechanisms of children. It is known that a child's physical and psychological make-up is different than an adult's. Literature on general childhood accidents points to the "obvious fact that learning and perception are probably the most important factors involved in childhood accidents", noted the Calspan report. In addition, the lack of experience with the environment and the child's normal tendency to imitate parental and adult behavior may make him more often injured in the home than an older person. The child also lacks the ability to recognize potential hazards of objects and behaviors. Education and supervision cannot be entirely responsible for children's behavior, but supervising adults must be made aware of the child's changing physical, cognitive and perceptual capabilities in order to better understand, maintain vigilance, supervise and train the child accordingly.

Calspan reported that it is known that "children tend to suffer more severe accidental burns than adults" [18] and attempted to determine the reason for this. A consistant pattern found with respect to young children was the "nearly universal failure of the victim to remove himself rapidly from the hot surface when it was apparently within his power to do so". [19] As a result, the severity of the burn was increased. This response could be caused by misperception of the danger or inappropriate reaction to a perceived danger. In addition, "during exposure to extreme heat during unexpected or misperceived thermal contact, the slowed reaction can cause destruction of the skin's thermal and bright pain receptors. The deeper pain receptors, having slower response time, especially during certain childhood developmental stages, allows longer contact time before perception and sensation, therefore allowing more tissue damage to occur before reaction is initiated" [18]. In some instances the "contact times which produce injury are relatively short and may be at or below the response time of adults (about 1 second)". As children's response times are often longer than an adults's, a more severe burn would result. [18]

Gibson [20] gives two general causes for childhood accidents: the child's failure in perceiving and his failure in reacting. He writes that "in the case of a child, motor development may be immature. There may occur conflicting tendencies to react - that is, habit interference. There may sometimes be inhibitions of reaction by fear. But the main reason is what is called insufficient motor skill. The essence of skill lies not so much in the connecting of single reactions to single stimuli as in the control of the flow of action and the co-ordering of output to input."

The Calspan study concluded that a child cannot be treated, or thought of, as a miniature adult. Cited in this area was research by Krech, et al (1969) [21] showing that a child differs from an adult in physical characteristics, neurological structure and, most importantly, in behavior potentials. By physical characteristics is meant size, abilities and body porportions. A child's neurological structure is undergoing development, with resulting changes in his organs and sensory mechanisms. A child goes through a maturation-learning process which involves learning to react to stimuli according to the stages of his developing sensory limits and limited perceptions. These stages include the cephalocaudal (head to foot) and proximodistal (center to periphery) neurological developments. These sequences are partially caused by the axon myelinizations of certain neurons which increases their transmission speed. What this means is that a child's reaction, both in time and behavior, is constantly changing and different during various stages of maturation and development.

Equally important is the child's learning process and perception of possibly dangerous situations. All perception depends on attention and past experience. The child observes his mother working around the range without harm and perceives this as a desireable situation. He may then try to imitate his mother's actions. Reaching for a pan on a hot burner or touching the oven door or handle is a normal desire. The child does not perceive the danger and his attention is on his desire to duplicate the parent's activity and not on any apparent danger. [21]

Calspan researchers also cited Ruch (1963) [21] who wrote that attention is a matter of both physiological and psychological selectivity and can modify sensory and cognitive perceptions. Attention involves what an individual expects to hear, see or feel based on past experience or learning. This will modify an individual's reaction time to unexpected stimuli. The child touches the hot surface and does not immediately react because he is not expecting to be harmed, especially doing something that seems to duplicate his parent's actions. Adding to the problem could be that the child's neurological structure and sensory mechanisms could be at a developmental stage which slows down physical reaction time.

In calculating safe surface temperatures, Calspan [18] noted that although temperatures in ANSI Standard Z21.1 are measured at oven temperatures of 400°F except for self cleaning ovens, in operation oven temperatures may reach more than 400°F. Some cooking operations may have temperatures set at 450°F or above. Even more severe may be oven temperature during broiling. Lower temperature limits may need to be set to protect people from burns at all times during cooking operations, according to Calspan researchers.

As a recommendation to appliance designers, the investigators at Calspan stated that the engineer "must assume that areas of an appliance accessible to a child will be touched by a child since there is no inherent "fear factor". Secondly, the designer must take into account longer contact times for children than for adults as the withdrawal response in young children is not an instantaneous reflex action." [19]

The author's correspondence with several physicians indicated some disagreement as to whether 1) a child's skin is thinner than an adult's, and therefore would burn more easily and 2) a slower reaction time is common in children, since studies report that children do not react normally when exposed to a hot surface. Dr. Hugh D. Peterson [22], DDS, MD of Brooke Army Medical Center at Fort Sam Houston replied that, "There is no exact measurement of the thickness of the child's skin compared to an adult's skin. What can be said is that the skin of the palm and the soles of the feet are thicker than his other skin, but all skin of children less than five years old is markedly thinner than adult skin and therefore full thickness burns are more easily incurred." Dr. Peterson also wrote that "children from six months to two years are perhaps a bit more slow to react to pain than an adult because the pain message from the receptor to the reflex arc and back to the muscle is a little slower because of its conduction time."

Dr. David W. Robinson [23], MD, University of Kansas Medical Center in Kansas City agreed, "Skin thickness in children is thinner than in adults". He explained that the thick kertin or horny layer adapted for protection of the hands is not developed in children so, therefore, their hands cannot withstand as much heat. He said, however, that in his opinion there is no difference in reaction time between children and adults, although coordination in children is not as developed.

Stoll [24] comments that the "thickness of the skin varies widely over the surface of the body. It may be more than 5 mm on the back and only .5 mm on the eyelids. The usual thickness is 1-2 mm."

Thermesthesiometer development

For researchers, one of the major problems in hot surface investigations was measuring the temperature of the surface and determining a safe temperature. It was done by a thermocouple, then calculations were made considering the material of the surface and its thermal properties to indicate a safe reading. A recent research program at the National Bureau of Standards in Washington, funded by the Consumer Product Safety Commission, has enabled

NBS scientist Louis Marzetta to design and construct a new instrument to measure the burn hazard of the heated surfaces of consumer products. This instrument, called a thermesthesiometer, is intended to duplicate the temperature that would be experienced if human contact were made with the heated surface in question.

The thermesthesiometer consists of a measuring probe that is cylindrical in shape and made of silicone rubber. The thermal properties of this material are close to those of human tissue. The probe, which has been likened to a human finger, is attached by cable to an electronic unit that provides a digital reading of the contact temperature. The instrument contains a temperature controlling circuit that maintains the probe assembly at 33°C - the temperature of human finguer tissue. A measuring thermocouple is located just below the surface of the end of the probe at a depth equivalent to the dermal layer containing the nerve endings in human skin. [25]

The thermesthesiometer will automatically take into account all of the variables that effect the severity of a burn and give scientist an easy method of identifying hazardous surfaces. Use of this instrument is required in the 1980 range standards.

STANDARDS FOR HOUSEHOLD GAS AND ELECTRIC RANGES

History of standard development

Voluntary standards have been developed for use by gas and electric range manufacturers to ensure quality construction, performance and safety. Most manufacturers readily support the development of voluntary safety standards because they realize that neither the retailer nor the consumer are able to adequately judge the safety of products displayed in the marketplace. The voluntary system practically becomes a mandatory program, however, because local authorities having jurisdiction over installation of appliances usually require that appliances installed in their area be constructed in compliance with nationally recognized standards. The system is not without flaws, however. The testing laboratories or organizations do not require the testing of an entire line of products. Manufacturers submit those models they wish to have tested for certification and may hold back those that may be substandard. Another major problem is that not every product on the production line is tested, though all will be certified if the tested model passes the tests. While 100% inspection would be a difficult task, it would ensure total compliance. Third, it is the manufacturers themselves who have a major role in writing the standards by which they will be regulated [26].

There are several organizations which have or have had a significant part in the development of standards for household gas and electric ranges.

Gas range standards

The first performance or construction standard for gas ranges was developed by the Philadelphia Gas Works in 1903. Shortly after this, proceedings of meetings of the American Gas Institute and the National

Commercial Gas Association show that they also considered specifications to be adopted for the building of gas ranges. In June 1918, these two organizations amalgamated to form the American Gas Association (AGA). A Subcommittee on Approval Requirements for Domestic Gas Ranges was formed for the purpose of revising existing standards and placing them in a form which would meet industry needs and enable the AGA's newly created Testing Laboratories to enforce them. The first AGA Approval Requirements were published in 1926. On September 11, 1930, the AGA Approval Requirements Committee became a Sectional Committee Z21 of the American Standards Association. Temperature limits for surfaces of ranges were first included in the standard in 1942 and since that time 11 editions have been published with only one major temperature change. That change lowered temperature limits by 20°F for all surfaces on the range and took place in 1972. Free-standing and built-in range standards were separated in 1956 to allow for more specific requirements for each of these two types.

The testing and certification agency is the AGA Laboratory. If a product passes all tests, it is certified and listed in the AGA directory. Certified products may display the "Blue Star" seal. [27]

Electric range standards

Electric range manufacturers voluntarily submit their products to Underwriter's Laboratories (UL) for testing and certification. UL was founded in 1894 with its purpose to conduct product tests, publish standards for manufacturers of products and to certify qualifying products. Those passing the standards may display the UL seal.

The first UL Standard for Household Electric Ranges was published in 1919; however, no surface temperature limits appeared in the standard until

1971. Temperature limits were lowered 20°F for the door and frame areas and 10°F for the window area in 1973. Limits were also set at this time for ovens operated on the self clean cycle. There have been a total of 12 editions of the standard from 1919 to 1978.

Industry and UL engineers are the major contributors in the process of development of a standard until the late stages, when comments from consumers and others are requested. Only one of the nine categories of representatives on UL standards committees is directly representing the consumer, although consumer interests are covered indirectly through categories of Government agencies and public safety organizations.

At one time the National Electrical Manufacturer's Association (NEMA) also issued standards for household electric ranges. In the 1950 edition of the NEMA standard, surface temperature limits were given for metallic and non-metallic surfaces that would be handled in the use of the appliance. About 1964 NEMA endorsed the UL standard for household electric ranges and dropped this part of its standard publication work.

NEMA is a trade association of manufacturers of almost every kind of equipment used for the generation, transmission, distribution and utilization of electric power. The organization is composed of subdivisions, called Sections, each representing a group of manufacturers of a certain class of products (e.g. water heaters, ranges, wire). NEMA has published over 150 separate standards for electrical equipment and cooperates with UL and the American National Standards Institute in the development of standards [28].

American National Standards Institute

The American National Standards Institute (ANSI), formerly the American Standards Association (ASA) and the United States of America Standards Institute (USASI), serves as a national clearinghouse for standards and provides machinery for developing and approving standards which are supported by a national consensus. Basic principles which apply to all standardization work under ANSI are: 1) standardization is voluntary; 2) the committee to develop standards must be balanced among producers, consumers, general interests and regulatory bodies. Each standard must be reviewed every five years [28].

Under ANSI is the Committee Z21, which writes gas range standards and is composed of gas industry representatives, insurance industry representatives and members representing the government as well as many other concerned groups. The Z21 Subcommittee on Standards for Domestic Gas Ranges does the major work of writing the standards.

The UL standards are also endorsed by ANSI.

Constant revisions to the standards, in temperature limits, testing method and instruments used have been made which would relate to this investigation. Tables 5 and 6 summarize requirements related to surface temperatures and measurement techniques for both gas and electric ranges under these standards.

Table 5. Household Gas Range Test Standards for Surface Temperatures.

Effective Dates	Temperatures Allowed Rise above room °F	Exceptions	Method of Test	Instruments Needed
Nov. 6, 1942 (Part II, Z21.1 1942 Performance Requirements Natural and Manufactured Cases Sec. 24a pp. 49-50)	Ave. weighted surface temp. - - - - - - - 65° Max. Metal door panel temp. - - - - - - - 95° Max. double glazed oven door panel temp.- 110° Max. single glazed oven door panel temp.- 125° Max. oven (broiler) side, top and back temp.- - - - - - - - - - - - - - - - - - - 110° Max. frame temp.- - - - - - - - - - - - - 125° Max. thermostat knob temp. - - - - - - - 40° Max. door handle temp.- - - - - - - - - - 40°		The gas input to the oven shall be regulated to maintain an oven temp. of 330°F $\pm$ 5° above room temp. Surface temps shall be taken 1 hour after a constant temp. has been reached in the oven. The temp. readings shall be taken at the center of equal areas on the top, sides, back of the oven (broiler) and the door panels. The top, back, door and sides shall each be divided into 16 areas, all areas on the same sheet being similar and equal. Surface temps. on exposed door frames and front frames shall be taken along their center lines at intervals of 4 in. where door frames are not exposed to view or where they are not used in the construction of doors, the surface on door panels bounded by each edge and a line parallel to and 1 in. from each edge shall be considered as the door frame. The temps. of such surfaces shall be taken at 4 in. intervals along their center lines. The temps. for each section shall be averaged and a weighted average calculated on the basis of the area of the section. Temps. shall not be taken closer than 1 in. to objects such as thermostats which come in contact with the products of combustion or the heated interior of the oven. Temps on the oven and broiler door handles and on the thermostat knob shall be made by means of the surface temp. thermocouple described above. Temps. shall be taken on those portions of the handles or knobs normally touched in opening the doors or setting the thermostat.	The (interior) temperature reading shall be made with an indicating or recording potentiometer / 5 parallel-connected thermocouples, one located at the center of the oven and the other 4 equally spaced between the center and the corners of the oven on the diagonals of a horizontal plane through the center of the oven. The surface temp. shall be determined by means of an indicating potentiometer and an iron-constantan thermocouple with its junction blazed in the face of a copper plate 7/32 in in diameter +0.024 in. thick. Iron Constantan lead wires from the junction shall be No. 24 AWG.

Effective Dates	Temperatures Allowed Rise above room °F	Exceptions	Method of Test	Instruments Needed
Sept. 21 1948 (Z21.1 1948 Part II Performance Requirements Natural, Manufactured and Mixed Gases Sec. 19 p. 36-37)	Ave. weighted surface temp. - - - - - - - - 65° Max. metal door panel temp. - - - - - - - - 95° Max. glazed door panel temp. * - - - - - - 110° Max. exterior side, top, and back temp. - - 110° Max. frame temp.- - - - - - - - - - - - - - 125° Max. door handle temp.- - - - - - - - - - - 40° Max. thermostat knob temp.- - - - - - - - - 40° Max. valve handle temp. - - - - - - - - - - 40° Recommended: Max. timing device knob temp. - - - - - - - 40° Max. auto pilot button temp. - - - - - - - 40° *no temp. shall be taken closer than 1 in. to the opening framing the glazed panel		No Change Temps on the oven and broiler door handles, valve handles and on the thermostat knob shall be determined with the surface temp. thermocouple, described above. Temps. shall be taken on those portions of the handles or knobs normally touched in opening the doors, manipulating the valves or setting the thermostat.	No Change
Jan. 1 1953 (Z21.1 1953 Part III Domestic gas ranges for use with natural, manufactured and mixed gases. Sec. 2.20 p. 39	Rise above room °F Ave. weighted surface temp. - - - - - - - - 65° Max. metal door panel temp. - - - - - - - - 95° Max. glazed door panel temp. * - - - - - - 110° Max. exterior side, top and back temp.- - - 110° Max. frame temp. - - - - - - - - - - - - - 125° Max. door handle temp.- - - - - - - - - - - 40° Max. thermostat knob temp.- - - - - - - - - 40° Max. valve handle temp. - - - - - - - - - - 40° Recommended: Max. timing device knob temp. - - - - - - - 40° Max. auto pilot button temp.- - - - - - - - 40° *No temp. shall be taken closer than 1 in. to the opening framing the glazed panel.		The thermostat shall be set to maintain an oven temp.	No Change

Effective Dates	Temperatures Allowed Rise above room °F	Exceptions	Method of Test	Instruments Needed
Jan. 1, 1956 (Z21.1 1956 Approval Requirements for Domestic Gas Ranges Sec. 2.20 p. 44-45)	Ave. weighted surface temp.- - - 65° Max. metal door panel temp.- - - 95° Max. glazed door panel temp.*- - 110° Max. ext. side, top, back temp.- 110° Max. frame temp. - - - - - - - - - 125° Max. door handle temp. - - - - - 40° Max. thermostat knob temp. - - - 40° Max. valve handle temp.- - - - - 40° Recommended: Max. timing device knob temp.- - 40° Max. auto pilot button temp. - - 40° *No temp. shall be taken closer than 1 in. to the opening framing the glazed panel.		No Change	No Change
Oct. 10, 1956 (Z21.1 1956 Sec. 2.19 p. 38)	No Change		No Change	No Change
July 21, 1959 (Z21.1 1959 Sec. 2.19 p. 39-40)	No Change		No Change	No Change
Oct. 30, 1961 (Z21.1 1961 Sec. 2.19 p. 40-41)	No Change		No Change	No Change
Jan. 1, 1965 (Z21.1 1965 Sec. 2.19 p. 42)	No Change (instead of auto pilot) Max. safety shutoff device button temp. -40		No Change	No Change

Effective Dates	Temperatures Allowed Rise above room °F	Exceptions	Method of Test	Instruments Needed
Nov. 8, 1967 (Z21.1 1967 Sec. 2.19 p. 38-39)	No Change	*For combinations of top section and elevated oven or broiler, surface temp. rises for oven or broiler metal or glazed door frames may exceed the applicable limits by no more than 30°F for areas that will be more than 4 ft. above floor level in the normally installed position except for such surfaces as must be contacted in use of the door handle.	No Change	No Change
Sept. 15, 1969 (Z21.1.2b 1969 USA Standard for Domestic Gas Ranges Vol. I Free-standing Units Sec. 2.19 p. 7)	Max. metal door panel temp.- 95° Max. glazed door panel temp*110° Max. ext. side, back temp. -110° Max. frame temp. - - - - - -125° Max. door handle temp. - - - 40° Max. thermostat knob temp. - 40° Max. valve handle temp. - - 40° Recommended: Max. timing device knob temp 40° Max. safety shutoff device button temp.- - - - - - - - 40° * temps shall not be taken closer than 1 in. to the opening framing the glazed panel.	No Change	No Change	No Change
Jan. 12, 1972 to Feb. 12, 1974 (new range designs) Sept. 30, 1975 (old range designs)	Max. Surface Temps. Rise above Room Metal door panels - - - - - 75° Glass door panels *- - - - - 90° Exterior side & back - - - - 90° Frame- - - - - - - - - - - - -105°	No Change	An oven or a combination oven & broiler which is heated by the oven burner shall be tested with the thermostat set to maintain an oven temp. of 330°F ± 5° above room temp.	

Effective Dates	Temperatures Allowed Rise above room F		Exceptions	Method of Test	Instruments Needed
	Door handle - - metal - -	40°		With the unit at room temp. the gas shall be turned on, ignited and the door closed. Surface temps shall be taken 1 hour after constant temp. has been reached in the compartment. Surface temps. shall be taken at the center of equal areas on the door panels	Surface temps. shall be determined by means of an indicating potentiometer and an iron constantan thermocouple with its junction brazed in the face of a copper plate 7/32" in diameter and 0.024 in. thick. Iron constantan leads wires from the junction shall be No. 24 AWG.
	nonmetallic-	60°			
	Thermostat knob-metal - -	40°			
	nonmetallic-	60°			
	Valve handle- - metal - -	40°			
	nonmetallic-	60°			
	*Temps. shall not be taken closer than 1 in. to the opening framing the glass panel.			No Change	
	Recommended: Timing device knobs and safety Shutoff device buttons -				
	metal - - - - - - - - - -	40°			
	nonmetallic - - - - - -	60°			

Table 6. Household Electric Range Test Standards for Surface Temperatures.

Effective Date	Temperatures Allowed	Exceptions	Method of Test	Instruments needed
May 4 1950 issuing agent: NEMA	Metallic surfaces to be handled not to exceed 130° Non-metallic surfaces to be handled not to exceed 150° (Based on ambient temp. of 75°)		Oven will be brought up to a steady internal temp with the thermostat set at 400°F (through first 4 cycles) Operate oven, deep well and surface elements for ½ hr. on high and measure surface temp of areas to be grasped firmly.	Use thermocouple wires not larger the .02" in diameter with the tip fastened to the surface with cement
1962	Standard for electric ranges to be followed: UL 858 latest revision			
June 1, 1971 - May 31 1973 issuing agent: UL Standard for Safety Household Electric Ranges UL 858 April 19, 1971 pp. 48a-48d	Max. Acceptable Temp. Rise — Test 1 & 2a °C °F — Test 3a °C °F Door panel[bc] - - - -53 95 -- -- Viewing area of glass window in door[bc] - - - - - - -61 100 -- -- Exposed door frames and front frames[bd] - - -69 125 -- -- Side surfaces[b] (including cook top & backguard sides) - - - - - -61[g] 110[g] -- -- Handles & knobs[eh] Metallic - - - - 22 40 22[f] 40[f] Nonmetallic - - - 33 60 33[f] 60[f] a. See para. 224D-224F b. Items 1-4 may exceed the limits by no more than 30°F (17°C) for areas that will be more than 3 ft. above floor level as installed. c. Temp limits not applicable in areas 1 in. on either side of opening framing the viewing area of the glass window d. Not applicable to front areas between the top of the oven and below the cooking platform, except for knobs and handles e. Plated plastic and plastic or vinyl covered metal are considered nonmetallic f. These temp. limits apply only during the time the door can be opened. At peak cleaning temps limits for handles and knobs are the same as given under item 3. g. An appliance is considered to comply with these limits since it complies with the requirements in para 201-224. h. See para. 224J	Temp limits do not apply A. A back-guard front B. The bottom of an eye-level oven C. The front surface between the top of the oven door and the horizontal surface of the cook-top D. The front surface between the oven doors of a double built-in oven. E. A combination range as described in para. 204, 205 or 206.	The range or oven is to be installed as described in para 201-224 for the normal temp. test, except that the booth wall is to be omitted from any side on which temps are to be measured. Test 1 - The oven thermostat (or both thermostats if 2 ovens are provided) is to be set to maintain an average oven temp of 183 ±3° C (330±50° F) above room temp. All surface elements are to be turned off. Test 3 - If the appliance included 1 or 2 pyrolytic self-cleaning ovens, the test is to be started at room temp, the oven or ovens are to be clean & no surface element is to be operated. In a dual oven appliance 1) the non-self cleaning oven is to remain de-energized during the test, and 2) two self-cleaning ovens are to be operated simultaneously if the controls permit such operation. Operation is to be continued through the longest-attainable self cleaning cycle or until temps are constant, whichever results in the shorter operating interval. Temps are to be observed one hour after constant temp has been attained in the oven or on the stove plate or griddle, whichever condition occurs later, and temps are to be observed continuously during the cleaning cycle of a pyrolytic self cleaning oven. Temp readings are to be taken at the centers of equal areas on the side panels of the range and on the door panels. (For illustration see Fig. 10 in standard)	Temps are to be measured by an indicating potentiometer & iron constantan thermocouples. The thermocouple is to be broght through a hole in a 7/32" diameter, 0.024 in thick copper plate and brazed so that the temp. measuring face is smooth and flat. The thermocouple lead wires are to be no larger than No. 24 AWG. A suitable temp. measuring probe may be used for determining the critical points, but the temp measurements are to be made by the thermocouple and disc mentioned above. An oven temp is measured by a single thermocouple and disc located in the center of the oven.

Effective Date	Temperatures Allowed	Exceptions	Method of Test	Instruments needed
June 1 1971- May 31, 1 1973 Cont.			The panels are to be divided into 16 areas, all areas on the same panel being similar in shape and of equal area. Surface temps on an exposed door frame and on a front frame are to be taken along the center lines on the front side only. If a frame is not exposed to view or if a frame is not employed in the construction, the surface bounded by each edge and a line parallel to and one inch from that edge is to be considered as the frame. If the side of an oven door is exposed when the door is closed, this area is considered to be part of the area of the side panel. The temp. rises of handles, knobs, grips and the like are to be determined at all points that are grasped during normal use.	
June 1 1973- Sept 30 1975 Standard for Safety Household Electric Ranges UL 858 Aug. 7, 1974 pp. 41-43 Sec. 51.52-51.56	Max. Acceptable temp rise — Test 1&2 °C °F, Test 3 °C °F Door panel[bc]: 42, 75, 53, 95 Viewing area of glass window in door[bc]: 50, 90, 61, 110 Exposed door frames & front frames[bd]: 58, 105, 69, 125 Side surfaces (including cook top sides & back guard sides): 50, 90, 61, 110[?] Handles & knobs[ch] Metallic: 30, 54, 30[f], 54[f] Non-metallic: 50, 90, 50[f], 90[f] Glass: 40, 72, 40[f], 72[f] No Change except: e. Includes plastic with a metal plating not more than 0.005" thick; and metal with a plastic or vinyl covering not less than 0.005" thick	Temp. limits do not apply to: A. The horizontal surface of the cooktop containing the surface cooking units & surfaces facing the cooktop B. The front surface between the top of the oven door & the horizontal surface of the cook top. If no cooking surface is provided the exempted area is considered to extend 6"above the top edge of the oven door. C. Areas higher than 60" above the floor D. Flue deflectors or vent openings & areas within 1" of such deflectors or openings E. The front surface between the oven doors of a double built-in oven	No Change	No Change

EXPERIMENTAL PROCEDURE

The testing procedure was a composite developed from standards used for evaluating ranges submitted for UL or AGA listing. Ranges used for the study were located in the home economics teaching and research laboratories at Kansas State University and in the homes of community volunteers. A wide variety of brands and ages of ranges was used.

Pre-test procedures

Before each test, room temperature, time, address and range information such as model number, serial number, brand, cleaning features, door and handle material was recorded for use during analysis and in case it was necessary to contact the volunteer again. The data sheet is located in the Appendix.

The oven door was cleaned with a damp cloth before testing to remove any grease or soil which might prevent good contact between the temperature sensing probe and the door's surface. The door fit was checked to determine if there was any relationship to poor fitting door gaskets and hot spots on the surface. Van Zante [32] suggests that the fit of the oven door be checked by closing it upon a piece of paper, then attempting to withdraw the paper while the door remains closed. The paper will be tightly held by a well fitted door. This technique was adopted for the tests.

After cleaning, a grid was drawn on the door with a washable marker, to indicate where temperatures would be taken. Figures 1 and 2 show the grid schematic. The grid included a one inch border around the outside frame area of the door. The border was marked for temperature measurement every four inches, beginning at the upper right corner and proceeding down and

Figure 1: Example of grid on oven door without window.

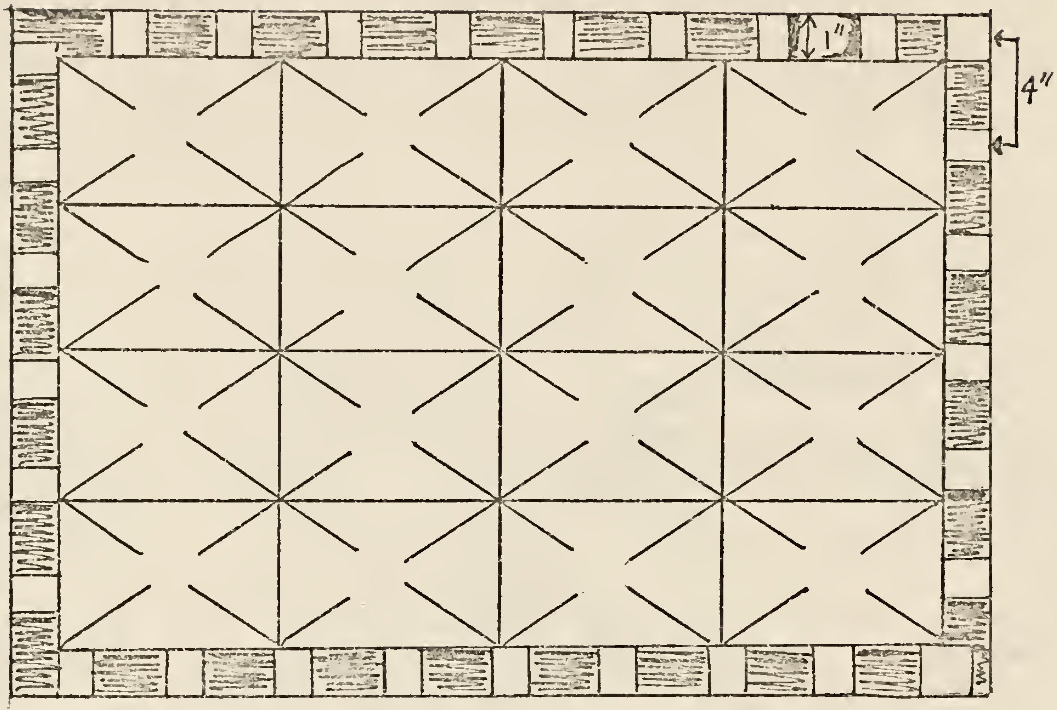
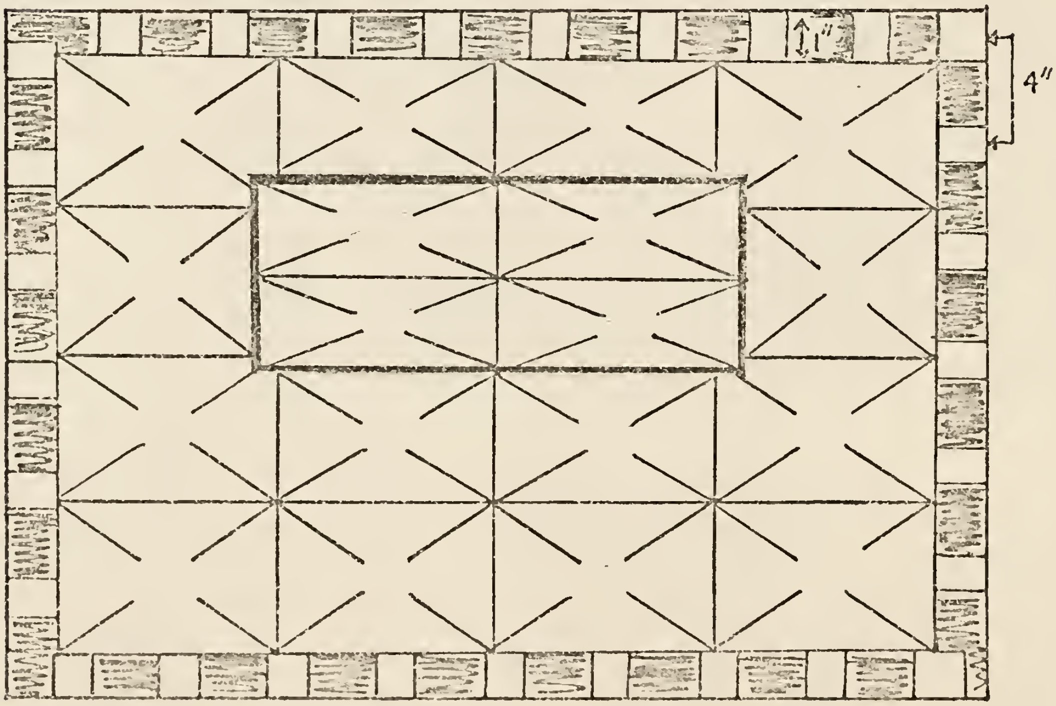


Figure 2: Example of grid on oven door with window.

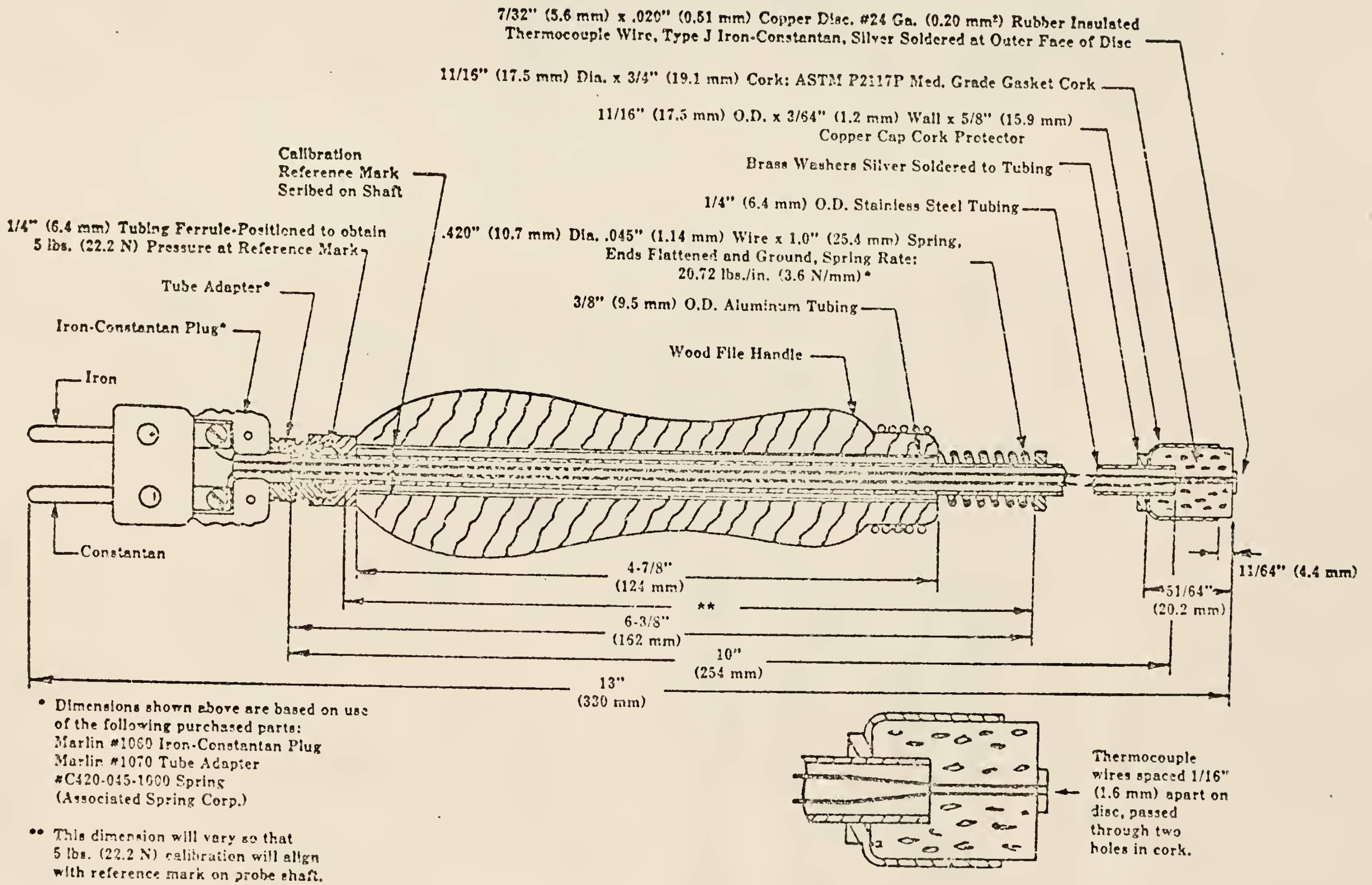


around the door. If the beginning and ending point on the strip were closer than one inch, the last point was not used. If the handle covered the strip and the temperatures could not be taken in the border area on the proper points, no readings were taken on the section. If the handle was attached so that readings could be taken normally under the handle, temperatures were recorded for the section. The center area of the oven door was divided into 16 equal areas with the temperatures taken in the center of each. To locate the exact center and to be able to take the temperature at the same point with each trial, an X was drawn in the square. As can be noted on the drawings, the X does not intersect. It was left open in the center so that the marker lines would not prevent good contact between the probe and the door surface. If the door had a window, it was divided into four equal areas and the temperature taken in the center of each.

Instrumentation

A thermocouple, shielded with foil, was placed in the center of the oven during preheating and operation for the test. This was to indicate if the oven was reaching the proper temperature during the test. The thermocouple was attached to a Rustrak recording potentiometer, model number 2155A. Temperature in the oven was to average 400°F and before the test began, the oven thermostat was adjusted so that the 400°F temperature was reached. The interior temperature of the range was not measured during the tests of the self cleaning ranges.

A temperature measuring probe was built according to specifications in UL 858 Standard for Household Electric Ranges. A diagram for the probe is shown in Figure 3. It consisted of #24 iron-constantan thermocouple wires that were drawn through a wooden handle and silver soldered to a copper disk, 7/32" x .020", imbedded in cork. A spring made it possible to calibrate the



* Dimensions shown above are based on use of the following purchased parts:
Marlin #1060 Iron-Constantan Plug
Marlin #1070 Tube Adapter
#C420-045-1000 Spring
(Associated Spring Corp.)

** This dimension will vary so that 5 lbs. (22.2 N) calibration will align with reference mark on probe shaft.

Figure 3. Temperature-Measuring and Accessibility Probe

instrument so that an even five pound force would be exerted on each point during testing. The probe was attached to a Rustrak recording potentiometer model number 107. Other instruments used were a GraLab universal timer, for measuring the seconds that the probe was held in contact with the door at each point, and a thermometer to measure room temperature. It was necessary to warm up the potentiometer for 30 minutes before each test for accurate readings. It and the probe were checked for proper calibration and operation periodically by checking room temperature and the temperature of boiling water.

Test procedures

The temperature setting for the oven and length of oven operation before the test were suggested by the UL and AGA standards. For self cleaning ranges, the ovens were operated for two hours in the cleaning cycle before the test began and were in this cycle the entire time the door temperatures were taken. For the ranges tested on the bake cycle, the oven was brought to 400°F and operated for one hour at an average internal temperature of 400°F before the testing began. The oven temperature was held at 400°F the entire time the door temperatures were being taken. The standards state, in some years, that this temperature should be 330°F $\pm$ 5°F above room temperature; however, for this testing an oven temperature of 400°F was used without allowing for the variation in room temperature. None of the other units on the range was operated during the preheating or testing and the oven door was not opened after operation began.

A checklist of steps, developed by the investigator to ensure against omissions and guarantee reproduceability is as follows:

1. Plug in and warm up the recorder
2. Clean surface of oven door
3. Check door fit with paper

4. Record all information at the top of data sheet

5. Place shielded thermocouple sensor in oven and preheat range

6. Draw grid on surface of oven door

7. Adjust interior oven temperature if necessary for 400°F average

8. Draw and number grid on data sheet

9. Measure and record temperatures

The grid on the data sheet was numbered sequentially so that the investigator took readings in the proper order and that order would be recorded.

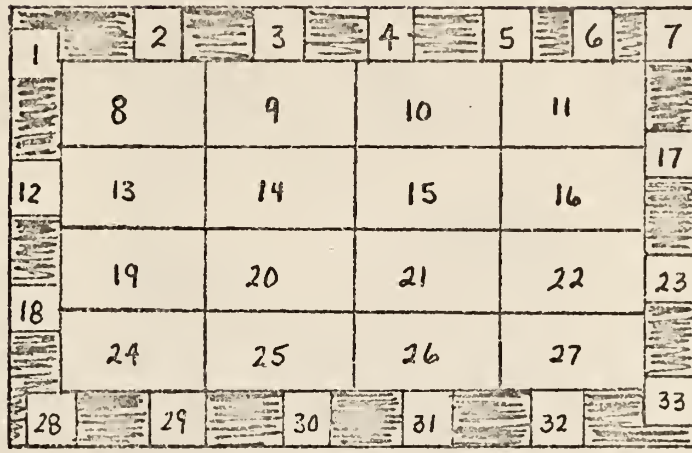
The probe was preheated for 1½ minutes by holding it on the first point, before beginning the test. After that, the probe was preheated for 15 seconds on each point, five pounds of pressure was applied for 10 seconds, the reading was taken and five seconds was allowed for movement to the next point.

The temperature of each point was taken three times in the sequence shown in Figure 4. Temperatures were taken starting at the upper left corner and going across, then returning to the second row and working from left to right again. After all points were taken in rows left to right, the order was reversed and all points were taken a second time. For the third trial, temperatures were taken beginning at the upper left and working from top to bottom in columns. At the end of the three trials, if two readings differed more than 7.5°F, a fourth reading was taken. Accuracy of readings was ± 3°F.

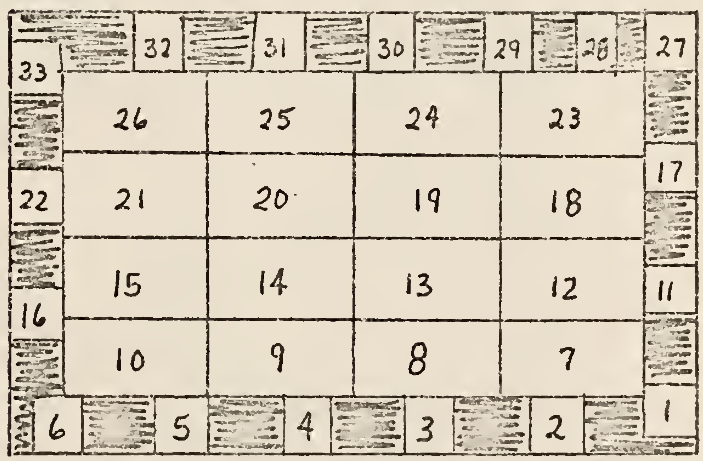
Figure 4: Order in which temperatures at points were measured & recorded.

Begin

Trial 1



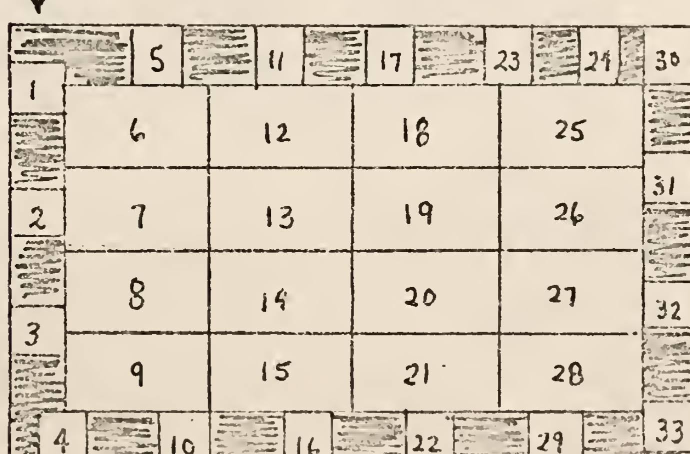
Trial 2



Begin

Begin

Trial 3



RESULTS

For this study 55 ranges were tested to determine the temperatures of various surfaces on the oven door. Of these, 20 were gas ranges manufactured from 1948 through 1974 and 35 electric ranges produced from 1949 through 1974. Since annual model changes are not common in the major appliance industry, the exact dates of manufacture had to be obtained from each manufacturer using serial numbers.

For analysis, ranges of each type (gas or electric) were grouped by date of manufacturer and the standard in effect at the time of production, as seen in Table 7. No UL standard specifying maximum range surface temperatures were in effect prior to June 1, 1971. The first UL standard extant was applied when test results for ranges manufactured from 1949 through May 31, 1971 were compared to standard requirements.

Several modes of comparison are appropriate or necessitated by the wording of the various standards. The standards specified different temperature limits for window area, frame area and porcelain door, so a range could be in noncompliance if a single temperature at any specified point was in excess of the appropriate limit. Such temperature limits, in terms of degrees Fahrenheit above room temperature, are tabulated in Table 8 for gas ranges and in Table 9 for electric ranges. Figures 5, 7 and 10 (for gas) and Figures 13, 15 and 18 (for electric) classify, in 10-degree increments, the percentage of ranges in each group above and below the appropriate surface temperature limit specified in a standard.

Although the standards did not require it, the average of the four hottest points was determined for each area, in order to lend greater credance to judgements of noncompliance. Lateral temperature gradients proved

Table 7. Range Groupings by Applicable Standards.

<u>Gas Ranges</u>

Group G-1 (1972-1975)

1974 Tappan
1974 Hardwick
1974 Hardwick
1974 Hardwick
1974 Roper
1974 Roper
1974 Firestone
1974 Penney's
1973 Tappan
1973 Magic Chef
1972 Tappan

Group G-2 (1948-1972)

1970 Royal Chef
1970 Whirlpool
1969 Tappan
1969 Sears
1969 Magic Chef
1961 Tappan
1955-62 Chambers
1951 Roper
1948 Roper

<u>Electric Ranges</u>

Group E-1 (June 1, 1973-Sept. 30, 1975)

1974 Westinghouse
1974 Sears
1973 Frigidaire

Group E-2 (June 1, 1971-May 31, 1973)

1973 Corning
1973 Westinghouse
1972 Hotpoint
1972 Hotpoint
1972 Corning
1971-72 Frigidaire
1971-72 Frigidaire
1971-72 Frigidaire
1971 Sears

Group E-3 (before June 1, 1971-no standard in effect

1971 Hotpoint	1962 GE
1971 GE	1960 Hotpoint
1971 Hotpoint	1959 Westinghouse
1970 GE	1959 Frigidaire
1970 GE	1959 Kelvinator
1970 Hotpoint	1957 GE
1969 Sears	1956 Westinghouse
1965 GE	1956 GE
1964 Frigidaire	1955 Westinghouse
1964 Frigidaire	1949 Frigidaire
1964 Hotpoint	
1964 Hotpoint	
1963 Hotpoint	

Table 8. Summary of Temperatures Allowed by Standard, Household Gas Ranges AGA/ANSI Z21.1.

	Degrees above room temperature	
	1948 - 1972 (Group G-2)	1972 - 1975 (Group G-1)
Maximum metal door panel	95°F	75°F
Maximum window panel(glazed panel)	110°F	90°F
Maximum frame	125°F	105°F

Table 9. Summary of Temperatures Allowed by Standard, Household Electric Ranges UL 858.

		Degrees above room temperature	
	Before June 1, 1971 (Group E-3)	June 1, 1971 - May 31, 1971 (Group E-2)	June 1, 1973 - Sept. 30, 1975 (Group E-1)
Door panel	No	95°F	75°F
Glass window	Standard	100°F	90°F
Frames	Applicable	125°F	105°F

to be considereable, allowing small variations in grid delineation or sensor placement to appreciable affect reproducibility. Figures 6, 8 and 11 (for gas) and Figures 14, 16 and 19 (for electric) compare the average temperature of the four hottest points with the appropriate standard.

Since "hot spots" may be more an indication of careless assembly than inadequate design, the average of all temperatures measured on each area was determined for comparison. Figures 9 and 12 (for gas) and Figures 17 and 20 (for electric) show the relation between such averages and the standards in force. Since only four points were tested on each window, the average of the four hottest points was also an overall average.

At the bottom of each of the aforementioned figures is a plot of each data point included in the classified data. They show the actual data spread, although they do not lend themselves to histograph plotting.

Figures 21-36 present the data of Figures 5-20, classified in 10-degree increments, in absolute terms rather than in comparison to a standard. This allows for an historic perspective of the range industry's attitude toward and remedies for a serious safety problem.

Evaluation of compliance with standards

Gas Ranges. When considering the window at the hottest point (Figure 5), 88% (all except one range in group G-1) were above the standard. All ranges in group G-2, the older set, were above the prescribed temperature limits, indicating slightly better compliance in recent models. Averaging the four highest temperatures (Figure 6) brings the temperature closer to the AGA standard, but still only one G-1 range is within the limits. The same pattern is seen for the older models, G-2.

The hottest point on the porcelain door was above the standard for six of

Fig..5 Hottest point on window, degrees above or below standard, gas ranges.

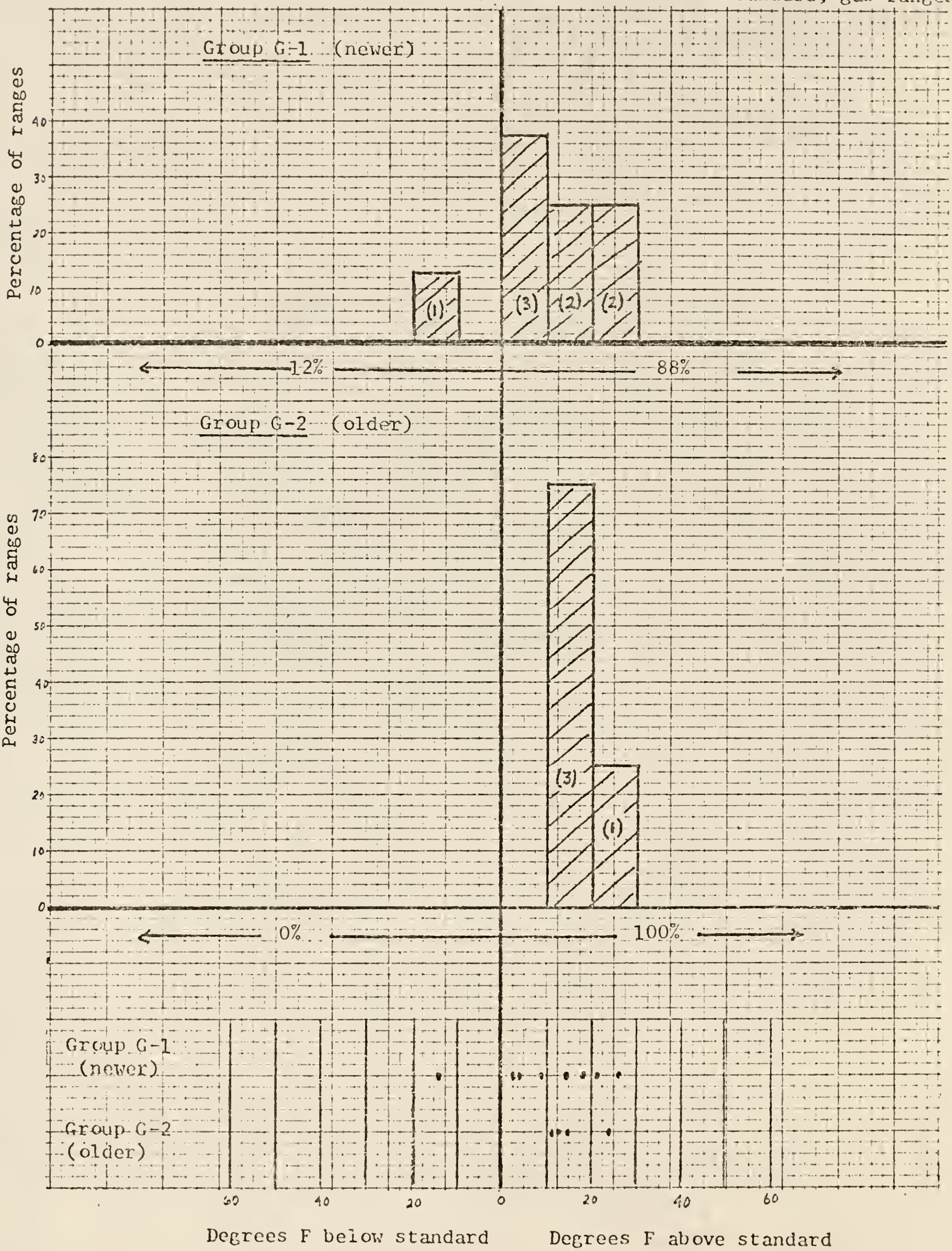
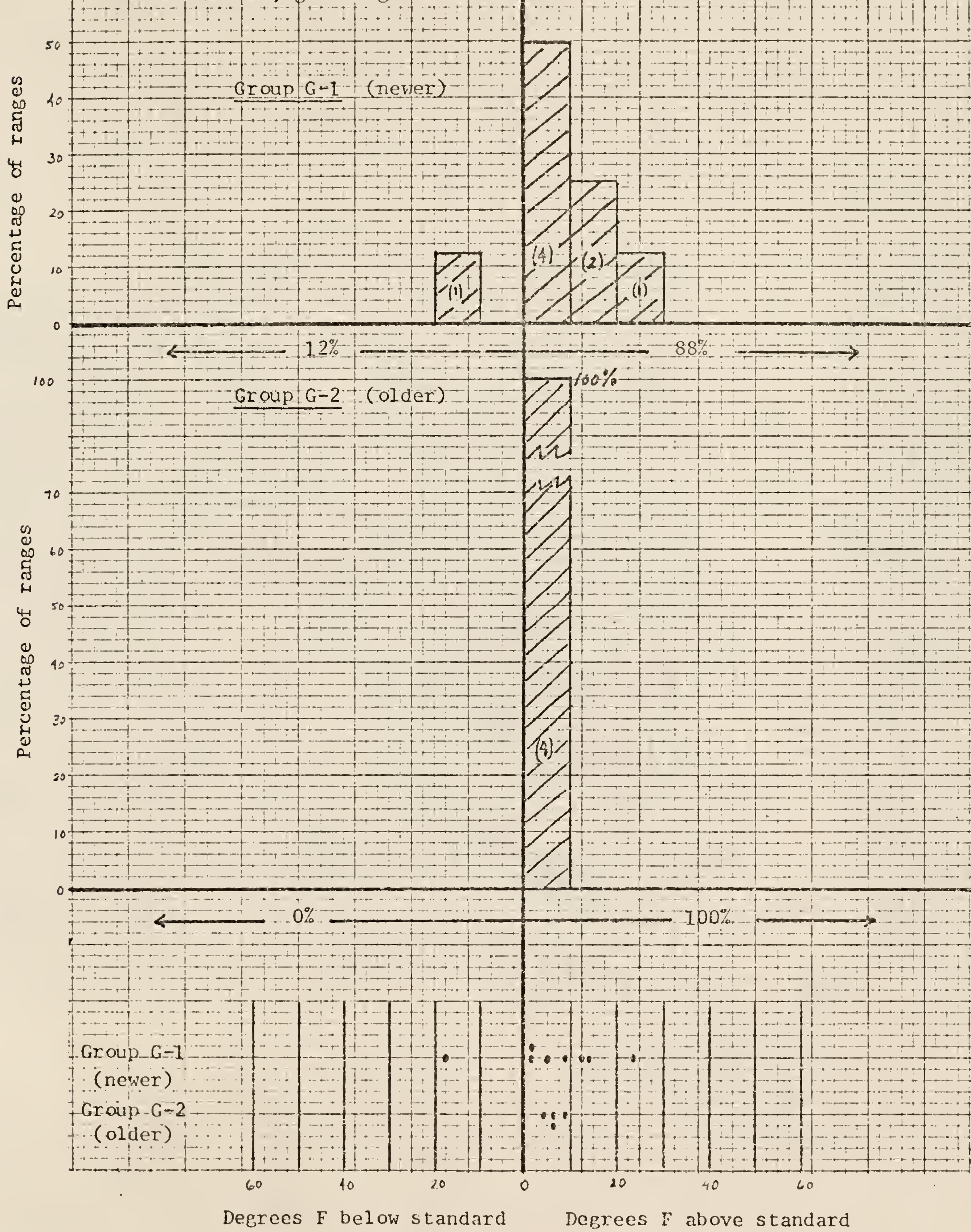


Fig. 6. Average of 4 highest points on window, degrees above or below standard, gas ranges.



the nine ranges in group G-1, or 67% (Figure 7). One of these ranges had a temperature 69°F above the standard. The older ranges, group G-2, were more in compliance, with only 22% above limits. When considering the average of the four highest points on the porcelain door (Figure 8), compliance improved slightly for both groups. Group G-1 still had one range more than 60°F over standard limits, but the percentage exceeding the limits had decreased from 88% to 67%. Group G-2 still had 22% above limits, but not by as much as previously. Averaging the readings from all points on the door brought 67% of the group G-1 and all of G-2 into compliance (Figure 9). It should be remembered, however, that the standard states that all points should be below the temperature limits, making no allowances for averaging any points.

Comparison of the two groups for the hottest point on the frame (Fig. 10) shows almost equal compliance, 55-56%. Averaging the four hottest points (Fig. 11) improves compliance to 64% for G-1 and 89% for G-2, indicating some slippage for newer ranges. After averaging all frame points (Fig. 12), 100% of the older G-2 ranges were well under the limit, but 27% of the newer G-1 ones were still too hot.

<u>Electric Ranges</u>. Compliance with the electric range standard showed drastic improvement in recent years, as non-compliance for the hottest window temperature dropped from 100% for groups E-2 and E-3 (Fig. 13) to 33% for group E-1. In this, as in all electric range comparisons, there was no range standard for surface temperatures during the period of group E-3 coverage, so the comparison shown (Fig. 13-20) is with the standard in force during group E-2 time period. The average temperatures of the four hottest points were out of compliance to the same degree as the single highest temperatures.

Fig. 7. Hottest point on porcelain door, degrees above or below standard, gas ranges

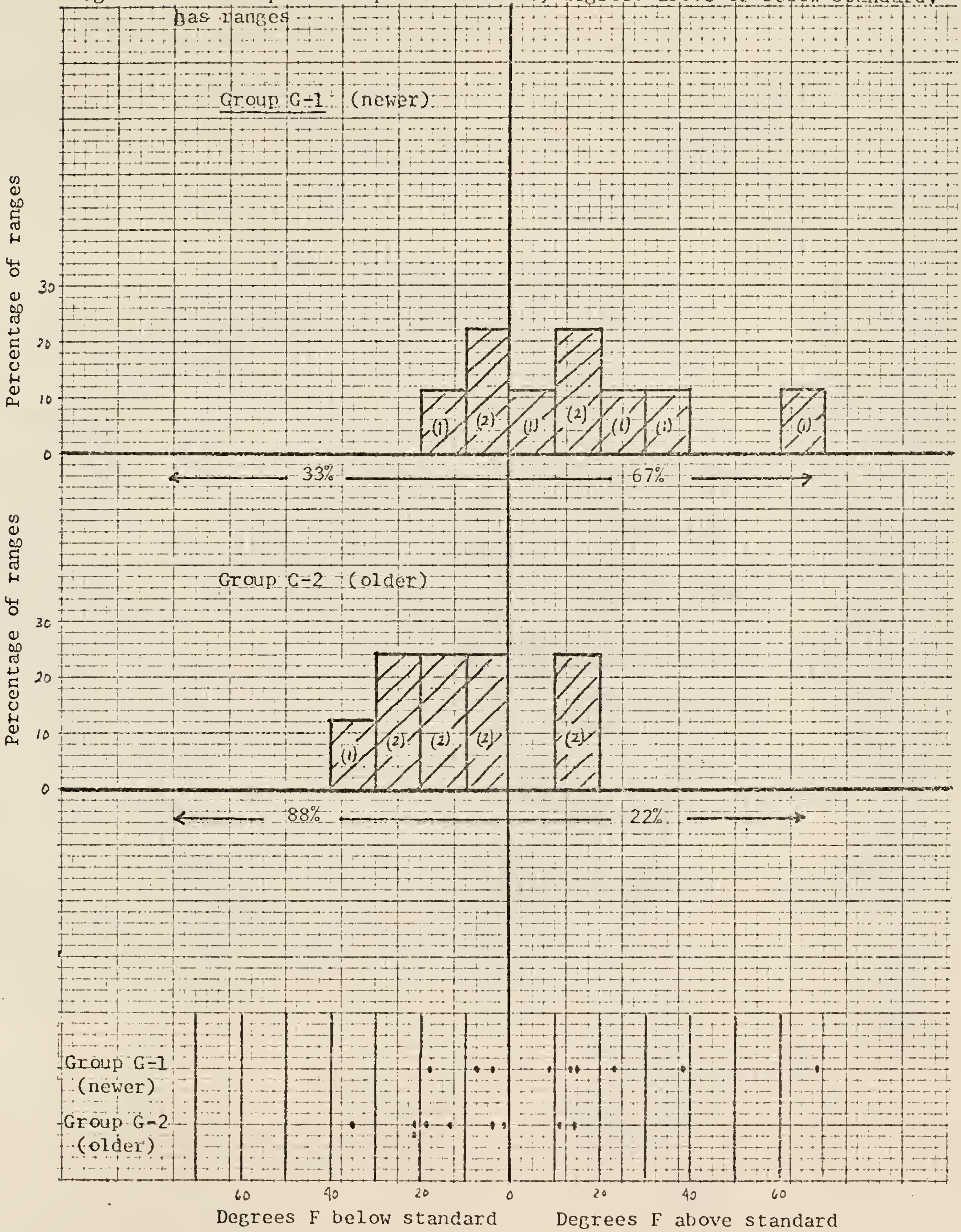


Fig. 8. Average of 4 highest points on porcelain door, degrees above or below standard, gas ranges.

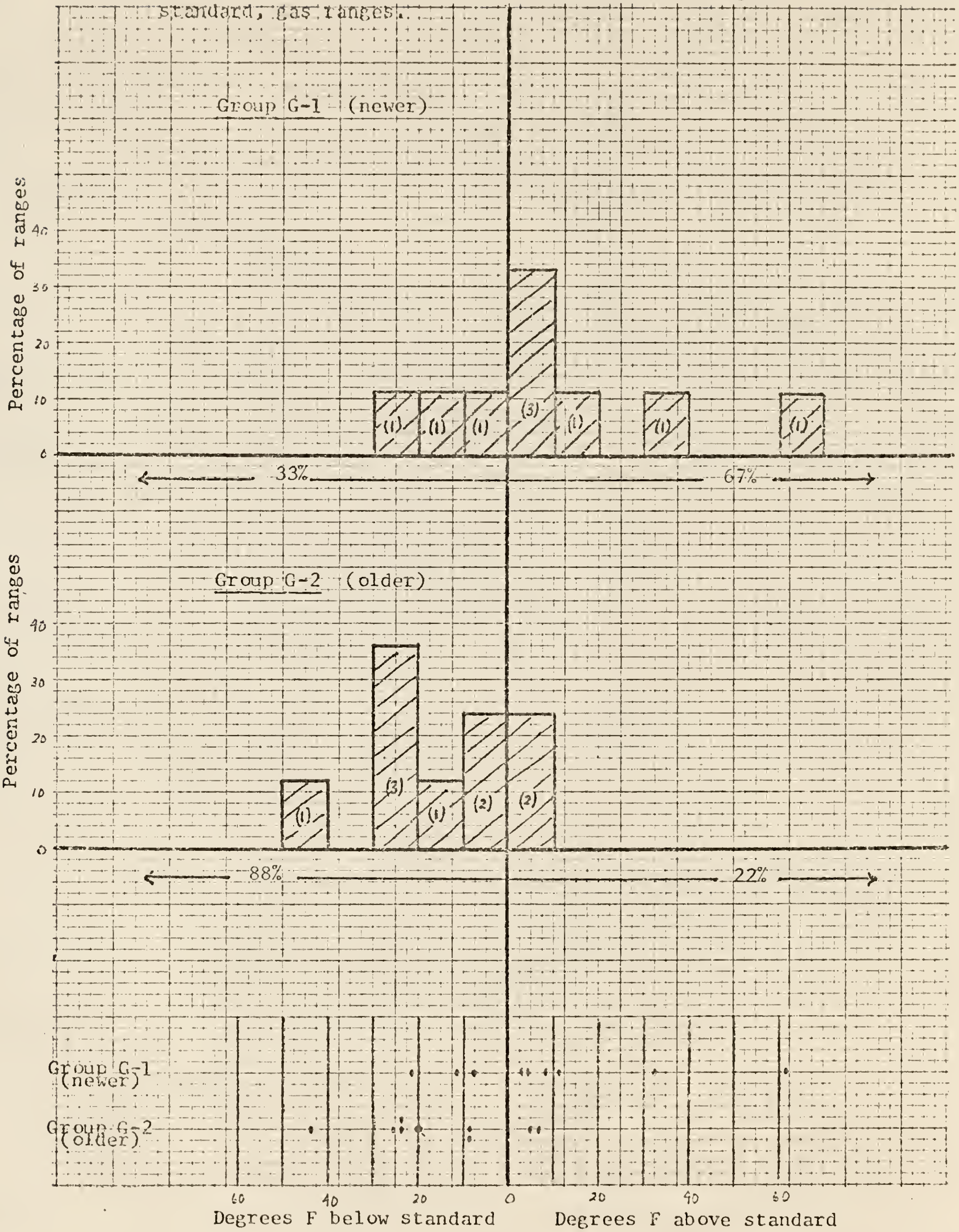


Fig. 9. Average of all points on porcelain door, degrees above or below standard, gas ranges.

Fig. 10. Hottest point on door frame, degrees above or below standard, gas ranges.

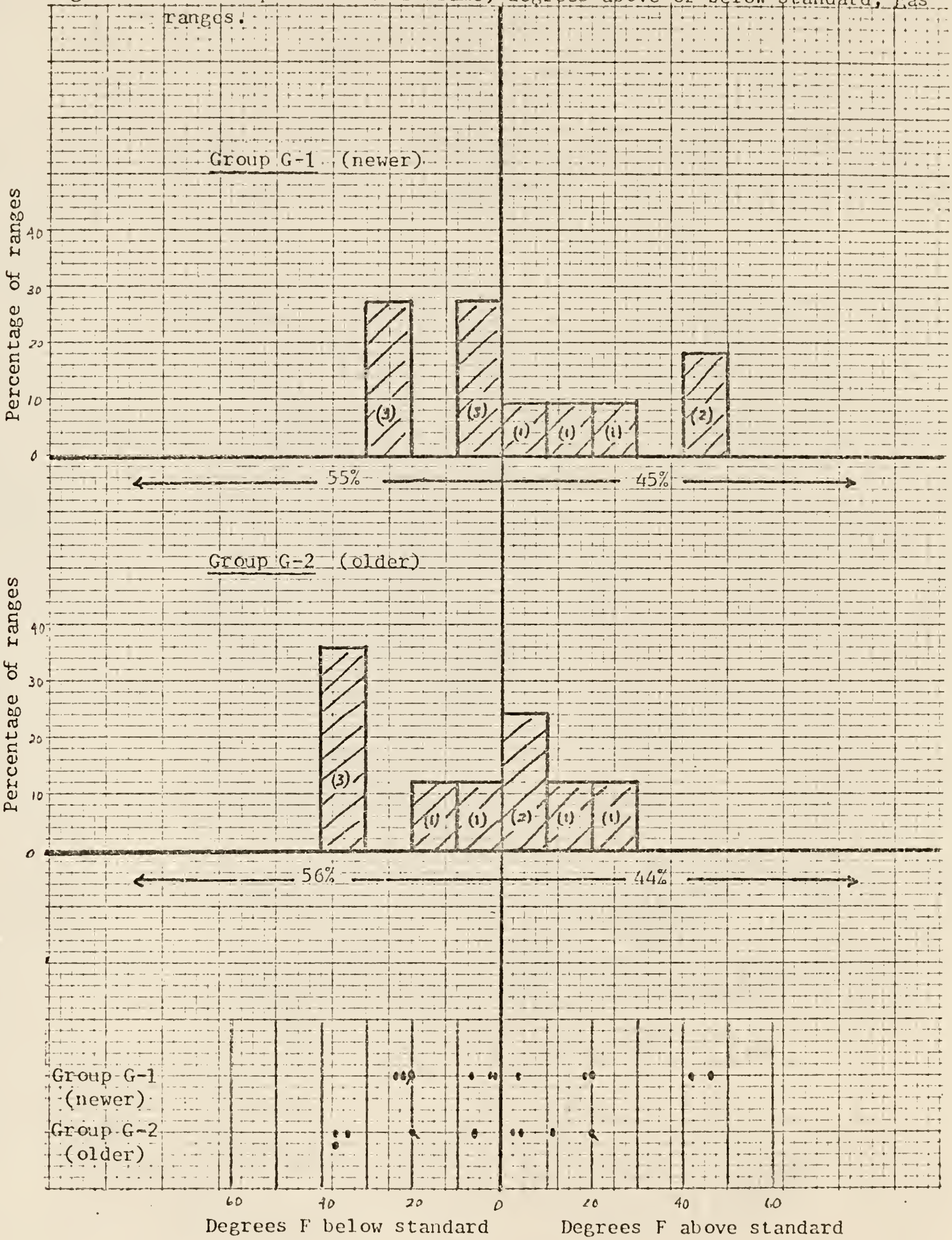


Fig. 11. Average of 4 highest points on door frame, degrees above or below standard, gas ranges.

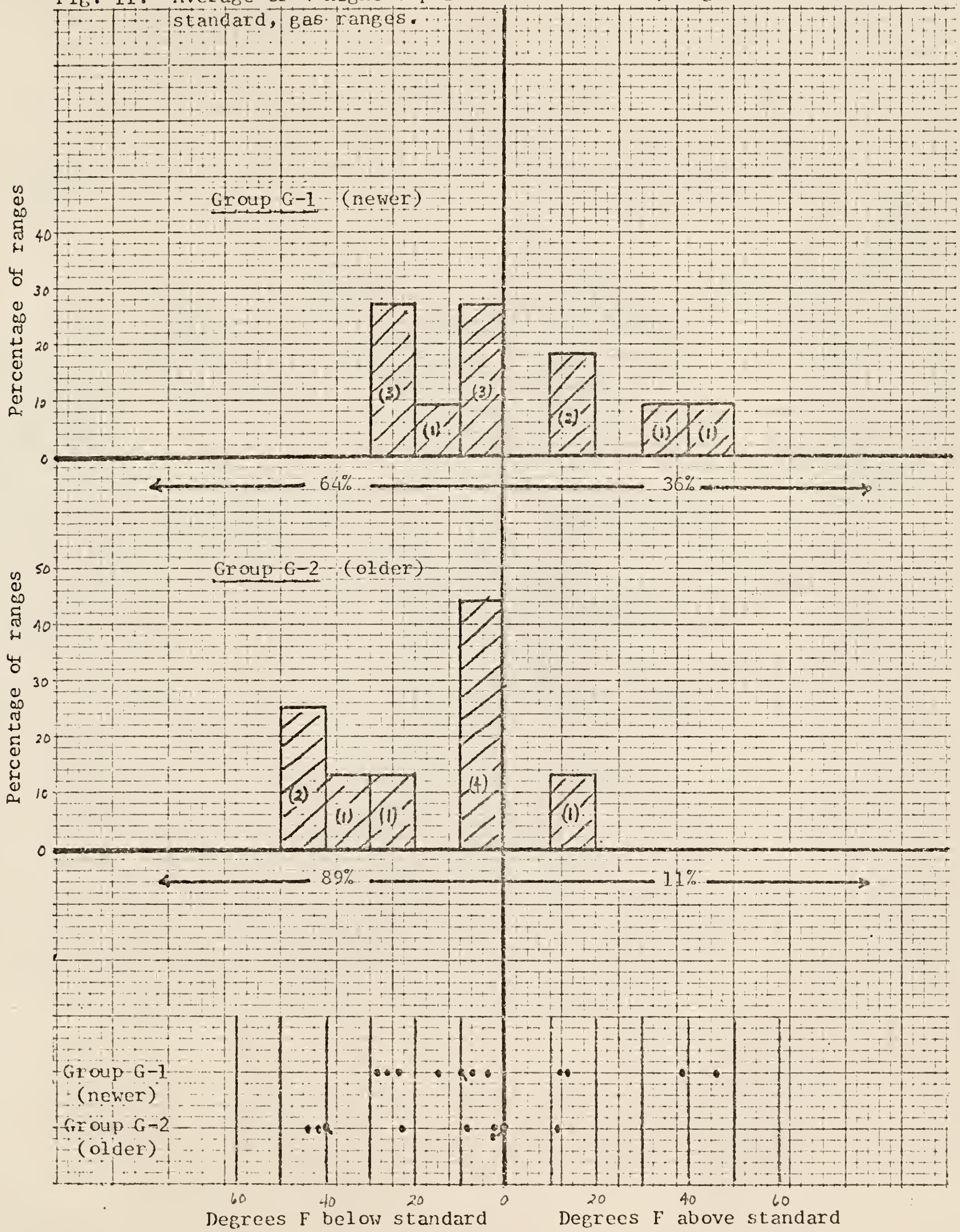


Fig. 12. Average of all points on door frame, degrees above or below standard, gas ranges.

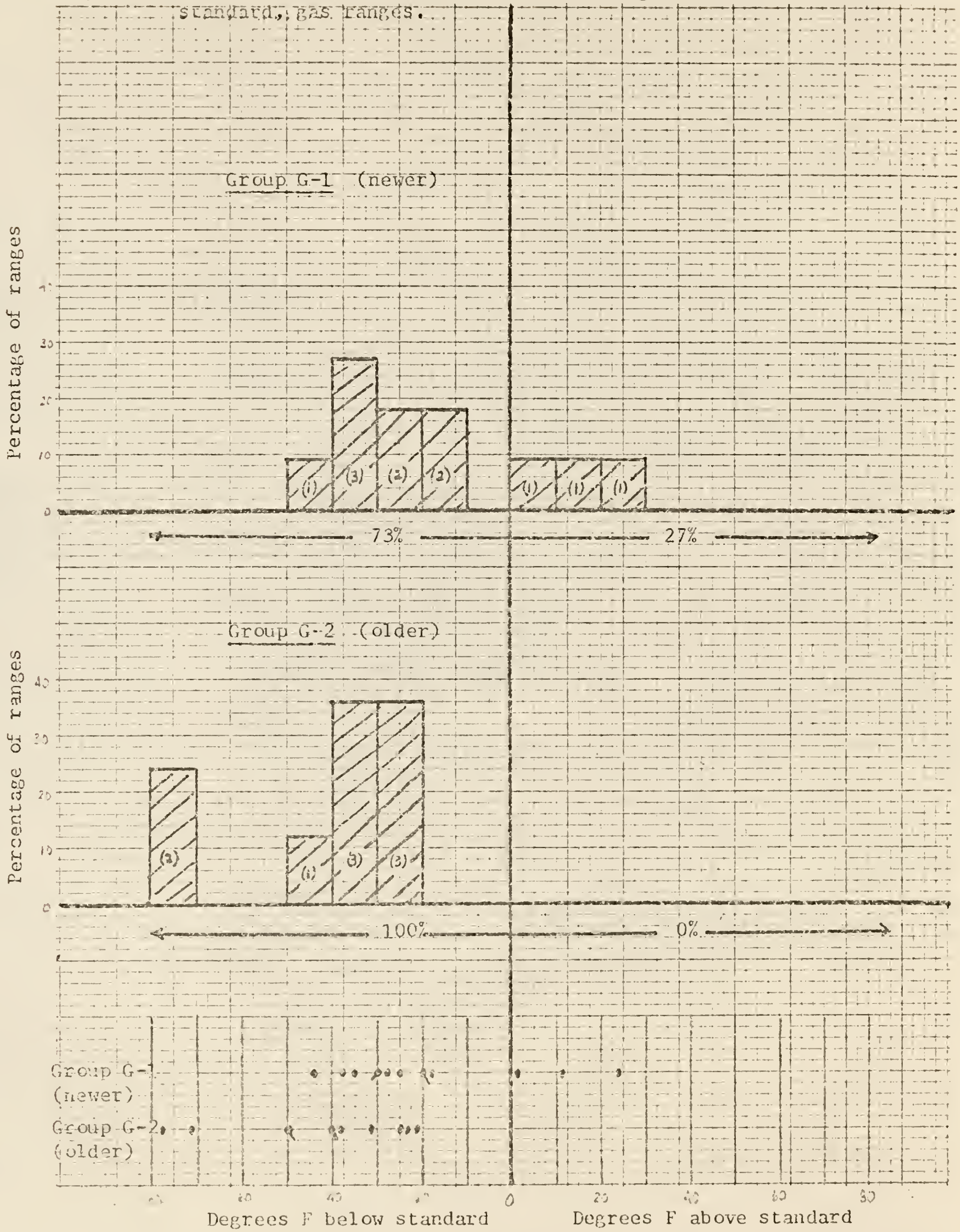


Fig. 13. Hottest point on window, degrees above or below standard, electric ranges.

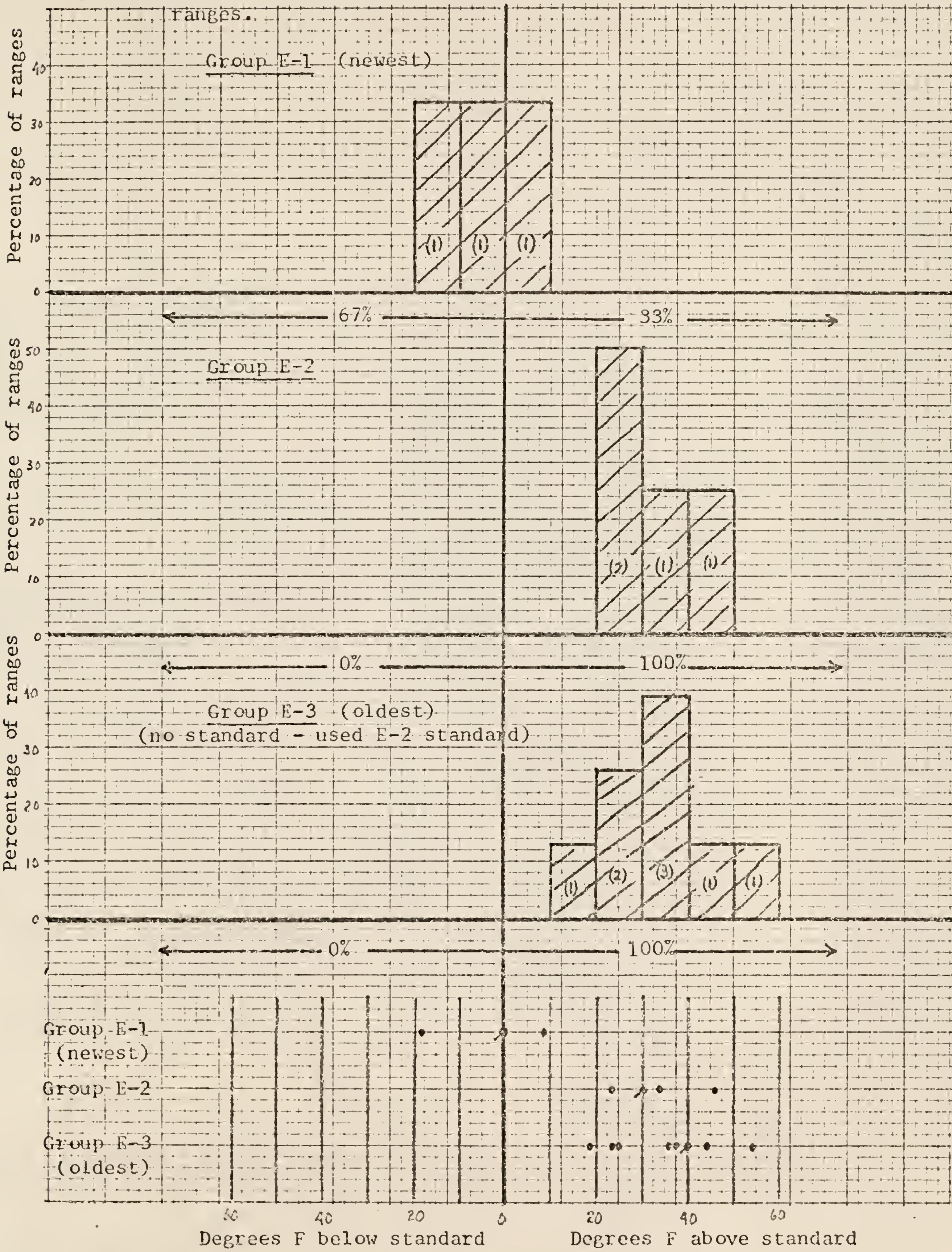
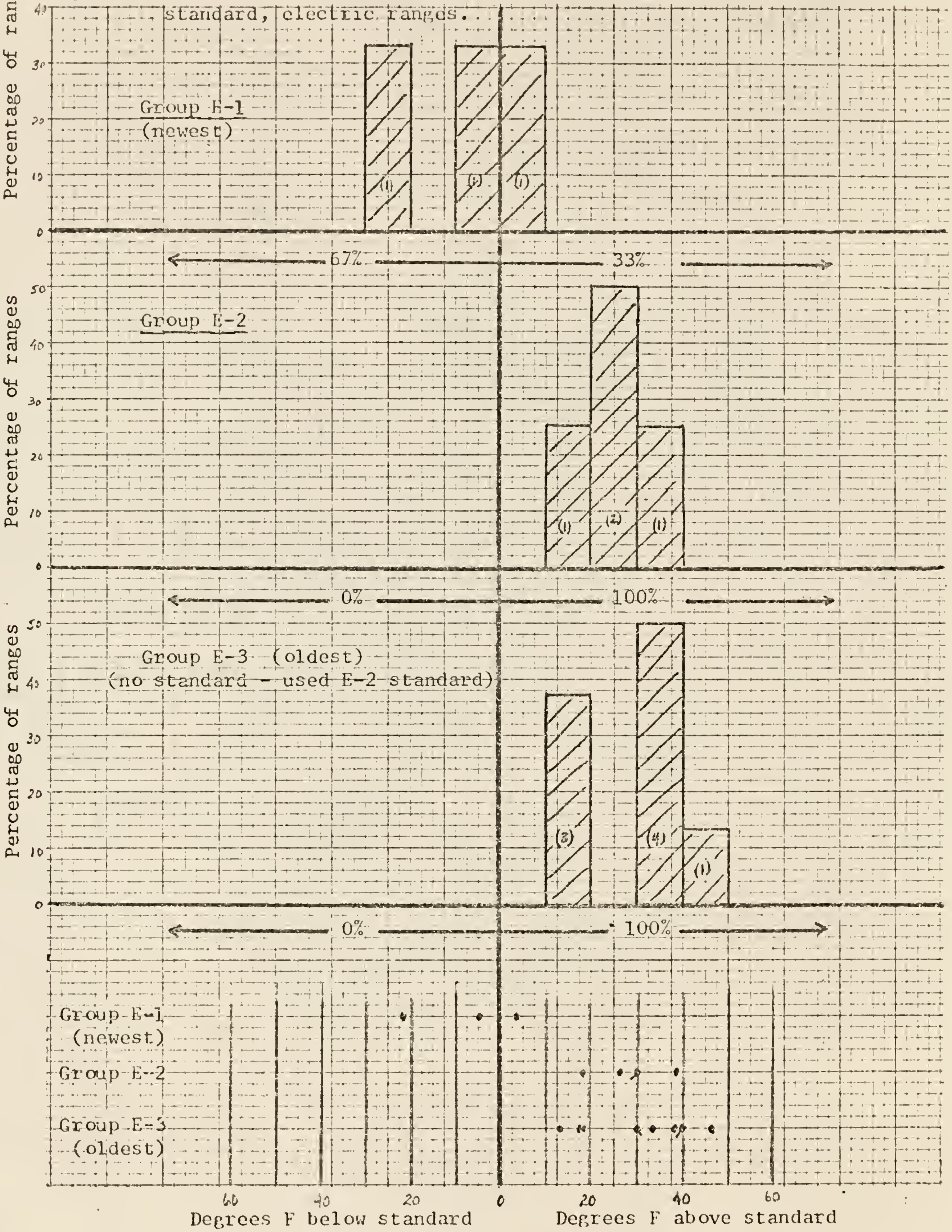


Fig. 14. Average of 4 highest points on window, degrees above or below standard, electric ranges.



Determination of the hottest point on the porcelain door (Fig. 15) showed 67% of the E-1 ranges above standard, whereas only 33% of the E-2 and 22% of the E-1 ranges were above. It should be noted, however, that three group E-3 ranges were above the limit by 30° to 60°F. Averaging the four highest points brought all but three ranges, all in group E-3, into compliance (Fig. 16). The overall door averages (Fig. 17) show further decline in temperatures for all groups, but two E-3 ranges were still too high in surface temperature.

The hottest point on the frame area shows significant improvement, with non-compliance decreasing from 13% for E-3 and 22% for E-2 to none for group E-1. Averaging the four hottest points had little effect on compliance, with only group E-2 changing, from 22 to 11%. When all frame area temperatures were averaged, compliance for all groups was perfect, with all E-1 and E-2 points being well below standard (Fig. 20). One range in group E-2 reached 104°F below the temperature limits set by UL.

Absolute temperatures reached

Gas Ranges. The hottest point on the window area (Fig. 21) exceeded 140°F for all gas ranges and most reached above 180°F. Group G-1 ranges, the newer models, did show somewhat lower temperatures than the older G-2 ranges. The average of the four highest points (Fig. 22) was slightly lower for both groups.

The highest single temperatures on porcelain doors (Fig. 23) ranged from 128°F to 217°F, with group G-1 showing a greater range of values. The highest temperatures, a 191°F and a 217°F, occurred with newer ranges. As the four highest were averaged (Fig. 24), temperatures decreased only slightly and G-1 ranges still produced values of 185°F and 210°F. Looking at the average of

Fig. 15. Hottest point on porcelain door, degrees above and below standard, electric ranges.

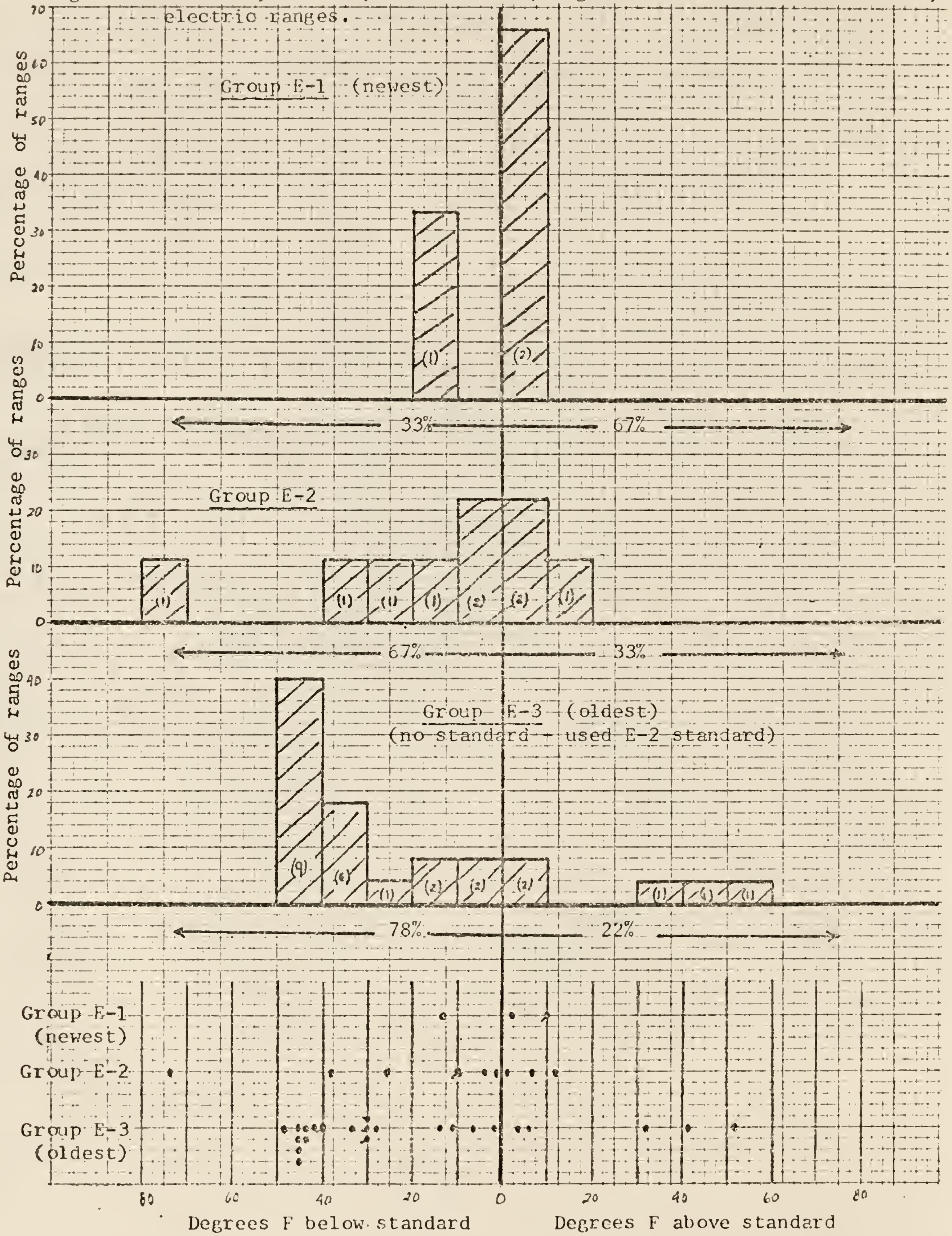


Fig. 16. Average of 4 highest points on porcelain door, degrees above or below standard, electric ranges.

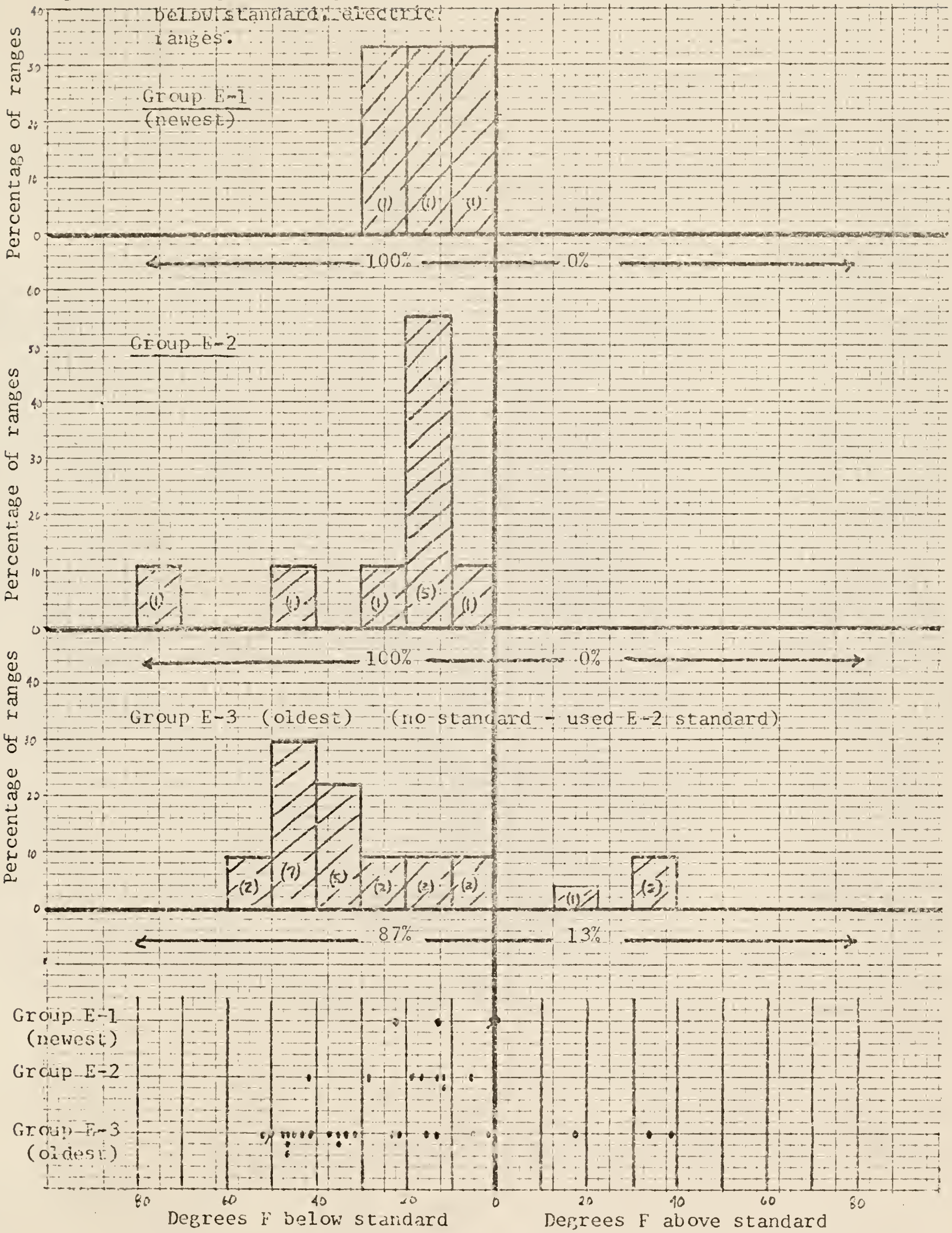


Fig. 17. Average of all points on the porcelain door, degrees above or below standard, electric ranges.

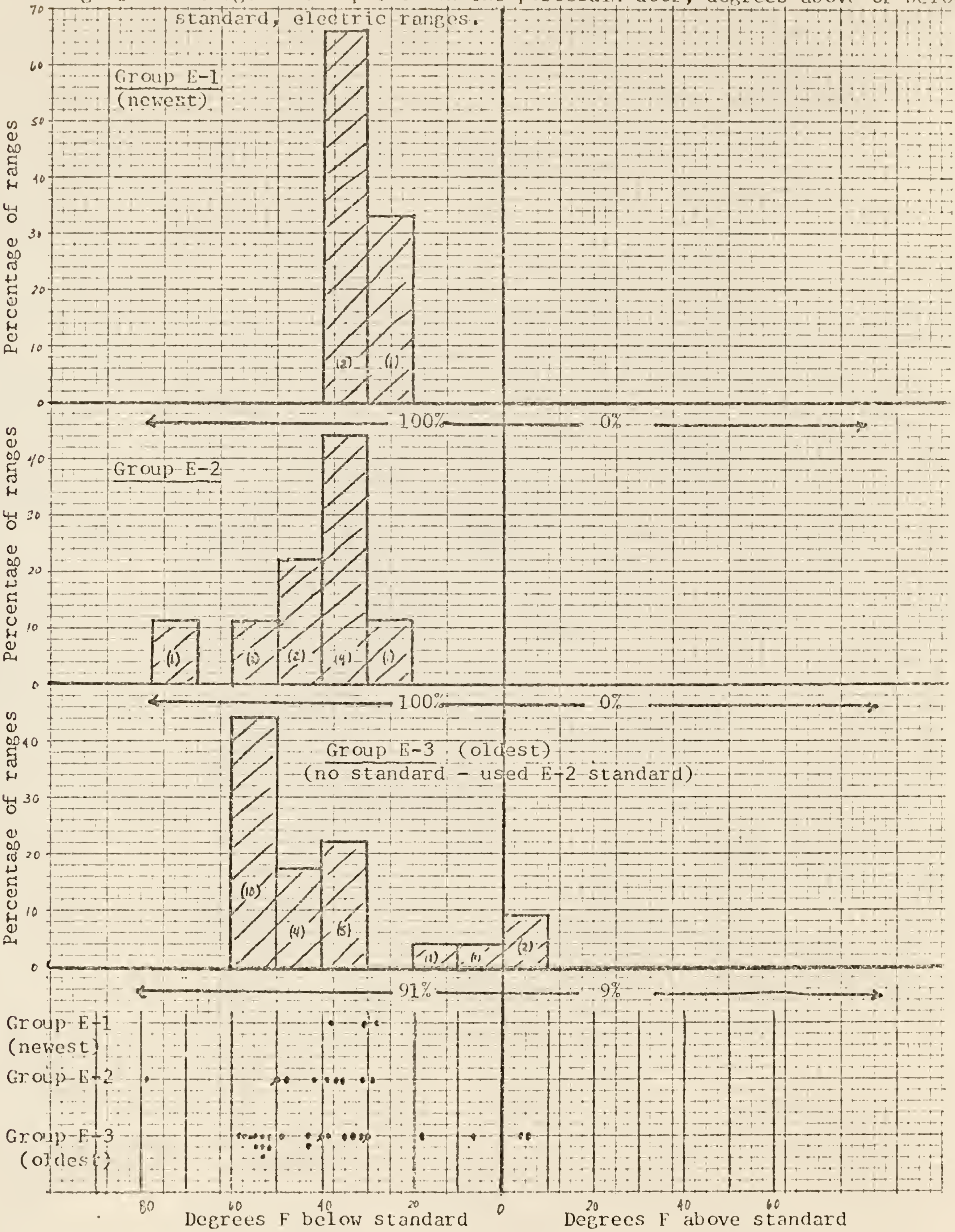


Fig. 18. Hottest point on door frame, degrees above or below standard, electric ranges.

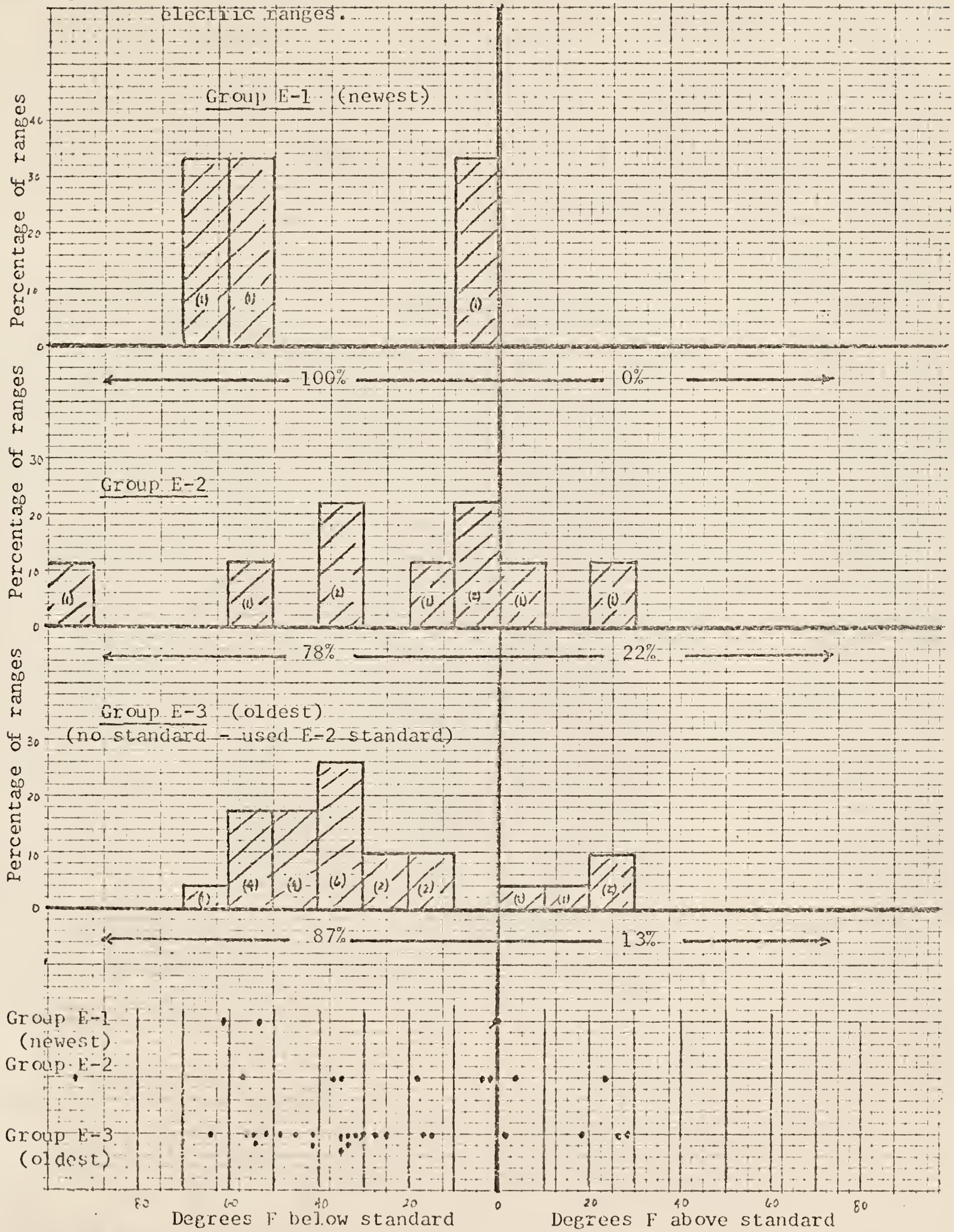


Fig. 19. Average of 4 highest points on door frame, degrees above or below standard, electric ranges.

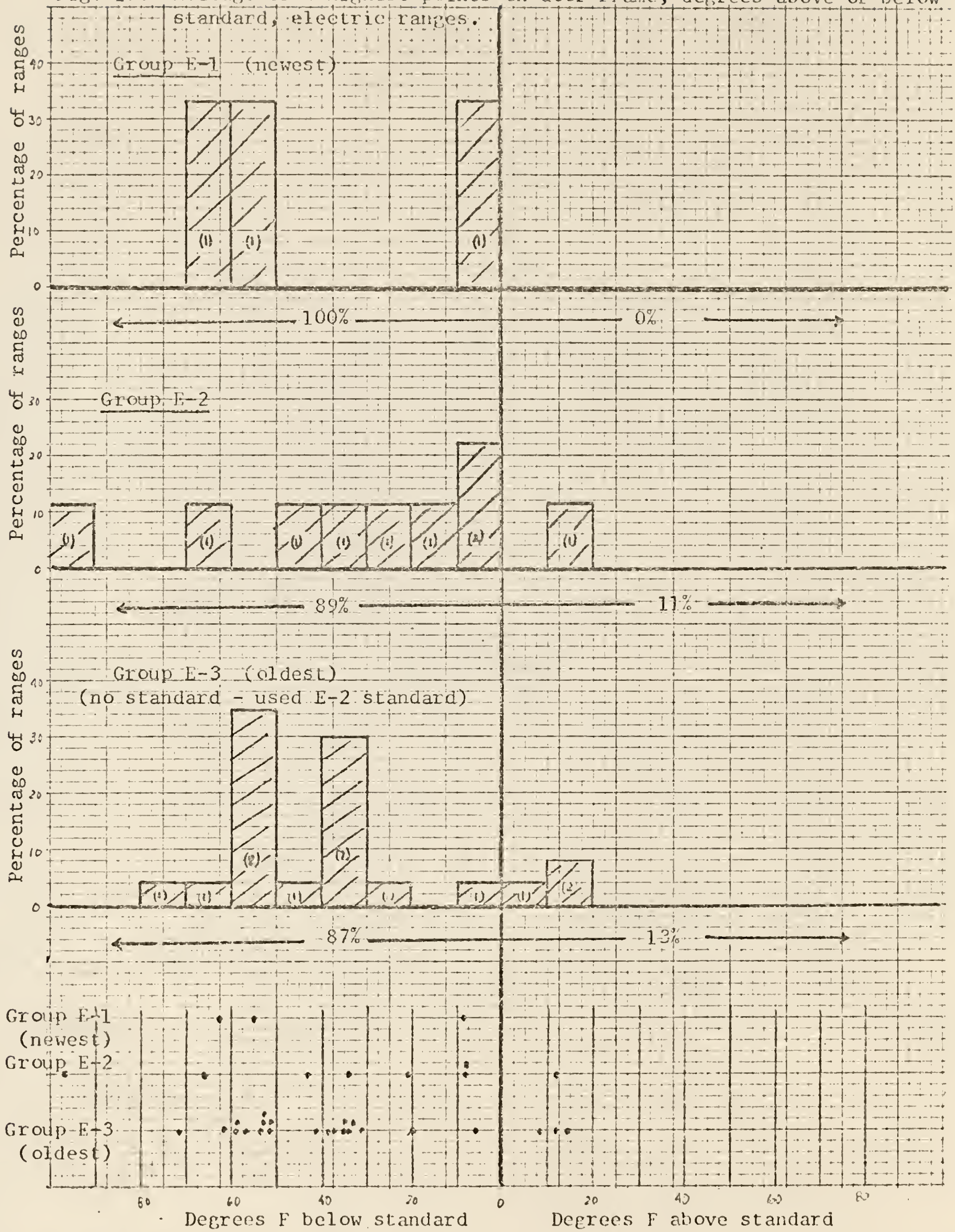


Fig. 20. Average of all points on door frame, degrees above or below standard, electric ranges.

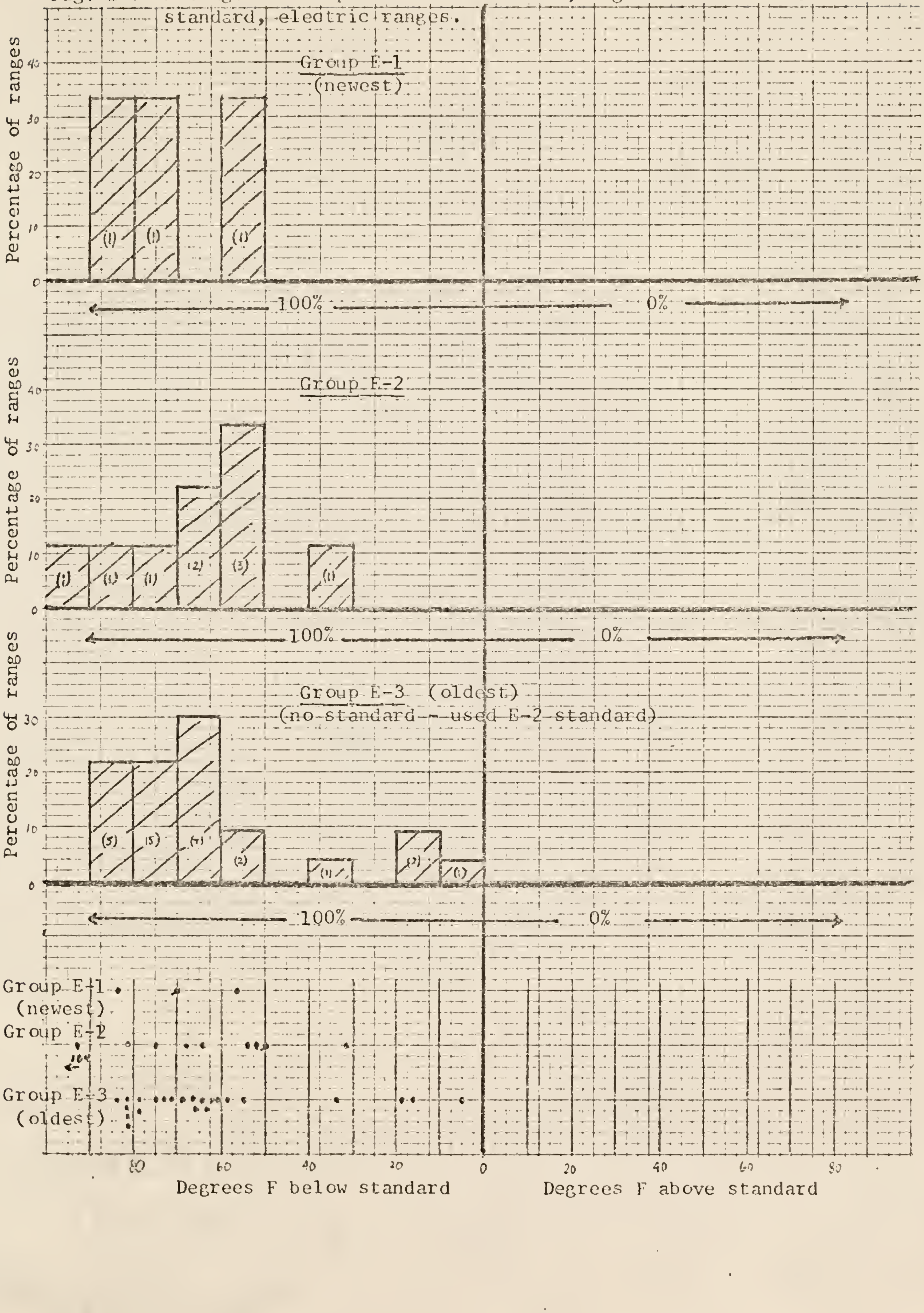


Fig. 21. Hottest point on window, absolute temperature, gas ranges.

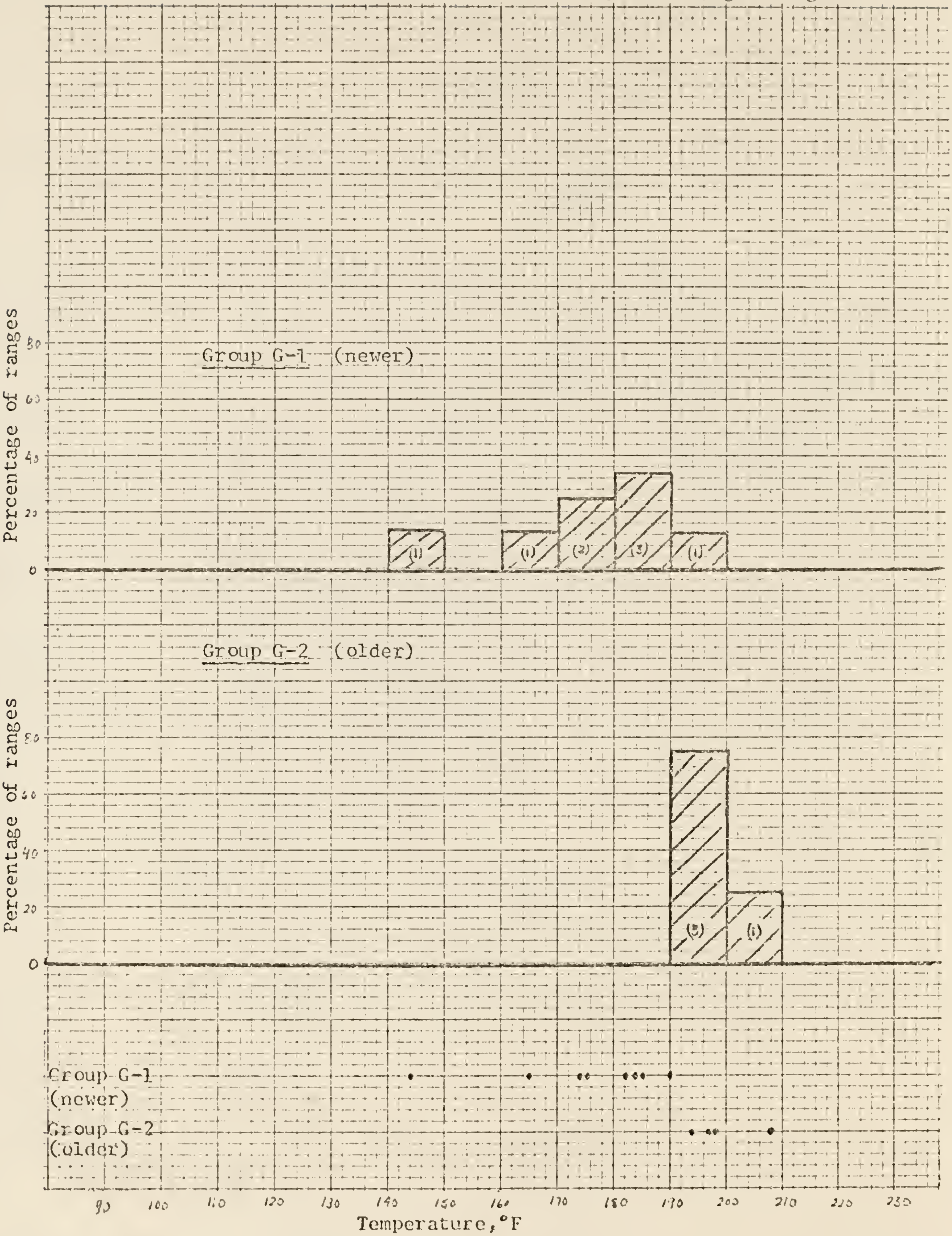


Fig. 22. Average of 4 highest points on window, absolute temperature, gas ranges.

Fig. 23. Hottest point on porcelain door, absolute temperature, gas ranges.

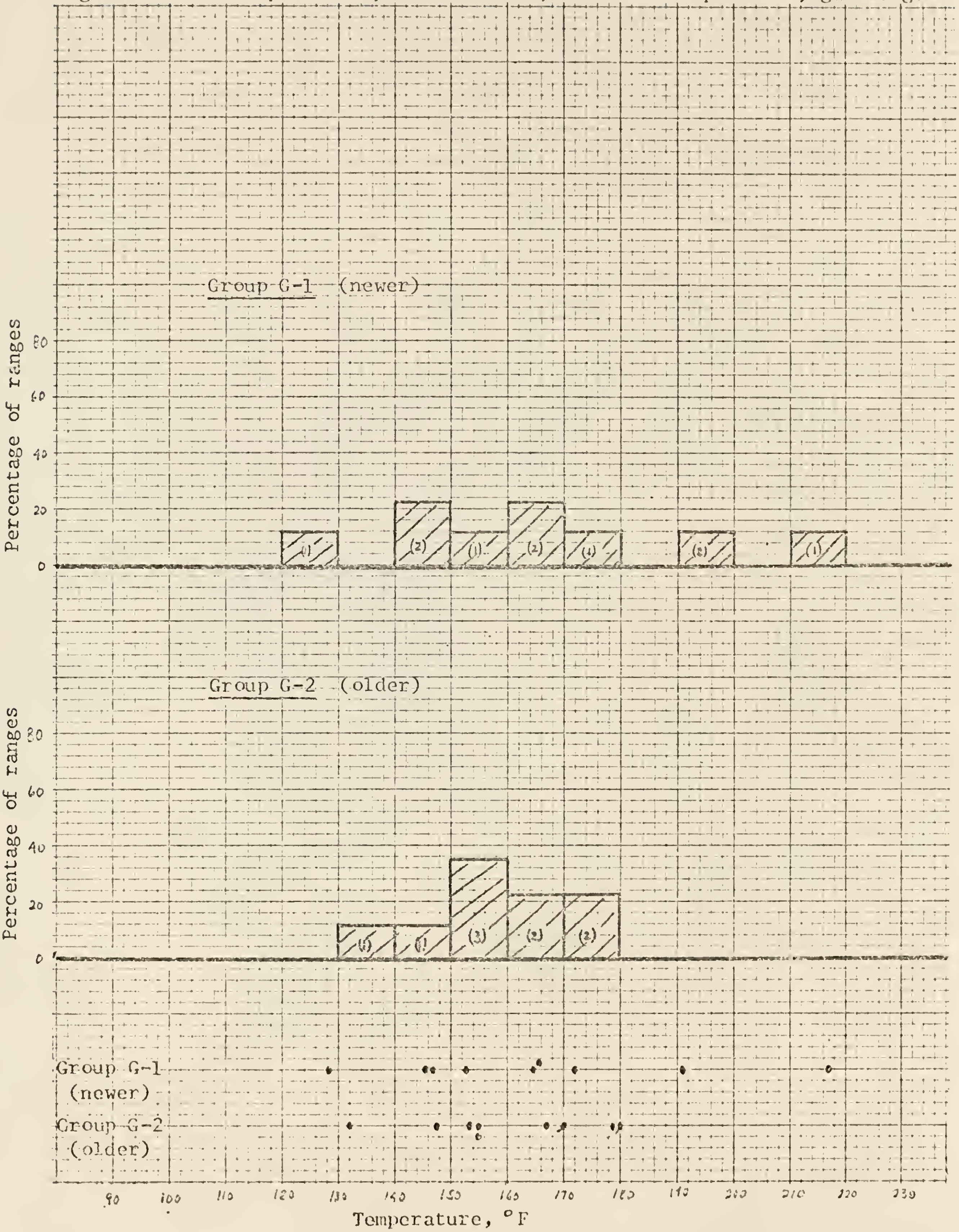
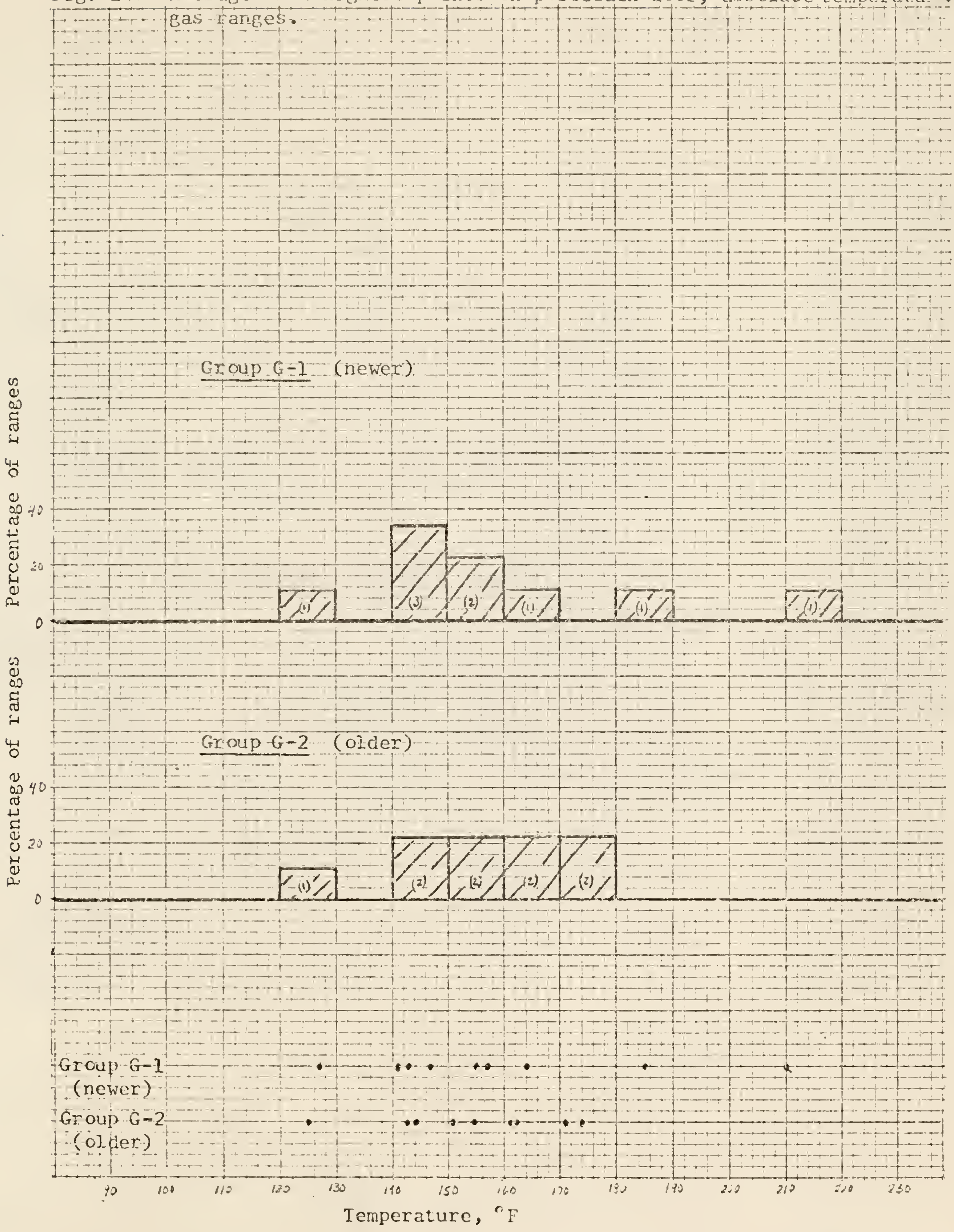


Fig. 24. Average of 4 highest points on porcelain door, absolute temperature, gas ranges.



all points on the doors (Fig. 25), temperatures decreased somewhat but one G-1 range still yielded 186°F. All methods of analyzing door data showed the newer models to be hotter, on the average, than the older ones.

The pattern revealed by the gas range frame area temperatures was much like that of the other areas. The hottest points (Fig. 26) exceeded those for the doors and windows, with eight out of twenty being over 200°F and two exceeding 220°F. When averaging the four highest temperatures (Fig. 27), the range decreased only slightly, two ranges still exceeding 220°F. When all frame points were averaged (Fig. 28), one of the G-2 ranges dropped to 120°F but a newer G-1 range still attained 202°F.

Electric Ranges. The hottest points on electric range windows (Fig. 29) exceeded those of gas ranges for older models, but were slightly better on newer models. There were three ranges in group E-3 and one in group E-2 that reached temperatures in excess of 220°F. All ranges in those two groups exceeded 189°F. The newest ranges, group E-1, had window readings that were much cooler, ranging from 143°F to 175°F. Averaging of the four hottest window points reduced readings little, indicating only minor temperature gradients (Fig. 30). In groups E-2 and E-3, eleven of the twelve ranges still exceeded 190°F. The improvement in newer ranges was still evident.

Comparison of the high points on the door (Fig. 31) showed most grouped in the 120°F to 190°F range. Three group E-3 ranges were extremely hot, exceeding 210°F, and one E-2 range extremely cool (93°F). The low value was measured on a self-cleaning range being tested at 400°F oven temperature. When averaging the four highest points, temperatures were lower (Fig. 32). Most of the improvement was in group E-2, with three of the E-3 ranges still exceeding 197°F. The averages of all door temperatures (Fig. 33) revealed less spread and all newer ranges (E-1 and E-2) being below 140°F.

Fig. 25. Average of all points on porcelain door, absolute temperature, gas ranges.

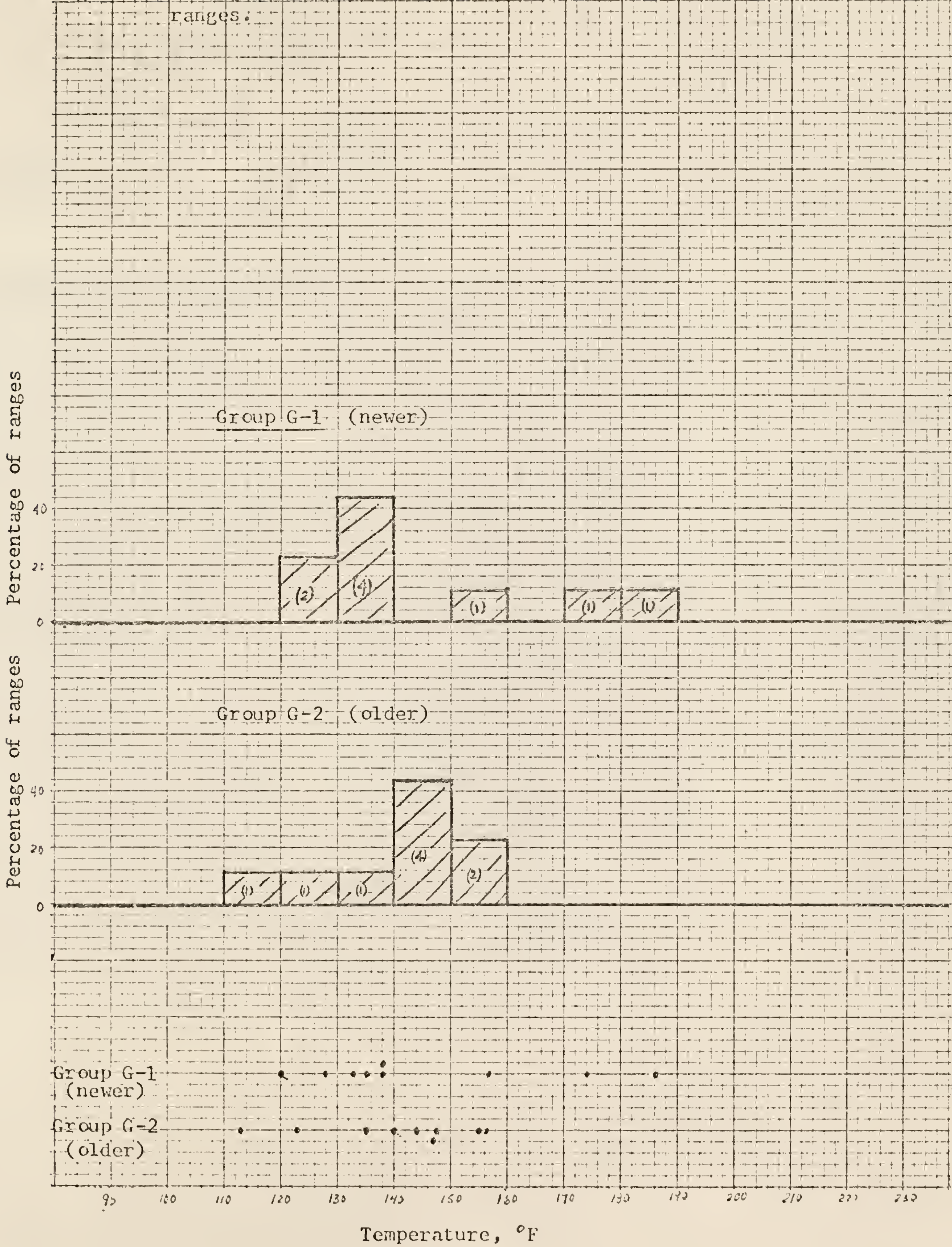


Fig. 26. Hottest point on door frame, absolute temperature, gas ranges.

Fig. 27. Average of 4 highest points on door frame, absolute temperature, gas ranges.

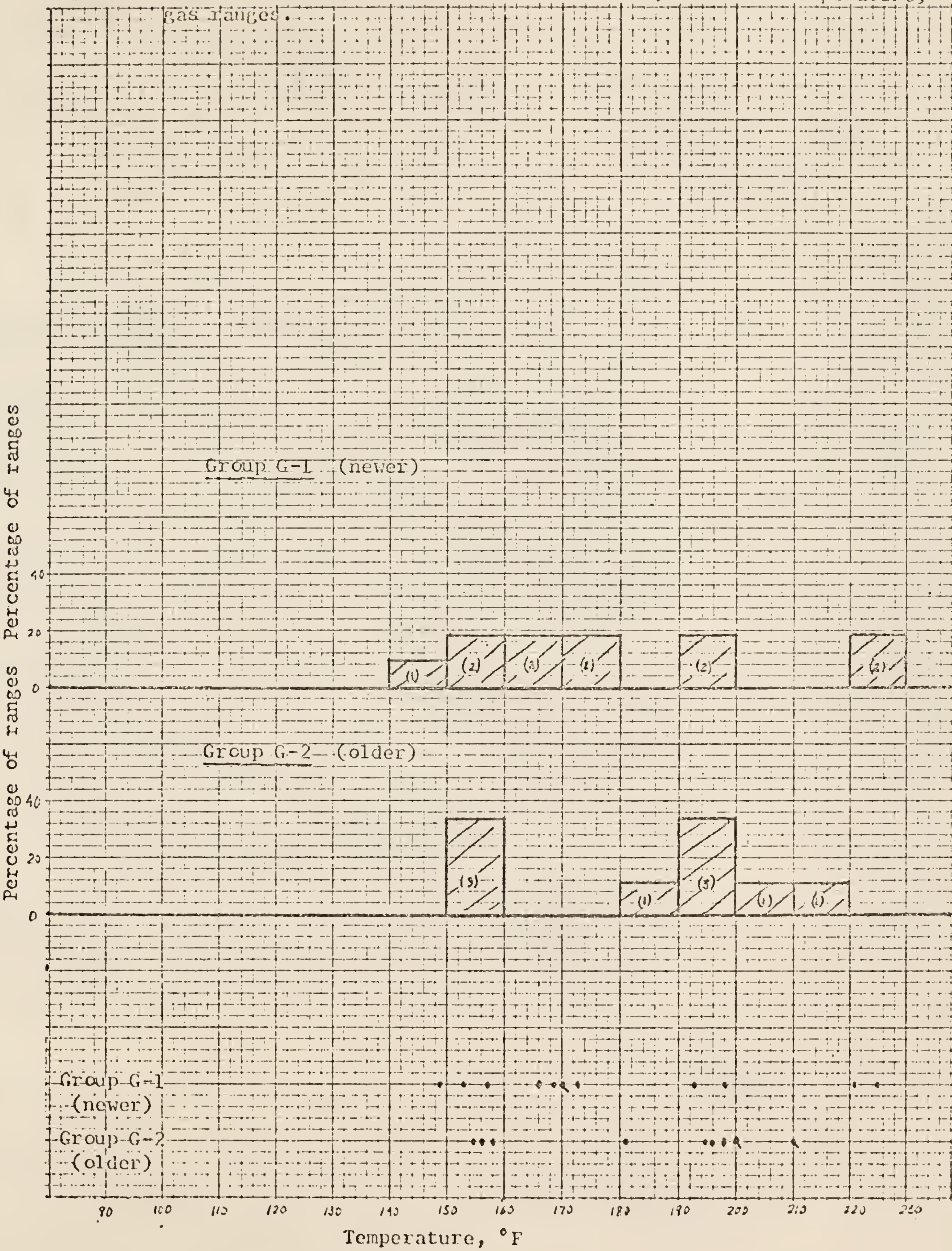


Fig. 28. Average of all points on door frame, absolute temperature, gas ranges.

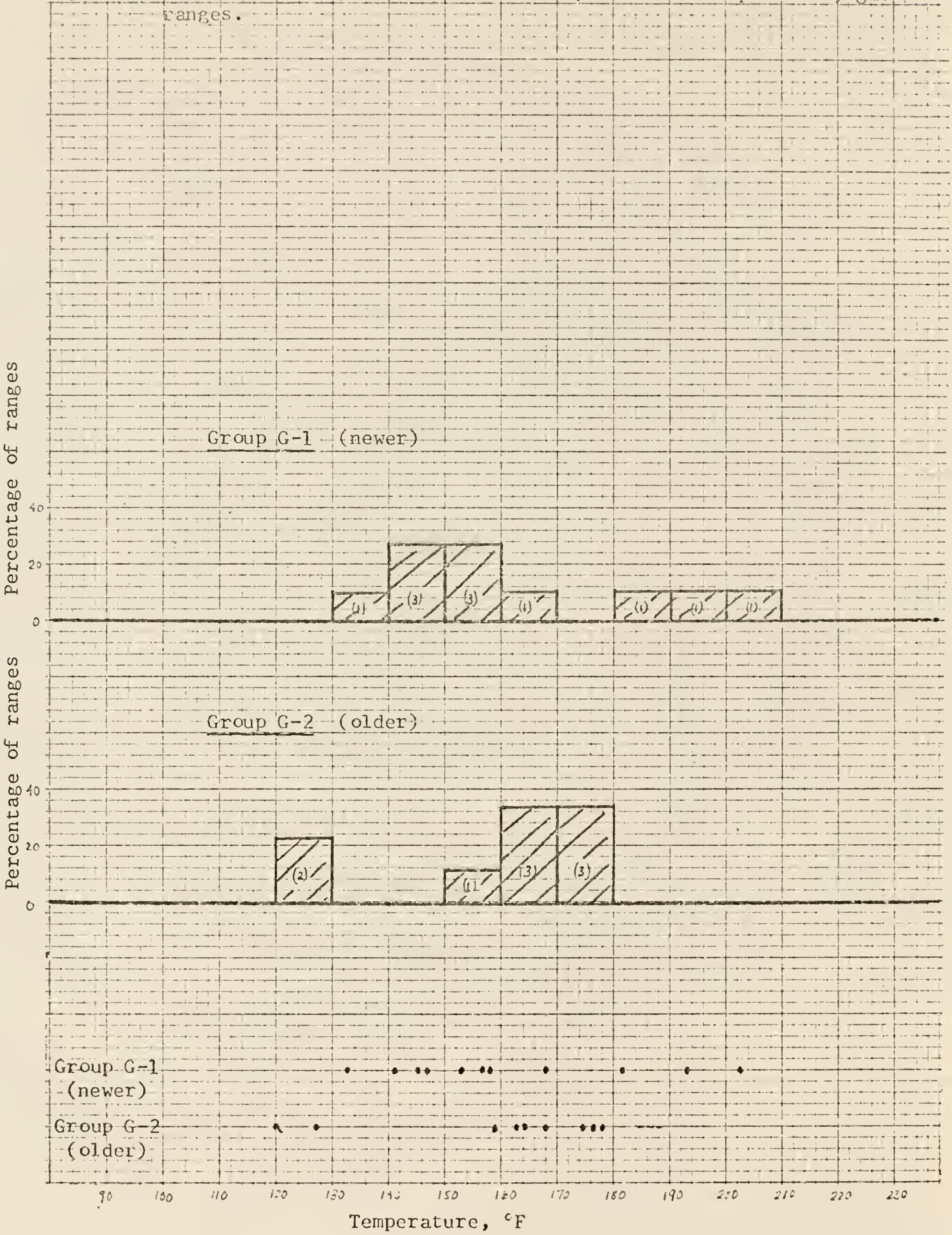


Fig. 29. Hottest point on window, absolute temperature, electric ranges.

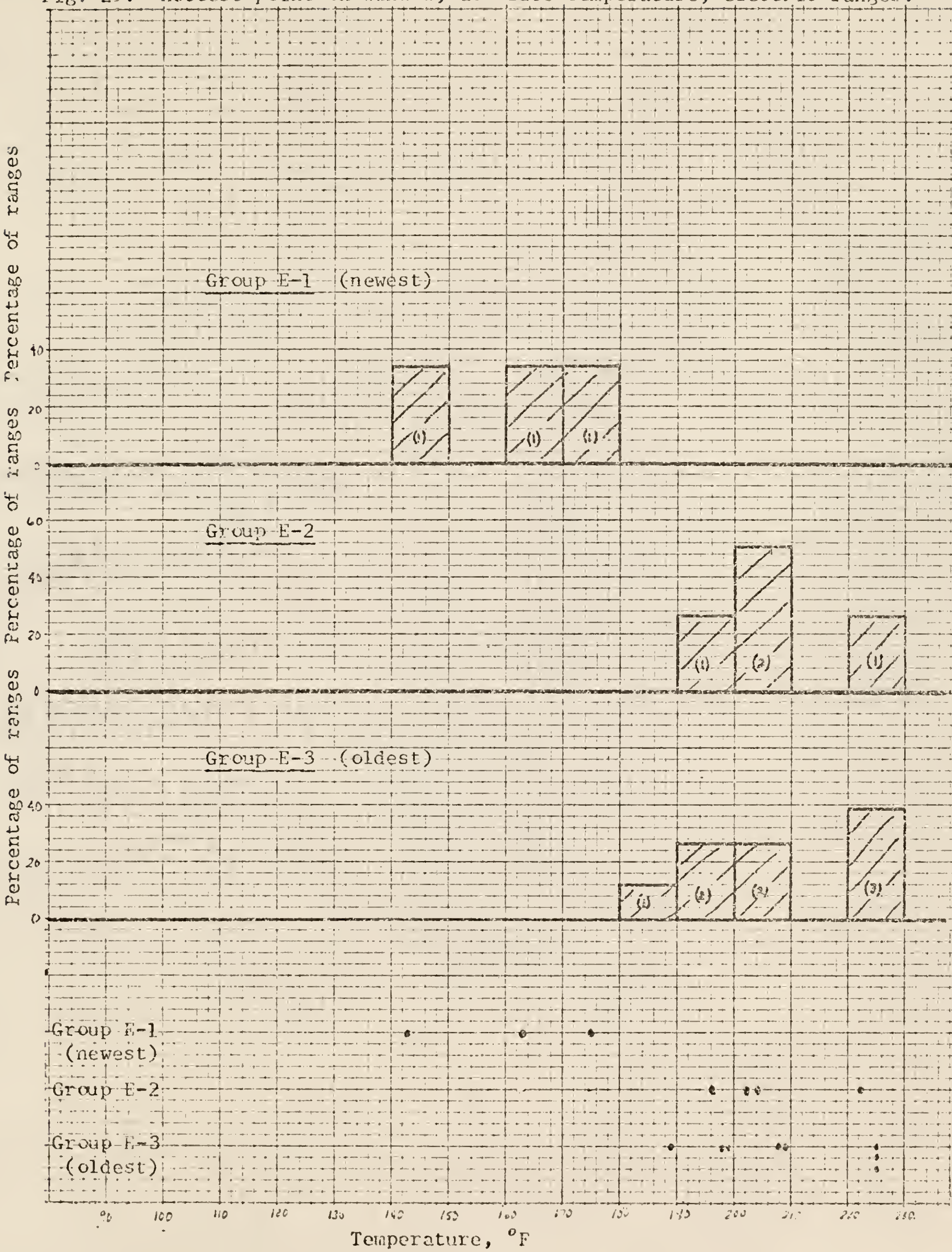


Fig. 30. Average of 4 highest points on window, absolute temperature, electric ranges.

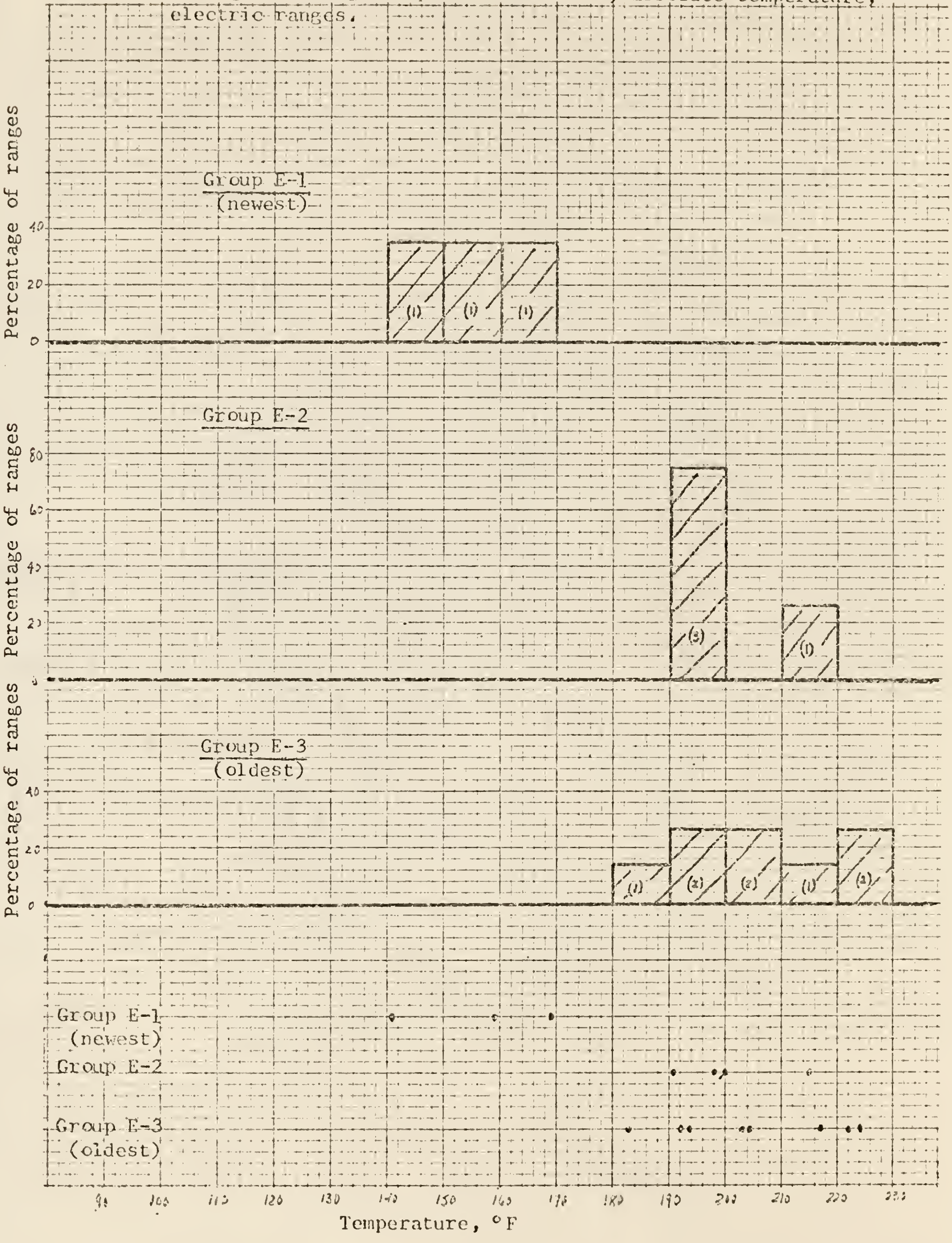


Fig. 31. Hottest point on porcelain door, absolute temperature, electric ranges.

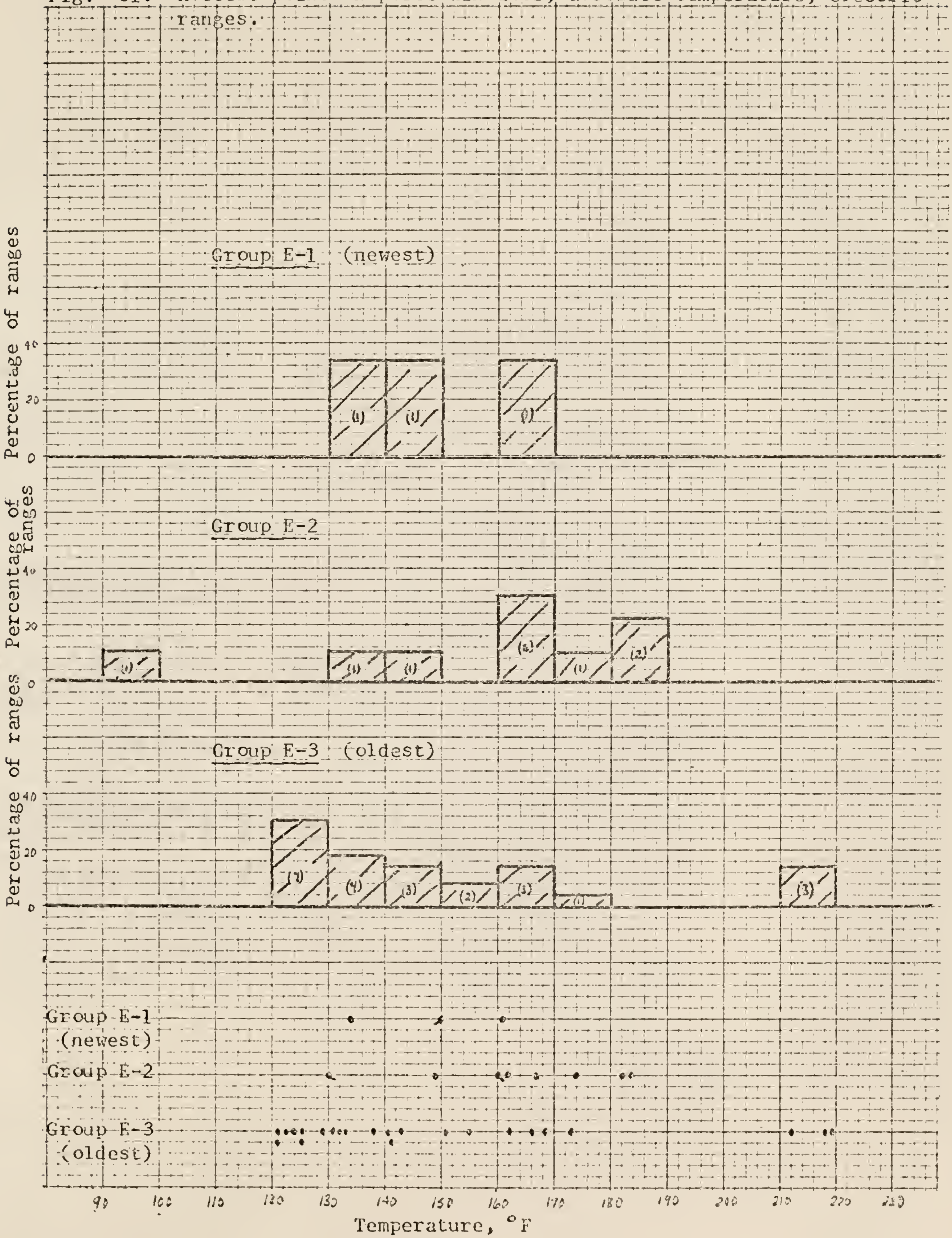


Fig. 32. Average of 4 highest points on porcelain door, absolute temperature, electric ranges.

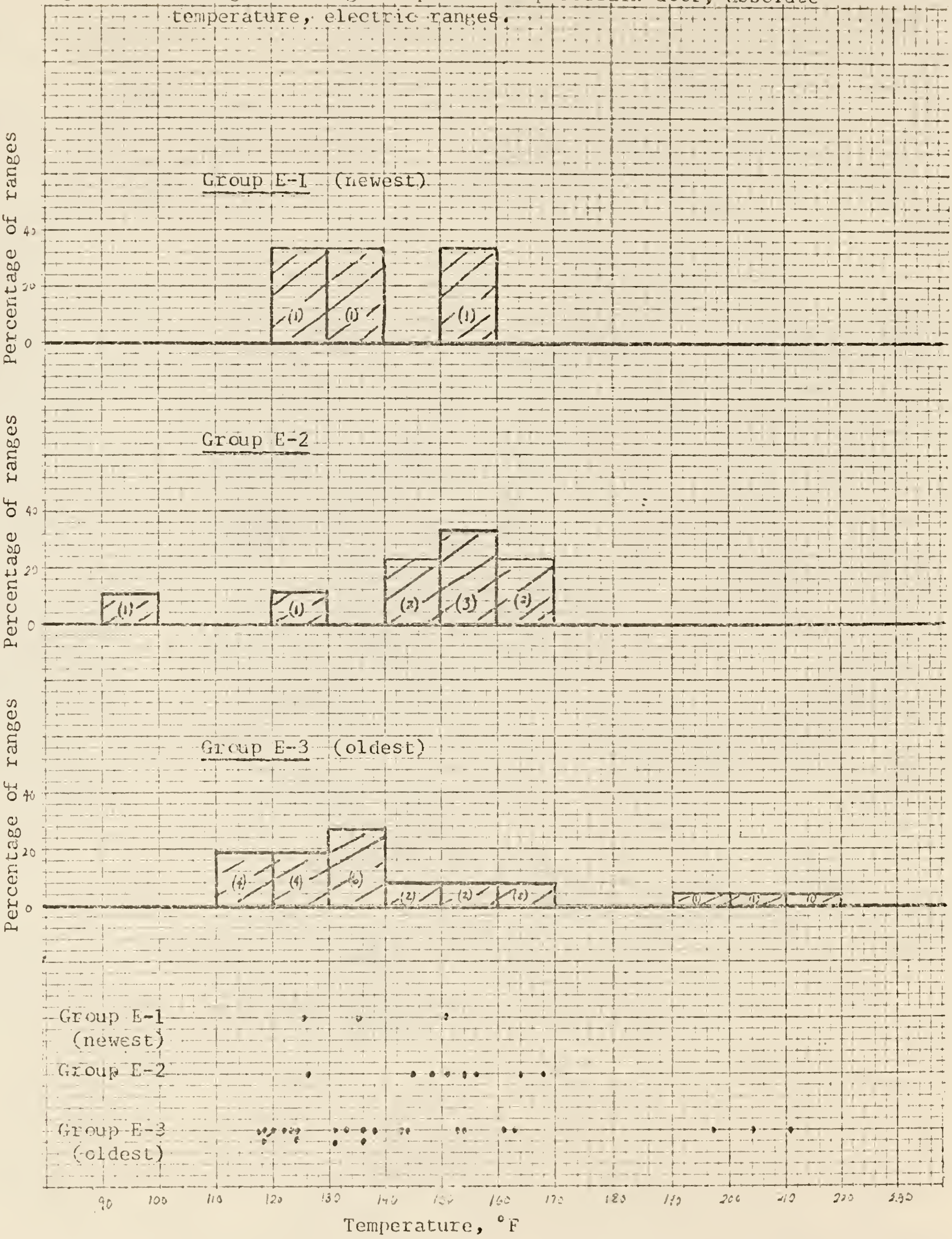
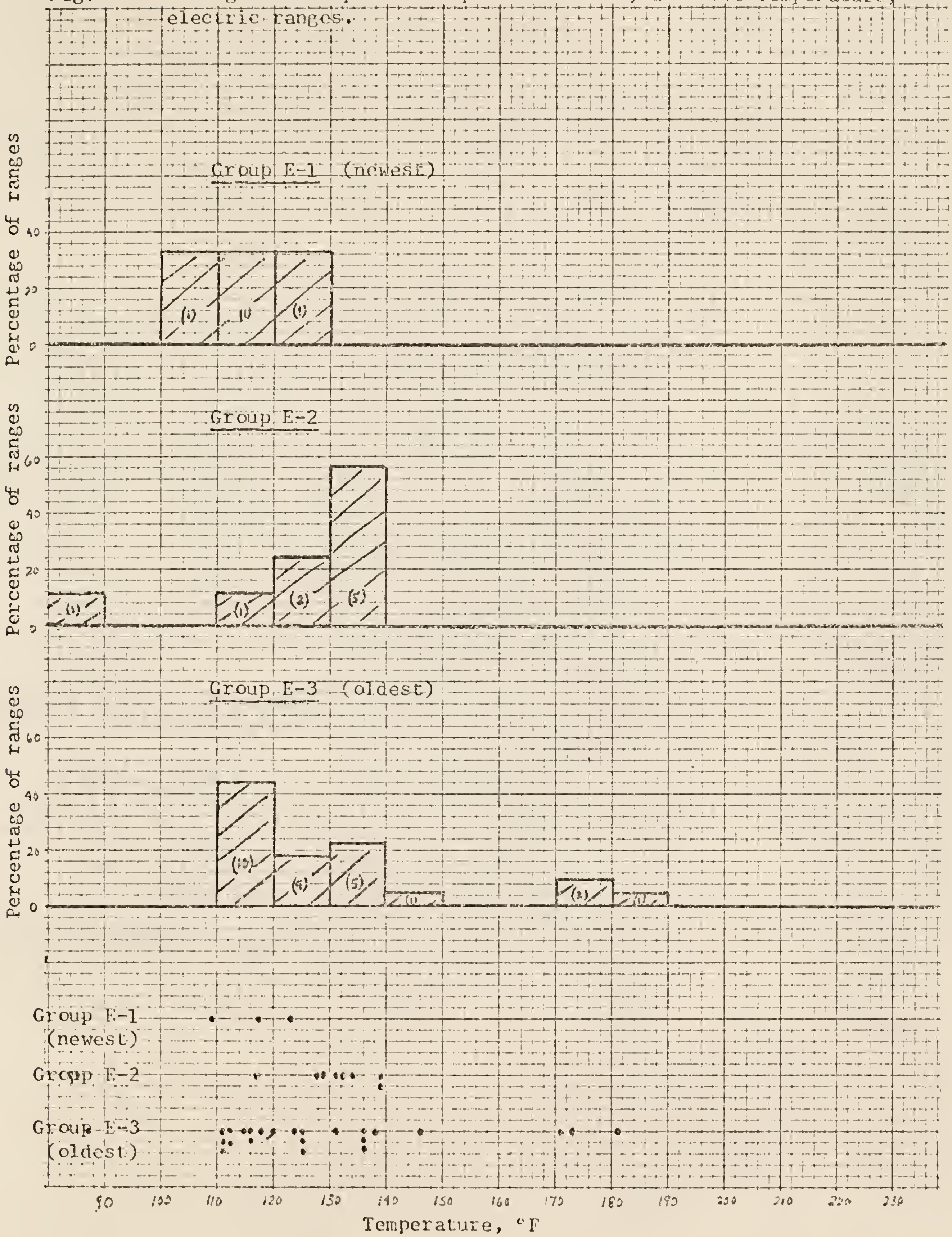


Fig. 33. Average of all points on porcelain door, absolute temperature, electric ranges.



The frame temperature showed a wide variety of readings. The hottest point ranged from 101°F (E-2) to 225°F (E-3). Group E-1 was the coolest, the worst range being 181° F, whereas group E-3 had three ranges exceeding 222°F. Averaging the four hottest points (Fig. 35) evened the spread but lowered values only slightly. Group E-1 was again cooler than the older grouped ranges. An overall lowering of temperatures occurred when all points on the frame were averaged (Fig. 36). In measuring these temperatures it was usually found that the frame was hottest at the top or bottom (including corner points), and was much cooler in the other areas.

There were some extremely hot temperatures reached in each of the test areas by both gas and electric ranges. Table 10 shows the high temperatures for each area.

Table 10. Highest Temperatures Recorded on Test Areas, Gas and Electric Ranges, Degrees F.

Test Area	Gas	Electric
Window (glass)	208	3 pts. at 225+
Door (porcelain enamel)	217	3 pts. over 210
Door frame	2 pts. at 225+	4 pts. over 220

Historical patterns

The data from the tested ranges was also analyzed to see if there was evidence to indicate that ranges have been getting hotter in recent years. Using the average of the highest four temperatures of the window, the door and the frame, the historical pattern was graphed from the oldest group of ranges to the newest. Because group G-2 covered such a long period of time, it was divided into two smaller groups, each covering approximately 10 years. Figure 37 shows that the temperatures of the gas range window and the frame

Fig. 34. Hottest point on the door frame, absolute temperature, electric ranges.

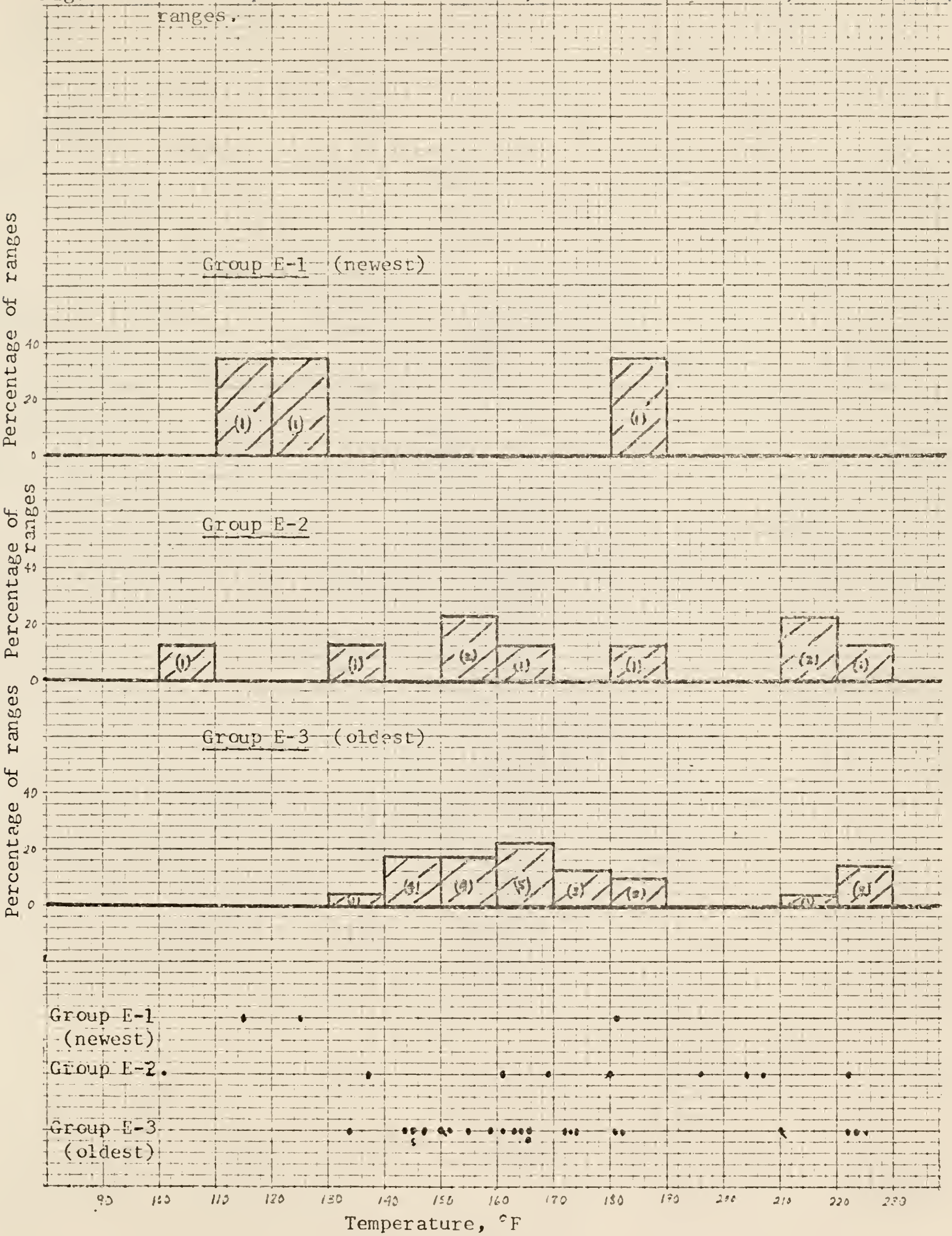


Fig. 35. Average of 4 highest points on door frame, absolute temperature, electric ranges.

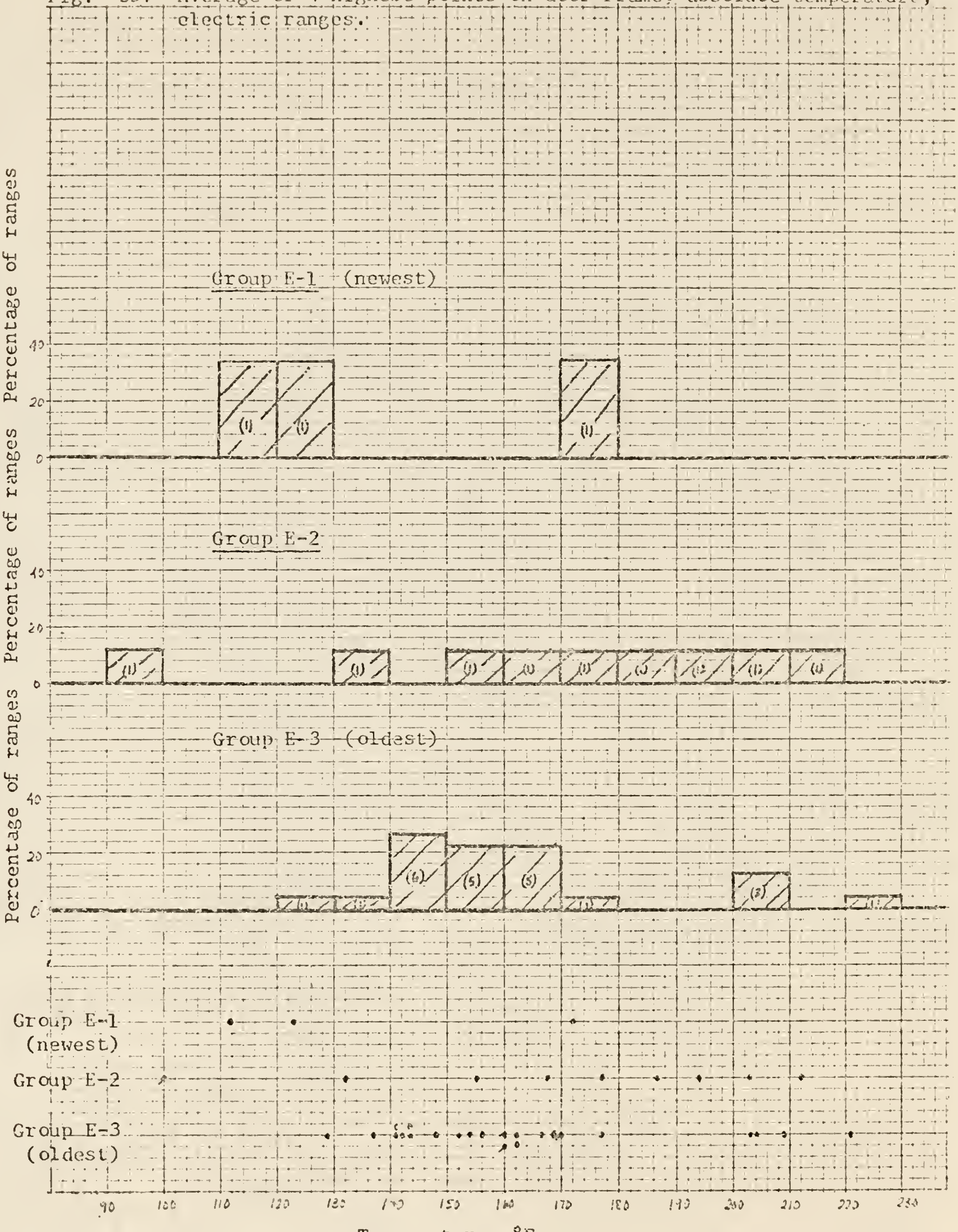


Fig. 36. Average of all points on door frame, absolute temperature, electric ranges.

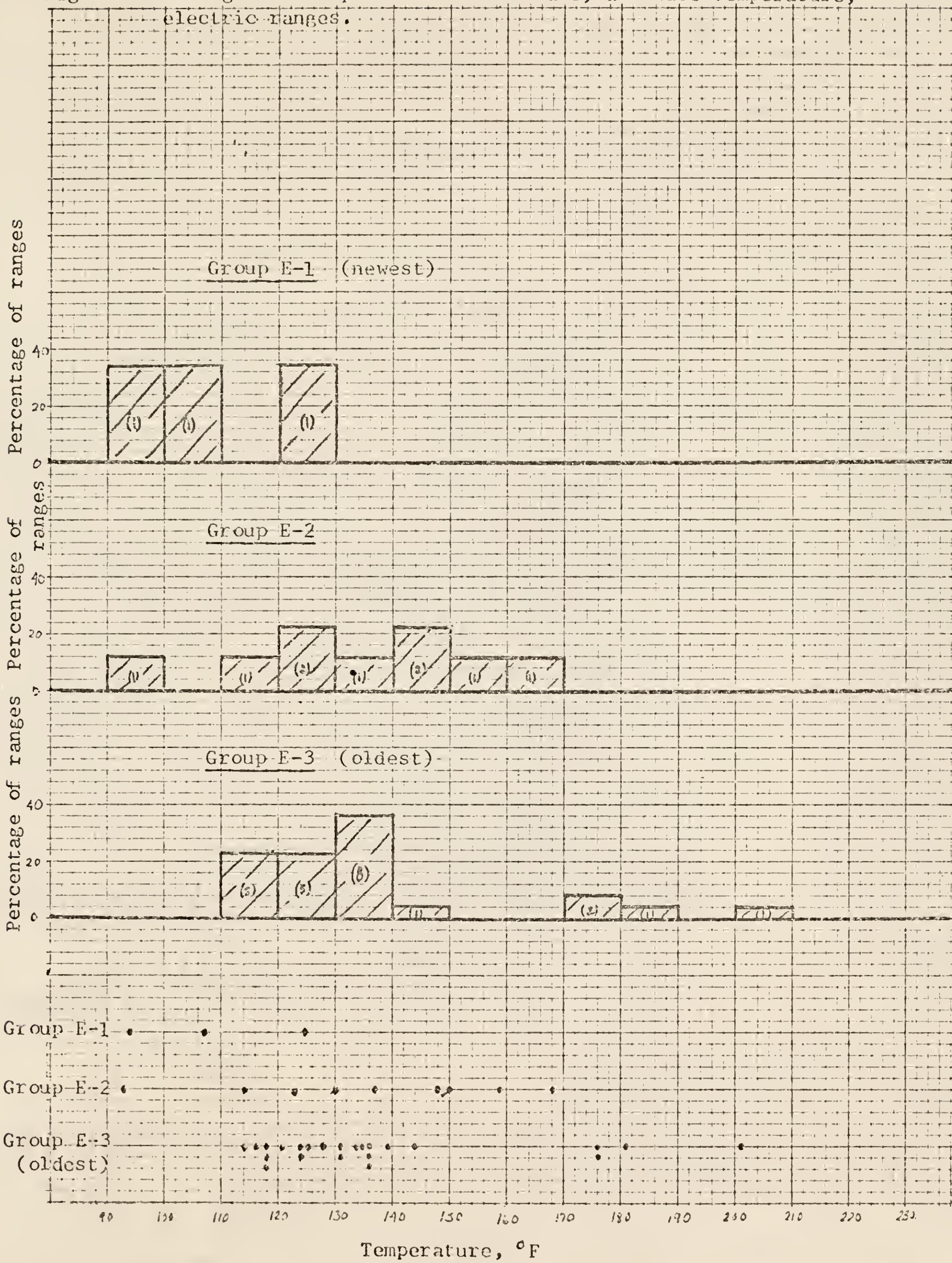
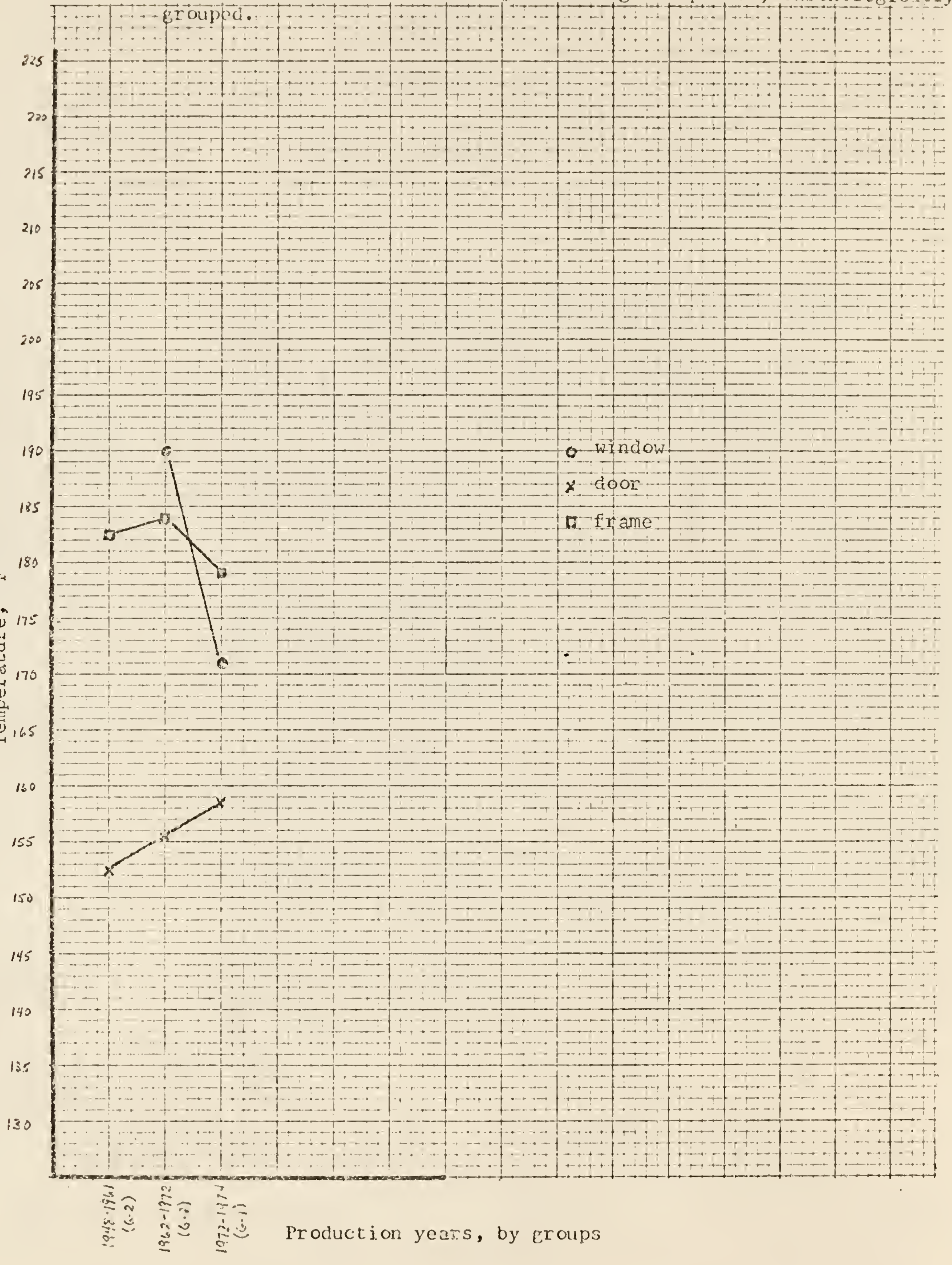


Fig. 37. Gas range temperatures, average of 4 highest points, chronologically grouped.



have decreased over the years while the temperature of the door area has increased over this period.

For electric ranges the same type of comparison was made. Because group E-3 was large and covered a long period of time, it was divided into three smaller groups. Each of these groups represented 5-10 years and were kept fairly equal in size. Figure 38 shows that temperatures for electric ranges were generally increasing over the 1949 to 1971 period. The peak is from 1966 to 1971. The UL Standard for Household Electric Ranges was adopted and went into effect on June 1 of 1971 and after this time the temperatures dropped dramatically for all areas of the range.

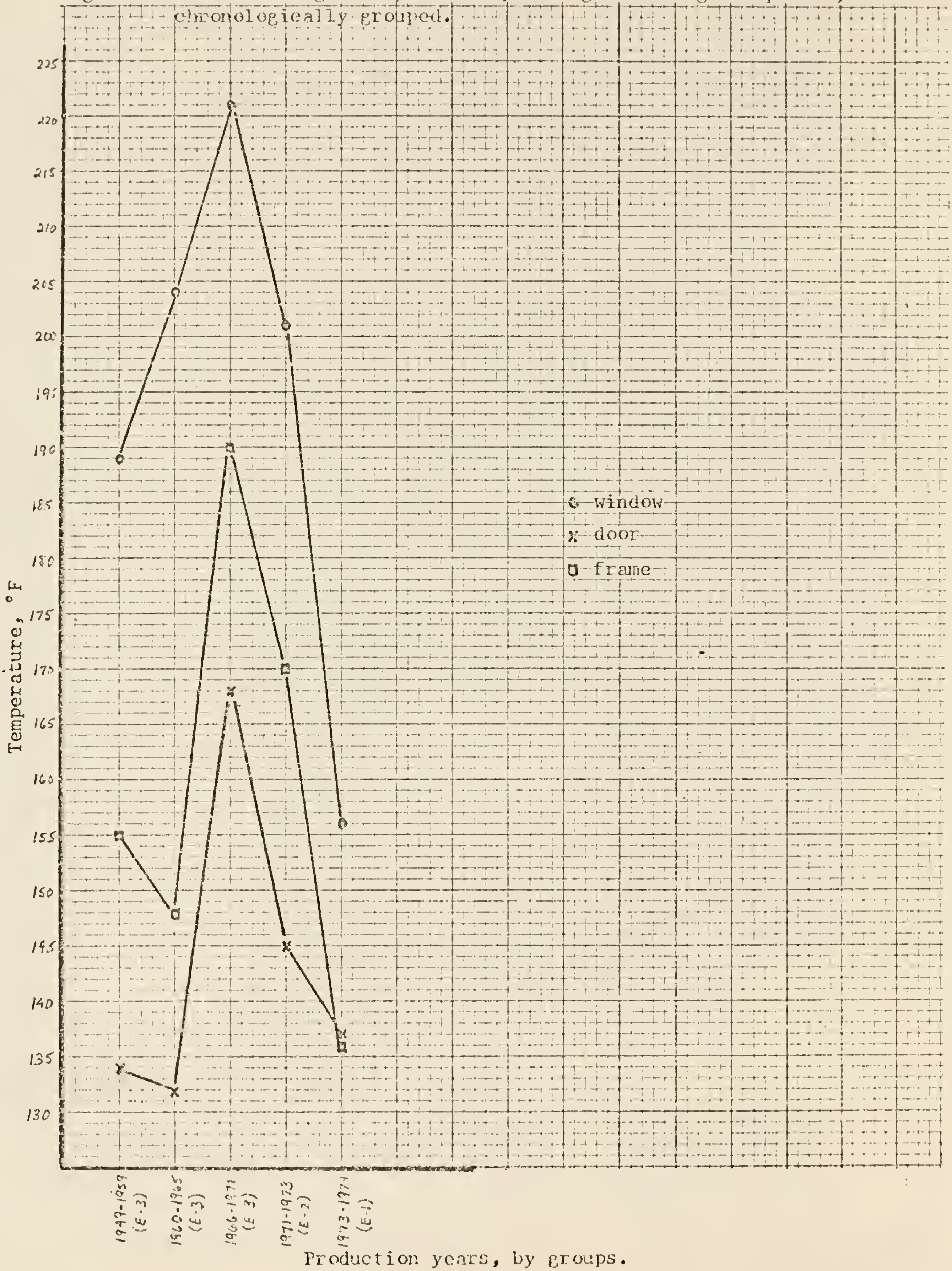
Another area to be investigated was the history of temperatures within a particular brand. There were four brands that were represented in the test sample several times over a number of years so it was possible to plot the average temperatures of the window area, the door and the frame of these ranges against the years of production.

Figures 39 and 40 show two brands of gas ranges and their temperature history. Although these were not the same model, they were the same brand. Neither show a definite trend for all areas except perhaps the Tappan a downward jump between 1969 and 1972. This coincides with a new, lower standard put into effect in 1972.

Figures 41 and 42 illustrate histories of electric ranges of two brands. The electric range standard went into effect in 1971 and a downward trend in temperatures can be noted in these brands close to this date.

The temperatures of doors with and without windows were also compared. Ranges were separated into gas and electric types and the averages of the highest four points on the door were averaged to calculate the total mean. The temperatures of doors of ranges with windows were generally 20° to 30° higher

Fig. 38. Electric ranges temperatures, average of 4 highest points, chronologically grouped.



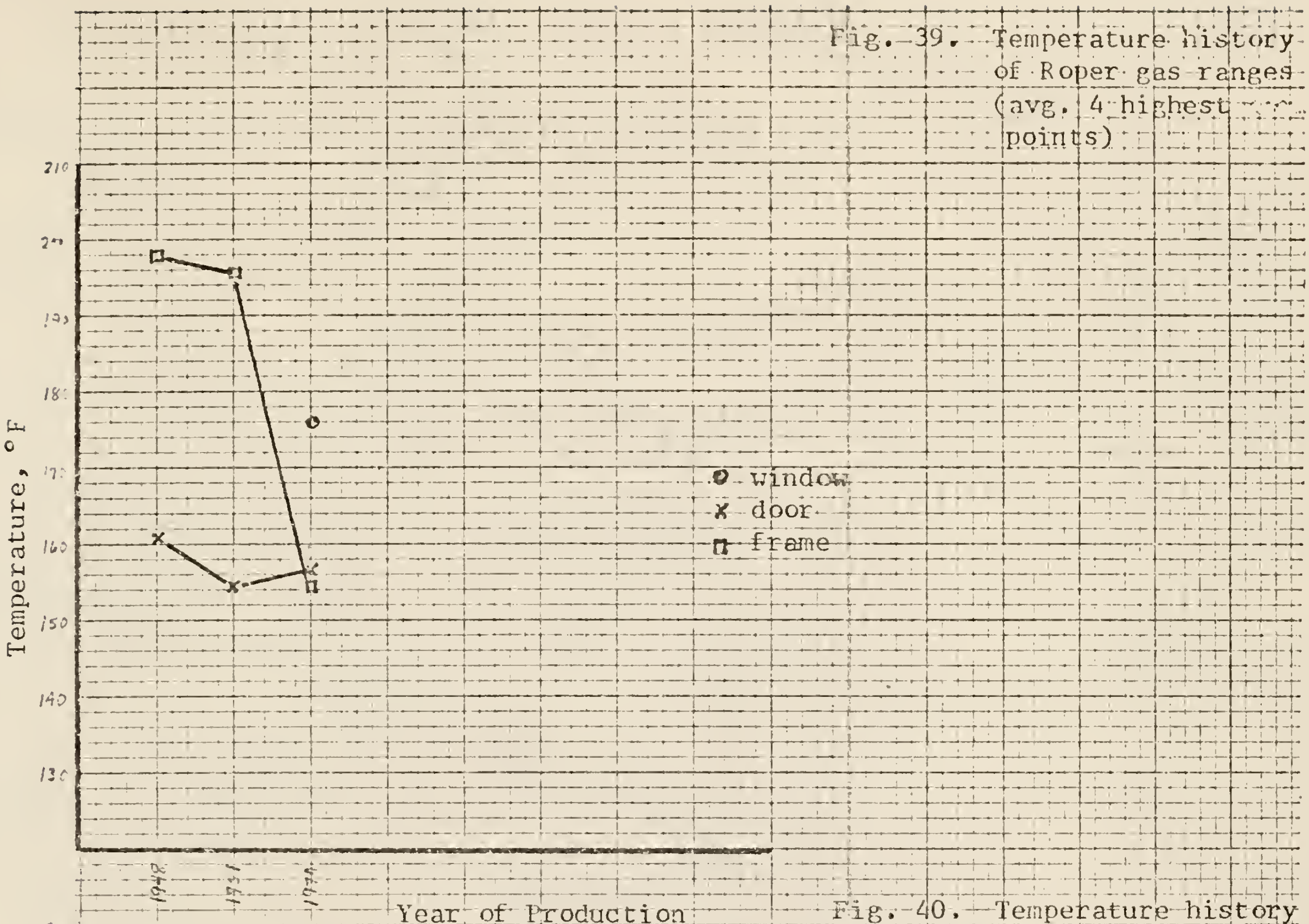


Fig. 39. Temperature history of Roper gas ranges (avg. 4 highest points)

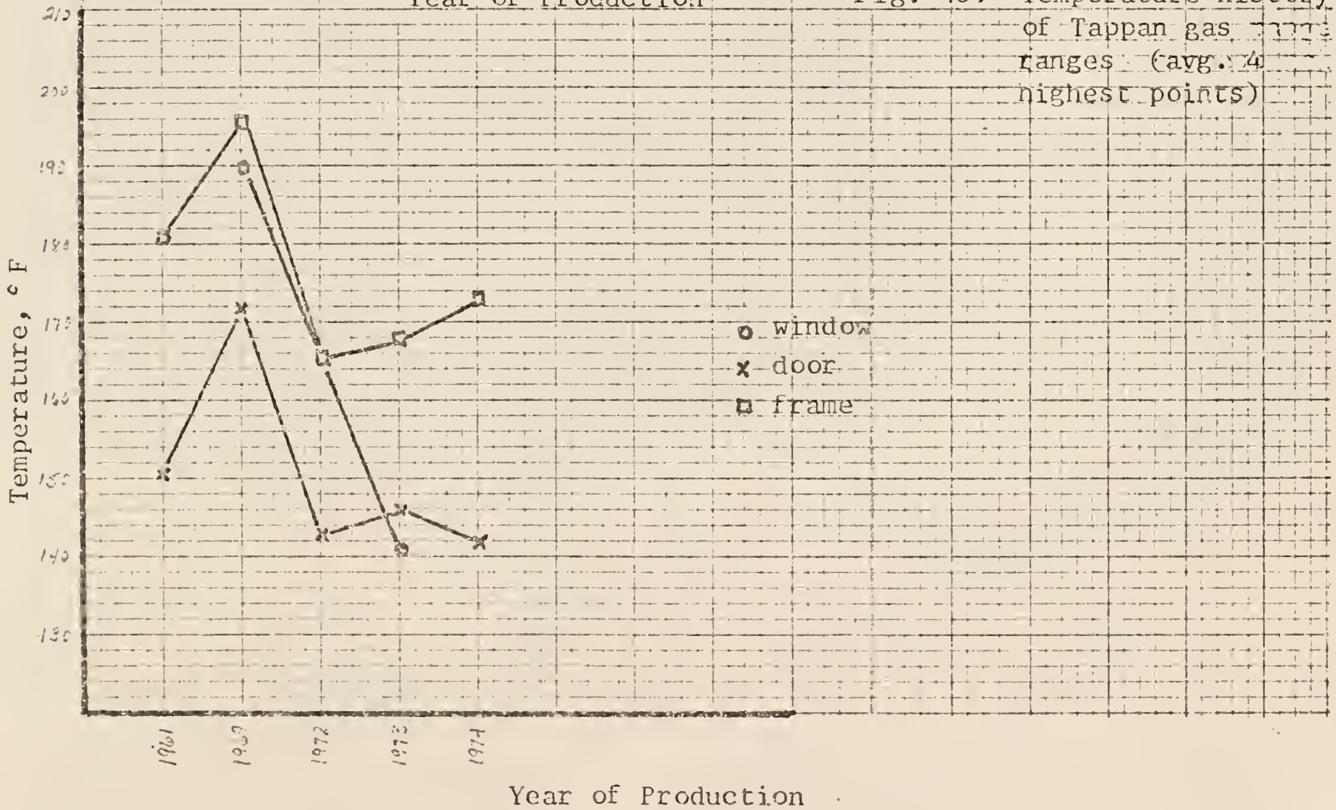


Fig. 40. Temperature history of Tappan gas ranges (avg. 4 highest points)

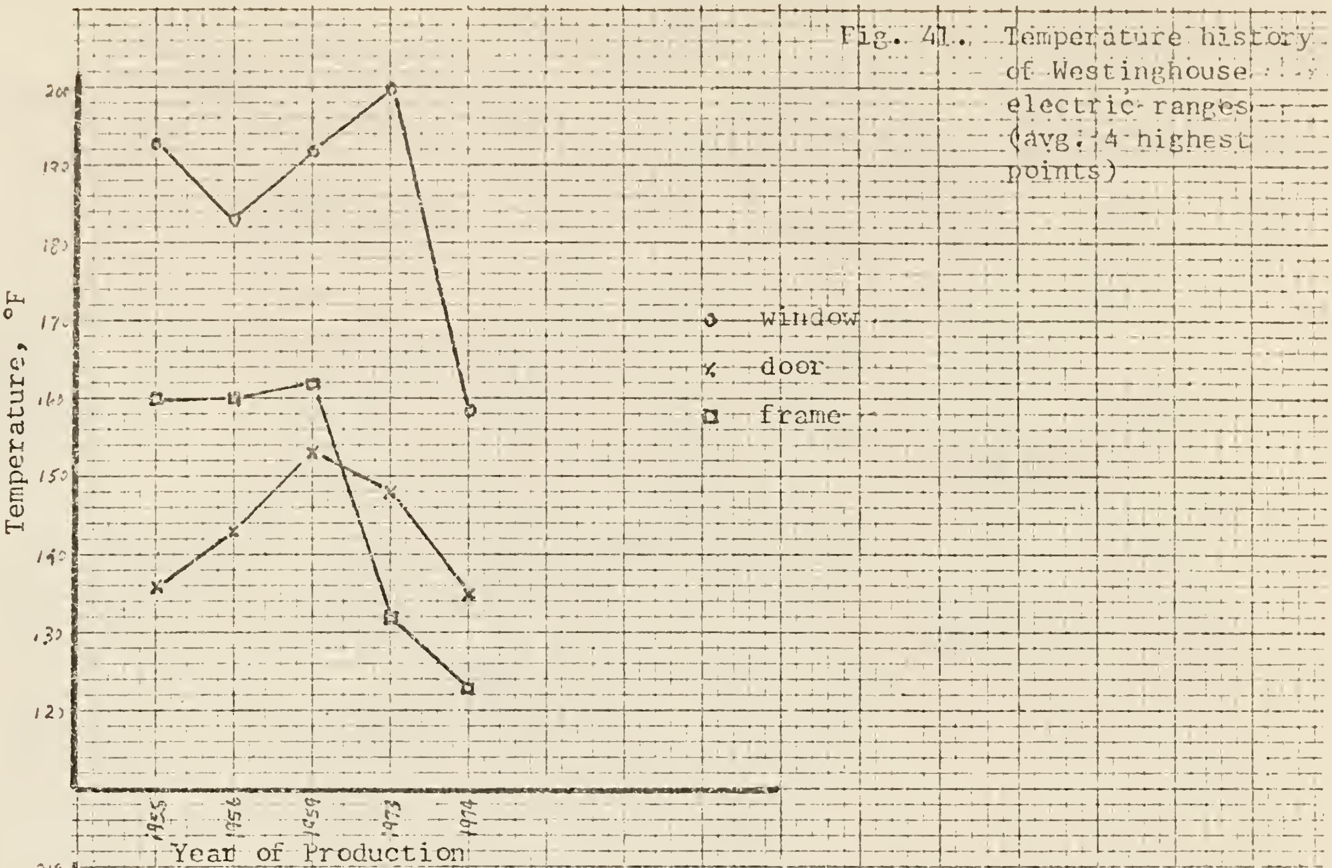


Fig. 41. Temperature history of Westinghouse electric ranges (avg. 4 highest points)

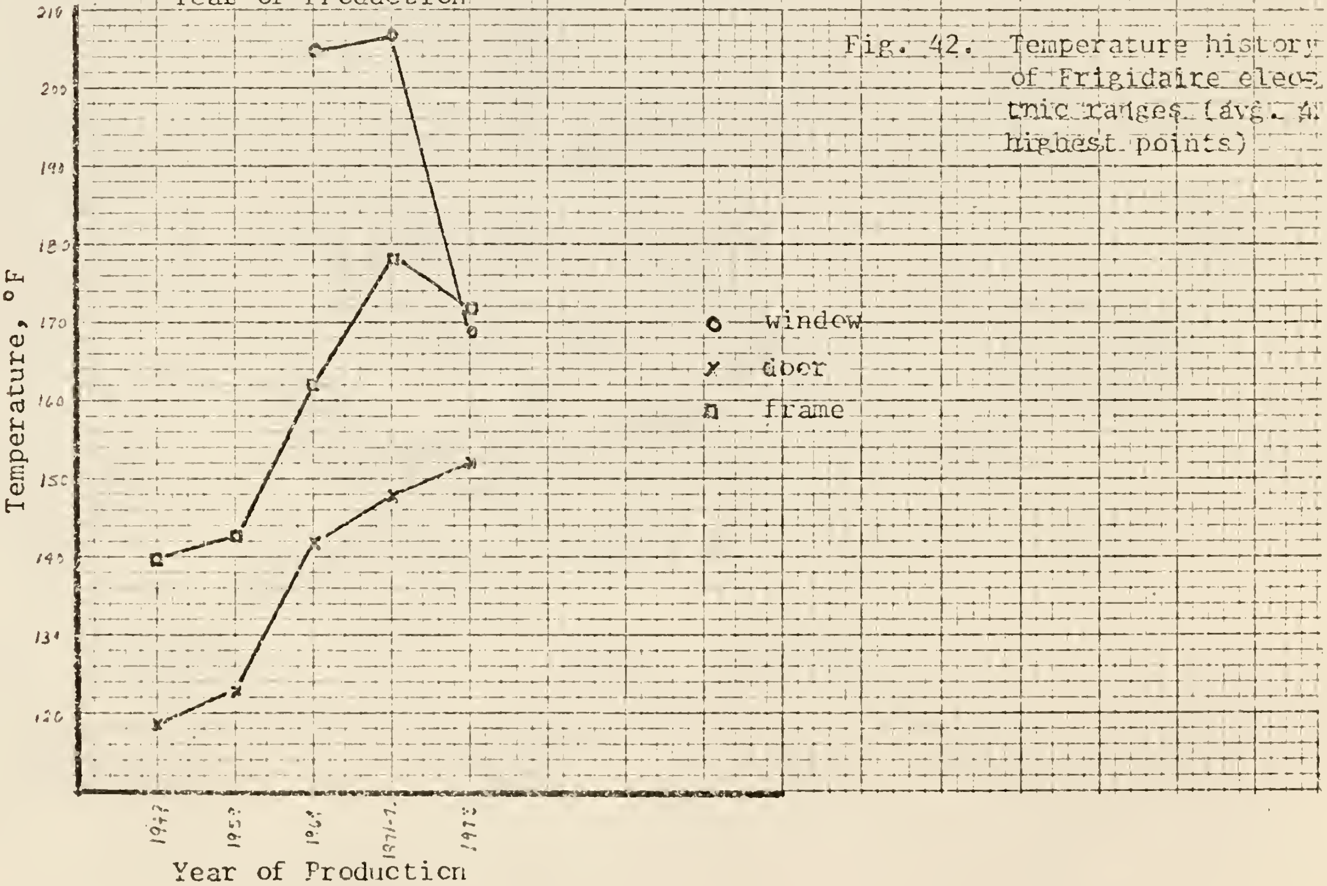


Fig. 42. Temperature history of Frigidaire electric ranges (avg. 4 highest points)

than temperatures of doors of ranges without windows. Table 11 shows the results.

Table 11. Average Door Temperatures of Ranges With and Without Windows, Degrees F.

	With Windows	Without Windows
Gas ranges	166.8	143.25
Electric ranges	159.8	131.5

Evaluation of quality control

To determine if the quality control with respect to hot spots was improving, the ratio (R_1) of the porcelain door high point to the average of all points on the door and the ratio (R_2) of the average of the four highest points to the average of all points on the door were figured. The results were then plotted in Figures 43-46 according to year of production in the same groups used for the chronological temperature average graphs. With both comparisons, gas range ratios began rather low, peaked during the 1962-72 period and then lowered somewhat during the 1972-74 period. For electric ranges, the ratios showed a drop during the 1960-65 period then a steady rise. With both gas and electric ranges, the trend of the curves for both ratios was the same, but the ratio (R_2) was smaller than R_1 for both cases.

Comparison with critical burn temperatures

For determining a temperature at which burns would occur, the Kodak Laboratory report [6] was used. It gave a temperature for the material surface itself and took into consideration variables such as thermal properties of the skin and the material, initial skin temperature, a one second contact time, skin thickness and a 1st percentile burn threshold. While pain would be

Fig. 43. Porcelain door, ratio (R_1) high point to average of all points, chronologically grouped, gas ranges.

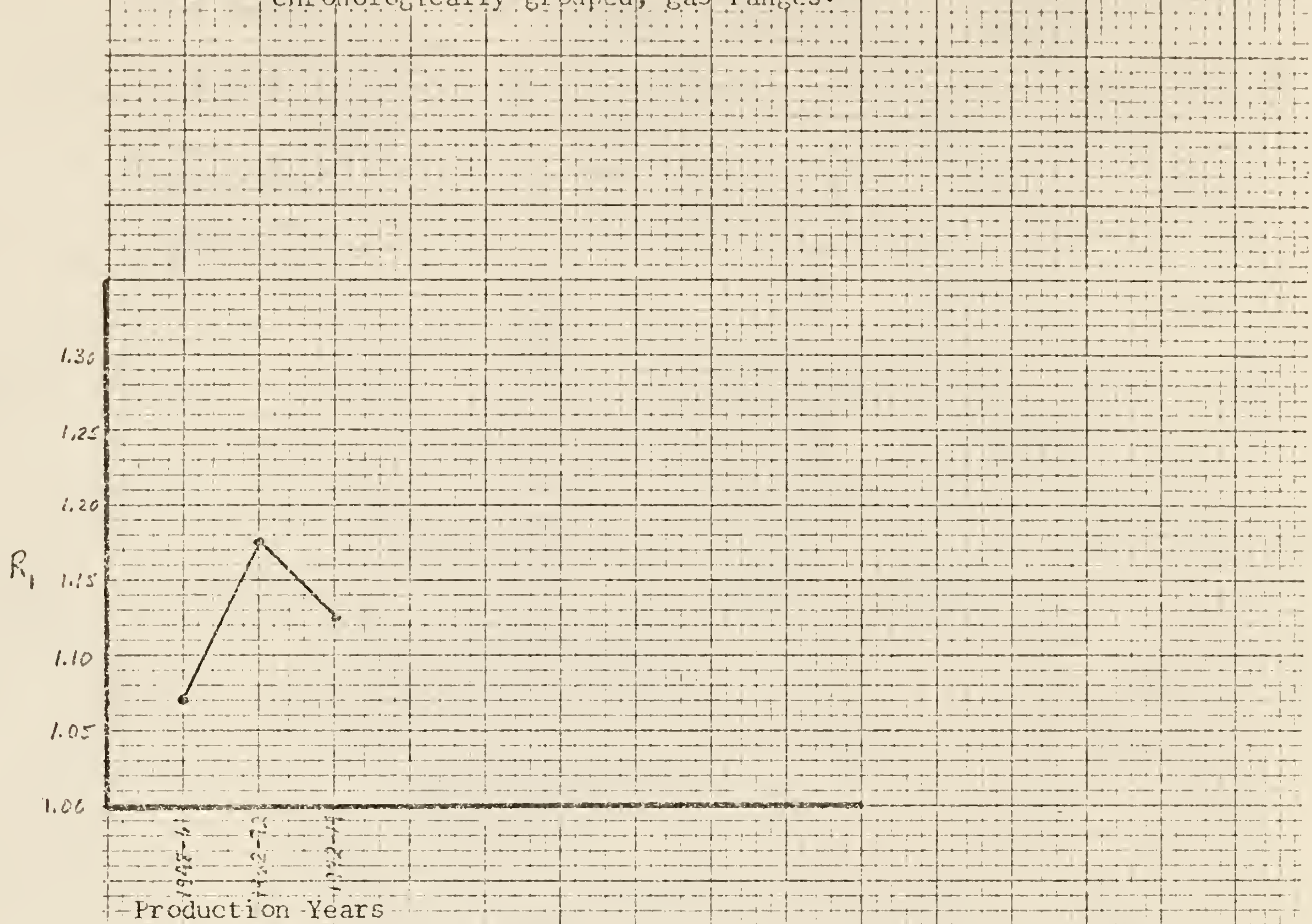


Fig. 44. Porcelain door, ratio (R_2) average 4 high points to average of all points, chronologically grouped, gas ranges.

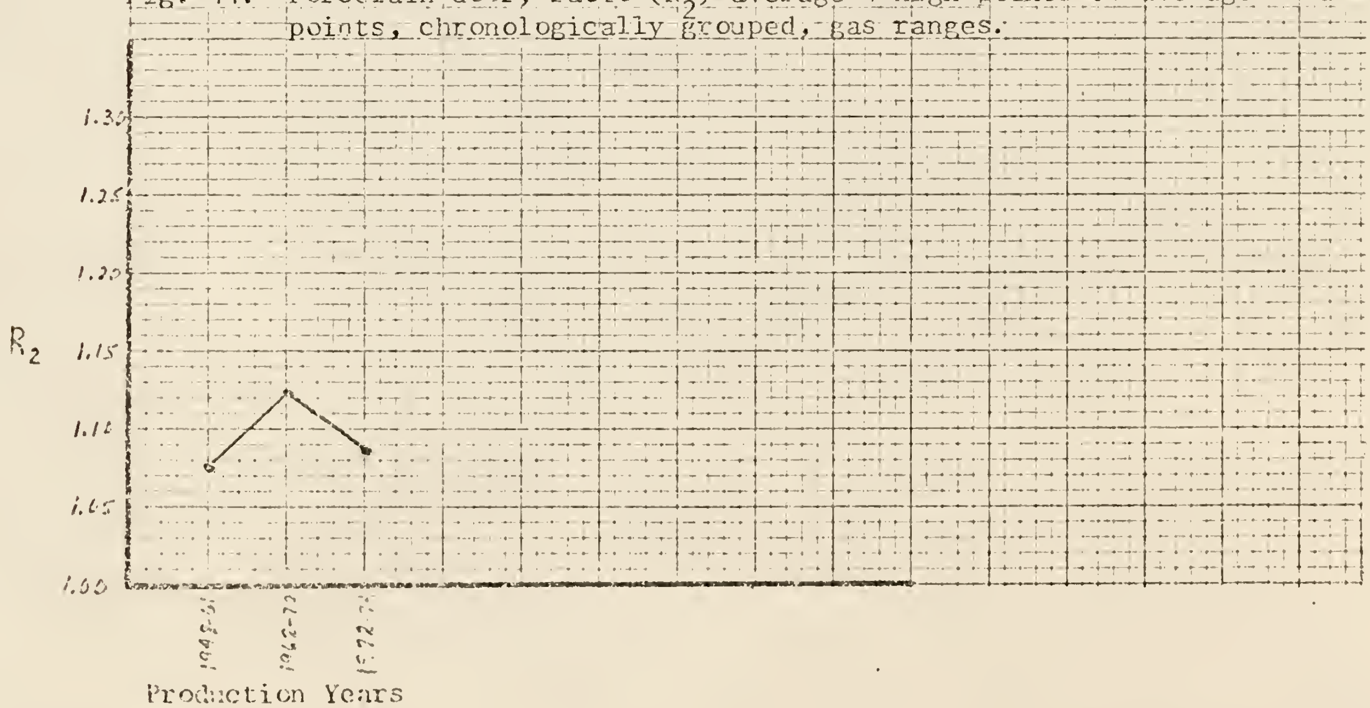


Fig. 45. Porcelain door ration (R_1) of high point to average of all points, chronologically grouped, electric ranges.

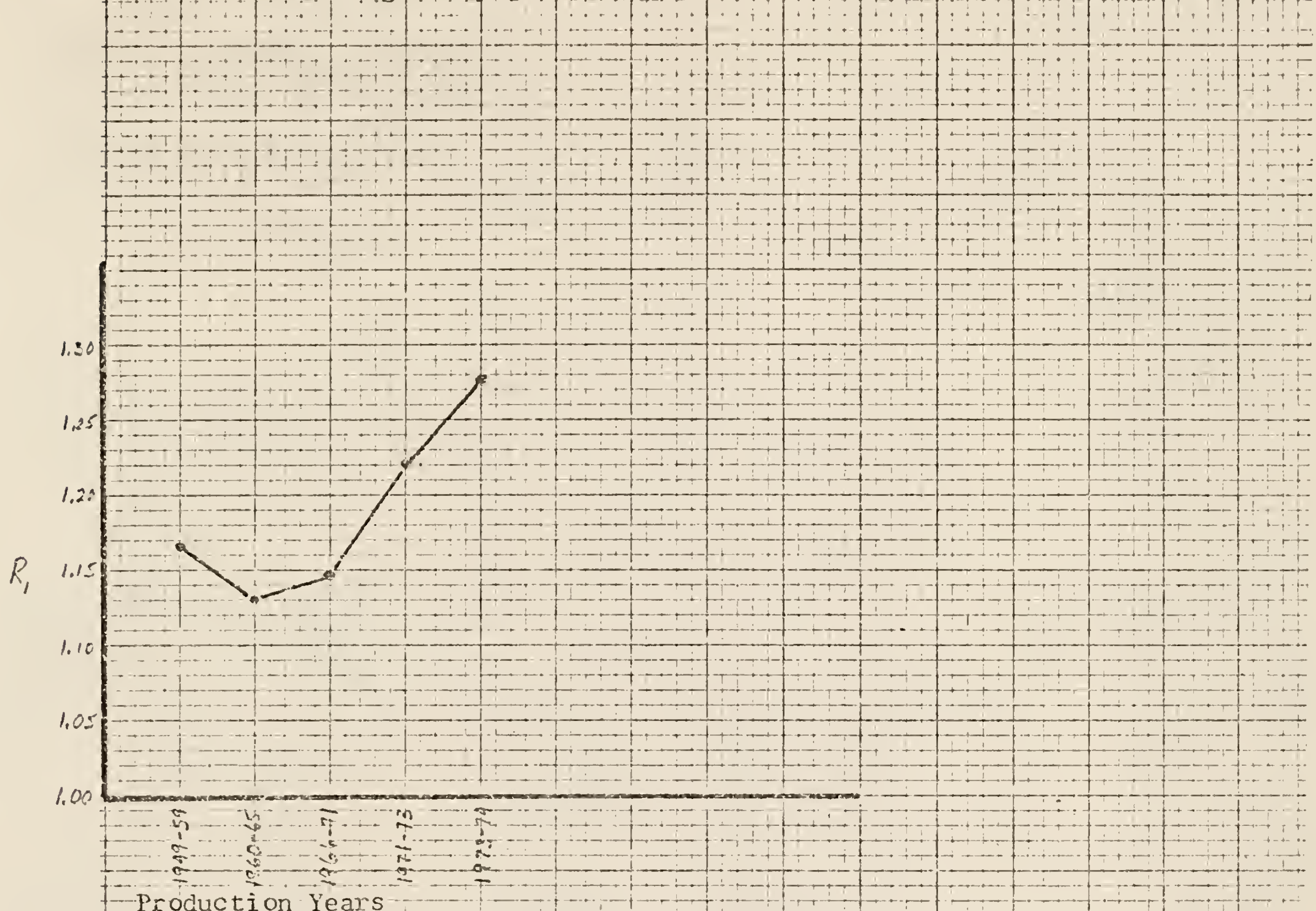
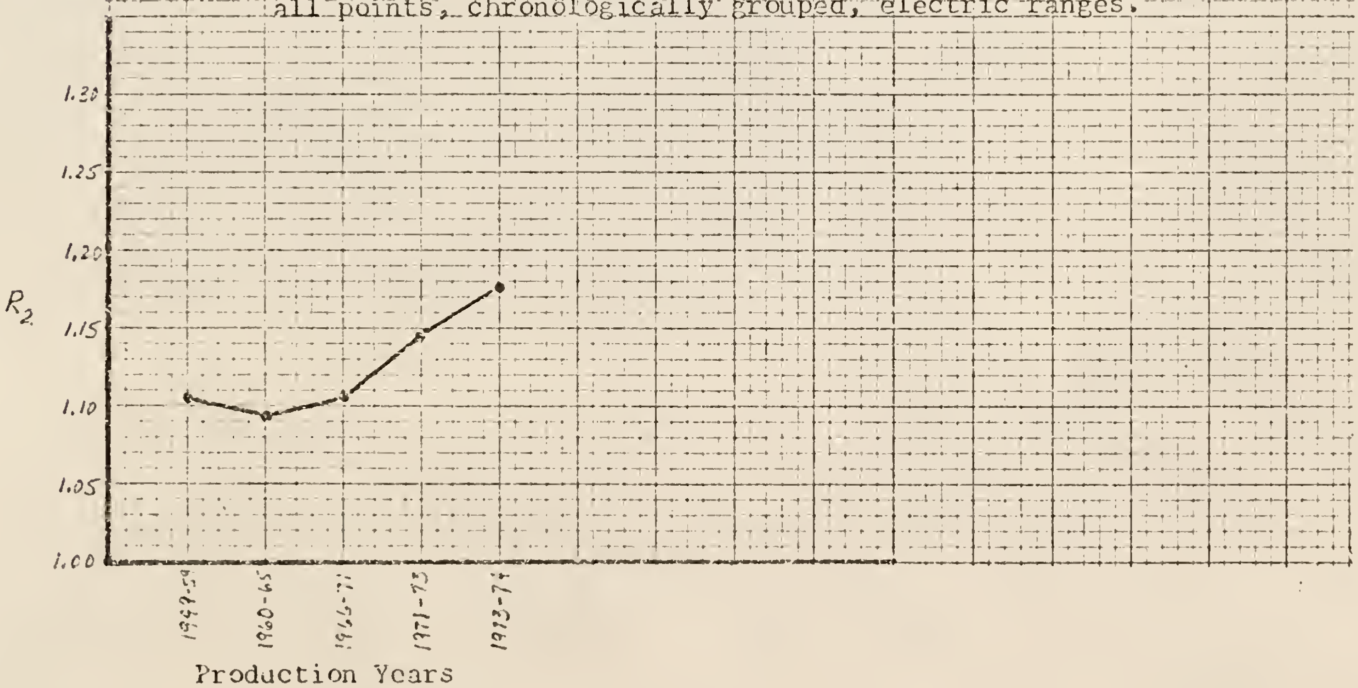


Fig. 46. Porcelain door, ration (R_2) average 4 high points to average of all points, chronologically grouped, electric ranges.



elicited by one second contact with glass at 129°F, a first degree burn would not occur until it reached 180°F. Temperature limits for steel were listed but porcelain enamel was not included in the findings.

A critical burn temperature for porcelain enamel was derived from a combination of information from the Kodak [6] and the Calspan [18] studies. The Calspan report gave a thermal inertia for porcelain enamel (0.00167) that was much closer to glass (0.0013) than to steel (0.092), so it was assumed that for a one second contact the temperature limit for porcelain would be only slightly lower than that for glass. A 175°F temperature was interpolated as the critical temperature for burns from porcelain enamel for this comparison. The Kodak formula for computing the critical temperature for various materials was unusable for porcelain enamel as the Calspan report did not include individual values for the variables used in computing thermal inertia. Porcelain enamel is also a bonding to two materials and the formula as written was for only one material and its properties. The thickness of porcelain enamel may vary from appliance to appliance as well.

By using these critical burn temperatures, it was possible to determine what percentage of ranges exceeded the safety limits by groups, as shown in Table 12.

Table 12. Percent of Ranges Over Critical Burn Temperatures by Groupings.

Group	Window	Door	Frame
G-1	25%	22%	33%
G-2	100%	0%	67%
E-1	0%	0%	0%
E-2	100%	0%	56%
E-3	100%	13%	22%

DISCUSSION AND CONCLUSIONS

The information and data collected for this study and analysis of it have allowed several conclusions to be reached about trends in surface temperatures reached, industry compliance with standards and hazards presented by the hot oven door.

The first objective of the research was to determine if manufacturers were meeting the industry safety standards for household gas and electric ranges. In this area it appeared that electric range manufacturers were doing a better job than their counterparts in the gas range industry. According to this sample, 88% of gas ranges in the newest group tested did not meet industry standards for the window or door areas and only about half of the ranges complied with the frame temperature requirement. Electric ranges had a much better record of compliance for the latest models.

The second objective was to determine if newer ranges are safer than those manufactured several years ago. Since both UL and AGA have lowered allowable temperatures for new ranges and electric ranges are complying well with this standard, it would be correct to assume that most new electric ranges are cooler than older models. This is also indicated by the chronological temperature average graph done for electric ranges which shows a lowering of temperatures for all surfaces on the range. In looking at the absolute temperatures reached, the door and frame areas of gas ranges were slightly higher than in the past and the window slightly lower, so safety of these ranges was no better than older models.

Electric range temperatures were increasing from 1949 until 1971. Manufacturers may have been aware of this increasing temperature problem through consumer complaints and their own quality control testing, and decided a range standard for surface temperatures was necessary. After the standard was put into effect, temperatures of all surfaces of the electric range exterior dropped dramatically. Manufacturers were technically able and willing to decrease temperatures. Further reduction took place with the revised standard of 1973. It is also interesting to note that the standard was put into effect only a short time after the Consumer Product Safety Commission had finished its investigation of product hazards. The report mentioned ranges in relation to burns.

The history of temperature fluctuations within brands show much the same pattern as the overall histories. Manufacturers have been able to reduce temperatures when changes in the standard demanded it, although increased cost was perhaps a result. Because range standards are published several years in advance of their effective date, range designs and changes in temperature patterns are not always pin-pointed on the date of standard change.

The third objective was to determine if companies were complying with standards better than in the past. Electric ranges demonstrated improved compliance for new ranges compared to older ranges for the window area. Some improvement was also seen in the door temperature standard compliance and a slight improvement for the frame. Gas ranges did not fare as well in compliance with the standard. An approximately equal percentage complied for newer and older models in the window temperature area and compliance for newer models was worse for the door and frame area. It should be noted that for groups E-1 and G-1 the temperature limits were lowered for both gas and electric ranges.

The fourth objective was to determine if quality control, with respect to surface temperatures and hot spots, was improving. For gas ranges, the newest group of ranges showed an improvement in the number and temperature of the hot areas on the door. For electric ranges, the quality control has been worse with newer ranges. Causes of this increase might be less care in the application of insulation in the factory.

In trying to correlate gasket condition and hot spots, very few cases could be specifically identified of much higher temperatures in an area where there was poor door fit. Many ranges had poorly fitting doors, however. This may be an area which range manufacturers should investigate for heat loss.

The fifth objective was to determine if present range standards are adequate to protect both children and adults. An absolute temperature should be indicated as the standard because degrees above room temperature allows far too much variation and with an extremely high room temperature, the standard allowed might present a burn hazard. The 180°F for glass and 175°F for porcelain used in the comparisons as the critical burn temperature should be the upper limit allowed. Surfaces at these temperatures could be painful to the touch and might burn a small child, as there is evidence to suggest that the child's skin is thinner and his reaction time longer.

The window was the most dangerous area, however the newer ranges were safer than older models. The frame area also had a high percentage of ranges over the critical temperature. The door was a hot area for the newer group of gas ranges and the oldest group of electric ranges. The newest electric ranges had temperatures under the critical limit for all three test areas.

Range standards have, through the years, had a separate temperature limit for the frame area than for the porcelain door even though the surfaces of both are porcelain. The rationale for this is questioned. Why is it less hazardous to reach a particular temperature on the frame than on the door? On one range tested, the frame area and the door averaged the same temperature, yet the frame was 22°F below standard and the door 8°F above. One can as easily come in contact with the frame surface as with the door surface, and the same temperature will produce a burn in either case.

Other observations can also be made from the analysis of data. Windows are consistantly a problem area for both gas and electric ranges. Only seven of the 27 ranges with windows met the standard. Also, oven doors with windows were hotter than doors without windows. It was found that doors with metal strips around the glass door portion were extremely hot, with temperatures of 216°F to over 225°F.

There were very hot and very cool models in each type, so statements must be made according to averages and general trends. Use of the thermesthesiometer, with one allowable temperature and reaction like a human finger, will probably increase the effectiveness of the standard.

It is recommended to UL and AGA testing laboratories, that the initial model for testing for compliance with standards should be randomly selected from the manufacturer's assembly line and spot checks be made periodically from the assembly line and in homes of consumers.

In conclusion, it can be said that a significant portion of ranges in use in homes have exterior oven door temperatures which could cause burns to children and adults under normal operating conditions.

ACKNOWLEDGEMENT

Sincere appreciation is expressed to Patty J. Annis, Assistant Professor, Department of Family Economics, and to Dr. Jason C. Annis, former Associate Professor, Department of Mechanical Engineering, for their guidance and assistance during the investigative study and manuscript preparation.

Gratitude is also expressed to Dr. Richard L.D. Morse, Professor and Head, Department of Family Economics and to Dr. Stephan Konz, Professor, Department of Industrial Engineering, for their constructive criticism of the manuscript.

LITERATURE CITED

1. Cone, T.E. Jr. "Scalds from Cooking Liquids, Book of Accidents published in 1830." Pediatrics. September, 1971. Vol. 48, No. 3. p. 482.

2. Cone, T.E. Jr. "Playing with Fire, Book of Accidents published in 1830." Pediatrics. November, 1971. Vol. 48, No. 5. p. 839.

3. National Commission on Product Safety. "Hearing Proceedings." October, 1968. Vol. 1. pp. 1-43.

4. National Commission on Product Safety. "Cooking Range Exterior Surface Burns." 1973. pp. 1-3.

5. Bullerick, W.A. and Adams, D.E. "Investigation of Safety Standards for Flame Fired Space Heaters." Calspan Technical Report. February, 1976. Report # YG-5569-D-4. pp. 30-36.

6. Faulkner, Terrence W. "Touching Hot Surfaces." Eastman Kodak Co., Human Factors Section, Health and Safety Laboratory. July, 1974. No. HF-74-20. pp. 14-48.

7. Faulkner, Terrence W. "Comfort/Safety Guidelines for Touching Hot Surfaces." Eastman Kodak Co., Human Factors Section, Health and Safety Laboratory. August, 1974.

8. Moritz, A.R. (MD) and Henriques, F.C. Jr. (PhD). "Studies of Thermal Injury, II, The Relative Importance of Time and Surface Temperature in the Causation of Cutaneous Burns." American Journal of Pathology. 1947. Vol. 23

9. Wu, Yung-Chi. "Materials Properties Criteria for Thermal Safety." Journal of Materials, JMLSA. December, 1972. Vol. 7, No. 4. pp. 573-579.

10. ____________. "Perspective on Product Safety." Consumer Reports. September, 1970. Vol. 35, No. 9. pp. 560-564.

11. Waller, Julian A. (MD, MPH) and Manheimer, Dean I. (MA). "Non-fatal Burns of Children in a Well Defined Urban Population." Journal of Pediatrics. December, 1964. Vol. 65, No. 6, part 1. pp. 863-869.

12. Verhalen, Robert. Internal memorandum to Bernard Schwartz concerning petition CP-75-24, Oven Doors. National Commission on Product Safety. August 11, 1975.

13. U.S. Consumer Product Safety Commission. "Ranges." NEISS News. April, 1975. Vol. 3, No. 5.

14. Dana, Margaret. "Consumers Ask Column." Wichita Eagle Newspaper. July 4, 1973.

15. ______________. "Ranges with Self Cleaning Ovens." Consumer Reports. July, 1972. Vol. 37, No. 7. p. 439.

16. Ehrenkranz, Florence and Inman, Lydia. Equipment in the Home. 1966. New York: Harper and Row. p. 170.

17. ______________. "Freestanding Gas Ranges." Consumer's Research Magazine. May, 1976. Vol. 59, No. 5. pp. 30-31.

18. Bullerick, W.A., Adams, D.E. and Cozard, C.P. "Investigation of Safety Standards for Flame-fired Furnaces, Hot Water Heaters, Clothes Dryers and Ranges." Calspan Informal Monthly Progress Report #6. January, 1975. Contract No. CPSC-C-74-131. pp. 1-24.

19. Bullerick, W.A. and Adams, D.E. "Identification and Classification of Potential Hazards Associated with the Use of Residential Flame-fired Furnaces, Hot Water Heaters, Clothes Dryers and Range." Calspan Technical Report. 1975. Report # YG-5569-D-2. pp. 10-13.

20. Jacobs, H.H., et al. Behavorial Approaches to Accident Research. 1961. New York: Association for the Aid of Crippled Children. pp. 85-86.

21. Cozard, C.P. "Factors Leading to Accidental and Severe Contact Burns of Children." Calspan Monthly Report #6. January, 1975. CPSC contract #CPSC-C-74-131. pp. 2-8.

22. Peterson, Hugh D. (D.D.S., M.D.) Written Correspondence. July 22, 1974. U.S. Army Institute of Surgical Research, Brooke Army Medical Center, Fort Sam Houston, Texas.

23. Robinson, David W. (M.D.) Written Correspondence. June 10, 1974. University of Kansas Medical Center, Kansas City, Kansas.

24. Stoll, A.M. "The Role of the Skin in Heat Transfer." Journal of Heat Transfer, Transactions of the ASME. August, 1960. pp. 239-242.

25. Institute of Applied Technology, National Bureau of Standards. "The Thermesthesiometer - An Innovation in Heat Measurement." Lab Data. Winter 1975. Vol, 6, No. 1. pp. 13-14.

26. Elkind, A.B. (chairman). Final Report of the National Commission on Product Safety. June, 1970. Library of Congress Card #76-606753. pp. 47-57.

27. GAMA Report on Gas Range Safety, prepared for the National Commission on Product Safety. March 31, 1975. pp. 1-69.

28. Booth, Sherman F. Standarization Activities in the United States, A Descriptive Directory. August 1, 1960. Washington, D.C.: Superintendent of Documents, U.S. Government Printing Office. U.S. Department of Commerce and National Bureau of Standards, Misc. Pub. #230. pp. 49-52, 144-145 and 186-189.

29. American Gas Association. "Approval Requirements for Domestic Gas Ranges, Z21.1". (see table 5 for further information.)

30. National Electrical Manufacturers Association. "American Standard for Household Electric Ranges". May 4, 1950. Pub. No. ER-1-1950.

31. Underwriters Laboratory. "Standard for Safety, Household Electric Ranges." UL 858. (see table 6 for further information.)

32. Van Zante, Helen. Household Equipment Principles. 1964. Prentice-Hall Inc. pp. 282-283.

APPENDICES

Appendix A. Data sheet.

Test number ________

Actual interior temp ________

Oven setting 400 F
Self clean

Date of test ________

Address ________

Brand ________

Model # ________

Serial # ________

Year ________

Room temp(recorder) ________

Room temp (thermo) ________

Phone ________

Features: window no window
self clean continuous clean
no cleaning feature

Handle material ________

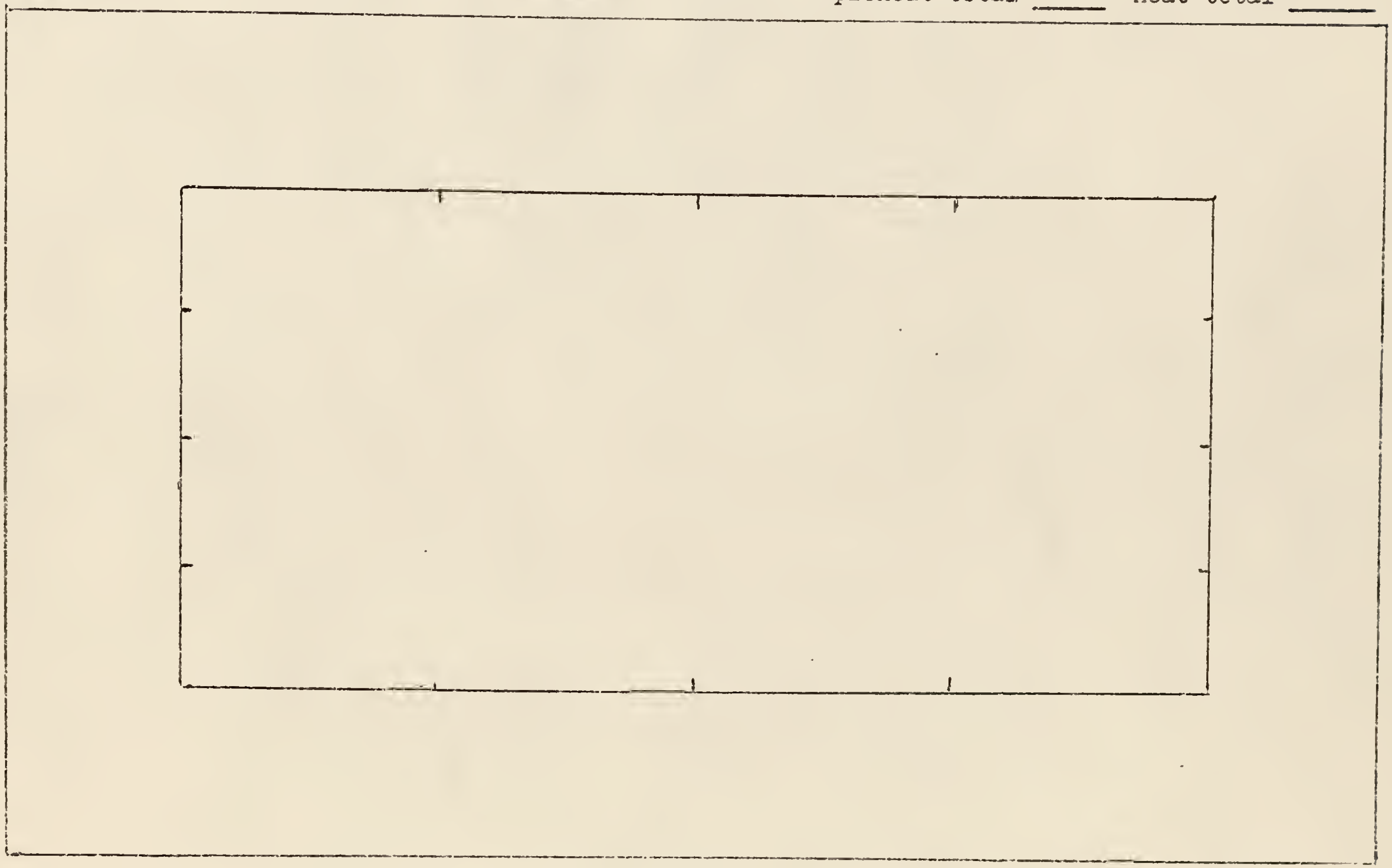
Door material ________

preheat end ________ heat end ________

preheat start ________ heat start ________

preheat total ________ heat total ________

Door seal:



Appendix B. Group G-1
Temperatures reached and temperatures allowed by standard and room temperature.

Year & Brand	Window high point	Window avg. 4 high pts	Door high point	Door avg. 4 high pts	Door avg. all pts	Frame high point	Frame avg. 4 high pts	Frame avg. all pts	Room temp °F
1974 Tappan	no window		146 / 153	142 / 153	133 / 153	187 / 183	173 / 183	158 / 183	78
1974 Hardwick	no window		glass 174 / 170	door 172 / 170	161 / 170	204 / 185	198 / 185	168 / 185	80
1974 Hardwick	no window		glass 165 / 162	door 164 / 162	152 / 162	175 / 177	170 / 177	157 / 177	72
1974 Hardwick	176 / 166	171 / 166	165 / 151	162 / 151	156 / 151	201 / 181	193 / 181	182 / 181	76
1974 Roper	185 / 164	177 / 164	172 / 149	157 / 149	138 / 149	157 / 179	153 / 179	141 / 179	74
1974 Roper	184 / 166	175 / 166	165 / 151	155 / 151	138 / 151	161 / 181	157 / 181	146 / 181	76
1974 Firestone	182 / 168	180 / 168	191 / 153	185 / 153	174 / 153	225 / 183	222 / 183	193 / 183	77.5
1974 Penney's	190 / 164	187 / 164	218 / 149	210 / 149	186 / 149	225 / 179	225 / 179	203 / 179	74
1973 Tappan	144 / 158	141 / 158	153 / 143	146 / 143	128 / 143	172 / 173	169 / 173	147 / 173	68
1973 Magic Chef	no window		129 / 147	126 / 147	120 / 147	154 / 177	149 / 177	133 / 177	72
1972 Tappan	no window		147 / 151	143 / 151	135 / 151	174 / 181	166 / 181	153 / 181	76

Appendix C. Group G-2

Temperatures reached and temperatures allowed by standard and room temperature.

Year & Brand	Window high point	Window avg. 4 high pts	Door high point	Door avg. 4 high pts	Door avg. all pts	Frame high point	Frame avg. 4 high pts	Frame avg. all pts	Room temp °F
1970 Royal Chef	no window		133 / 168	125 / 168	113 / 168	164 / 198	158 / 198	127 / 198	73
1970 Whirlpool	197 / 183	188 / 183	155 / 168	145 / 168	123 / 168	161 / 198	156 / 198	120 / 198	73
1969 Tappan	194 / 181	190 / 181	180 / 166	172 / 166	155 / 166	200 / 196	196 / 196	175 / 196	71
1969 Sears	198 / 186	194 / 186	167 / 171	162 / 171	148 / 171	212 / 201	200 / 201	163 / 201	76
1969 Magic. Chef	208 / 184	190 / 184	180 / 169	174 / 169	156 / 169	219 / 199	210 / 199	168 / 199	74
1961 Tappan	no window		154 / 174	151 / 174	140 / 174	184 / 204	181 / 204	164 / 204	79
1955-62 Chambers	no window		148 / 169	144 / 169	135 / 169	162 / 199	155 / 199	149 / 199	74
1951 Roper	no window		155 / 174	154 / 174	144 / 174	198 / 204	196 / 204	179 / 204	79
1948 Roper	no window		170 / 170	161 / 170	147 / 170	203 / 200	198 / 200	177 / 200	75

Appendix D. Group E-1 & Group E-2

Temperatures reached and temperatures allowed by standard and room temperature.

	Year & Brand	Window high point	Window avg. 4 high pts	Door high point	Door avg. 4 high pts	Door avg. all points	Frame high point	Frame avg. 4 high pts	Frame avg. all points	Room temp. °F
	1974 Westinghouse	163 / 163	158 / 163	150 / 148	135 / 148	117 / 148	125 / 178	123 / 178	108 / 178	73
Group E-1	1974 Sears	143.5 / 162	141 / 162	134 / 147	125 / 147	109 / 147	115.9 / 177	112 / 177	94 / 177	72
	1973 Frigidaire	175 / 166	169 / 166	161 / 151	151 / 151	123 / 151	181 / 181	172 / 181	124 / 181	76
	1973 Corning	no window		160 / 170	151 / 170	128 / 170	222.5 / 200	212 / 200	168 / 200	75
	1973 Westinghouse	204.5 / 170	200 / 170	161 / 165	148 / 165	129 / 165	137.5 / 195	132 / 195	114 / 195	70
	1972 Hotpoint	no window		149 / 174	145 / 174	135 / 174	169 / 204	168 / 204	150 / 204	79
	1972 Hotpoint	no window		93 / 167	92 / 167	88 / 167	101 / 197	100 / 197	93 / 197	72
Group E-2	1972 Corning	no window		182 / 181	169 / 181	133 / 181	207 / 211	204 / 211	159 / 211	86
	1971-72 Frigidaire	202.9 / 173	199 / 173	175 / 168	156 / 168	131 / 168	196.5 / 198	187 / 198	130 / 198	73
	1971-72 Frigidaire	no window		131 / 168	126 / 168	118 / 168	161 / 198	155 / 198	123 / 198	73
	1971-72 Frigidaire	221.5 / 176	215 / 176	183 / 171	165 / 171	140 / 171	204 / 201	194 / 201	137 / 201	76
	1971 Sears	196 / 173	191 / 173	167 / 168	155 / 168	139 / 168	180 / 198	177 / 198	148 / 198	73

Appendix E. Group E-3
Temperatures reached and temperatures allowed by standard and room temperature.

Year & Brand	Window high point	Window avg. 4 highpts	Door high point	Door avg. 4 high pts	Door avg. all points	Frame high point	Frame avg. 4 high pts	Frame avg. all points	Room temp °F
1971 Hotpoint	225 / 185	224 / 185	212 / 180	197 / 180	173 / 180	210.5 / 210	204 / 210	176 / 210	85
1971 G.E.	no window		133 / 174	131 / 174	123 / 174	159 / 204	154 / 204	131 / 204	79
1971 Hotpoint	225 / 182	222 / 182	219 / 177	211 / 177	181 / 177	225 / 207	221 / 207	202 / 207	82
1970 G.E.	no window		143 / 173	138 / 173	138 / 173	173 / 203	169 / 203	136 / 203	78
1970 G.E.	no window		141 / 171	137 / 171	131 / 171	174 / 201	170 / 201	140 / 201	76
1970 Hotpoint	225 / 171	218 / 171	218 / 166	204.5 / 166	171 / 166	222 / 196	209 / 196	180 / 196	71
1969 Sears	no window		168 / 165	164 / 165	147 / 165	223 / 195	203 / 195	176 / 195	70
1965 G.E.	208.5 / 172.5	203 / 172.5	166 / 167.5	155 / 167.5	136 / 167.5	165 / 197.5	156 / 197.5	128 / 197.5	72.5
1964 Frigidaire	209.5 / 172	205 / 172	173 / 167	162 / 167	137 / 167	182 / 197	177 / 197	135 / 197	72
1964 Frigidaire	no window		125 / 170	122 / 170	116 / 170	151 / 200	148 / 200	125 / 200	75
1964 Hotpoint	no window		122 / 171	120 / 171	113 / 171	145 / 201	141 / 201	118 / 201	76
1964 Hotpoint	no window		129 / 172	125 / 172	117 / 172	147 / 202	143 / 202	121 / 202	77

Appendix E. Group E-3 (con't)

Year & Brand	Window high point	Window avg. 4 high pt	Door high point	Door avg. 4 high pts	Door avg. all points	Frame high point	Frame avg. 4 high pts	Frame avg. points	Room temp °F
1963 Hotpoint	no window		122 / 165	119 / 165	111 / 165	142.5 / 195	137 / 195	116 / 195	70
1962 G.E.	no window		133 / 173	130.5 / 173	120 / 173	161.5 / 203	152 / 203	124 / 203	78
1960 Hotpoint	no window		126 / 169	124 / 169	116 / 169	134.5 / 199	129 / 199	118 / 199	74
1959 Westinghouse	198 / 174	192 / 174	162 / 169	153 / 169	136 / 169	165 / 199	162 / 199	144 / 199	74
1959 Frigidaire	no window		131 / 166	123 / 166	112 / 166	155.5 / 196	143 / 196	115 / 196	71
1959 Kelvinator	no window		142 / 170	133 / 170	118 / 170	172.5 / 200	167 / 200	134 / 200	75
1957 G.E.	no window		156 / 167	144 / 167	124 / 167	181 / 197	162 / 197	125 / 197	72
1956 Westinghouse	189 / 170	183 / 170	151 / 165	143 / 165	126 / 165	163 / 195	160 / 195	131 / 195	70
1956 G.E.	no window		122 / 165	118 / 165	112 / 165	150.5 / 195	143 / 195	136 / 195	70
1955 Westinghouse	199 / 174	193 / 174	139 / 169	136 / 169	126 / 169	164 / 199	160 / 199	136 / 199	74
1949 Frigidaire	no window		124 / 169	119 / 169	112 / 169	145 / 199	140 / 199	118 / 199	74

Appendix F.
Degrees F above (+) or below (-) standard, gas ranges.

Group	Year & Brand	Window high point	Window avg 4 high pts	Door high point	Door avg 4 high pts	Door avg all points	Frame high point	Frame avg 4 high pts	Frame avg all pts
Group G-1	1974 Tappan	no window		- 7	-11	-20	+ 4	-10	-30
	1974 Hardwick	no window		+ 4	+ 2	- 9	+19	+13	-17
	1974 Hardwick	no window		+ 3	+ 2	-10	- 2	- 7	-20
	1974 Hardwick	+10	+ 5	+14	+11	+ 5	+20	+12	+ 1
	1974 Roper	+21	+13	+23	+ 8	-11	-22	-26	-38
	1974 Roper	+18	+ 9	+14	+ 4	-13	-20	-24	-35
	1974 Firestone	+14	+12	+38	+32	+21	+42	+39	+10
	1974 Penney's	+26	+23	+69	+61	+37	+46	+46	+24
	1973 Tappan	-14	-17	+10	+ 3	-15	- 1	- 4	-26
	1973 Magic Chef	no window		-18	-21	-27	-23	-28	-44
	1972 Tappan	no window		- 4	- 8	-16	- 7	-15	-28
Group G-2	1970 Royal Chef	no window		-35	-43	-55	-34	-40	-71
	1970 Whirlpool	+14	+ 5	-13	-23	-45	-37	-42	-78
	1969 Tappan	+13	+ 9	+14	+ 6	-11	+ 4	=	-21
	1969 Sears	+12	+ 8	- 4	- 9	-23	+11	- 1	-38
	1969 Magic Chef	+24	+ 6	+11	+ 5	-13	+20	+11	-31
	1961 Tappan	no window		-20	-23	-34	-20	-23	-40
	1955-62 Chambers	no window		-21	-25	-34	-37	-44	-50
	1951 Roper	no window		-19	-20	-30	+ 6	- 8	-25
	1948 Roper	no window		=	- 9	-23	+ 3	- 2	-23

Appendix G.
Degrees F above (+) or below (-) standard, electric ranges.

Group	Year & Brand	Window high point	Window avg 4 high pts	Door high point	Door avg 4 high pts	Door avg all points	Frame high point	Frame avg 4 points	Frame avg all points
Group E-1	1974 Westinghouse	=	- 5	+ 2	-13	-31	-53	-55	-70
	1974 Sears	-18.5	-21	-13	-22	-38	-61.5	-65	-83
	1973 Frigidaire	+ 9	+ 3	+10	=	-28	=	- 9	-57
Group E-2	1973 Corning	no window		-10	-19	-42	+22.5	+12	-32
	1973 Westinghouse	+34.5	+30	- 4	-17	-36	-57.5	-63	-81
	1972 Hotpoint	no window		-25	-29	-39	-35	-36	-54
	1972 Hotpoint	no window		-74	-75	-79	-96	-97	-104
	1972 Corning	no window		+ 1	-12	-48	- 4	- 7	-52
	1971-72 Frigidaire	+29.9	+26	+ 7	-12	-37	- 1.5	-11	-68
	1971-72 Frigidaire	no window		-37	-42	-50	-37	-43	-75
	1971-72 Frigidaire	+45.5	+39	+12	- 6	-31	+ 3	- 7	-64
	1971 Sears	+23	+18	- 1	-13	-29	-18	-21	-50

Appendix H.

Degrees F above (+) or below (-) standard, electric ranges.

Year & Brand	Window high point	Window avg 4 high pts	Door high point	Door avg 4 high pts	Door avg all points	Frame high point	Frame avg 4 high pts	Frame avg all points
1971 Hotpoint	+40	+39	+32	+17	- 7	+.5	- 6	-34
1971 G.E.	no window		-41	-43	-49	-45	-50	-73
1971 Hotpoint	+43	+40	+42	+34	+ 4	+18	+14	- 5
1970 G.E.	no window		-30	-35	-35	-30	-34	-67
1970 G.E.	no window		-30	-34	-40	-25	-31	-61
1970 Hotpoint	+54	+47	+52	+38.5	+ 5	+26	+13	-16
1969 Sears	no window		+ 3	- 1	-18	+28	+ 8	-19
1965 G.E.	+36	+30.5	- 1.5	-12.5	-31.5	-32.5	-41.5	-69.5
1964 Frigidaire	+37.5	+33	+ 6	- 5	-30	-15	-20	-62
1964 Frigidaire	no window		-45	-48	-54	-49	-52	-75
1964 Hotpoint	no window		-49	-51	-58	-56	-60	-83
1964 Hotpoint	no window		-43	-47	-55	-55	-59	-81
1963 Hotpoint	no window		-43	-46	-55	-52.5	-58	-79
1962 G.E.	no window		-40	-42.5	-50	-41.5	-51	-79
1960 Hotpoint	no window		-43	-45	-53	-64.5	-70	-81
1959 Westinghouse	+24	+18	- 7	-16	-33	-34	-37	-55
1959 Frigidaire	no window		-35	-43	-54	-40.5	-53	-81
1959 Kelvinator	no window		-28	-37	-52	-27.5	-33	-66
1957 G.E.	no window		-11	-23	-43	-16	-35	-72
1956 Westinghouse	+19	+13	-14	-22	-39	-32	-35	-64
1956 G.E.	no window		-43	-47	-53	-44.5	-52	-59
1955 Westinghouse	+25	+19	-30	-33	-43	-35	-39	-63
1949 Frigidaire	no window		-45	-50	-57	-54	-59	-81

Group E-3

Appendix I. Door temperature ratios, chronologically by groups.

Gas	high point / avg. entire door	avg. 4 high points / avg. entire door	Electric (cont)	high point / avg. entire door	avg. 4 high points / avg. entire door
1974 Tappan	1.097	1.067	1972 Corning	1.368	1.271
1974 Hardwick	1.080	1.068	1971-72 Frigidaire	1.336	1.191
1974 Hardwick	1.086	1.080	1971-72 Frigidaire	1.110	1.068
1974 Hardwick	1.058	1.038	1971-72 Frigidaire	1.307	1.179
1974 Roper	1.246	1.138	1971 Sears	1.201	1.115
1974 Roper	1.196	1.123	1971 Hotpoint	1.225	1.139
1974 Firestone	1.098	1.063	1971 G.E.	1.064	1.048
1974 Penney's	1.172	1.129	1971 Hotpoint	1.210	1.166
1973 Tappan	1.195	1.140	1970 G.E.	1.036	1.000
1973 Magic Chef	1.075	1.050	1970 G.E.	1.076	1.046
1972 Tappan	1.089	1.059	1970 Hotpoint	1.275	1.196
1970 Royal Chef	1.177	1.106	1969 Sears	1.143	1.116
1970 Whirlpool	1.260	1.179	1965 G.E.	1.220	1.140
1969 Tappan	1.161	1.110	1964 Frigidaire	1.263	1.182
1969 Sears	1.128	1.095	1964 Frigidaire	1.078	1.052
1969 Magic Chef	1.154	1.115	1964 Hotpoint	1.080	1.061
1961 Tappan	1.100	1.079	1964 Hotpoint	1.103	1.068
1955-61 Chambers	1.096	1.067	1963 Hotpoint	1.099	1.072
1951 Roper	1.076	1.070	1962 G.E.	1.108	1.088
1948 Roper	1.156	1.095	1960 Hotpoint	1.086	1.069
Electric			1959 Westinghouse	1.191	1.125
1974 Westinghouse	1.282	1.154	1959 Frigidaire	1.170	1.098
1974 Sears	1.229	1.146	1959 Kelvinator	1.203	1.127
1973 Frigidaire	1.309	1.228	1957 G.E.	1.258	1.161
1973 Corning	1.250	1.180	1956 Westinghouse	1.198	1.135
1973 Westinghouse	1.248	1.147	1956 G.E.	1.089	1.054
1972 Hotpoint	1.104	1.074	1955 Westinghouse	1.103	1.079
1972 Hotpoint	1.057	1.045	1949 Frigidaire	1.107	1.072

AN INVESTIGATION OF OVEN DOOR SURFACE TEMPERATURES
OF HOUSEHOLD GAS AND ELECTRIC RANGES

by

CHRISTINE M. GEE

B.S. Kansas State University, 1972

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

1979

For this study 55 household ranges, both gas and electric, were tested to determine temperatures reached on the exterior of the oven door during operation at 400 F and on the self clean cycle. These temperatures were then compared to temperatures which are allowed by the American Gas Association and Underwriter's Laboratories standards for ranges and the temperatures that will cause burns to human skin. Historical trends for temperature flucuations for gas and electric ranges were also traced from the data gathered.

The testing procedure and testing instrument used were taken from the AGA and UL standard test procedures for household ranges. Allowable temperatures were traced back through the years of standard development and ranges were compared to the standard of the year of their production.

Variables to the severity of thermal injury were researched with contact time, temperature and thermal properties of the surface being touched, initial skin temperature and skin thickness being the most important. Knowledge of children's physiological and psychological characteristics was important as burn case studies indicated responses different from those of adults and a high percentage of child victims.

Results indicated that newer electric ranges complied with industry safety standards better than newer gas ranges. Over the period of 1948-74, electric ranges have demonstrated improved compliance in window area temperatures with some improvement in door temperature standard compliance and a slight improvement for the frame. During this period, an approximately equal percentage of newer and older models of gas ranges complied with the standard for the window area and newer models had less compliance for the door and frame area. Electric range temperatures have decreased during the most recent period, while temperatures of gas ranges have increased.

Quality control with respect to extremely hot areas on the door has improved for gas ranges while declining for electric ranges. Doors with windows were found to have higher temperature averages than doors without windows. There were a significant portion of the ranges tested, both gas and electric, that reached temperatures on the exterior oven door that would present a burn hazard to children and adults if contacted while in operation.