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NBSIR 81-2347

Field Measurement of Branch Circuit Wire Temperatures

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Building Equipment Division
Washington, DC 20234

September 1981

Issued November 1981

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Prepared for:
The U.S. Department of Energy
Washington, DC 20461

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FIELD MEASUREMENT OF BRANCH CIRCUIT WIRE TEMPERATURES

Thomas K. Faison

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
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Washington, DC 20234

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

The National Bureau of Standards (NBS), under the sponsorship of the U.S. Department of Energy (DoE), planned and conducted a program to monitor temperature excursions of residential branch circuit wiring under field conditions. This program was conducted to develop a field data base needed to determine the prevailing conditions in the field and to respond to various assertions that the encapsulation of branch circuit wiring within thermal insulation is a potential hazard. It has been demonstrated through previous laboratory investigations that buried wires, when operated continuously at rated ampacity, will exceed the thermal limit established by the National Electrical Code (NEC). Approximately 2,800 circuits in 667 residences were monitored through a volunteer program with the utilities. The results of the study show that slightly more than one-third of the circuits monitored operated at or above the thermal limit established by the NEC, 60°C (140°F). Thermal distributions are shown for variables such as: region, season, and age.

Key words: branch circuit; electric wire; field measurements; temperature excursions; thermal insulation.

PREFACE

This is one of a series of reports documenting National Bureau of Standards (NBS) research and analysis efforts in developing energy and cost data. The data supports the Building Energy Conservation Criteria Program sponsored by the Office of Buildings and Community Systems, U.S. Department of Energy (DoE). The work described in this report was supported by DoE/NBS Task Order No. A008-BCS under Interagency Agreement No. EA 77 A 01 6010.

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1. INTRODUCTION

The National Bureau of Standards (NBS), under the sponsorship of the Department of Energy (DoE), planned and conducted a program to monitor maximum temperature excursions of branch circuit wiring under field conditions. This program was carried out to gain information on in-service temperatures of branch circuit wiring and to respond to the uncertainty that encapsulation of branch circuit wiring within thermal insulation is a potentially serious hazard. Through previous laboratory experiments it was known that the rise in temperature of branch circuit wiring, when buried in thermal insulation, could exceed the National Electrical Code limit.

The National Electrical Code [1] requires that branch circuit wiring of the type generally found in residential applications be operated at temperatures not exceeding 60°C (140°F). Under normal operating conditions, the maximum rated continuous current allowed by the overcurrent protection device is 110 percent of its rating. A 20 ampere fuse or circuit breaker would be allowed to operate continuously at 22 amperes. The overcurrent protection device could, based upon the test standards for performance, operate without breaking the circuit for up to one hour at 135 percent of its rating (27 amperes for a 20 ampere device [2, 3]). Under these loading conditions, it has been shown in the laboratory [4] that the 60°C limit will be exceeded when the full ampacity rating of the wire is applied to the conductor buried in thermal insulation. The temperature rise for selected wire sizes as a function of time under laboratory conditions is presented in figure 1. The objective of the field measurements was to gain information on the actual maximum temperatures experienced in the field under general usage conditions when the branch circuits are installed or buried in thermal insulation.

2. TECHNICAL APPROACH

2.1 DEVELOPMENT OF THERMAL INDICATORS

In planning for the collection of field data on maximum temperatures produced in the use of branch circuit wiring, it was necessary to identify or develop a cost-effective means of measuring temperatures of the wiring under conditions of general use. Off the shelf data acquisition methods of sensing and logging of temperature data as a function of time and load were available at the time the project was planned which could record time history and extent of thermal excursion. The device was investigated but found to be far too expensive for the scope of the proposed project.

Requirements for only the temperature indicators included: dependability, low cost (because of the large number to be used) and assurance that there would be no degradation effects upon the wire to which the indicator was attached. Several methods of measurement were considered prior to arriving at the final selection. A commercially available adhesive-backed strip having thermal indicating phase change or color change material was investigated. Because of the limited range, cost, the possibility of leaving a residue of adhesive on the wire, and the potential for damage during the retrieval, the tape-on indicators were not selected. The indicator finally selected, custom designed by NBS staff and a local specialty company, was made of a helical plastic strip with six waxes contained in metal eyelets. The waxes were color coded and were formulated to melt at discrete temperatures within the temperature range of interest. A series of tests was carried out to check the indicated and actual melting temperatures of the waxes and correlation was found to be acceptable within 3-4°F (1.6-2.2°C) of the indicated temperature. These indicators were given the name of thermal indicating flexible strips (TIFS). The indicator is shown in figure 2. Numbered identification tags were supplied with each indicator so that the records could be kept on individual indicators. The helical split in the plastic strip allowed the indicator to be wrapped around the branch circuit cable. The normal configuration of the indicator when wrapped around the cable caused the waxes to be very close to the surface of the cable. The close proximity of the waxes to the cable surrounded by thermal insulation provided reasonable assurance that the cable temperature was near the indicated temperature. Because there is not perfect contact between the waxes and the cable, the cable temperature may be several degrees higher than indicated by the melted wax.

2.2 PARTICIPATION BY ELECTRIC UTILITIES

In order to carry out the program in a cost-effective manner and provide representative distribution in the several geographic regions of the U.S. many utilities across the country were contacted to gain an indication of interest in voluntarily participating in the program of field temperature measurements. It was planned that approximately 2,000 homes could be reached through a voluntary program involving the utilities. In each of the homes three to five indicators were to be placed on the wiring, thus the data base would be of significant size and geographically dispersed to give representative findings. A meeting was called by DoE and NBS in March 1979 to describe the program and discuss its objectives with the utilities. It was proposed that NBS would supply the participating companies with the necessary field measurement materials and pamphlet for recording data (see Appendix B). The staff of the utility companies would install the temperature indicators on the branch circuits, record specific data concerning the electrical system, retrieve the indicators at specified intervals, and return the indicators with the supporting data to NBS for analysis and final reporting.

The utilities which responded and participated in the program by installing and retrieving the indicators include:

- Louisiana Power and Light Company
  New Orleans, Louisiana

- New Orleans Public Service, Inc.
  New Orleans, Louisiana

- Public Service Company of Colorado
  Denver, Colorado

- Delmarva Power and Light Company
  Salisbury, Maryland

- Dallas Power and Light Company
  Dallas, Texas

- Detroit Edison Company
  Detroit, Michigan

- Public Service Company of New Hampshire
  Manchester, New Hampshire

- Tennessee Valley Authority
  Chattangooga, Tennessee

- Georgia Power Company
  Atlanta, Georgia

- Philadelphia Electric Company
  Philadelphia, Pennsylvania

- Gulf States Utilities
  Beaumont, Texas

- New York State Gas and Electric Company
  Binghamton, New York

2.3 REPORTING AND ANALYSIS OF DATA

The data provided by these utility companies was accepted by NBS without screening the quality of input, some of the supporting data was very complete and some responses had no supporting data (age, information on electrical systems, etc.). Because of the amount of data and the problems of contacting individuals in the field, along with problems of relying upon their memory for information, it was decided to accept the data on an "as received" basis with no followup. Thus, there was no control on quality of the data beyond the instructions provided by the NBS pamphlet to individual companies participating in the program. The individuals who collected the data for the utility companies did a commendable job of installing and retrieving the devices and recording pertinent data.

Each of the thermal indicators returned to NBS was analyzed to determine the maximum temperature within the range of 122 to 190°F to which the indicator had been exposed. Each data pamphlet which accompanied the indicators was also reviewed. The information was summarized to form the support data base and included such things as: maximum temperature for the branch circuit (indicated by the melted wax); age of the wiring system; amount and type of thermal insulation; and information on the electrical system (type and size of overcurrent protection devices and wire systems, when provided). Generally, the installer identified the location of the indicators on a diagram so that they could be found later for retrieval. Occasionally, information such as the particular circuit (HVAC, fan, light, etc.) on which the indicator was located was also given.

3. RESULTS

From the total of 667 houses which were monitored in the program, 2824 thermal indicators were returned. The majority of the houses had four individual indicators installed on branch circuit cables generally in the attic space. The distribution presented in figure 3 represents the total sample of all indicators returned by the participating utilities. The major finding from the analysis of this plot of wire temperature distribution is that 38 percent of the circuits monitored were operating for some undetermined period of time at or above the 140°F (60°C) NEC temperature limit. As indicated in the illustration, the largest individual segment of maximum temperatures was that of the 140°F (60°C) temperature range - 30 percent of the total sample; eight percent of the total sample equalled or exceeded the 155°F (68.3°C) temperature indication.

The seasonal effect upon observed maximum wire temperature was of interest and is illustrated in the distribution shown in figure 4. A distinct shift in the distribution can be observed between the cooler months - March through October - and the full year exposure. For the exposure which includes the warmer summer months, there is a shift in the distribution toward the higher temperatures.

Occasionally, an indicator was installed on a wire which was indicated as not being covered with insulation. Approximately 10 percent of the indicators were noted as being installed on or above the insulation. Figure 5 presents the distribution of the observed maximum wire temperatures for wires covered with thermal insulation and those either on or above the thermal insulation. For this very limited set of data the temperature distributions are very similar for the wires covered (surrounded) by thermal insulation and those either in free air or placed on top of the thermal insulation.

The supporting data reported that some of the indicators were located near light fixtures (within 12 inches of the fixtures). These data are plotted in figure 6. At the higher end of the temperature range, a significant number of the total high temperature readings are found to be near light fixtures. The indicators which were located near light fixtures show that for all measured wire temperatures greater than 180°F (82.2°C) but less than 190°F (87°C), one out of five, or 20 percent, were near light fixtures, and 70 percent of all indicators recording temperatures of 190°F (87.8°C) or above were near light fixtures.

Figure 7 shows the age distribution of the wiring systems sampled. The average of the wiring system was found to be 13 years. One-half of the samples fell in the age bracket of 10 years or less with an even split between the 0-5 and the 6-10 years. Approximately two percent of the samples exceeded 35 years of age. The maximum age was indicated as being 72 years.

Having information on the age of the wiring system along with the indicated temperatures, an analysis was made to determine if there is a correlation between age of system and the thermal excursions. Table 1 presents the percentage distribution of temperatures for each of the age groups.

From the analysis of the wire temperatures as a function of age, it was found that the age of the wire does not influence the observed thermal distribution. Each of the age groups seem to have similar distributions.

To gain a feel for the affect of geographic location upon the temperature of the branch circuit wiring, the temperature distributions of figure 8 are presented. A major portion of the data base comes from the South/Southeastern states of Texas, Tennessee, Louisiana, Mississippi, and Georgia. The North/Northeastern states are comprised of the mid-Atlantic states (eastern shore) of Delaware, Maryland, and Virginia in addition to Pennsylvania, New York, New Hampshire, Michigan, and Colorado. There appear to be slight shifts to higher temperatures in both regions for the data which includes both summer and winter conditions. The South/Southeastern region has the more dramatic shift as might be expected with the warmer summer exposures. The circuits monitored for the South/Southeastern region for the two exposure periods are approximately equal in number. In the North/Northeastern region, there appears to be only a slight shift to higher temperatures during the longer exposure period. The circuits monitored for the longer period numbered approximately 20 percent more than those monitored for the winter period only. This difference in data base size could account for what appears to be a slight shift.

Table 1. Thermal distribution within specific age increments (percent)

Age Increment (years)	TEMPERATURES (°F)						
	<122	≥122 <133	≥133 <140	≥140 <155	≥155 <180	≥180 <190	≥190
>30	23	26.5	23	26.5	0	1	0
26-30	17	26	22	30	4	1	0
21-25	22	20	22	31	3	1.5	.5
16-20	24	30	20	28	6	1.5	1
11-15	26	27	18	33	3	2	1
6-10	23	23	22	31	8	2	.5
0-5	17	25	23	27	6	1.5	

The diversity of electrical loads patterns cannot be considered in the analysis of the data since the frequency, magnitude, and duration of the load was not measured. This study provides only the maximum temperature experienced. There is no indication of the duration of the exposure at peak conditions. It is possible that the maximum temperature could have been a relatively short period* or it could have been a gradual buildup and sustained for a considerable time period. It is possible and indeed probable that some of the indicators were installed on circuits that were inactive for the total period, or at least drawing minimal loads during the period of test. A few indicators, on the other hand, were reported to have been installed on circuits drawing heavy loads, such as central air conditioning units in hot climates. It was apparent, in some of these cases, that the length of exposure to these heavy loads was over an extended period.

From the data collected in this "pilot study", there were very few cases which could be classified as an immediate hazard. In one residence the insulation batt material was discolored from the heat of the wire. In another, heat from the wire caused the resin sap to drip from the rafter to which the wire was attached. The installers noted these findings and advised the homeowner of the need to take corrective measures. As indicated earlier, many of the indicated higher temperatures resulted from heat generated by light fixtures. Several of the higher temperatures were caused by combination heater/ventilator/light fixtures. Care should be taken to prevent thermal insulation from coming into contact with the fixture housings. Insulation if combustible, could present a potential fire hazard if placed in contact with lighting fixture. Also, the thermal resistance of the insulating material can cause a build up of temperature if the heat generated by the lamp is not allowed to dissipate through convection.

From the supporting data on the electrical system, there was sufficient data on wire size, type of wire, and breaker or fuse size to gain some insight on the issue of oversized overcurrent protection devices. It has been reported in a recent investigation [5] for the Community Services Administration (CSA) that a substantial number of houses in the Weatherization Demonstration Project had oversized overcurrent protection devices, i.e., a fuse or circuit breaker of a larger size than required for the size wire used in the circuit. Of the total 667 residences reported, only 172 submittals had enough information on the electrical systems to assess compatibility of overcurrent protection and wire size. Of the 172 systems, there was evidence that 64 had at least one circuit with an oversized circuit breaker or fuse, thus there was a 37 percent occurrence of oversizing of fuses or circuit breakers for this small sample of residential buildings. The CSA study indicated that 44 percent (two sets of data) of the houses included in that study had at least one circuit with an oversized fuse or circuit breaker. The age of systems was compared to the occurrence of oversizing of overcurrent protection devices in the 172-house sample and was found not to be a factor.

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* The rise to near-equilibrium, or peak temperature conditions found in laboratory experiments and computed temperatures from analytical modeling required time intervals greater than 0.5 hours.

Analysts that "blindly" use this data base must do so with the knowledge that the data base is subject to uncertainties which cannot be resolved. This statement in no way is meant to reflect on the character of the data source but is intended to make the point that there was no quality control on the data acquisition procedure. The sampling of homes in this "pilot project" does not satisfy the statistical criteria for random sampling. There are regional biases because the volunteering utilities happened to fall primarily in the eastern half of the nation. The information provided, although the best known to exist, was not complete with respect to individual data reports. Some reports were very complete and some submittals were returned with only the indicators and very little supporting data.

4. CONCLUSIONS AND RECOMMENDATIONS

It is evident from this study that there is a significant number of residential branch circuits operating at or above the temperature limit of 140°F (60°C) recommended by the National Electrical Code. The data from field measurements indicated that at least 38 percent of the circuits monitored were operating at or exceeded the NEC temperature limit. Exceeding the thermal limit is technically a violation of the code. Many jurisdictions adopt the NEC as part of their building code; thus any violations to the NEC necessarily become building code violations in those jurisdictions. The severity of the hazard that may be posed by the violation is yet unknown. It is felt that operation of the branch circuit wiring at temperatures above the recommended 140°F (60°C) limit may, over the long term, cause problems of degradation of the electrical insulating material. Future research should be directed toward measurement and better understanding of the degradation process as may be caused by the buildup of heat. Both physical and electrical performance of the branch circuit wiring must be investigated.

From analysis of the seasonal data the hot summer temperatures in the Southeastern states appeared to have some small effect upon the temperature distribution. The temperature distribution which included summer exposure showed a slight shift toward higher temperatures.

Because of the small data base and the lack of controls on the sampling techniques, further extrapolation of the material discussed in Section 3 "Results" is discouraged.

5. ACKNOWLEDGEMENTS

The author wishes to acknowledge the contributions of Dr. Lawrence S. Galowin of the Center for Building Technology, NBS, and Ms. Shelly Launey of the Department of Energy for their efforts in developing and planning the program. NBS' Dr. Galowin, and Mr. Henry Hahn of ARTEC Corporation are recognized for their development of the thermal indicating flexible strips (TIFS) which proved to be a very effective measuring tool. To the many field workers with the utility companies, sincere appreciation is expressed in addition to management of the individual companies who volunteered their services.

6. REFERENCES

[1] National Electrical Code, 1981 Edition, National Fire Protection Association 470, Boston, Massachusetts.

[2] U.L. 198.5, Plug Fuses, Underwriters Laboratories Inc., May 1973.

[3] U.S. 489, Moulded-Case Circuit Breakers and Circuit Breaker Enclosures, Underwriters Laboratories Inc., November 1972.

[4] Exploratory Study of Temperatures Produced by Self-Heating of Residential Branch Circuit Wiring When Surrounded by Thermal Insulation, R. W. Beausoliel, W. J. Meese, and L. S. Galowin, NBSIR 78-1477, National Bureau of Standards, July 1978.

[5] Electrical Aspects of the CSA/NBS Weatherization Study, Marianne P. Vaishnav, NBSIR 81-2203, National Bureau of Standards, January 1981.

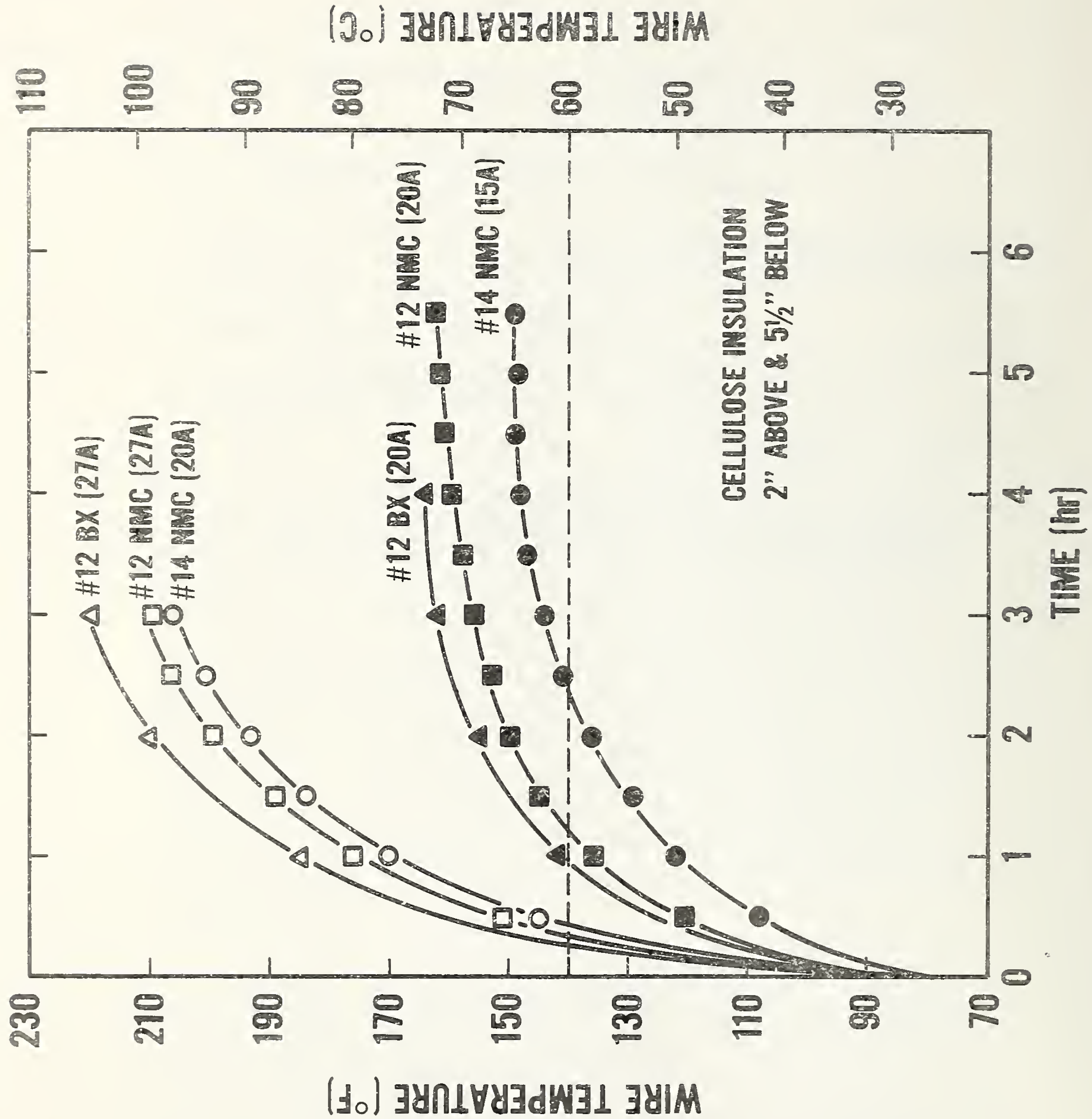
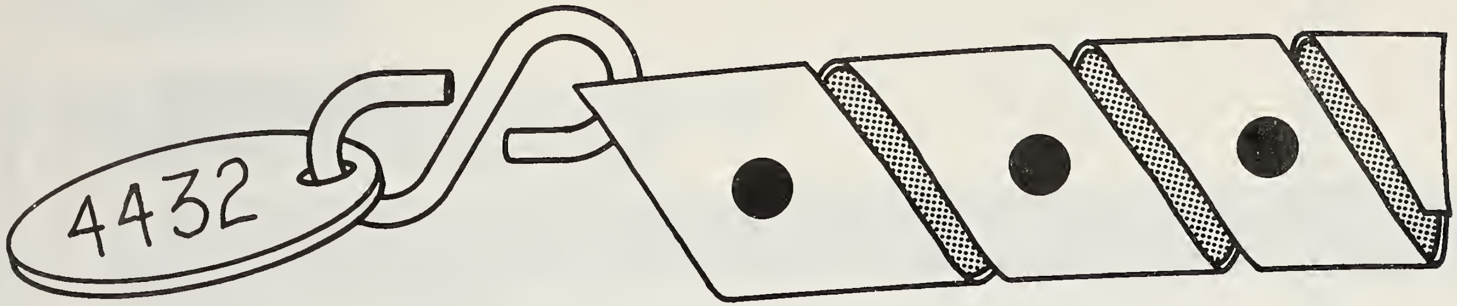


Figure 1. Profile of wire temperature rise when encapsulated in thermal insulation

Figure 1. Profile of wire temperature rise when encapsulated in thermal insulation

THERMAL INDICATING FLEXIBLE STRIP
(TIFS)



WAX	TEMP. RANGE (°F)
GREEN	122-126
BLACK	133-135
YELLOW	140-143
ORANGE	155-160
BLUE	180-185
WHITE	190-195

Figure 2. Thermal indicator developed to measure branch circuit wire temperatures in the field

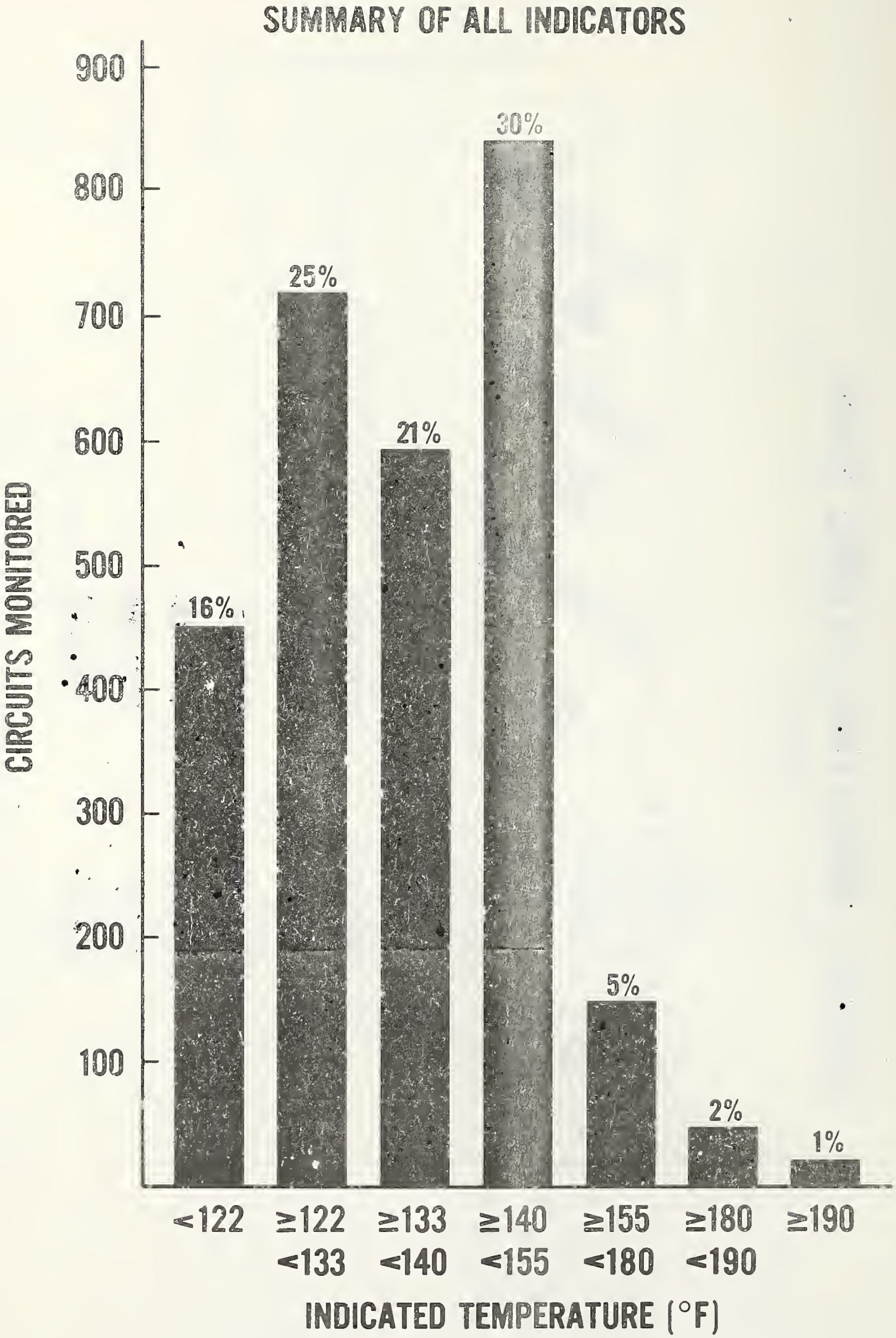


Figure 3. Distribution of indicated wire temperatures for all circuits monitored

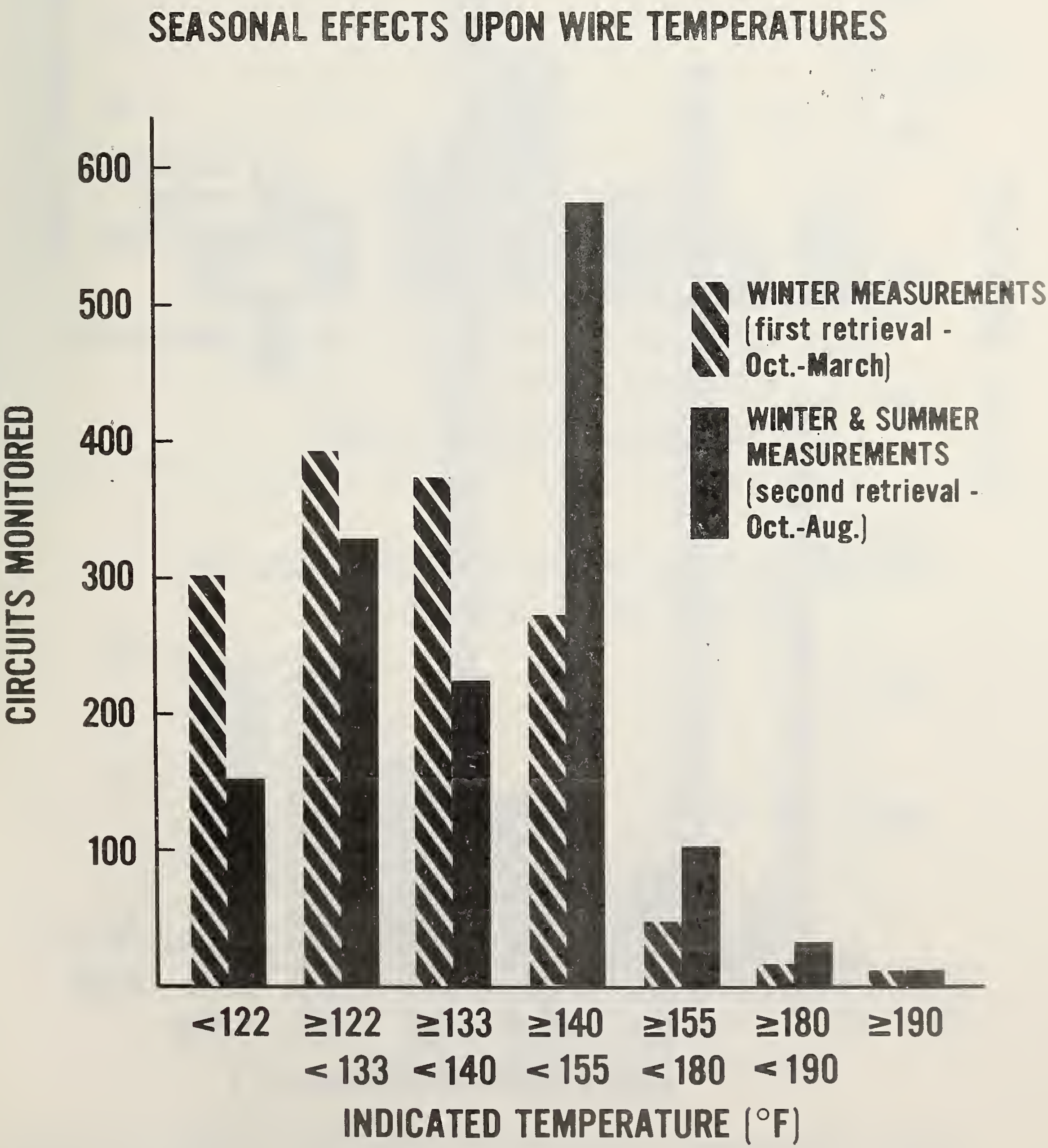


Figure 4. Distribution of indicated wire temperatures as affected by seasonal exposure

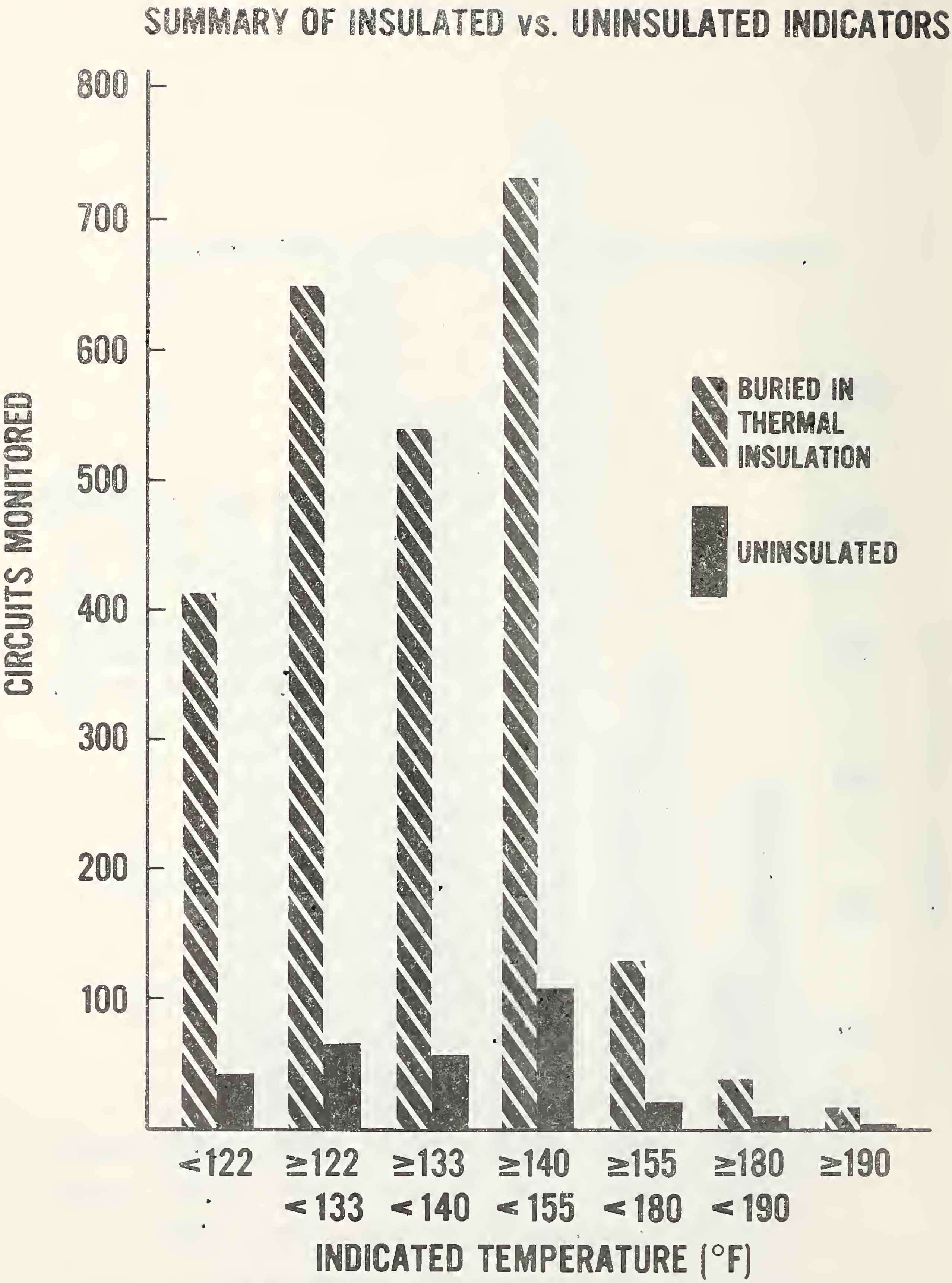


Figure 5. Distribution of indicated wire temperature for those wires covered with insulation and those either on or above the thermal insulation

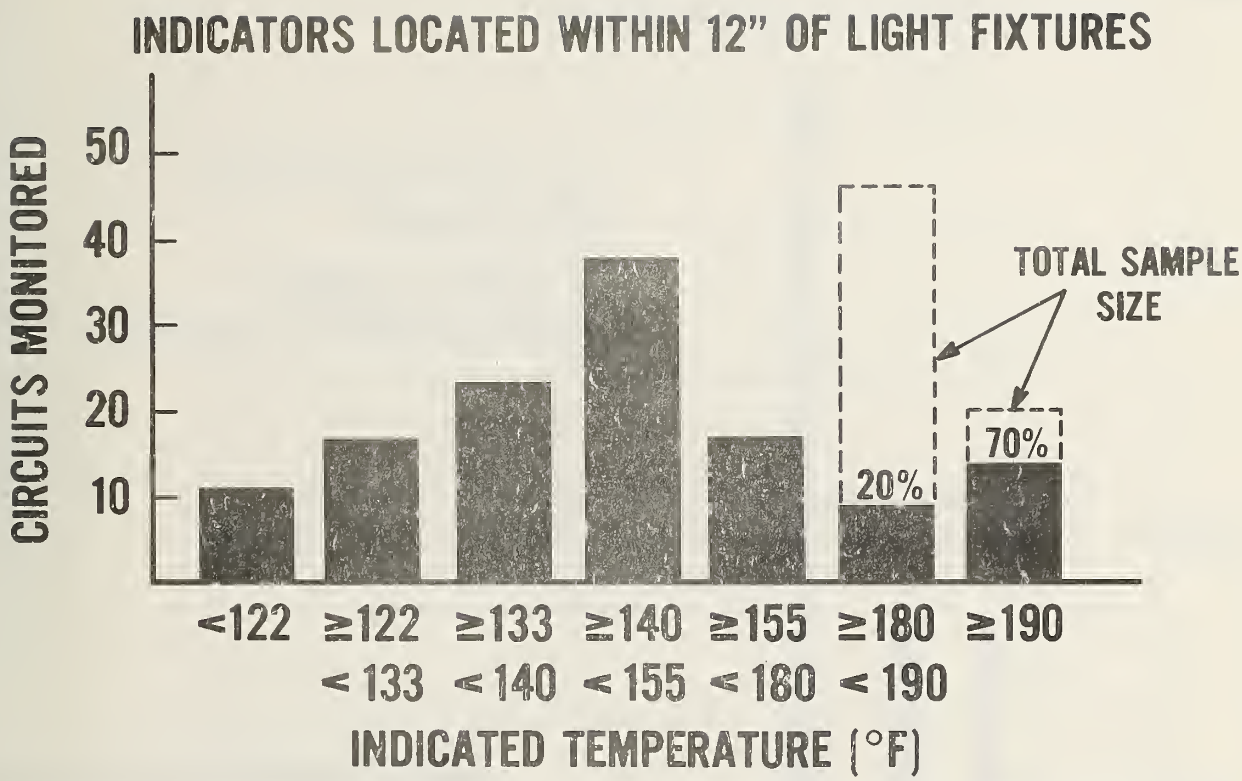


Figure 6. Distribution of indicated wire temperatures near lighting fixtures

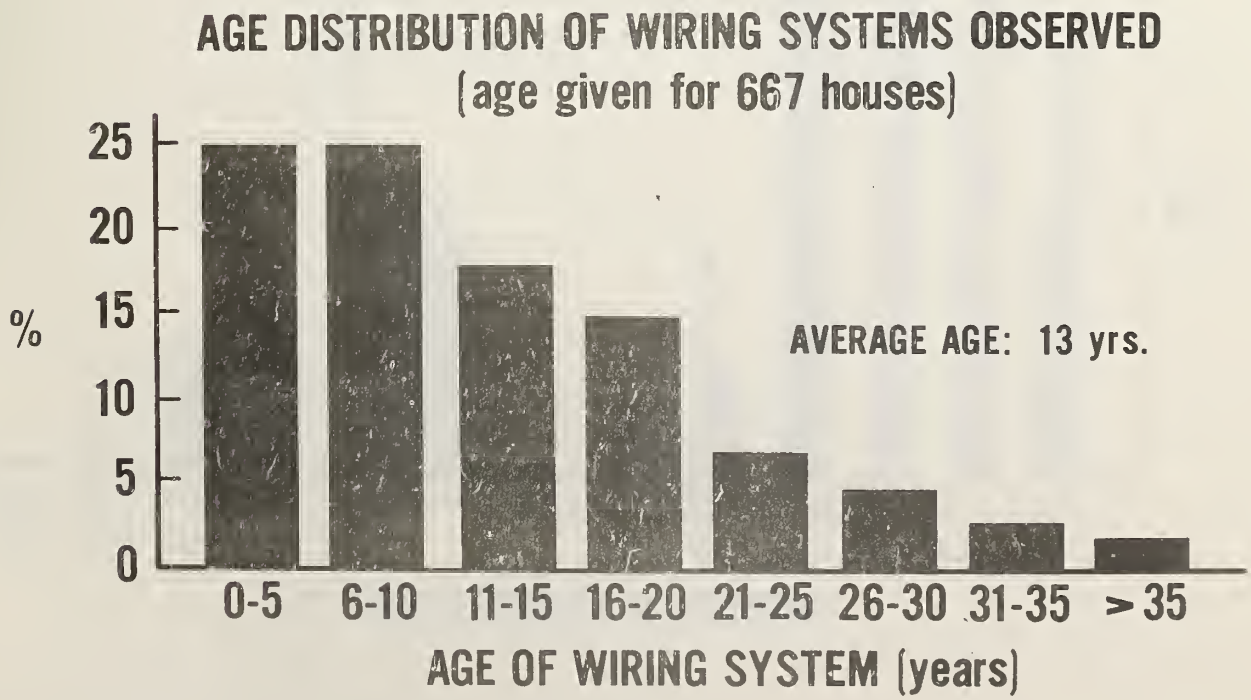


Figure 7. Distribution of age of electrical systems monitored

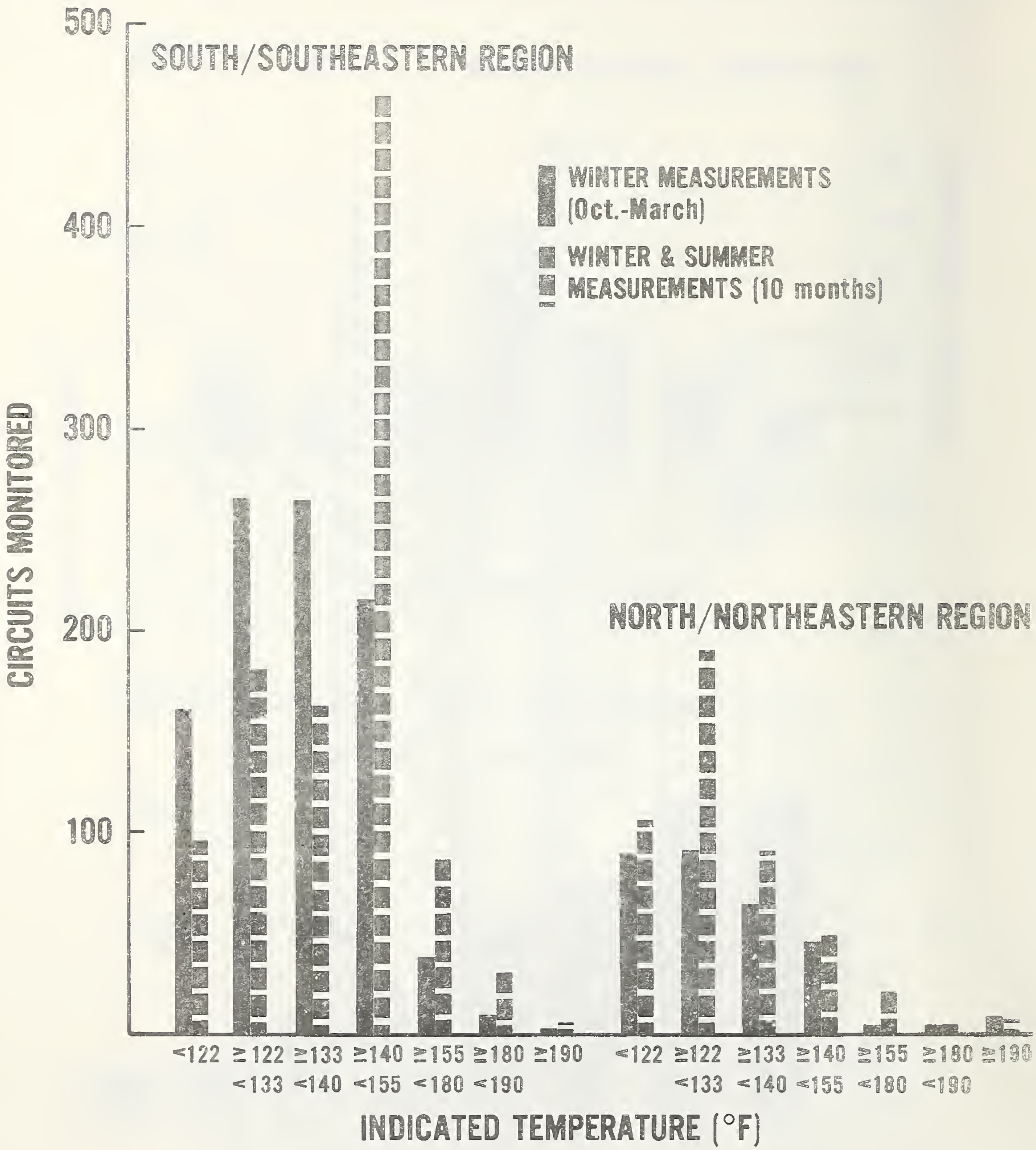


Figure 8. Thermal distribution of branch circuit wire temperature as a function of geographic regions

APPENDIX A.

Electrical System Checkpoints:

Before adding thermal insulation around existing wiring, the following precautions should be taken (electrical modifications and/or inspections should be carried out only by qualified electricians).

- ° Make sure that the branch circuit of a given size wire is protected with the proper size fuse or circuit breaker.
- ° If screw base fuses are installed in the residence, it is recommended that "Type S" fuses be used. This will prohibit larger size fuses from being mistakenly used.
- ° Check the illumination system - ceiling fixtures, wall fixtures, and moveable lamps - to determine if they are over-lamped, that is, do they have lamp bulbs larger than recommended. If so, the lamp should be replaced with the proper size bulb.
- ° Check recessed lighting fixtures to make sure that thermal insulation is not allowed to touch the fixture housing (three-inch minimum clearance required).
- ° If the coating of the wire, the dielectric insulating material, is cracked or appears to be brittle, expert opinion should be obtained before making the decision to cover the wire with thermal insulation. It is generally recommended that wire in a deteriorated condition be replaced.

Appendix B

Pamphlet on Field Measurements of Wiring Temperatures

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

May 1979

MEMO TO: Participants in Field Measurements of Wiring Temperatures

FROM: Lawrence S. Galowin, Group Leader
Service Systems Program
Building 226, Room B306
National Bureau of Standards
Washington, D.C. 20234

Your participation in assisting DoE/NBS in obtaining field measurements of wiring temperatures in thermally retrofitted dwellings is greatly appreciated. The correlation or variations between laboratory test results with actual electrical loading conditions under normal usage conditions in dwellings is critical to the success of the project.

The attached information package and forms which are supplied consist of:

A. Precautions
B. Instructions for Electrical Inspection Reports
C. Electrical Systems Inspection Forms
D. Temperature Indicator Mounting and Removal
E. Projected Schedule of Measurements

Also, a package of TIFS (temperature indicating flexible strips) and numbered identification tags are supplied. One form is provided for each dwelling, the identification tag numbers must be noted in item 14 for each mounted TIFS. The dates on first page of the form D are filled in when the TIFS are mounted and removal date projected. The actual removal date is entered when performed.

The safety of the installers, occupants of the dwellings and preventing the introduction of new hazards are of foremost priority. Consequently, where any situations develop which could be difficult to overcome it is recommended the installation or searching for data to enter on the forms be curtailed, i.e. do not fill out that portion of the form or stop installation of the TIFS. See the list of precautions.

The planning schedule for the groups are provided on attachment E At the scheduled time intervals for removal of the TIFS the forms and temperature indicators should be packaged together for delivery to the above address.

Mr. A.J. McCubbin
Baltimore Gas and Electric
P.O. Box 1475
Baltimore, MD. 21203

Mr. J.F. O'Malley
Director of Marketing
Public Service Co., of New Hampshire
P.O. Box 330
Manchester, New Hampshire 03105

Mr. R.N. Arcari, Director
Central Commercial Services
Con Ed Company of NY, Inc.
4 Irving Place
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Assistant to the Vice President
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Mr. W.R. Coleman, Director
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Mr. William Bowers, Manager
Applications Department
Philadelphia Electric Company
P.O. Box 8699
Philadelphia, PA 19101

Mr. Jackson Mueller, Manager
Energy Conservation and Services
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Consumer Service
Louisiana Power and Light Co.
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Mr. O.A. Dulle, Manager
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Mr. Dal J. Frandsen, Jr., Commercial Manager
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Mr. Richard Hallenus, Manager
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Mr. Dave R. Highland, Manager
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Mr. D.P. Kelley
New York State Electric and Gas
4425 Old Vestal Road
Binghamton, New York 13902

A. PRECAUTIONS

- LOAD CENTERS, FUSE BOXES, WALL OUTLETS SHOULD BE OPENED BY ONLY TRAINED STAFF AND/OR KNOWLEDGEABLE PERSONNEL.

- CONSIDER POWER TURN OFF WHEN MOUNTING TEMPERATURE INDICATOR FLEXIBLE STRIPS (TIFS) PARTICULARLY IF VISUAL INSPECTION OF WIRING INDICATES CRACKS OR SERIOUSLY AGED CONDITION (HARDENED, RIGID).

- HANDLE WIRES WITH CARE - OLD WIRING MAY BE FRAGILE (ELECTRICAL INSULATION)

- DO NOT CONTACT METAL DUCTS, PIPES, ETC., WHEN MOUNTING INDICATORS TO ENERGIZED CABLES.

- IN ATTICS DO NOT STEP ON GYPSUM OR PLASTER CEILINGS. PREVENT FALL THROUGH USE PLATFORM OF WOOD PLANKS OR PLYWOOD SUFFICIENT TO SUSTAIN WEIGHT.

- SUGGEST EYE PROTECTION, GLOVES, MASKS (PREVENT INHALATION OF FIBERS)

- DO NOT SMOKE (PARTICULARLY IN ATTICS).

- USE CARE WITH DROP LIGHTS TO AVOID CONTACT WITH OR RESTING ON ANY FLAMMABLE MATERIALS OR THERMAL INSULATION - FLASHLIGHTS ARE GOOD SUBSTITUTES.

- DO NOT USE OPEN FLAMES

- TRY TO WORK IN A "BUDDY" SYSTEM.

- DO NOT USE ELECTRICAL WIRES AS HANGER FOR LIGHTS, EQUIPMENT. DO NOT USE WIRING AS A HANDHOLD.

B. INSTRUCTIONS FOR ELECTRICAL INSPECTION REPORTS

PURPOSE OF INSPECTIONS

These electrical inspections are made to characterize electrical systems in houses that are insulated.

ELECTRICAL DATA ASPECTS

The impact of thermal insulation on wiring systems is of concern.

(a) OVERFUSING

In residential occupancies branch circuits may be overfused if wire sizes are larger than shown below. Wire sizes are usually marked with indelible stamp or pressed into the electrical insulation.

Wire Size (AWG)		Rated Size of Fuse (in amperes)
Copper	Aluminum	
#14	#12	15
#12	#10	20
#10	# 8	30

If wiring size is not marked limit attempts to answer 3-C.

NOTE: Wires of a given size with some types of superior electrical insulations may be rated at higher ampacities (current carrying capacity in amperes) than shown above. However, nonmetallic-sheathed cable (romex) and most other wiring used in houses (see C, Photographs)do not have these superior electrical insulations.

(b) OVERLAMPING

Thermal insulation over surface-mounted ceiling lights is of concern. This is the reason for obtaining detailed information on recessed and surface-mounted ceiling light fixtures. Unless otherwise marked, most such light fixtures are overlamped if bulbs larger than 60 watts are used.

RECORDING INFORMATION

A form on which to record information when marking electrical system inspections is provided. Also provided are additional sheets on which to record notes or comments. Please identify item on the form to which the comment applies. Items No's are (1) through (14) and 3-A through 3-I, and 6-A through 6-M. Blank sheets are provided to identify essential home plans, layouts and locations of mounted TIFS.

INSTRUCTIONS CONCERNING SPECIFIC ITEMS FOR D

Fill out requested information above item 1, no names are requested.

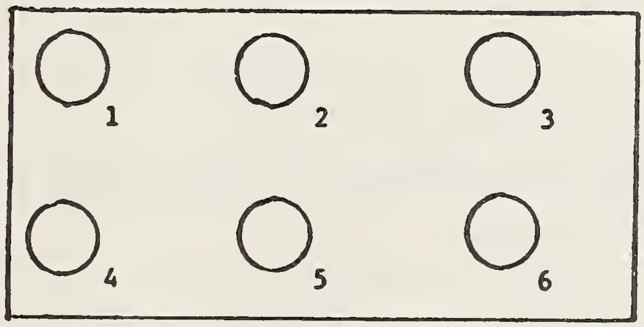
Item (1) - SERVICE ENTRANCE CONDUCTORS

Please give information requested. Assess condition of conductors, their fastenings, etc. Detail damage, any hazards, unusual situations, etc. See Item 9.

Please estimate the length of service entrance cable which is inside of the house. Indicate places within house (such as "unfinished attic", "exterior wall", "interior wall", etc.) where service entrance cables are located. (We are concerned about heat dissipation after thermal insulation is installed).

Item (2) - FUSE/CIRCUIT BREAKER ARRANGEMENT (See C Photographs)

Please draw sketch.
Example for fuse panel:



Item (3) - BRANCH CIRCUIT INFORMATION

The cover of the fuse or circuit breaker panel(s) should be opened. Information recorded for each circuit should be in accordance with the numbering on the fuse or circuit breakers in the sketch prepared under Item (2).

Item 3-A - Type of Overcurrent Protection

Use the following symbols:

CB - Circuit Breaker
S - Type S Fuse
E - Edison Base Fuse
CART - Cartridge Fuse

Identify any hazards, blown fuses, unusual conditions, etc. in Items 3-I or on separate sheet.

Item 3-B - Size of Fuse or Circuit Breaker (amperes)

Record the size of each fuse or circuit breaker presently used.

Item 3-C - Size of Conductor

Please record (#14, #12, etc.) for each circuit.

Item 3-D - Conductor Material

Use abbreviations:

C - copper
AL - aluminum
C-clad - Copper clad aluminum

Item 3-E - Insulation Material

Please try to determine if insulation is rubber or plastic (thermoplastic). Use R for rubber, T for plastic.

Item 3-F - Wiring Method

Use symbols:

NM - nonmetallic - sheathed cable (romex)
BX - armored cable
EMT - electrical metallic tubing
RC - rigid conduit
FMC - flexible metal conduit
Others - specify, use Item 3-I or separate (Item 9) if necessary.

Item 3-G - Grounding Conductor

Indicate "yes" or "no" for each circuit.

Item 3-H - Nominal Voltage

If circuit voltage is 110 to 125 indicate "120", if circuit voltage is 220 to 240 (single phase) indicate "240". If circuit is three phase, please indicate this. Most circuits will be "120".

Item 3-I - Notes/Comments on Branch Circuit Items Listed Above

Indicate applicable information from Items 3-A through 3-H above. Identify items being commented on.

Example of filled out information:

Circuit No.	3A	3B	3C	3D	3E	3F	3G	3H
#1	Edison Fuse	15 Amp	#14	Copper	Plastic	BX	Armored Sheath	110

Item (4) - BACK-UP/OTHER OVERCURRENT PROTECTION

List type, size and other applicable information on any fuses or circuit breakers not listed in Item 3 above. Give appropriate details such as "current from circuits #1, 2, 3 and 4 pass through this fuse."

Item (5) - NAMEPLATE INFORMATION/CONDITION/LOCATION OF FUSE/CIRCUIT BREAKER PANEL

Please give any legible nameplate data and assess condition of panel. Detail hazards, unusual situations, etc. Please indicate room (or basement) in house where panel if located and indicate whether it is on an interior or exterior wall.

Item (6) - RECESSED AND SURFACE-MOUNTED CEILING LIGHTS

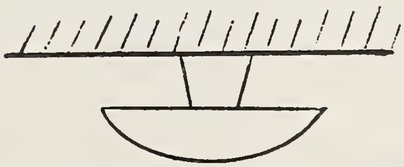
Please record data requested in Item 6-A through 6-M. Remove fixture glass, etc., so that lightbulbs and other items can be observed (if feasible).

Item (6-A) - Location

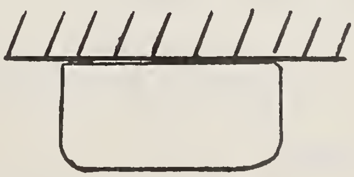
Indicate room such as "kit" (kitchen). If in bedroom indicate specific one, use Item 6-M if necessary.

Item (6-B) - Type of Fixture (Requires survey from within room(s) or living areas under attic).

Only surface-mounted ceiling light fixtures of the types shown below and recessed light fixtures are of interest:



TYPE A



TYPE B

Where there is considerable distance between lightbulbs and the ceiling (such as with most chandeliers) do not list the fixture.

Use the following symbols:

R - Recessed light fixtures
A - Type A surface mounted ceiling fixture shown above
B - Type B surface mounted ceiling fixture shown above.

Item 6-C - Number of Lights

List the number of lights which can be used in the fixture.

Item 6-D - Size of Lightbulbs

List the wattage of each bulb now in the fixture. Use Item 6-M if necessary.

Item 6-E - Type of Bulbs

Are lightbulbs incadescent (use symbol I), flourescent (use symbol F) or other (specify such as "heat" or "infrared").

Item 6-F - Scorching/Damage

Note if there is evidence of scorching or damage in fixture or ceiling or other surface above fixture. Indicate "yes" or "no." Detail any scorching or other damage in Item 6-M or on separate sheet.

Item 6-G - Condition of Wiring

Examine and assess the condition of the fixture wiring. If there is scorching or damage to the fixture wiring or to other parts of the fixture, the ceiling, etc., be sure to also examine the wiring (including the building supply wires) in the outlet box for the fixture. If the present condition of the wiring is not satisfactory or "OK," please give the details in Item 6-M or on separate sheet.

Item 6-H - Size of Enclosure

Please indicate approximate length, width and depth dimensions, respectively, of recessed and Type A surface-mounted ceiling light fixtures. If round, indicate diameter and depth (such as 9 1/2"d x 3 3/4"). For Type B indicate dimensions of glass or other bowl and its minimum distance to ceiling or other top surface.

Item 6-I - Distance of Bulbs to Top Surface

Measure minimum dimension from top of bulbs to the ceiling or top surface of the light fixture.

Item 6-J - Is Warning on Fixture?

Please indicate "yes" or "no." If "yes" please list warning in Item 6-M or on separate sheet (i.e. "Do not use bulbs greater than 60 watts," etc.)

Item 6-K - Is Thermal Insulation Above Fixture Now?

Indicate "yes" or "no." If "yes," describe amount of coverage, any scorching or damage to insulation, outlet box, supply wiring, etc., in Item 6-M or on separate sheet.

Item 6-L - Is Thermal Insulation Above Fixture Likely?

Indicate "yes" or "no" as to whether the addition of thermal insulation would cover the fixture or its outlet box unless precautions were taken. Generally, fixtures in or on the surface of top floor ceilings are subject to being covered by thermal insulation.

Item 6-M - Notes/Comments on Light Items Listed Above

If there is insufficient space for comments please use separate sheet of paper, Item 9.

Item (7) - CONDITION OF BRANCH CIRCUIT WIRING

Please examine as much of the wiring as feasible and assess its general condition. Detail any hazards or unusual conditions. Use Item 9 or separate sheet, if necessary.

If wiring appears to approach the condition of new wiring and does not have fraying, cracking or other deterioration indicate "Good" or "G," if no excessive fraying, cracking or other deterioration and wiring appears to still be serviceable even though it looks old indicate "Satisfactory" or "S," if it is in such condition that it should be replaced indicate "Unsatisfactory" or "U." If necessary indicate condition of each circuit.

Please indicate, if possible, whether grounding conductor is metallically continuous to the fuse or circuit breaker panel. Please also indicate whether receptacles have provisions to accept grounding-type attachment plugs. If some receptacles are the grounding type and some are not, please indicate locations of each type.

Item (8) - TEMPORARY/EXTENSION CORD WIRING

Please detail any unusual or extensive use of non-permanent wiring.

Item (9) - DETAILS ON OTHER ELECTRICAL HAZARDS

Please identify any other electrical hazard and their location. Some examples of such hazards are:

° Loose/broken light fixtures
° Loss of electrical insulation or cracked electrical insulation around wires.
° Badly damaged/frayed wire
° Receptacles broken loose
° Outside wires not of outdoor type
° Outside wire not properly buried or supported
° Shock hazard situations
° Etc.

Two circuits of opposite polarity may share a common neutral. However, if two circuits of the same polarity share a common neutral, the current in the neutral will be the sum of the currents in the two circuits. Instances of the current in the neutral conductors being large enough to start fires have come to our attention. Three-wire (with ground) cables were used for the two circuits. If you see this situation please report it.

Items 10-13 - DWELLING INFORMATION

Item 14 - TEMPERATURE INDICATORS NUMBER RECORD

From "dog-tag" record numbers for each TIFS placed on wires.

C. ELECTRICAL INSPECTION

DATE:________________

PROJECTED REMOVAL DATE:________________

ACTUAL REMOVAL DATE:________________

Dwelling Address:____

Inspection Performed by:____

(1) SERVICE ENTRANCE CONDUCTORS	(2) FUSE/CIRCUIT BREAKER ARRANGEMENT
Size________________ Material - Copper ___ Alum.____ Other (specify)____________ Nom.Voltage 110/120 ___220/240__ Underground________Overhead____ Condition and Comments: ________________________ ________________________ ________________________	Sketch (see instructions)

(3) BRANCH CIRCUIT INFORMATION (SEE INSTRUCTIONS)

Circuit No. (In Sketch)	3-A Type of Over-current Protection	3-B Size of Fuse or Circuit Breaker (Amperes)	3-C Size of Conductor (AWG)	3-D Conductor Material	3-E Insulation Material	3-F Wiring Method	3-G Grounding Conductor	3-H Nominal Voltage
#1								
#2								
#3								
#4								
#5								
#6								
#7								
#8								
#9								
#10								
#11								
#12								

(3-I) Notes/Comments on Branch Circuit Items Listed Above

(4) BACK-UP/OTHER OVERCURRENT PROTECTION (see instructions):

(5) NAMEPLATE INFORMATION/CONDITION/LOCATION OF FUSE/CIRCUIT BREAKER PANEL:

(6) RECESSED AND SURFACE-MOUNTED CEILING LIGHTS

	6A	6B	6C	6D	6E	6F	6G	6H	6I	6J	6K	6L
Light No.	Location	Type of Fixture	No. of Bulbs	Size of Bulbs	Type of Bulbs	Scorching/ Damage	Condition of Wiring	Size of Enclosure	Distance of Bulbs to Top Surface	Is Warning on Fixture?	Is Thermal-Insulation Above Fixture Now?	Is Thermal-Insulation Above Fixture Likely?
#1												
#2												
#3												
#4												
#5												
#6												
#7												
#8												

(6-M) Notes/Comments on Lighting Items Listed Above:

(7-A) CONDITION OF BRANCH CIRCUIT WIRING:

(7-B) RECORD OBSERVATION OF CORROSION ON OR ABOUT SERVICE ENTRY BOX, JUNCTION BOXES AND SWITCHES/RECEPTABLE PLATES DO NOT OPEN RECEPTACLE OR SWITCH BOXES.

(8) TEMPORARY/EXTENSION CORD WIRING (NUMBER OF ADD-ON WIRING CORDS)

(9) DETAILS ON OTHER ELECTRICAL HAZARDS: ______________________________

____

____

____

SUPPLEMENTARY NOTES/COMMENTS ON ELECTRICAL SYSTEM INSPECTION
(Please identify items on "Electrical System Inspection" for which comments apply)

Item No.	

10. Age of Dwelling ________ years

Has home been rewired? Yes ___ No ___ If yes, when? _______.

11. Has dwelling been retrofitted with thermal insulation? Yes___ No___

If yes, indicate type ___________; Walls ________ Attic ________.

Rated "R" value(s) _____________ ____________ ______________

12. List major appliances (check if installed)

Refrigerator ____

Range (electrical) ____

Electric Clothes Dryer ____

Garbage Disposal ____

Dishwasher ____

Central Air Conditioner ____

Window Air Conditioner(s) ____ How many?____

Attic Fan ____

Freezer ____

Heating System (if electric) ____ Where located? ____

Hot Water Heater (if electric) ____ Where located?____

Humidifier ____ Where located?_______________

13. Other Major Electrical Units (check or list)

Examples: Space Heater _________ _________________

Hobby Shop __________ _________________

______________________ _________________

______________________ _________________

14. Attach Identification Tag to Temperature Indicator. List Locations of Temperature Sensitive Indicator (Record number as tag is attached).

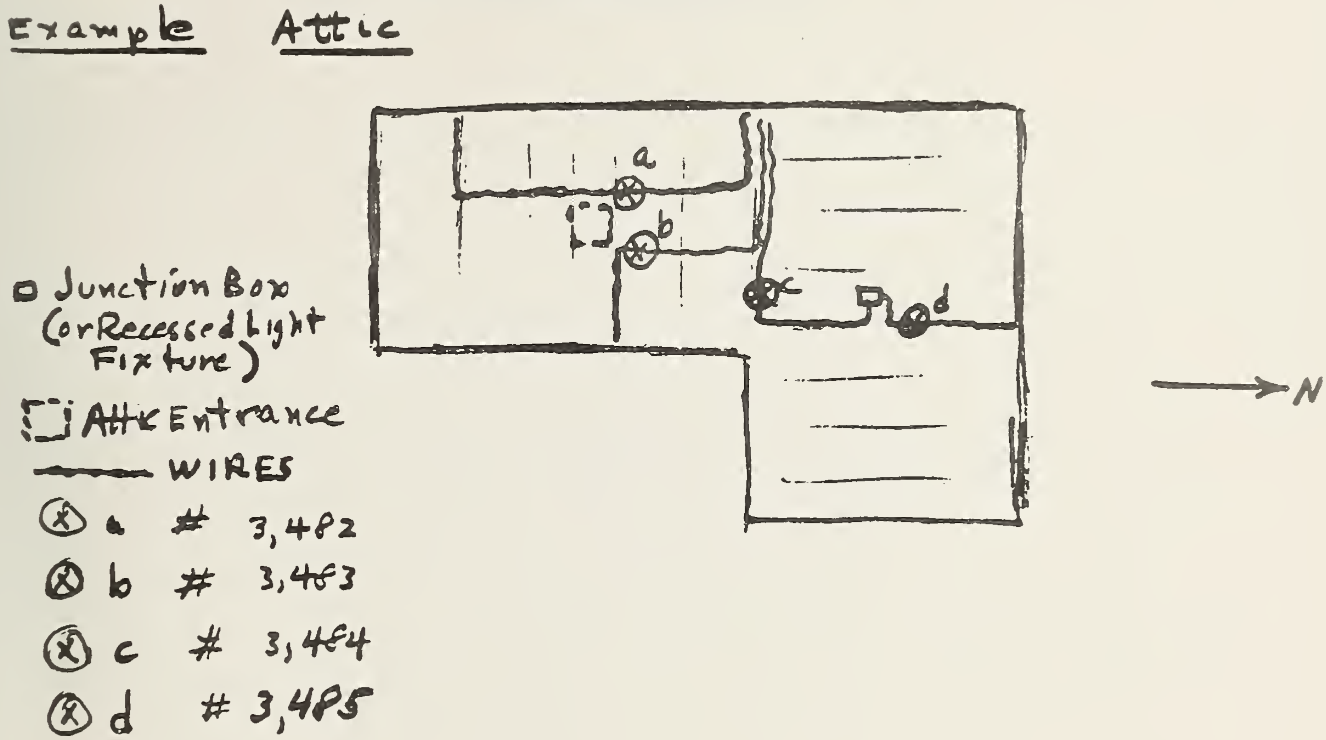
Attic, ______, ______, ______, ______, _______, ______, ______, _______,

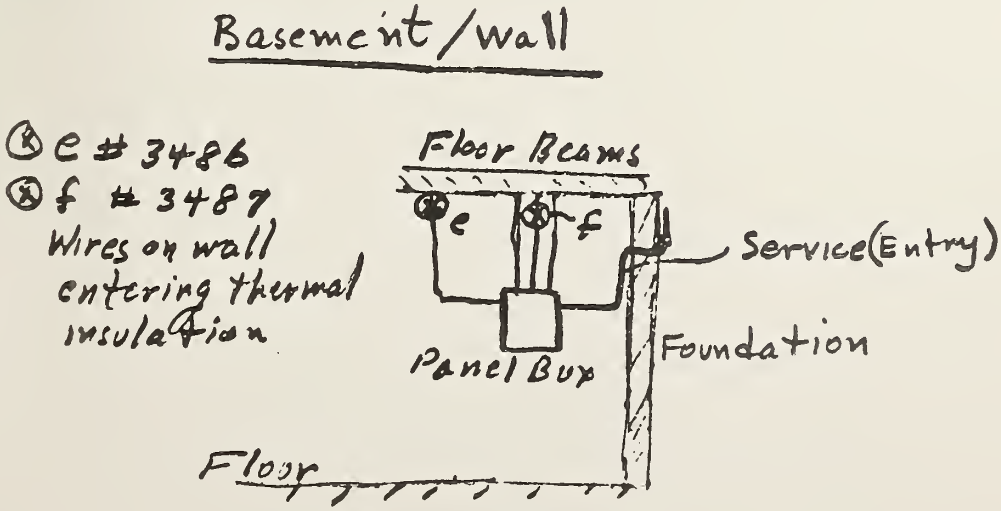
Service box, ______, ______, _______, ______, _______, ________, _______,

Others, _______, _______, _______, _______, _______, _________, _______/

Note: Groups of cables in close proximity under thermal insulation, are also desirable.

FLOOR PLAN/WIRING





Mark where wire indicators are located and if enclosed or sitting on thermal insulation. Type of thermal insulation.

FLOOR PLAN/WIRING

Mark where wire indicators are located and if enclosed or sitting on thermal insulation. Type of thermal insulation.

FLOOR PLAN/WIRING

D. TEMPERATURE INDICATOR-TIFS-MOUNTING AND REMOVAL INSTRUCTIONS

The TIFS identification number tags are mounted to the coil by the "S" hook enclosed in the transparent wrapper. The numbers are recorded under Item 14.

Mounting the TIFS is accomplished by either:

(a) Starting the end over the wire, slightly separting the end of the coil. A twisting motion will cause the coil to wind around the wire. Care is essential to keep the coil tip from "digging" into the wiring insulation.

(b) Untwist the coil TIFS in both hands and place against the wiring with the "curling" toward the wire. Release the coil from one hand and restrain the other end on the wire. The coil will tend to "snap" or wind around the wire. A final twisting of the coil will complete the mounting.

Place the "S" hook and number tag away from the coil TIFS and wire.

Removal of the TIFS is accomplished by reversing (a) or (b) above. Leave the number tag attached.

E. Planning Schedule

Projects Schedule of Measurements

Utility	Sample Size: Total	Early	Late	Approximate Start Date	Approximate Completion Date: Early Group	Late Group
1. Ga. Power	200	150	50	May 15	July 1	Aug 15
2. PG&E	500	400	100	May 15	July 15	Sept 1
3. Dallas P&L	200	150	50	May 15	July 1	Aug 1
4. Louisiana P&L	50	50	--	May 15	June 20	---
5. New Orleans PS	50	30	20	June 1	July 15	Sept 15
6. TVA	500	400	100	June 1	Aug 15	Sept 30
7. PS of NH	50	50	--	June 15	July 15	---
8. Con.Ed. of NY	50	50	--	June 15	Aug 1	---
9. Am Elec.P.	200	150	50	June 1	July 15	Sept 1
10. Union Elec.	50	50	--	June 1	July 1	---
11. Atlantic Elec.	50	50	--	June 1	Aug 15	---
12. Phil.Elec.	50	50	--	June 15	Aug 1	---
13. Delmarva Power	50	30	20	June 1	Aug 15	Sept 15
14. Detroit Elec.	50	50	--	June 1	July 15	---

NBS-114A (REV. 2-80)

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4. TITLE AND SUBTITLE

FIELD MEASUREMENT OF BRANCH CIRCUIT WIRE TEMPERATURES

5. AUTHOR(S)

Thomas K. Faison

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

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U.S. Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20585

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

The National Bureau of Standards (NBS), under the sponsorship of the U.S. Department of Energy (DoE), planned and conducted a program to monitor temperature excursions of residential branch circuit wiring under field conditions. This program was conducted to develop a field data base needed to determine the prevailing conditions in the field and to respond to various assertions that the encapsulation of branch circuit wiring within thermal insulation is a potential hazard. It has been demonstrated through previous laboratory investigations that buried wires, when operated continuously at rated ampacity, will exceed the thermal limit established by the National Electrical Code (NEC). Approximately 2,800 circuits in 667 residences were monitored through a volunteer program with the utilities. The results of the study show that slightly more than one-third of the circuits monitored operated at or above the thermal limit established by the NEC, 60°C (140°F). Thermal distributions are shown for variables such as: region, season, and age.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

branch circuit; electric wire; field measurements; temperature excursions; thermal insulation

13. AVAILABILITY

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