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September 26, 2011

Ms. Renee Bryant, Administrative Assistant, Board Support
Division of Building Safety
1010 East Watertower Street, Suite 150
Meridian, ID 83642

RE: Insulation Contractors – Idaho's Electrical Code, Amendment to Install Insulation over and around Knob & Tube Wiring

Dear Ms. Bryant:

Universal Energy, along with other Energy Conservation Contractors and the non-profit organizations that manage the Low-Income Weatherization Assistance Programs (WAP), appreciates the opportunity to provide information to the Electric Board, regarding an amendment to Idaho's Electric Code concerning Knob and Tube Wiring.

In 1987, an amendment to the National Electric Code (NEC) prohibited the placement of insulation in contact with Knob and Tube wiring. This amendment had significant ramifications for low-income weatherization programs and other private companies installing insulation in older housing stock. Older dwellings, which have live Knob and Tube wiring, were missing the most cost effect energy retrofits (energy saving for dollars spent), such as dense pack sidewalls and attics with insulation, were not achievable due to the wiring. Soon after, the NEC passed an amendment, allowing States to adopt numerous approaches and protocols to address this concern.

Replacing the existing Knob and Tube with an updated electrical system is the best fix, but it also can be very expensive. Most homeowners and especially low income homeowners in general do not have the extra resources to complete the electric retrofit. We are here today to present information from other States and Local Jurisdictions that have adopted an amendment to the NEC that allows insulation to cover Knob and Tube wiring. This is a notable option for homeowners with knob and tube wiring that wants to receive cost effective Home Performance Energy Conservation measures, while maintaining a safe and comfortable indoor environment.

Thank you for the opportunity to provide comments. Please do not hesitate to contact me if you should have questions or additional concerns.

Sincerely,

Thomas Brodbeck
Owner, Universal Energy

University of Illinois
at Urbana-Champaign

School of Architecture

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Building Research Council

217 333-1801
217 244-2204 *fax*

January 19, 2001

Tom Brodbeck
Multnomah County Weatherization
421 SW 6th Avenue, Ste 500
Portland, OR 97204

Dear Tom,

I spoke with you last year regarding the issue of installing cellulose insulation over existing knob-and-tube wiring. I have completed and submitted my report on this topic to the Illinois Department of Commerce and Community Affairs (DCCA). Many people provided me with assistance in researching this topic, and I thought I would share the results of the research with them. Enclosed is a copy of that report for your use.

I appreciate the contributions of everyone who shared their experience and insight on this subject. If you have any comments on the report, do not hesitate to call or e-mail me. Thanks for you help.

Sincerely,

Jeff Gordon

Jeff Gordon

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

1867

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Retrofitting Insulation in Cavities with Knob-and-Tube Wiring
An Investigation into Codes, Safety, and Current Practices

Submitted to:
Illinois Department of Commerce and Community Affairs

June 5, 2000

Prepared by:
Building Research Council
School of Architecture
University of Illinois at Urbana/Champaign
Principal Investigator: Jeffrey R. Gordon
Model Development: William B. Rose

Retrofitting Insulation in Cavities with Knob-and-Tube Wiring An Investigation into Codes, Safety and Current Practices

Table of Contents

A. Introduction

In 1987, an amendment to the National Electric Code (NEC) prohibited the placement of insulation in contact with knob-and-tube wiring. This amendment had significant ramifications for low-income weatherization programs around the country. By their nature, these programs deal with older homes where retrofitting sidewalls and attics with insulation often provide the most return in energy savings for dollars spent. In the twelve years since the amendment, weatherization agencies have adopted numerous approaches and protocols for dealing with this issue.

This report examines the code change, the safety issues that prompted the code change, and the range of actions taken by state code bodies and weatherization agencies in response to the code change. In an attempt to ease the narrative flow of the report, it was determined to place the most technical discussion in the appendix. The first two appendices are of critical importance and are referenced at several points in the main text. Appendix 1 examines the issues of voltage drop, resistance, heat generation, and circuit analysis. Appendix 2 contains spreadsheets showing the calculations of a simplified model whose results are reported in Section D.

B. Overview of Knob-and-Tube Wiring

Knob-and-Tube wiring was the predominant wiring system through the 1920's and 1930's; some installations of knob-and-tube wiring continued in houses up until 1950. There are several distinguishing characteristics of knob-and-tube wiring in comparison to current wiring methods:

- When running perpendicular to structural components (such as floor joists), modern wiring runs directly through holes in the components. Knob and tube wiring used protective ceramic tubes placed in the holes to prevent the wire from chafing against the structure.
- Modern wiring uses staples to hold the wiring against structural components when the wire is running parallel to the component. Knob-and-tube wiring used ceramic knobs to clamp the wire to the structural member.
- Connections between modern wires are completed within enclosed electrical junction boxes. Knob-and-tube wiring had visible connections. The wires were spliced and soldered together and then wrapped with electrical tape. These connections are called "pig-tail" connections because one wire is wrapped several times around the other wire before the two are soldered together. Ceramic knobs were strategically placed to protect the splice ensuring that inadvertent tugging on the wire would not stress the electrical connection.
- In modern wiring, the hot wire (black) and neutral wire (white), along with a ground wire, are insulated separately and bundled in a single plastic sheathing. In knob-and-tube wiring, the hot and neutral were insulated and run through a house separately,

usually several inches apart. (3 inches is the minimum separation prescribed by the NEC). Knob-and-tube wiring did not include a ground wire.
- In a modern system, many branch circuits use 14 gauge conductors protected by a 15-amp circuit breaker. Larger, 12 gauge conductors are required for 20 amp circuits. Knob-and-tube wiring typically consists of 12 gauge conductors.

While the differences are considerable, there is nothing inherent in knob-and-tube wiring that makes it dangerous. Knob-and-tube wire, properly installed, is not inherently a problem. While opinions regarding the safety of knob-and-tube wiring vary widely, the concerns are not with the original wiring, but rather with what has happened after the fact.

Older homes with knob-and-tube wiring were often supplied with 60-amp service at the main electrical panel. They were also subject to limited distribution in two forms: (1) limited number of circuits, and (2) limited number of electrical outlets per room. Both of these factors opened knob-and-tube wiring to potential abuses of the electrical system after the initial installation.

Over the years, the demand for household electrical capacity has grown dramatically. Most knob-and-tube systems predate television, computers, and dozens of other appliances that are today taken for granted. As the need for electrical capacity grew, older wiring systems were modified for the convenience of the occupants. In some cases, these modifications put undue stress on the wiring system.

In response to the limited number of outlets per room, additional outlets were added on to the existing circuits. In many cases, the quality of the connections was not up to the standards of the original system. For instance, a portion of an existing wire conductor would be stripped of its insulation, and new wire taped on to service a new outlet. The connection may not have been soldered, and the new wire may have been of a lighter gauge. Stress protection for the new connection was rarely considered.

With additional outlets and increased electrical consumption, problems also arose with circuit protection. If circuits became overtaxed and 15 amp fuses were constantly blowing, some ill-informed homeowners would put in 25 or 30 amp fuses to rid themselves of the annoyance. Allowing excessive current to flow through the conductors could lead to overheating, which, in turn, could lead to degradation and embrittlement of the wire insulation and the wire itself. The problem of overfusing can be difficult to determine. A home that has been upgraded to 100-amp service, and is currently properly fused, may have experienced a decade of past overfusing on the knob-and-tube circuitry that is still in use.

Finally, the wiring could suffer from physical abuse over time. Rather than hugging structural components, knob-and-tube wiring was suspended (a minimum of one inch prescribed by the NEC) away from surrounding surfaces. Bumping the wiring could place stresses and cause resultant damage on a portion of the wire. This could be particularly true in accessible attics.

The conditions outlined above can be categorized as an abuse of a home's electrical system. These abuses (improperly added connections, overfusing and wire embrittlement, physical damage) can result in point sources of high resistance. It is at these points that fire potential is greatest. (See Appendix 1). Ultimately, it is wiring that has been abused that is potentially dangerous.

C. Building Code Issues – History

1. National Electric Code (NFPA – 70): 1987 amendment

Section 324 of the NEC deals with "Concealed Knob-And-Tube Wiring." Prior to 1987, article 324-4 stated:

> "Concealed knob-and-tube wiring shall not be used in commercial garages, theaters and similar locations, motion picture studios, hazardous (classified) locations.

In 1987 article 324-4 was amended to read (additional wording in Italics):

> "Concealed knob-and-tube wiring shall not be used in commercial garages, theaters and similar locations, motion picture studios, hazardous (classified) locations *or in the hollow spaces of walls, ceilings and attics when such spaces are insulated by loose or rolled insulating material.*"

The amendment was submitted to Panel No. 7 by Jarrell B. Blair, Building Inspector from the City of Augusta, Kansas, at the May, 1986 NFPA annual meeting in Atlanta, Georgia. The substantiation for the additional wording was as follows:

> "SUBSTANTIATION: a. Concealed knob-and-tube wiring is designed for the hollow spaces of walls, ceilings and attics, utilizing the free air in such spaces for the dissipation of heat.
> b. Weatherization of the hollow spaces by blown-in insulation or roll insulation prevents the dissipation of heat into the free air space; resulting in higher (dangerous) conductor heat buildup, conductor insulation breakdown resulting in a probable or possible fire situation."

Clearly, heat dissipation, overheating, and fire potential was the sole concern that prompted the amendment.

There was some public comment on the amendment at the meeting. Mr. David C. Roberts, a panel member representing the American Electric Power Service Corp., stated for the record:

> "The substantiation to support this proposal does not contain the necessary factual data to support this restriction on concealed knob and tube wiring. There are a large number of installations of concealed knob and tube wiring. I have neither heard of any problems with this wiring method nor have I seen any studies on actual inservice installations that will support this restriction on concealed knob and tube wiring."

Larry Seekon of the Minneapolis Electrical Inspections Department submitted a public comment (7-16):

> "No factual substantiation of dangerous overheating has been submitted to justify prohibiting loose or rolled insulation material in contact with concealed knob and tube wiring.
>
> I am not aware of fires due ONLY to insulation touching knob and tube wiring. However fires do occur because of overfusing and improper splicing or tapping of these circuits. These hazardous conditions are already Code violations.
>
> In the colder regions of the United States there are many thousands of homes now existing with loose or rolled insulation in contact with concealed knob and tube wiring. Most current building codes require the insulation to be fire retardant.
>
> To comply with such a restriction would result in a substantial increase in the cost of rewiring existing homes. New wiring would have to be fished in or surface raceway would have to be installed to replace existing knob and tube wiring. Both of these methods are very labor extensive and would substantially increase the cost of rewiring. Many people also object to the installation of surface raceway in the nicely decorated homes.
>
> In many circumstances, it would be very difficult if not impossible without damaging the walls or ceilings, for an electrical inspector to determine if insulation material had been installed.
>
> I am very apprehensive of what a judge would think about an inspector issuing an elderly widow on Social Security an order to eliminate all concealed knob and tube wiring in contact with loose or rolled insulation, especially when the home was reinsulated ten years ago and there have been no electrical problems."

The panel rejected this comment and informed the submitter that it was not the intent to make this change retroactive.

In response to the rejection of comment 7-16, panel member Roberts went on record:

> "The Panel Action to reject this comment will require that concealed knob and tube wiring installations in older homes be replaced if, in the process of insulating the home, the wiring becomes embedded in insulation. The Panel has no substantiating evidence to reject this comment. The substantiation stated in Comment 7-16 is correct. Concealed knob and tube wiring systems in thousands of residences are now embedded in insulation and no overheating problems have been reported."

The panel approved the amendment by a vote of ten to one, with panel member Roberts the lone dissenting vote.

Thomas Guida, of Underwriters Laboratory, was a member of Panel No. 7 at the time of the 324-4 amendment, and is the only panel member who is still serving. In a telephone interview, Mr. Guida did not recall that the code change caused much controversy on the panel. He described the change as an "obvious" fire safety improvement. When asked about substantiating evidence, Mr. Guida recalled UL reports on the issue, but thought that these were unpublished.

During the course of this study, the amendment was discussed with Jeff Sargent of the electrical engineering section of the National Fire Protection Agency (NFPA). NFPA is the sponsoring agency of the NEC. Mr. Sargent had no knowledge of fire loss data pertaining to this amendment, and suggested that the code change may have been a "pre-emptive" move based on the original design of knob-and-tube wiring. In this view, knob-and-tube wiring was designed to function in "free air", and thus encasement in an insulating material represents a practice contrary to the original design.

There is no evidence that there is any sentiment to rescind the amendment. Since the adoption of the amendment in 1987, only one minor change has been made to article 324-4 of the NEC. The recent NEC versions include a prohibition of "foamed in-place" insulation in addition to "loose or rolled insulating materials."

2. Local/State Amendments to NEC

While the NEC is a national code, it is not administered and enforced nationally. Building codes are administered on the state, county or local level. Some states have developed statewide building codes, while in other states it is up to local jurisdictions to adopt and enforce a building code. In most cases, one of the national model codes (BOCA, CABO, UBC) forms the basis of the state or local code. Since the national model codes reference the NEC for electrical requirements, it is almost certain that the NEC applies wherever a building code is in use. For instance, in Illinois, the BOCA National Building Code is the most prevalent model code. The first article in Chapter 27 *Electrical Wiring*, states, ". . . installations shall conform to the provision of NFPA 70 (NEC) listed in Chapter 35."

State or local jurisdictions can amend or augment the model code they have adopted to meet specific local concerns. In the course of the investigation, two Ohio cities were identified that developed specific rewiring codes. For instance, the City of Massilon, Ohio rewiring code states:

> "(10) Knob and tube wiring. All original knob and tube branch circuit wiring shall be reconnected on fifteen-ampere circuits, and any tampered wire shall have its original insulation integrity replaced. (11) Fuse. If Edison-Base fuse holders are used they shall be fitted with type "S" fuse adapters and fuse stats."

Wadsworth City, Ohio adapted similar language. This language does not appear in the NEC.

Given the potential impact of NEC 324-4 on weatherization activities, successful campaigns were initiated in several states to amend 324-4 locally, and allow for insulation around knob-and-tube wiring under certain conditions. These campaigns were possible in states that operated statewide building codes as compared to "home rule" states where building code administration was scattered throughout numerous local jurisdictions.

On 10/11/90, the State of Washington amended NEC 324-4 as follows:

"The provision of Section 324-4 of the National Electrical Code shall not be construed to prohibit the installation of loose or rolled thermal insulating material in spaces containing existing knob-and-tube wiring provided that all the following conditions are met:
(1) The wiring shall be surveyed by an appropriately licensed electrical contractor who shall certify that the wiring is in good condition with no evidence of improper overcurrent protection, conductor insulation failure or deterioration, and with no improper connections or splices.
Repairs, alterations, or extensions of or to the electrical system shall be inspected by an electrical inspector as defined in RCW 19.28.070.
(2) The insulation shall meet class I specifications as identified in the Uniform Building Code, with a flame spread factor of twenty-five or less as tested using ASTM E84-81a. Foam insulation shall not be used with knob-and-tube wiring.
(3) All knob-and-tube circuits shall have overcurrent protection in compliance with the 60 degree C column of Table 310-16 of the National Electrical Code. Overcurrent protection shall be either circuit breakers or Type S fuses. The Type S fuse adapters shall not accept a fuse of an ampacity greater than that permitted in this chapter."

Following on the heals of Washington State's success, the State of Oregon amended the state code in a similar manner:

"The provisions of Section 324-4 shall not be construed to prohibit the installation of loose or rolled thermal insulating material in spaces containing existing knob-and-tube wiring provided that all the following conditions are met:

(1) The visible wiring shall be inspected by a certified electrical inspector
(2) All defects found during the inspection shall be repaired prior to the installation of insulation
(3) repairs, alterations or extensions of or to the electrical systems shall be inspected by a certified electrical inspector.
(4) The insulation shall have a flame spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with ASTM E84-87. Foamed in place insulation shall no be used with knob-and-tube wiring.
(5) Exposed splices or connections shall be protected from insulation by installing flame resistant, non-conducting, open top enclosures which provide at least 3 inches, but not more than 4 inches side clearance, and a vertical clearance of at least 4 inches above the final level of the insulation
(6) All knob-and-tube circuits shall have overcurrent protection in compliance with the 60 degree C column of Table 310-16 of NFPA 70-1990. Overcurrent protection shall be either circuit breakers or Type S fuses. The Type S fuse adapters shall not accept a fuse of an ampacity greater than that permitted in this chapter."

The States of Nebraska, Massachusetts, and California also amended state codes to allow for insulation around knob-and-tube wiring under specific protocols. With these amendments in hand, it was possible for state weatherization agencies to develop insulation programs that did not violate ruling building codes, and that provided specific documentation of safety procedures when insulating older homes. "Home rule" states (such as Illinois) did not have this course of action available. In these states, ensuring compliance with building codes would require amendments to all local building codes served by weatherization programs, implying dozens, if not hundreds, of local code amendment campaigns.

3. Department Of Energy Policy

Prior to the NEC code change in 1987, The U.S. Department of Energy (DOE) policy on the knob-and-tube issue was stated in a memorandum from Joseph Flynn, Director of the Weatherization Assistance Programs. The memorandum, date July 25, 1983, stated:

> "It is believed that insulation can be safely placed over knob-and-tube wiring provided that:
>
> - The wiring is in good condition; and
> - The circuits do not carry an amperage greater than the rated current for that size wiring.
>
> In all cases, before insulating over knob-and-tube wiring is approved, personnel authorizing work orders or contracts will conduct a thorough inspection of the areas to be insulated and ensure that:
>
> 1) All wiring to be covered is examined and pronounced safe and in good condition;
> 2) The electrical system has protective devices matched to the wire sizes which discontinue the flow of electrical current when the circuits are overloaded"
>
> The inspector should check to determine if there is evidence of cracked or frayed electrical insulation or exposed conductors. Installers of the insulation should be cautioned to use care not to damage the old wiring as the new insulation is applied.
>
> Installation of type "S" fuses is required in fuse boxes in homes where knob-and-tube wiring systems are used. Type "S" fuses ensure against overloading by making it impossible to put in a larger rated fuse. Permission must be obtained from the client to modify the fuse box. If the client does not consent, the insulation cannot be installed.
>
> Subgrantee personnel who authorize work should be aware that in some cases, when older homes have been re-wired, the knob-and-tube system has been left in place. An inspector may see only the abandoned wiring and take appropriate action. Inspectors will verify that knob and tube systems are, in fact, in service before disqualifying homes.
>
> A word of caution: Since this condition is potentially dangerous, States and their subgrantees must continue to exercise uncompromising caution when insulating homes with knob-and-tube wiring. The responsibility for safety and the use of good judgment rests with the person authorizing performance of the work. When in doubt, they should ask a local building inspector or fire marshal to inspect the wiring and issue a certification. Advise the subgrantees not to insulate over knob-and-tube wiring unless they are satisfied that it is safe and has met the above conditions."

While expressing clear concern and emphasizing caution, DOE gave the ultimate responsibility to the states and subgrantees for determining the safety of insulation retrofits on a case-by-case basis. Visual inspection and type "S" fuses were required.

In 1988, following the NEC code change, DOE went through a period of reconsideration of this policy. The policy was formally changed in a memorandum dated July 13, 1988 from Andre W. Van Rest, Chief of the Weatherization Assistance Programs Branch. Following acknowledgement of the NEC code change regarding knob-and-tube wiring (KTW), the memorandum states:

> "DOE has allowed installation of insulation over KTW as a weatherization measure only when precautions outlined in our attached memorandum dated July 25, 1983, are taken. These precautions included an examination of the condition of the wiring and the installation of proper electrical protective devices (typically, properly sized type "s" fuses). Although the application of insulation over KTW may raise the operating temperature of the wire, we are unaware of any problems with homes that contain KTW and have been insulated under the Weatherization Assistance Program.
>
> However, we feel that the most prudent course of action is to comply with the requirements of the 1987 NEC. Therefore, effective immediately, all Support Offices should notify their States that installation of thermal insulation over KTW is no longer permitted. This action does not affect homes already weatherized."

The memorandum placed a clear ban on the installation of insulation around knob-and – tube wiring. The policy, however, was short-lived. Prior to September 1988, Mary E. Fowler became the Chief of the Weatherization Assistance Programs Branch. In a memorandum of September 7, 1988, she requested input from the Support Offices regarding this question. In the responses to this request, DOE became aware of the states that were preparing building code modifications to NEC 324-4. In a memorandum of October 21, 1988, examples of these modifications were distributed. As stated in this memorandum:

> "These examples are cited because the approach taken by these States conforms to the general WAP policy that jurisdiction in health and safety matters related to program-funded work resides with State and/or local authorities."

The memorandum acknowledged the state and local administration of the NEC, and went on to officially change DOE policy once more:

> "In light of the above, the revised DOE-WAP policy on installation of thermal insulation around KTW is that it is the State's responsibility to ensure that such work be in conformance with the applicable codes in the jurisdiction where the work is being performed. Therefore, the KTW guidance issued on July 25, 1983, and on July 13, 1988, is superseded by this memo.
>
> Please convey to your WAP grantees: (1) the revised DOE-WAP policy on installing thermal insulation around KTW, as stated in the previous paragraph; (2) the attached information on the 1987 National Electrical Code change related to KTW; (3) the Washington State material if you think it will be helpful in understanding how other States are handling KTW; (4) that those homes which were completed without insulation since July 13, 1988, may now be insulated under the revised policy. The prohibition against reweatherization found in section 440.18 (e) (2) (i) will not apply to such insulation work and those homes may not be reported as new completions. In addition,

> each grantee should be advised to check with the appropriate electrical code authorities in its State to determine whether the NEC KTW change has been adopted as is, has been adopted with modifications, or has not been adopted and, therefore, whether any modification in KTW work performed under the WAP is required within the State."

According to DOE's Greg Reamy, this memorandum of October 21, 1988 remains the stated policy of DOE. Once again, responsibility is placed on the State programs rather than a DOE mandate. The State's responsibility, however, is redirected specifically toward code compliance as the assurance of safety. To reiterate, ". . . it is the State's responsibility to ensure that such work be in conformance with the applicable codes in the jurisdiction where the work is being performed." In states with local "home rule" building codes, this would require each subgrantee to examine the local code to identify whether NEC 324-4 "has been adopted as is, has been adopted with modifications, or has not been adopted."

D. Substantiating Evidence and Fire Hazard Potential

1. Fire Incidence Statistics

In the NEC code change hearings, panel member David Roberts stated,

> "The substantiation to support this proposal does not contain the necessary factual data to support this restriction on concealed knob and tube wiring."

With regard to available fire statistics, a review of the data supports this claim. While an excellent system of fire incident reporting is established in the U.S., providing remarkable detail in some areas, this system does not provide sufficient detail to pinpoint a fire source resulting from insulation over knob-and-tube wiring.

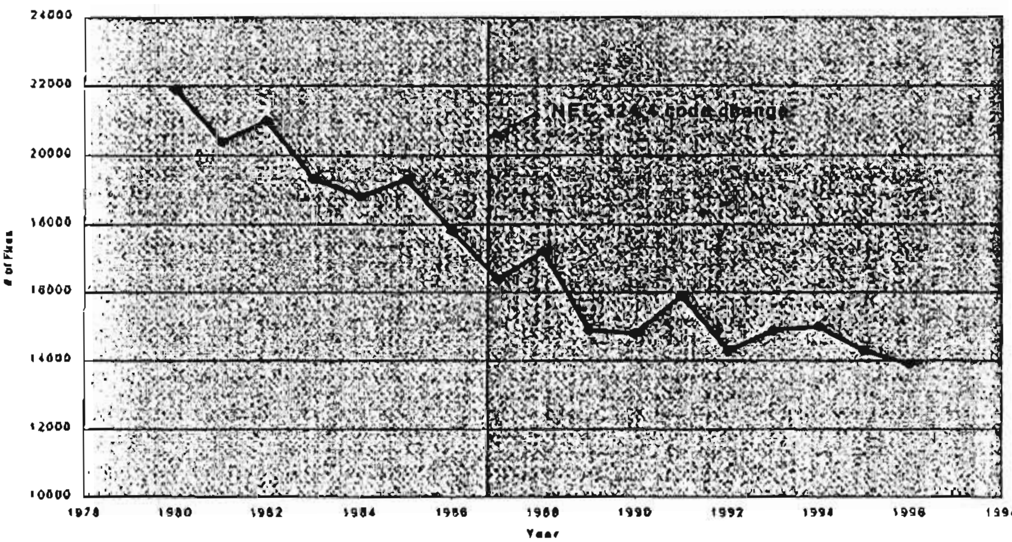
About one third of U.S. fire departments participate in the National Fire Incident Reporting System (NFIRS). The NFIRS data is gathered by the NFPA and organized into statistical reports. Kimberly Rohr, of the Fire Analysis and Research Division of the NFPA, provided the latest report relating to electrical fires: *Electrical Distribution Equipment Fires* from the *U.S. Home Products Reports, 1992 – 1996*, NFPA, February 1999.

According to this report, electrical distribution equipment was the fifth leading cause of all home fires. The report categorizes these fires into 9 classes. The class, "fixed wiring" accounts for 35.2% of electrical fires. Within this class, there are six subcategories (short circuit, lightning, etc.). The only subcategory that would seem to pertain to overheating of conductors is "overloaded" circuits. This category represents 2.5% of fixed wing fires, and 0.9% of all electrical fires. There is no further delineation within the report. It is not possible to determine the percentage of these fires that may have resulted from insulation over knob-and-tube wiring.

The report also details the form of material that first ignited. In fixed wiring fires, 42.6% (easily the largest percentage) started in the wire or cable insulation, itself. Thermal or acoustical insulation was the material of first ignition in 4.7% of fixed wiring fires, 1.65% of all electrical fires. Again, it is not possible to determine how many of these fires resulted from overheating as a result of insulation in contact with knob-and-tube wiring.

The report also details the annual number of fixed wiring fires from 1980 to 1996. From 1980 to 1987, the period before the NEC code change, the number of fixed wiring fires fell 25% (from 21,900 to 16,400). Following the amendment, the number of fixed wiring fires continued to fall by 15% (from 16,400 to 13,900). Given that the knob-and-tube issue represents a small fraction of fixed wire fires, at best, one would not expect to be able to identify an impact on this data as a result of the code amendment. This is the case, as the data indicates a continuing downward trend both before and after the code change.

Fixed Wire Fires 1980 – 1996



During their deliberations in 1988, DOE investigated the issue by filing a Freedom of Information request to the Consumer Product Safety Commission (CPSC). The CPSC provided DOE with printouts form the National Injury Information Clearinghouse. The clearinghouse database, covering the years 1977 to 1986, was searched for incidents containing "thermal or sound insulation materials" as part of the incident. The information on the printouts were not compiled or subjected to statistical analysis. In their raw form they represent a series of anecdotes that list date, location, source of report, and a brief synopsis or narrative of the incident.

A review of the printouts indicates that the great majority of the incidents do not relate to overheating as a result of insulation covering knob-and-tube wiring. There are numerous reports dealing with recessed lighting, short circuits, electrical heaters, wood burning stoves, and work-related incidents that ignited insulation. Also, the narrative in many of the reports is too sketchy to determine the relevance to this topic. There are, however, some reported incidents in the database that clearly provide evidence of a potential problem. Some examples:

- "Residence fire apparently began by insulation being blown over electrical wiring" Sileston, MO
- "Fire was confined to the wall area where an overloaded circuit ignited insulation." Owosso, MI
- "Residence fire was result of insulation being placed over electrical wiring." Bainbridge Island, WA
- "Overheated wiring may have ignited insulation and caused fire." Hawley, IA
- "Overheated electrical wiring caused insulation to catch fire." Jennings Twp., IN
- "Fire apparently caused by buildup of heat in wiring which became covered by blown insulation." Decatur, IL

While the descriptions are brief in the reports of these incidents, little interpretation is required. These reports provide some evidence that wiring embedded in insulation has been associated with fire hazards. It also raises concerns regarding the flammability of some thermal insulation. Neither cellulose insulation nor knob-and-tube wiring, however, is specifically mentioned by name in any of the reports.

David Clark is Associate Director of Academic Affairs at the Illinois Fire Service Institute in Champaign. In his career he has served as a firefighter, fire chief, and instructor for over 30 years. In his experience, retrofitting insulation has been a major concern in the fire protection community as it pertains to overheating of recessed light fixtures. In contrast, concerns pertaining to insulation over the wires, themselves, have not been a primary source of concern in his experience. A search at the Fire Service Institute library provided no substantiating evidence regarding the insulation over knob-and-tube wiring.

Generally, fire incidence statistics are not sufficiently detailed to identify blown-in insulation over knob-and-tube wiring as a source of fires in any statistical meaningful way. A review of National Injury Information Clearinghouse printouts provides some anecdotal evidence that this situation can be a source of fire hazards. Other anecdotal evidence provided by weatherization agencies is contained in Section F of this report.

3. Research Reports

On the heels of the oil crisis in the 1970s, a national emphasis on energy efficiency and weatherization produced a rapid increase in blown-in insulation in existing residences. This clearly led to a widespread concern over the fire safety of cellulose insulation. A number of research studies were performed which examined several facets of the cellulose question: heat transmission, smolder initiation, the effects of additives, contact with recessed lighting, etc. Some of this research pertained to insulation performance when in contact with electrical conductors.

Ohlemiller and Rogers (1979) and Issen (1980) examined fire performance and smoldering combustion hazards of loose-fill cellulosic insulation. Both research efforts looked at the effectiveness of fire retardant commonly in use. While fire retardant treatments (borax, boric acid, etc.) provide increased flame resistance, they have a lesser effect on smoldering. Ohlemiller concluded that retardant treatments reduced smoldering ignition temperature by only 20 C°. By comparison, he found that heat source and insulation geometry were far more critical (up to 100 C° variation) than the presence of fire retardant. Issen recognized that the fineness and dispersion of the retardant chemicals were critical to both flame and smolder resistance.

Zicherman and Fisher (1978) provide a concise appraisal of fire protection problems associated with cellulose based insulation products. They detail (1) the combustible properties of the materials, (2) the difficulties found in the manufacturing methods which do not guarantee fire retardancy, and (3) installation techniques which can introduce fire hazards. They evaluate optimum testing techniques and criteria in an emerging industry lacking committed capital and technological expertise.

In a National Bureau of Standards research report, Gross, (1978) provided an analysis of currently used standard test methods for measuring insulation flammability or combustibility and their principle limitations. A series of laboratory tests was conducted using an attic floor radiant panel test a cigarette smoldering test. Based on these tests, changes were recommended to federal specifications. Gross also examined fire statistics, and came to similar conclusions as Section D.1. of this report.

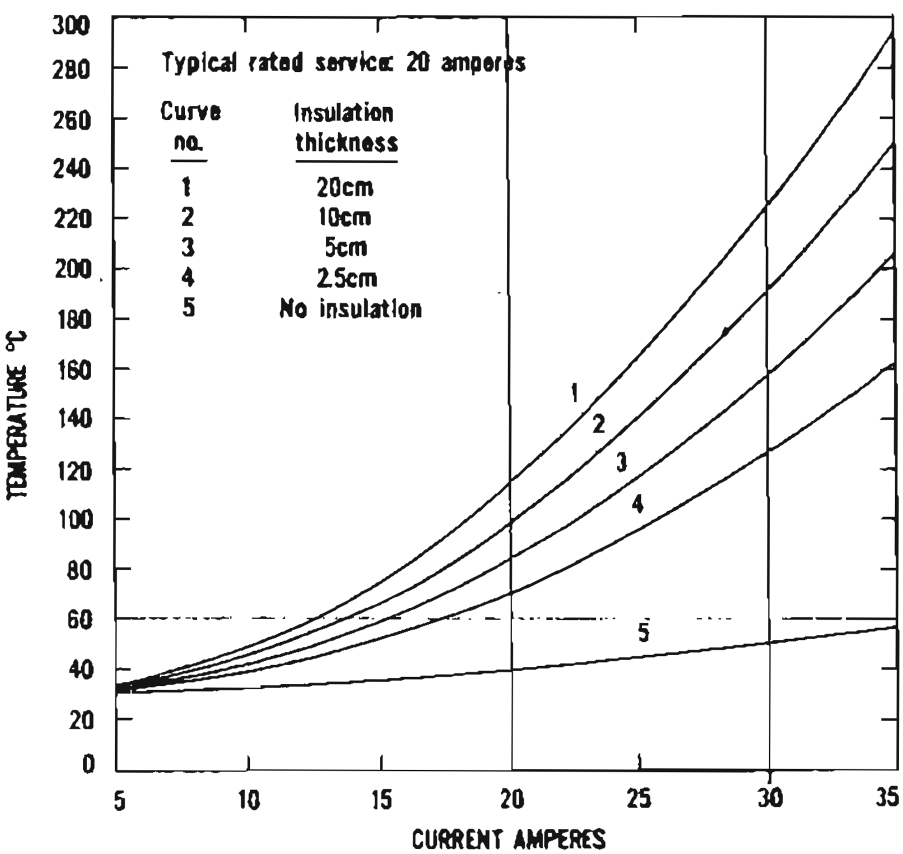
> "Extensive data on the contribution of thermal insulation to fires are not available. . . The intent of this review of fire incidence statistics was not to measure or estimate the magnitude of the problem, inasmuch as the data are uneven in quality, are not statistically representative, and do not reflect the potential future problems associated with retrofit insulation. They are useful, however, in providing an indication of possible patterns of ignition types and sources. . . These data illustrate the two most significant potential fire scenarios for insulation:
> (1) a covered electrical (or heating) device, or a wiring hot spot, may cause smoldering ignition of insulation or ignition of a flammable vapor barrier;
> (2) Open flame from a plumber's torch, a match, or a spark from an appliance may cause ignition of exposed insulation."

Beausoliel, Meese and Galowinn (1978) examined temperatures produced by self-heating of branch circuit wiring when surrounded by thermal insulation. Their tests involved 12-gauge wire covered, top and bottom, with R-11 fiberglass insulation. Temperatures were recorded based on the following variables:
(1) three wires bundled closely together vs. one single wire, and
(2) rated amperage for 12-gauge wire (20A) vs. 135% of rated amperage (27A).
The single wire tests best simulate a knob-and-tube situation. In this case, they recorded 66.6 C° (152 F°) after one and one-half hours at 20A, and 97.8 C° (208 F°) after one hour at 27A. Based on these results, it was concluded that:

> (b) . . . These cable temperatures exceed the 140 F° maximum allowable operating temperature of Underwriters" Laboratories Standard for nonmetallic-sheathed cable,

(c) Temperatures generated on cables during the tests presented in this report did not become high enough to ignite thermal building materials.
(d) The insulated wiring often resulted in high temperature in violation of NEC-Article 310-9 which states: "No conductor shall be used under such conditions that its operating temperature will exceed that specified for the type on insulation involved."

In a report prepared for the Consumer Product Safety Commission (Evans, 1981), the operating temperature of electric cables were calculated based on a detailed mathematical model. The calculated temperatures were presented on a series of charts based on wire gauge, type of insulation, current load, and thickness of insulation. The following chart is reprinted from that report as an example:



This chart predicts temperatures for 12 gauge copper cable surrounded by a dense insulation. The 60 C° allowable operating temperature is indicated by a horizontal line. Line #3 would approximate the thickness of insulation in a wall cavity. Lines #1 and #2 approximate attic insulation depth. The chart illustrates that at the maximum rated current of 20A, cable temperatures exceed the allowable operating temperature in all insulation cases. Evans concludes:

"Electric cables carrying the typical rated current can exceed the common 60°C (140°F) operating temperature limit for common jacket materials with a 5 cm thick layer and often just a 2.5 cm thick layer to thermal insulation wrapped circumferentially around the cable. This suggests that the jacket materials of electric cables that are frequently encapsulated in layers of building insulation could be exceeding recommended upper temperature limits for the materials, if the typical rated current load is maintained long enough."

Another pertinent study was undertaken by the Center for Fire Research (Ohlemiller, 1981). In this research, Ohlemiller picks up on a conclusion from his previous work and examines more thoroughly the effect of heat flow geometry on smolder initiation in cellulose insulation. Eight different geometries were devised which simulated field conditions – recessed lights, ceiling lights, a chimney face, etc – of typical spaces that may be enclosed with blown-in insulation. One of the geometries simulated an electrical wire. Ignition temperatures were determined by experiment and observation. A summary of the results is reproduced in the following chart, reprinted from the original report.

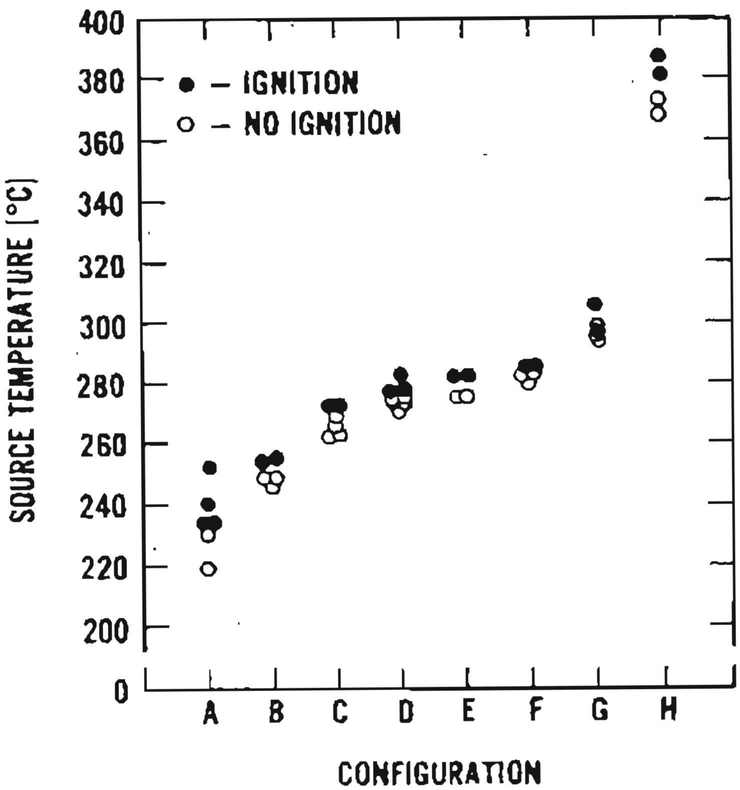


FIGURE 3 Results of ignition tests on the eight heat source configurations. F and G are the 1-D layers (7 cm and 5 cm, respectively).

The results of these tests indicate that "for cellulosic insulation the heat flow configuration has more impact on smolder ignition temperature than any other variable." Indeed, the geometry has a far greater impact than the use of fire retardants on cellulose, which induce only "a small change in ignition temperature" of 15-20^0 C (Ohlemiller and Rogers, 1979).

Of particular interest is the case of ignition temperature as a result of heating in an electric wire, which is test H in the above chart. While other geometries resulted in ignition temperatures of 240-300^{0}C (460-540^{0}F), ignition of the insulation did not occur in the heated wire configuration until over 380^{0}C (716^{0}F). This study showed that the dynamics of cellulose ignition for an electrical wire was significantly different from the other configurations. This lead Ohlemiller to conclude that "it is probable that the overload needed in a copper conductor to produce the observed ignition temperature would open a properly rated circuit breaker before it could be achieved." This is a conservative statement. When this temperature is examined in the light of Evans' mathematical modeling, a properly rated circuit breaker on a 12 gauge, 20-ampere circuit would trip at 120^{0}C (248^{0}F) under the worst conditions of insulation. This is only 35% of the temperature needed to ignite the insulation in this configuration.

In combining the results of the last three cited studies, it is clear that igniting cellulose insulation with an (undamaged) overheated electrical wire is unlikely except under the most extreme conditions of overcurrent load. The temperatures measured by Beausoliel do not approach the ignition temperatures measured by Ohlemiller. Evan's predictions produce somewhat higher temperatures than those measured by Beausoliel. (Evan's predictions are for steady-state temperatures. It is not clear that Beausoliel's test were run long enough to achieve steady-state temperatures.) In Evan's charts, the only conditions which would appear to approach cellulose ignition temperature is 14 gauge wire with a current approaching 30A, or double the listed rating for 14 gauge wire. Double the rated current load probably represents the lower bound of fire hazard. While insulating around electrical cables can result in operating temperatures above the rated temperature for the type of wire and wire insulation, igniting cellulose insulation appears to require a far greater temperature.

3. Fire Hazard Potential

In order to examine the fire hazard potential of insulating over electrical wiring, the BRC developed a mathematical model to calculate the temperatures of embedded electrical wiring under different conditions of resistance and current draw. The model was not designed to be a predictive tool, nor does it contain the level of complexity of the previously referenced model (Evans, 1981). Rather, the value of the model is in its ability to generally examine temperature outputs that can be expected under different scenarios. Essentially, it is an illustrative "what if" tool based on basic heat loss principles. In particular, the model was prepared to illustrate the condition of an isolated point of high electrical resistance (and subsequent heat generation).

The model, with the simplifying assumptions that were made, is presented in Appendix 2. The appendix includes four spreadsheets calculating the results in the examples presented below. An understanding of the material presented in Appendix 1 is presumed in the presenting the following examples.

Each scenario assumes: (1) a 15-amp circuit that terminates 30 linear feet from the main panel, and therefore contains 60 linear feet of wire (out and back). (2) Electrical wiring is centered in 3 ½" of blown cellulose insulation (a typical 2"x4" cavity). (3) The ambient temperature on either side of the wall is 70 F°. In the first two scenarios, the calculated temperature is compared to the predicted temperature derived from the

Scenario 1: The wiring is in good condition, meaning that there are no isolated points of high resistance that could overheat. A circuit load test at the farthest wall outlet measures a 4% voltage drop, representing a resistance (0.32 ohms) that is spread equally along the conductors and receptacles along the circuit. A sizable, but allowable, load of 10 amps runs on the circuit.

Calculated Temperature: 103 F^0. (Evans model: 14 gauge wire –115^0 to 126^0 F, 12-gauge wire - 102^0 to 106^0 F).

Analysis: This temperature is well below the maximum allowable temperature for knob-and-tube wiring of 140 F^0. With the wiring undamaged, this is unlikely to present a fire hazard under normal conditions.

Scenario 2: The homeowner has been trying to use two window air conditioners on the circuit in Scenario 1, but the 15 amp fuse keeps blowing. The homeowner replaces it with a 30-amp fuse. As a result, the circuit is now carrying a current load of 26 amps.

Calculated Temperature: 293 F^0. (Evans model: 14 gauge wire – 284^0 to 350^0 F, 12-gauge wire - 220^0 to 236^0 F)

Analysis: Overfusing significantly raises the temperature of the wires beyond the maximum allowable temperature. If in contact with combustible materials, this could present a fire hazard.

Scenario 3: Assume that the load test on the circuit showed a voltage drop of 8% instead of 4%. If 4% of the voltage drop is a result of the resistance in the circuit conductors and receptacles (as before), then there is an excess voltage drop of 4% at some point(s) on the circuit. This could be a result of a damaged wire, corroded connection, or improper splice. To consider the worst case, assume that all of the excess resistance is located at one point source. In this scenario, the circuit is lightly used, with just a couple of lamps and a clock radio pulling two amps. The maximum temperature occurs at the damaged wire.

Calculated Temperature: 96.4 F^0.

Analysis: Because the circuit is lightly used, the temperature of the wire at the point of damage is not severe, and is unlikely to represent a fire hazard.

Scenario 4: The situation is the same as in scenario 3, with a point source of resistance resulting from a damaged wire. The homeowner, during a particularly cold spell of weather, plugs a 1200W space heater into the circuit. Again, the maximum temperature occurs at the point of high resistance in the wire.

Calculated Temperature: 1022 F^0.

Analysis: The maximum temperature of the wire conductor soars past the maximum allowable temperature of 140 F^0. This extreme temperature occurs at the point of damage in the wire conductor or connection. In this case, a fire is not only possible, but also likely.

The preceding examples are presented for illustrative purposes. They point out that insulating over knob-and-tube wiring, when the wiring is free of problems, is rarely, by itself, a fire hazard. However, insulating over wires can be a critical contributing factor to creating a fire hazard when other problems, faults, or abuses are present.

Fire Hazards - Conclusions

There are two cases when insulating around existing wiring may contribute to a fire hazard, specifically:

1. A fire hazard can be created when a circuit is overfused and subjected to excessive current load that nearly doubles the rated current for the cable. This is true even with wiring in good condition. Under normal conditions, when existing wiring is in good condition, fire hazards are unlikely to occur.
2. Damaged wiring may contain points of high resistance. When this is the case, even a current load within the capacity of the circuit can cause overheating and create a fire hazard at the point source of the resistance.

It should be noted that the calculations in the preceding examples apply equally to modern wiring well as to knob-and-tube wiring. With the first type of hazard, overfusing and excessive current load presents fire hazards regardless of the type and age of wiring. The second type of hazard requires a point source of resistance as a result of damaged wiring. As discussed in Section B of this report, knob-and-tube wiring has an elevated potential for having suffered abuse and potential damage in the past. One could speculate that, in singling out knob-and-tube for the particular restriction of article 324-4, the NEC was addressing this second case.

A secondary hazard regarding insulating over knob-and-tube wring should be noted. The act of blowing in insulation into building cavities is physically intrusive. In a residence where a knob-and-tube circuit is in a fragile condition, blowing in insulation could stress the wiring and create a problem where no problem existed prior to insulation. This could be caused by a workman bumping the wiring, contacting the wiring with the hose, or simply by the velocity and force of the insulation, itself. If damage to the circuit results from installation, the second case described above applies; a point of high resistance and heat generation could be created.

E. Safety Approaches and Procedures

There are a number of safety approaches that have been identified that help to minimize fire hazards associated with retrofitting insulation in the presence of knob-and-tube wiring. These procedures have been used successfully individually and in combination.

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There are a number of safety approaches that have been identified that help to minimize fire hazards associated with retrofitting insulation in the presence of knob-and-tube wiring. These procedures have been used successfully individually and in combination.

1. Maintaining "Free Air" Around Wiring

This approach is essentially compliance with the restriction of NEC 324-4 in that, while insulating a residence, efforts are made to ensure that the insulation is kept out of contact with the wiring. In attics, wiring can be boxed around to maintain clearance (typically a minimum of 3 inches) between the wiring and the insulation. Alternatively, circuits in attics can be replaced with modem wiring after which the insulation project can proceed.

In sidewalls, boxing around insulation is not practical. Replacing the circuit is also difficult. In many cases, however, very little original knob-and-tube wiring may be in place in the outside walls. Sometimes only one or two exterior wall cavities contain knob-and-tube wiring. When it possible to map the existing electrical system with assurance, insulation projects may be able to achieve 90 to 95% coverage while still maintaining compliance with the NEC.

2. Professional Inspection

In the states that have modified NEC 324-4 in their state building code, inspection of the electrical system by a qualified, licensed electrician serves as the backbone of required safety procedures. The inspection serves to document that the wiring is in good condition with no evidence of improper overcurrent protection, conductor insulation failure or deterioration, and with no improper connections or splices.

3. Overcurrent Protection and Type "S" Fuses

Proper overcurrent protection is essential to preventing fire hazards, as excessive current load is common ingredient in electrical fires. An inspection of overcurrent devices should be performed prior to insulation. As the local city codes from Ohio required (see Section C.2.), downsizing knob-and-tube circuits to a maximum 15-amp overload capacity provides nearly complete protection from overheating. In a residence that uses fuses, replacement with type "S" fuses ensures against current overload by making it impossible (or at least very difficult) to put in a larger rated fuse.

4. Circuit Testing and Analysis

Branch circuit load testing and analysis can be used to identify circuits with an excess voltage drop. Excess voltage drop implies high resistance and heat generation in the circuit. Generally, this is a sign of faulty connections or damaged wiring. If the excess heat generation is located at a single point source, fire potential can be greatly increased, particularly if the point of damage is covered with insulation. In programs requiring circuit testing, a voltage drop above a prescribed limit triggers inspection, repair, or replacement activity. When using load testing as a part of an insulation safety program, it is advisable to perform a load test both before and after the installation. A post-insulation

F. Survey of Current Weatherization Practices

In order to identify current practices, a telephone and e-mail survey of weatherization agencies was performed. The initial list of contacts was provided by DCCA. Additional contacts were made as they were as they were identified in the course of the survey. Two observations from the survey are noteworthy.

1. This investigation centers on a building code issue. Weatherization programs, by their nature, have little to no contact with code enforcement departments. Building permits are rarely required for weatherization work, and building inspections almost never performed. (In one case, reference was made to requiring permits, with no follow-up inspection. In this case the local code enforcement department is clearly more interested in collecting a fee than ensuring safety.) Because building codes are not a part of their daily routine, it is not unusual to find weatherization practitioners with only a marginal understanding of code requirements in their jurisdictions.

2. The range of policies and practices relating to blown insulation and knob-and-tube wiring among those interviewed is wide ranging. While some agencies may be in technical violation of stated DOE policy regarding compliance with local building codes on this issue, the survey emphasized the spirit of DOE's "general WAP policy that jurisdiction in health and safety matters related to program-funded work resides with State and/or local authorities."

The following summaries are organized by state, and list the contacts that provided information.

1. State and Local Weatherization Agencies

Pennsylvania

Contacts: Bill Vandermeer, Pennsylvania Housing Resource Center, Williamsport, PA
Larry Armanda, Pennsylvania Housing Resource Center, Williamsport, PA
Guy Porcella, Philadelphia Housing Development Corporation, Philadelphia, PA

The experience of the Philadelphia Housing Development Corporation (PHDC) is one of the better known cases regarding insulation and knob-and-tube wiring. The PHDC works primarily on row house with flat roofs, many with original knob-and-tube wiring in the attic. When insulating these attics with blown cellulose, there were "four or five" incidents of fires that occurred within 24 hours of the installation. While the cause of the fires was not officially identified, it seemed likely that overheated wires were the source. It was the PHDC's hypothesis that "pre-existing conditions," or "wires that were in rough shape," were central to the problem. PHDC initiated a program that required load testing of the circuits prior to installation. In a memorandum to insulation contractors dated April 28, 1994, Jeff Allegretti, Director of Home Improvement Programs, stated:

> "In spite of precautionary steps taken to avoid electrical fires in roof cavities, there has been another occurrence, again following on the heels of insulation installation. The pattern of fires suggests that overloaded circuit wire (usually meaning damaged wire or poor connections when blanketed by insulation and in contact with combustibles) can cause enough heat to generate fire. . . Effective immediately, PHDC is requiring that contractors test all ceiling light fixtures located below areas to be insulated. If a circuit tested has a voltage drop of 10% or greater with a 15 amp load, insulation work should not proceed. PHDC is to be notified immediately and will correct the electrical wiring through its Basic Systems Repair Program. If the client is not eligible for these services, no insulation will be allowed in the roof cavity in question. . . . The attached form must be filled out for every insulation job."

Initial tests by PHDC indicated that 70% of the buildings failed a 5% voltage drop test, "including modern buildings." A 10% voltage drop standard was developed as a practical limit. The PHDC also requires load testing following installation to ensure that the application did not result in damage to the circuits. Since developing this policy, several thousand insulation projects have been completed without a fire incident.

Pennsylvania has been a "home rule" building code state. (A statewide code will be put in place in April of 2001.) Policy for this issue appears to up to local subgrantees. "Some are doing it, and some are not."

Vermont

Contact: Jules Junker, Office of Economic Opportunity, Waterbury, VT.

Mr. Junker states that his agency, "does not walk away" from a building with knob-and-tube wiring. There are a number of different approaches depending on circumstances, though all of the approaches maintain compliance with NEC in prohibiting contact with knob-and-tube wiring. If the wiring in the attic is fairly simple, they will install fiberglass batt baffles under and on the sides of the conductors; cellulose insulation is blown-in up to the baffles avoiding contact with the wiring. In some cases, particularly if an electrician is associated with the project anyway, they will do some rewiring in the attic.

Rewiring is occasionally performed in sidewalls. This decision depends on a savings-to-investment ratio calculation adding the electrical improvement costs with the insulation costs. In other cases, when it is possible to identify where the wiring is run, they will insulate all the wall cavities without knob-and-tube wiring, and leave the wired cavities alone. Pre- and post- branch circuit load testing is performed on all affected circuits regardless of the type of wiring. This procedure emphasizes a concern for avoiding insulating over electrical problems in all cases, not just with knob-and-tube wiring. In recent experience (since 1990), there have been no incidents of fire associated with the electrical distribution system in an insulation project.

Indiana

Contact: Dan Hartman, Indiana Community Action Association, Indianapolis, IN

Policy is not specific in Indiana. Some agencies insulate around knob-and-tube wiring, while other agencies avoid it. The suggested procedure when insulating is:

1. Identify what knob-and-tube circuits are energized,
2. Have the circuits inspected by a licensed electrician before insulating.

There is no state building code in Indiana, and agencies are subject to local building codes, if any. There have been no reported fire incidents associated with blown-in insulation

Washington

Contact: Allan Schein, State of Washington – Housing Division, Olympia, WA

The State of Washington was one of the first states to address and modify NEC 324-4 in a statewide building code. The state code amendment is presented on page 7. To summarize, it allows for insulation when:

1. The project is inspected and approved by a licensed electrician,
2. The insulation meets certain fire resistant specifications,
3. Proper overcurrent protection is provided in the form of circuit breakers or type "S" fuses.

In 1999, branch circuit load testing was added to state weatherization protocol.

Statewide, over 4000 units per year receive weatherization services. Since the local code amendment was approved in 1990, there have been no reported fires resulting from insulation projects.

Oregon

Contacts: Tom Brodbeck, Multnomah County Department of Community and Family Services, Portland Oregon
Jack Hurska, Oregon Housing and Community Services Department, Portland, OR
Allan Kramer, Oregon Housing and Community Services Department, Portland, OR

Oregon has a state building code. Prior to 1992, NEC 324-4 was in effect, and weatherization agencies complied with the restrictions. In attics, knob-and-tube wiring was baffled to prevent contact with insulation. Only wall cavities without knob-and-tube wiring were insulated.

Following the success in amending the Washington state code, a campaign was initiated to modify the Oregon state building code. An amendment was approved on November 18, 1992, and became effective January 1, 1993. The state code amendment is presented on page 7. The safety procedures outlined in the amendment are similar to the procedures in the State of Washington, professional inspection and repair, specified insulation, and overcurrent protection. There is one addition. It requires that exposed splices and connections be protected from contact with insulation "by installing flame resistant, non-conducting, open top enclosures." This provision is met by providing baffles around the connections, or by placement in junction boxes, installed to code. Tom Brodbeck estimates that it costs about $150 to meet the state code requirements when preparing to insulate a residence. While circuit load testing is not mentioned in the Oregon amendment, some electricians perform circuit testing as part of the required electrical inspection. There have been no reports of fire incidents since the safety procedures were implemented in 1993.

Four samples of electrical inspection reports in use in Oregon are provided in Appendix 3.

Wisconsin

Contacts: Martha Benewicz, Wisconsin Division of Energy and Public Benefits, New Auburn, WI
Larry Hastorek, The Energy Keep, Whitewater, WI
Tim Huck, Racine/Kenosha Community Action Agency, Racine, WI

The State of Wisconsin has a statewide code referencing the NEC. The Wisconsin code has not been modified to allow for insulating around knob-and-tube wiring. The Department of Commerce, which administers the code, has demonstrated a conservative stance on 324-4, and weatherization agencies have maintained compliance with the NEC. Generally, insulation projects baffle around wiring or rewire the attic, and skip wired cavities in sidewalls.

In Racine/Kenosha, attics are typically rewired prior to insulation. Through an arrangement with a local electrician, a flat fee of $350 per project is charged for rewiring. If property owners arrange to rewire the attics, the cost can be counted toward the required 35% contribution to the program. There has been one fire incident associated with attic insulation, though the incident was not associated with knob-and-tube wiring. This incident is described in the adjoining sidebar.

[redacted]

In a recent attic insulation project in Racine/Kenosha, the attic was rewired prior to insulation. There was a fire shortly thereafter, and the fire was traced to the new wiring underneath the insulation. In this case, the homeowner changed out the 15 amp circuit breaker for a 30-amp circuit breaker in order to operate two window air conditioners. This incident reinforces two essential facts associated with this issue:

1. Current load is a critical component in creating a fire hazard. Overcurrent protection is an essential safety precaution.

2. Overheating of conductors is not a solely a problem with knob-and-tube wiring, but is a concern with all wiring systems.

This incident is modeled in Scenario 2 in section D.2. of this report

Minnesota

Contacts: Mike Beberg, Ramsey Action Programs, Inc., Vadnais Heights, MN
Sharon Kline, Ramsey Action Programs, Inc., Vadnais Heights, MN

Minnesota has a state building code that incorporates the NEC. In Ramsey and Washington counties, insulation continues to be installed in attics and sidewalls. In attics, a visual inspection of the wire is performed to identify damaged or abused conditions. The agency or homeowner corrects problems. Sidewalls are blown without other testing. These procedures have not changed in 21 years of weatherization work. There have been no reported incidents of fire in this time. Insulating sidewalls in this extremely cold climate seems to be practiced throughout the state. "I don't know any agencies that don't insulate sidewalls."

Ohio

Contacts: Tim Lenahan, Ohio Office of Energy Efficiency
Jack Laverty, Corporation for Ohio Appalachian Development, Athens, OH

Ohio does not have a statewide building code; building codes are adopted and administered on the local level. Insulating around knob-and-tube wiring is permitted if the proper overcurrent protection is in place. A maximum of 15-amp protection is required. If the panel contains fuses, they are replaced by type "S" fuses. A visual inspection is also required. While recognizing the value of circuit load testing, Ohio does not require testing because of production issues. It is felt that the current safeguards are working adequately. The only insulation-related fires that have been reported have to do with insulation being placed over recessed lighting. There have been no incidents caused by overheating of wiring.

Tim Lenahan described the issue as a "balancing act." He observed that the housing that they work on often have other code violations. Insulation of sidewalls is cost-effective, and the need to fully benefit clients is the paramount consideration.

California

Contact: Margeret Sturch, Department of Community Services and Development

California has a statewide code. Similar to Washington and Oregon, the code has been amended to allow for insulation in contact with knob-and-tube wiring under certain conditions. In accordance with the state amendment on 324-4, written policies and procedures are enforced on the state level. This policy, developed and administered with the consulting firm of Richard Heath and Associates, are quite detailed and specific. A copy of the policy, inspection forms, and other attachments are contained in Appendix 3.

3. Insulation Contractors

Contacts: Rick Ariagno, Home Energy Control, Joliet, IL
John Watson, Precision and Snug Insulation, Rockford, IL
Jim Fitzgerald, MN

Three insulation contractors were contacted to review this issue. Both Illinois contractors were generally unfamiliar with the issue, as well as with NEC 324-4. Much of their work occurs in new construction that does not involve knob-and-tube wiring. With insulation retrofits, their clientele are usually middle to upper income, and the residences have been rewired prior to the insulation phase of a remodeling project. These private contractors apparently see little knob-and-tube wiring in the course of their work. As with other health and safety housing issues, fire hazards as a result of insulating knob-and-tube wiring appears to be mostly a middle to lower income issue.

Jim Fitzgerald has had more contact with low-income housing and weatherization in the course of his insulation work. His description of a safe procedure consists of the following steps:

1. Circuit load test
2. Physical inspection when the load test indicates a voltage drop above a prescribed limit
3. Repair electrical system as required
4. Insulate
5. Post-insulation circuit load test

Mr. Fitzgerald described this procedure as practiced in a couple of projects. One was the Philadelphia project, described earlier, where a 10% voltage drop was established as an allowable limit. A second project was with Hydro Quebec in Montreal, where a 5% voltage drop signaled a requirement for inspection and repair.

Mr. Fitzgerald also provided additional perspective on the situation in Minnesota. Because of the severe climate, many knob-and-tube wiring systems were buried in insulation at the time of original construction. There appears to be a very low incidence of problems in these cases.

G. Conclusions

1. Since 1987, the NEC has prohibited the placement of insulation in direct contact with knob-and-tube wiring. This prohibition will likely continue to stand in the code.

2. A number of state and local building codes have been amended to provide exceptions to NEC 324-4 and allow for the practice under prescribed safety conditions.

3. The stated policy of DOE Weatherization Assistance Program Branch requires States to "conform with applicable codes in the jurisdiction where the work is being performed." This would appear to prohibit the practice of insulating over knob-and-tube wiring in jurisdictions where NEC 324-4 (unmodified) is in effect.

4. Fire incidence data lacks sufficient precision to substantiate a claim that insulation around knob-and-tube wiring is the source of a significant number of house fires. Anecdotal evidence exists that indicating some fires have been caused by overheated wiring surrounded by insulation.

5. Research conducted in the late 1970s and early 1980s demonstrated that retrofitting insulation can result in heating electric wires above their rated operating temperatures when subject to a current load approaching the circuit rating. Heating electric wires to a level sufficient to ignite cellulose insulation, however, was shown to be possible only in the most extreme conditions.

6. There are two conditions that can present a fire hazard when insulating around knob-and-tube wiring, specifically:
   - When a circuit is improperly overfused, and an excessively large current load is placed on the circuit, and
   - When damage in a conductor or connection creates a point source of high resistance and a current load near the circuit rating is placed on the circuit.

7. There are safety measures that can be employed to lower the risk of fire. These methods include:
   - Maintaining separation between insulation and wiring
   - Ensuring proper overcurrent protection
   - Inspection and repair by licensed electrician
   - Circuit load testing and analysis for voltage drop.

8. There is considerable anecdotal evidence that insulation can be installed around knob-and-tube wiring in a safe manner. Weatherization programs, employing one or more of the safety measures, have been actively installing thermal insulation around knob-and-tube wiring for many years, both before and after the NEC code change. In the interviews for this report, there have been no reported fires specific to knob-and-tube wiring when the safety measures were followed. One fire was identified that resulted from insulation and overheating of modern wire (not knob-and-tube) under an extreme current load.

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18. Zicherman, J., and Fisher, F. Fire Protection Problems Associated With Cellulose-based Insulation Products, *Society of Fire Protection Engineering Technology Report #78-7*, Boston, Mass., 1978

Internet Resources

An Internet search revealed the following websites with information on knob-and-tube wiring:

1. http://search.leg.wa.gov/wslwac
2. www.abcinspections.com
3. www.allaroundthehouse.com
4. www.bufftech.com
5. www.carsondunlap.com
6. www.casemore.com
7. www.city.davis.ca.us
8. www.codecheck.com/volt_drop.htm
9. www.energydepot.com
10. www.hgtv.com
11. www.iceind.com/suretest
12. www.insure.com
13. www.kwrealestate.com
14. www.massillonohio.com/ordinances
15. www.ornl.gov
16. www.pillartopost.com
17. www.poppyware.com
18. www.soundhome.com
19. www.usinspect.com
20. www.wadsworthcity.com/ord
21. www.webcom.com/malin

Personal Interviews and Correspondence

The following individuals participated with telephone interviews and/or personal correspondence in the course of the study:

1. Rick Ariagno, Home Energy Control, Joliet, IL
2. Larry Armanda, Weatherization Training Center, Williamsport, PA
3. Michael Beberg, Ramsey County Action Program, Vadnais Heights, MN
4. Martha Benewicz, Wisconsin Division of Energy and Public Benefits, New Auburn, WI
5. John Birkby, Industrial Commercial Electronics Inc., Tonawanda NY
6. Mark Bixby, Rockford Human Services Deptartment, Rockford, IL
7. Tom Brodbeck, Multnomah County Weatherization, Portland, OR
8. Dave Clark, IL Fire Service Institute, University of Illinois, Champaign, IL
9. John Dunnigan, University of Illinois, Operations and Maintenance - Electrical Division, Champaign, IL
10. Jim Fitzgerald, Center for Energy and Environment, Minneapolis, MN
11. Richard Gann, National Institute of Standards and Technology, Building and Fire Research Laboratory, Gaithersburg, MD
12. Rose Geier-Grant, State Farm Insurance, Bloomington, IL
13. Tom Guida, Underwriters Laboratories, Inc., Melville, NY
14. Ed Haber, Illinois Department of Commerce and Community Action, Springfield, IL
15. Dan Hartman, Indiana Community Action Association, Indianapolis, IN
16. Larry Hasterok, The Energy Keep, Whitewater, WI
17. Tim Huck, Racine/Kenosha Community Action Agency, Racine, WI
18. Jack Hurska, Oregon Housing and Community Services Department, Portland, OR
19. Jules Junker, Office of Economic Opportunity, Waterbury, VT
20. Alan Kramer, Oregon Housing and Community Services Department, Salem, OR
21. Jack Laverty, Corporation for Ohio Appalachian Development, Athens, OH
22. Dan Lea, Cellulose Insulation Manufacturer's Association, Dayton, OH
23. Tim Lenahan, Ohio Office of Energy Efficiency, Columbus, OH
24. Thomas Ohlemiller, National Institute of Standards and Technology, Building and Fire Research Laboratory, Gaithersburg, MD
25. Guy Porcella, Philadelphia Housing Development Corporation, Philadelphia, PA
26. Greg Reamy, U.S. Dept. of Energy, Washington, D.C.
27. Kim Rohr, National Fire Protection Association, Quincy, MA
28. Jeff Sargent, National Fire Protection Association, Quincy, MA
29. Alan Schein, State of Washington-Housing Division, Olympia, WA
30. Margaret Sturch, Department of Community Services and Development, Sacramento, CA
31. William Van der Meer, Pennsylvania Housing Resource Center, Williamsport, PA
32. John Watson, Precision and Snug Insulation, Rockford, IL

Appendix 1

Voltage Drop and Resistance, Heat Generation in Electrical Circuits, and Circuit Analysis

Voltage Drop and Resistance

A voltage drop in an electrical circuit normally occurs when current is passed through the wire. The voltage drop is proportional to the resistance of the circuit; the greater the resistances of the circuit, the higher the voltage drop. All conductors and fixtures offer some resistance to current flow, so a small voltage drop is expected in all electrical branch circuits (1% to 5%). If a branch circuit has excessive voltage drop, there is concern over the safety of circuit.

Excess voltage drop is caused by high resistance in the circuit. High resistance can occur when:

1. The conducting wire is of insufficient gauge for the length of run, or
2. There is a point source(s) of high resistance. Point sources of high resistance include:

- poor splices in the circuit
- loose or intermittent connections in the circuit
- corroded connections in the circuit
- damaged (cracked or broken) conductors

There are several potential consequences to high resistance and excessive voltage drop. Low voltage can lead to poor efficiency, wasted energy, and damage to motors and equipment. In the context of this investigation, the critical consequence is that high resistance results in heat generation at the point of resistance.

Heat Generation in Electrical Circuits

Heat is generated in a circuit whenever current encounters a resistance to flow. This is how a fuse opens, as heat resulting from excessive current melts the metal link in a fuse. In some applications, the heat is desirable because the appliance must produce heat in order to do its job. A toaster, for instance, is designed with high resistance to produce the necessary amount of heat to toast bread. The filament in an incandescent light bulb must glow white-hot, so heat is a necessary byproduct in producing light. In other applications, however, the heat is an undesirable byproduct. Desktop computers include a fan to cool and dissipate the undesirable heat that results in the resistance of the circuitry.

The heat that is produced in a circuit can be calculated using the basic relationships of electronics:

Ohm's Law: $V = I \times R$, where

V = potential difference in volts
I = amount of current in amperes, and
R = resistance in ohms
Thus, volts = amperes x ohms.

Power Formula: P = V x I, where
P = power in watts
Thus watts = volts x amperes.

The power formula can be written in a second way by substituting (I x R, from Ohm's Law) for V, thus: $P = I^2 \times R$. This is a common expression of the power formula.

Watts can be directly converted to heat. 1 watt = 3.4 BTU/hr. As can be seen in the power formula, the heat generated is directly proportional to the resistance, and directly proportional to the *square* of the current. This is a critical fact, as the following example demonstrates.

Example: Assume that a receptacle has a single 50W bulb plugged into it. A 50W bulb draws 0.42 amps of power (50W/120V). If a damaged wire connection in the circuit has a resistance of 0.4 ohms, then the heat generated at that connection is:

$$(0.42)^2 \times 0.4 \times 3.4 = 0.24 \text{ BTU/hr}$$

If the wire connection is in a more degraded condition, resulting in twice (0.8 ohms) the resistance:

$$(0.42)^2 \times 0.8 \times 3.4 = 0.48 \text{ BTU/hr}$$

Twice the resistance results in twice the heat.

If the bulb is changed out for a 100W bulb (0.83 amps), then the heat generated at the 0.4-ohm wire connection is:

$$(0.83)^2 \times 0.4 \times 3.4 = 0.94 \text{ BTU/hr}$$

While doubling the resistance results in twice the heat, doubling the current drawn on the circuit results in four times the heat. This can be critical if an appliance with a large current demand is in use. For instance, assume that an electric iron is also plugged into the same receptacle in the example with the 60W light bulb. A 1000W iron draws 8.3 amps (1000W/120V). The heat generated at a 0.4-ohm wire connection is:

$$(8.3+0.42)^2 \times 0.4 \times 3.4 = 103.4 \text{ BTU/hr}$$

The simple act of plugging in an iron results in the generation of over 100 times the heat at the wire connection. When considering the possibility of fire, the current load on a circuit is the most critical dimension.

Circuit Analysis

A device, the SureTest ProPlus Branch Circuit Wiring Analyser,[1] is available to test the integrity of a branch circuit. This device has a built-in microprocessor that switches in a

[1] It was beyond the scope of the investigation to identify the range of circuit analyzers that might be on the market. Other machines may exist. The SureTest analyzer is the device that is in use with weatherization agencies that were contacted in this study. The SureTest ProPlus costs about $200, and is available through Industrial Commercial Electronics, Inc. 2421 Harlem Rd., Buffalo, NY 14225. Tel: (800) 442-3462.

15-amp load on the circuit being tested for a small fraction of a second. The voltage of the circuit is measured with and without the load. The digital display alternates between showing the voltage measured under no load and the percentage by which the voltage drops under the 15-ampere load. Based on the voltage drop measurements, the procedure measures the potential for heating of the line between the point of the measurement and the service entry. While the procedure does not measure where a high resistance point is located, multiple tests at various points in the circuit, along with some common sense, can narrow down the location considerably.[2]

Once the voltage drop is known, the resistance can be computed with Ohm's law:
$R = (V_{nl} - V_l) / I$, where
V_{nl} = voltage with no load,
V_l = voltage with 15 ampere load,
I = 15 amperes, and
R = resistance.
As was demonstrated in the last section, heat generation can be calculated from the resistance for any applied current with the formula, BTU/hr = $I^2 \times R \times 3.4$.

Practitioners of circuit testing prior to insulation retrofits do not go through all of the above calculations. They simply work off of a prescribed allowable voltage drop. The question as to what is the preferred allowable voltage drop that will provide a margin of safety is open to interpretation.

Voltage Drop – Revisited

The reference to voltage drop in the National Electric Code appears in article 210-19(a) FPN 4, which states:

". . . and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, will provide reasonable efficiency of operation."

This is not a mandatory rule in the NEC. Explanatory material is included in the code in the form of fine print notes (FPN). Fine print notes are informational only and are not enforceable as requirements. This note relates to providing "reasonable efficiency", implying protection of equipment rather than fire safety.

The Institute of Electrical and Electronic Engineers (IEEE) recommends that the resistance of any conductor in a branch circuit should not exceed 0.25 ohms. A complete circuit of two conductors – or a maximum of 0.5 ohms – would yield a voltage drop of 6.25% under a 15-ampere load test on a 120V circuit.

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[2] Larry Armanda, instructor at the Pennsylvania College of Technology points out, "I have found high resistance connections in meter bases, fuse panels, and on the connections at the weatherhead. Many weatherhead problems are created due to years of stress caused by rain, wind, snow, as well as dissimilar metals." In some cases, load testing may indicate voltage drop on the entry of the distribution panel.

According to a paper by John Birkby[3]:

"Many inspector members of the IAEI (International Association of Electrical Inspectors), ASHI (American Society of Home Inspectors) and NAHI (National Association of Home Inspectors) have reported feeling comfortable with gradually increasing voltage drops as high as 8 to 10 percent where the line voltage is near the nominal 120 volts. Most of the controversy over the 5 percent maximum voltage drop occurs during residential inspections. Some very capable contractors who are required to comply with the 5 percent drop, have reported experiencing a great deal of difficulty trying to achieve this in homes of 3,000 square feet or more. Even after all connections have been inspected and tightened, all receptacles "pig-tailed" and circuit breakers checked, the voltage drop remains in excess of 5 percent and yet, below 8 percent."

Harold P. Kopp is VP/Chief Engineer for ICE, Inc., the manufacturer of SureTest circuit analyzers. His recommendation for allowable voltage drop, both between receptacles on a circuit and for the circuit as a whole, is:

". . . any voltage drop difference of >1% from an adjacent receptacle should be investigated, that any voltage drop difference of >2% from an adjacent receptacle should be considered a hazard, and that using a maximum voltage drop criteria more than 8% (3% above the "efficiency" recommendation) is courting disaster"[4]

The Philadelphia Housing Development Corporation (PHDC) requires contractors to perform a 15-ampere load test prior to insulating existing homes with insulation blown into the tight attic spaces of older row homes. Prior to instituting the test, smoldering fires were associated with half a dozen installations. The PHDC found that 70% of the homes flunked the 5% maximum voltage drop test. They reported a cluster of homes with a 6% voltage drop. The PHDC arbitrarily established an allowable limit of 10% maximum voltage drop, beyond which repair and/or replacement of the circuit is required before insulation. At this allowable limit, approximately 25% of the homes flunk the load test. PHDC has been using these criteria since 1994, and have experienced no fires in over 2500 installations.

[3] *Five Percent Voltage Drop – A Closer Look.* John M. Birkby. July 1999. Posted on the Industrial Commercial Electronics, Inc. website. http://www.iceind.com

[4] Technical article. *Frequently Asked Questions – Voltage Drop.* Harold P. Kopp. Posted on the Industrial Commercial Electronics, Inc. website. http://www.iceind.com

Appendix 2

Modeling Temperature of Electrical Wiring Enclosed in Thermal Insulation

A model was developed to estimate wire temperatures, based on resistance and current load, when an electrical wire is enclosed in thermal insulation. The following four pages are spreadsheets presenting the outcomes of the four examples included in Section D.2 of the report.

The model is two dimensional, and assumes radial heat loss through a cylinder. That is, the electrical wire is enclosed at the center of a cylindrical container of insulation, 3 ½ " in diameter. The dimension was chosen to simulate temperatures in a 3 ½" wall cavity. Consideration of thermal values of wall sheathing and finishes are not included. The model assumes an ambient temperature of 70 F° on both sides of the wall.

The user inputs are:

Current – the current load in amperes flowing through the wire.
Resistance – the resistance in ohms of the circuit, or of a point source somewhere on the circuit.
Length (L) – the length of wire subject to the given resistance.

Constant values are:

Conductivity (k and k_in) – conductivity of cellulose insulation.
Dimensions (r_outside and r_wire) – the radius of the wire and insulation.
Ambient Temperature (T_ambient) – Temperature of the environment surrounding the insulation.

Calculated values are:

Power – the energy in watts produced by the resistance.
Conversion – conversion of power to heat generation in BTU/hr.
Temperature of wire (T_wire) – the calculated equilibrium temperature of the wire in F°, or in other words, the temperature of the wire when the heat gain from the resistance in the wire equals the heat loss through the insulation.

In the first two examples, the resistance is assumed to be equal along the entire 60 foot length of the circuit. The last two examples assume a point source of high resistance that required an additional simplifying assumption. While one poor connection or splice can be the cause of high resistance, the heat generated at this point will spread, to some degree, along the length of the wire. Copper is an excellent thermal conductor just as it is an excellent electrical conductor. Without extending the model to a third dimension, an assumption has to be made as to the extent of this heat transfer. For the sake of modeling, a "point source" was defined as heat generated and spread equally over 36 inches of the wire.

SCENARIO 1

Assume radial heat loss through a cylinder
(based on thermal conductivity of wire)

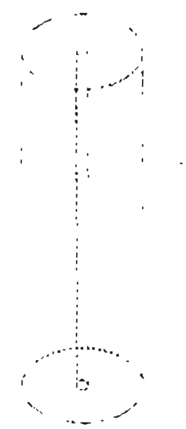
$$q = 2\pi Lk(T_{wire} - T_{ambient}) / \ln(r_{outside}/r_{wire})$$

item	value	units	formula
current	10	amps	
resistance	0.32	Ohm	
power	32.00	Watts	=current^2*resistance
conversion	108.80	Btu/hr	=power*3.4
Inputs			
q	108.80	Btu/hr	=conversion
k	0.3	Btu-in/hr-sf-degF	(average value for cellulose)
k_in	0.00208	Btu/hr-in-degF	=k/144
r_outside	1.75	in	
L	720	in	
r_wire	0.1	in	
T_ambient	70	degF	
Output			
ln	2.862		=LN(r_outside/r_wire)
T-wire	103.041	degF	=T_ambient+q*ln/(2*PI()*L*k_in)

SCENARIO 1: The wiring is in good shape, meaning that there are no isolated points of high resistance that could overheat. A circuit test at the farthest wall outlet measures a 4% voltage drop, representing a resistance (3.2 ohms) that is spread equally along the conductors and receptacles along the circuit. A sizable, but allowable, load of 10 amps runs on the circuit.

SCENARIO 2

Assume radial heat loss through a cylinder
(based on thermal conductivity of wire)



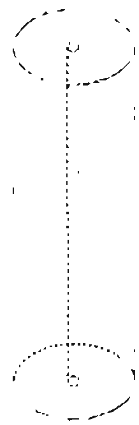
$$q = 2\pi Lk(T_{wire} - T_{ambient}) / \ln(r_{outside}/r_{wire})$$

item	value	units	formula
current	26	amps	
resistance	0.32	Ohm	
power	216.32	Watts	=current^2*resistance
conversion	735.49	Btu/hr	=power*3.4
Inputs			
q	735.49	Btu/hr	=conversion
k	0.3	Btu-in/hr-sf-degF	(average value for cellulose)
k_in	0.00208	Btu/hr-in-degF	=k/144
r_outside	1.75	in	
L	720	in	
r_wire	0.1	in	
T_ambient	70	degF	
Output			
ln	2.862		=LN(r_outside/r_wire)
T-wire	293.36	degF	=T_ambient+q*ln/(2*PI()*L*k_in)

Scenario 2: The homeowner has been trying to use two window air conditioners on the circuit in Scenario 1, but the 15 amp fuse keeps blowing. The homeowner replaces it with a 30-amp fuse. As a result, the circuit is now carrying a current load of 26 amps.

SCENARIO 3

Assume radial heat loss through a cylinder
(based on thermal conductivity of wire)



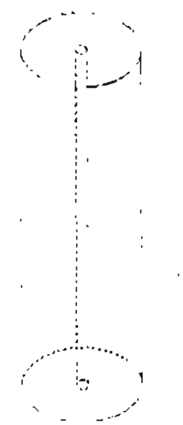
$$q = 2\pi Lk(T_{wire} - T_{ambient}) / \ln(r_{outside}/r_{wire})$$

item	value	units	formula
current	2	amps	
resistance	0.32	Ohm	
power	1.28	Watts	=current^2*resistance
conversion	4.35	Btu/hr	=power*3.4
Inputs			
q	4.35	Btu/hr	=conversion
k	0.3	Btu-in/hr-sf-degF	(average value for cellulose)
k_in	0.00208	Btu/hr-in-degF	=k/144
r_outside	1.75	in	
L	36	in	
r_wire	0.1	in	
T_ambient	70	degF	
Output			
ln	2.862		=LN(r_outside/r_wire)
T-wire	96.4331	degF	=T_ambient+q*ln/(2*PI()*L*k_in)

Scenario 3: Assume that the circuit showed a voltage drop of 8% instead of 4%. If 4% of the voltage drop is a result of the resistance in the circuit conductors and receptacles (as before), then there is an excess voltage drop of 4% at some point(s) on the circuit. This could be a result of a damaged wire, corroded connection, or improper splice. To cover the worst case, assume that all of the excess resistance is located at one point source. In this scenario, the circuit is lightly used, with just a couple of lamps and a clock radio pulling two amps. The maximum temperature occurs at the damaged wire.

SCENARIO 4

Assume radial heat loss through a cylinder
(based on thermal conductivity of wire)



$$q = 2\pi Lk(T_{wire} - T_{ambient}) / \ln(r_{outside}/r_{wire})$$

item	value	units	formula
current	12	amps	
resistance	0.32	Ohm	
power	46.08	Watts	=current^2*resistance
conversion	156.67	Btu/hr	=power*3.4
Inputs			
q	156.67	Btu/hr	=conversion
k	0.3	Btu-in/hr-sf-degF	(average value for cellulose)
k_in	0.00208	Btu/hr-in-degF	=k/144
r_outside	1.75	in	
L	36	in	
r_wire	0.1	in	
T_ambient	70	degF	
Output			
ln	2.862		=LN(r_outside/r_wire)
T-wire	1021.59	degF	=T_ambient+q*ln/(2*PI()*L*k_in)

Scenario 4: The situation is the same as in Scenario 3, with a point source of resistance resulting from a damaged wire. The homeowner, during a particularly cold spell of weather, plugs a 1200W space heater into the circuit. Again, the maximum temperature occurs at the damaged wire.

Appendix 3

California and Oregon Materials

The following pages contain information provided by Margaret Sturch (California) and Tom Brodbeck (Oregon). They provide details of the programs that have been developed in accordance with amendments to their state building codes, allowing for the placement of insulation in contact with knob-and-tube wiring.

The first 13 pages are from California, and include:

- Authorization letters from the Department of Community Services and Development and its consultant granting approval to a subgrantee
- The California building code amendment
- California's written knob-and-tube wiring policy
- A survey form for electrical inspection
- Required signage for attic insulation

The following 4 pages are from Oregon, and offer four types of electrical survey forms in use in that state.

RECEIVED CSD MAR 23 1999 PROGRAMS

COPY

RHA

Richard Heath and Associates, Inc.

31 Main Street, Suite A · Chico, California · 95928 · 530.898.1323 · Fax 530.898.1325

March 20, 1999

Toni Carrillo
Campesinos Unidos, Inc.
PO Box 203
Brawley, CA 92227

Dear Toni:

CSD has granted approval for you to employ specific knob-and-tube (K&T) procedures on a one-time basis for your problem attic. We hope this will enable you to economically resolve the K&T issue without the sizable expense of removing the insulation from the attic or rewiring the house. You will need the following enclosed documents:

1. **Copy of CSD 3/19 Letter** authorizing CUI to use specific K&T procedures.
2. **Section 324-4. of the CCR** (California Code of Regulations), which addresses insulating over K&T wiring. The italicized text under "Exception" is what pertains to your situation.
3. **An enlargement of the italicized text** for easier reading of a marginal-quality faxed copy.
4. **Conventional WIS Page 7-32**, which addresses policy regarding installation of insulation in attics containing K&T wiring (and references WIS pages 7-33 thru 7-39).
5. **"Summary of CSD Procedures: Knob-and-Tube Wiring Survey for Ceiling Insulation"**, which explains to the C-10 electrical subcontractor what needs to be done.
6. **Proposed CSD P&P Pages 9-1 thru 9-4 and Appendix A** (not yet adopted by CSD), which provide policies and procedures regarding installation of ceiling insulation in attics containing K&T wiring.
7. **"Notice of Survey by Electrical Contractor"** (abbreviated **"NSBEC"**). There are ten copies on laser-print paper. Save one for a reproduction master in case you need it.
8. **Attic "Warning Placard".** There are four copies on *card stock* (regular 20 lb. bond paper is not sturdy enough).

After the C-10 subcontractor properly completes the "Notice of Survey by Electrical Contractor" ("NSBEC"), several photocopies are needed. I suggest that you have the subcontractor fill out one original and give it to you to make copies. You will need: *one* for the occupant (and *one* for the owner or landlord if a rental), *two* for the subcontractor (one for the building department and one to file), *one* to post in the attic at the primary access (near the warning placard), and *one* to attach to the CSD invoice. The *original* goes in the client's permanent file.

I recommend that you provide each prospective C-10 electrical subcontractor with a copy of the following items: 1) the code page containing CCR Section 324-4., 2) the "Summary of CSD Procedures: Knob-and-Tube Wiring Survey for Ceiling Insulation", and 3) the "Notice of Survey by Electrical Contractor" (two or three copies).

Make sure the C-10 subcontractor you hire understands the procedures involved and what he is expected to do. If new overcurrent protection is installed, it is very important that the electrician explain to the occupant what will be done and, if applicable, explain possible nuisance tripping and what should be done to prevent it. (This is done *before* installing new tamperproof fuses, because if the customer refuses a needed overcurrent protection upgrade, ceiling insulation is not feasible.) In this case, however, you do not want to give the occupant the option to refuse new overcurrent protection if it is needed to make ceiling insulation feasible.

If this is a rental, also get written approval from the owner/landlord before doing any electrical alterations. A good way to do this is to get his signature next to the occupant's on the "NSBEC".

If the wiring can be certified safe, it is OK to leave the insulation as it is—but post an attic **"Warning Placard"** *inside* the attic near *each* access, and post a copy of the **"Notice of Survey by Electrical Contractor"** next to the placard at the *primary* access.

If the wiring cannot be certified safe, remedial action is required. You can: a) remove insulation from around the K&T wiring and install blocking as prescribed in CSD Conventional WIS pages 7-32 thru 7-39; or b) have new wiring installed as needed to eliminate insulation-related hazards.

Please let me know when corrections are complete on this unit. Hopefully you will not need to remove insulation and install blocking; but if you do, we need to reinspect the attic. If the wiring can be certified safe, we need a copy of the "NSBEC" but probably will not need to reinspect.

If you have any questions about the enclosed documents or the procedures involved, or if you have any problems during the course of resolving this case, you are welcome to contact me.

Sincerely,

Andre Grieco
Richard Heath & Associates
e-mail: agrieco@rhainc.com

Enclosures

cc: Margaret Sturch, CSD
Vinnie Scaglione, RHA-San Diego
Gary Bowman, RHA-Chico

COPY

STATE OF CALIFORNIA - HEALTH AND HUMAN SERVICES AGENCY GRAY DAVIS, Governor

DEPARTMENT OF COMMUNITY SERVICES AND DEVELOPMENT
A Quality Management Department
700 North 10th Street, Room 258
Sacramento, CA 95814
(916) 322-2940
(916) 327-3153 (FAX)
(916) 327-6318 (TDD)

March 19, 1999

Andre Grieco
Richard Heath and Associates
31 Main Street, Suite A
Chico, CA 95928

Dear Mr. Grieco:

The Department of Community Services and Development hereby authorizes the one-time use of the as yet unadopted Policies and Procedures Manual, pages 9-1 through and including 9-4, Knob-And-Tube Wiring Policy (attached), Appendix A pages A-1 and A-2 (attached), and the use of the "Notice of Survey by Electrical Contractor" form (attached) to resolve the hazardous fail situation in the area served by Campesinos Unidos, Inc. referenced in your fax to us dated March 16, 1999 (attached).

Please contact Margaret Sturch at (916) 327-6326 if you have any questions or further information about this matter.

Sincerely,

Toni Curtis
Chief Deputy Director

Attachments

cc: Pat Walsh, Field Representative
Toni Carrillo, Weatherization Manager

ARTICLE 324 — CONCEALED KNOB-AND-TUBE WIRING

324-1. Definition. Concealed knob-and-tube wiring is a wiring method using knobs, tubes, and flexible nonmetallic tubing for the protection and support of single insulated conductors concealed in hollow spaces of walls and ceilings of buildings.

324-2. Other Articles. Concealed knob-and-tube wiring shall comply with this article and also with the applicable provisions of other articles in this Code, especially Article 300.

324-3. Uses Permitted. Concealed knob-and-tube wiring shall be permitted to be used only for extensions of existing installations and elsewhere only by special permission under the following conditions:

(1) In the hollow spaces of walls and ceilings.

(2) In unfinished attic and roof spaces as provided in Section 324-11.

324-4. Uses Not Permitted. Concealed knob-and-tube wiring shall not be used in commercial garages, theaters and similar locations, motion picture studios, hazardous (classified) locations, or in the hollow spaces of walls, ceilings, and attics where such spaces are insulated by loose, rolled, or foamed-in-place insulating material that envelops the conductors.

Exception: This article is not intended to prohibit the installation of insulation where knob-and-tube wiring is present, provided the following are complied with:

(1) The wiring shall be surveyed by an electrical contractor licensed by the State of California. Certification shall be provided by the electrical contractor that the existing wiring is in good condition with no evidence of deterioration or improper over-current protection, and no improper connections or splices. Repairs, alterations or extensions to the electrical system will require permits and inspections by the authority having jurisdiction for the enforcement of this code.

(2) The certification form shall be filed with the authority having jurisdiction for the enforcement of this code and a copy furnished to the property owner.

(3) All accessible areas in the building where insulation has been installed around knob-and-tube wiring shall be posted with a notice, clearly visible, stating that caution is required when entering these areas.

(4) The insulation shall be noncombustible as defined by Section 215.2 of Part 2 of this Title.

(5) The insulation shall not have any electrical coductive material as part of or supporting the insulation material.

(6) Nothing in this exception will prohibit the authority having jurisdiction for the enforcement of this code, from requiring permits and inspections for the installation of thermal insulation.

324-5. Conductors.

(a) Type. Conductors shall be of a type specified by Article 310.

324-4. Uses Not Permitted. Concealed knob-and-tube wiring shall not be used in commercial garages, theaters and similar locations, motion picture studios, hazardous (classified) locations, or in the hollow spaces of walls, ceilings, and attics where such spaces are insulated by loose, rolled, or foamed-in-place insulating material that envelops the conductors.

Exception: This article is not intended to prohibit the installation of insulation where knob-and-tube wiring is present, provided the following are complied with:

(1) The wiring shall be surveyed by an electrical contractor licensed by the State of California. Certification shall be provided by the electrical contractor that the existing wiring is in good condition with no evidence of deterioration or improper over-current protection, and no improper connections or splices. Repairs, alterations or extensions to the electrical system will require permits and inspections by the authority having jurisdiction for the enforcement of this code.

(2) The certification form shall be filed with the authority having jurisdiction for the enforcement of this code and a copy furnished to the property owner.

(3) All accessible areas in the building where insulation has been installed around knob-and-tube wiring shall be posted with a notice, clearly visible, stating that caution is required when entering these areas.

(4) The insulation shall be noncombustible as defined by Section 215.2 of Part 2 of this Title.

(5) The insulation shall not have any electrical coductive material as part of or supporting the insulation material.

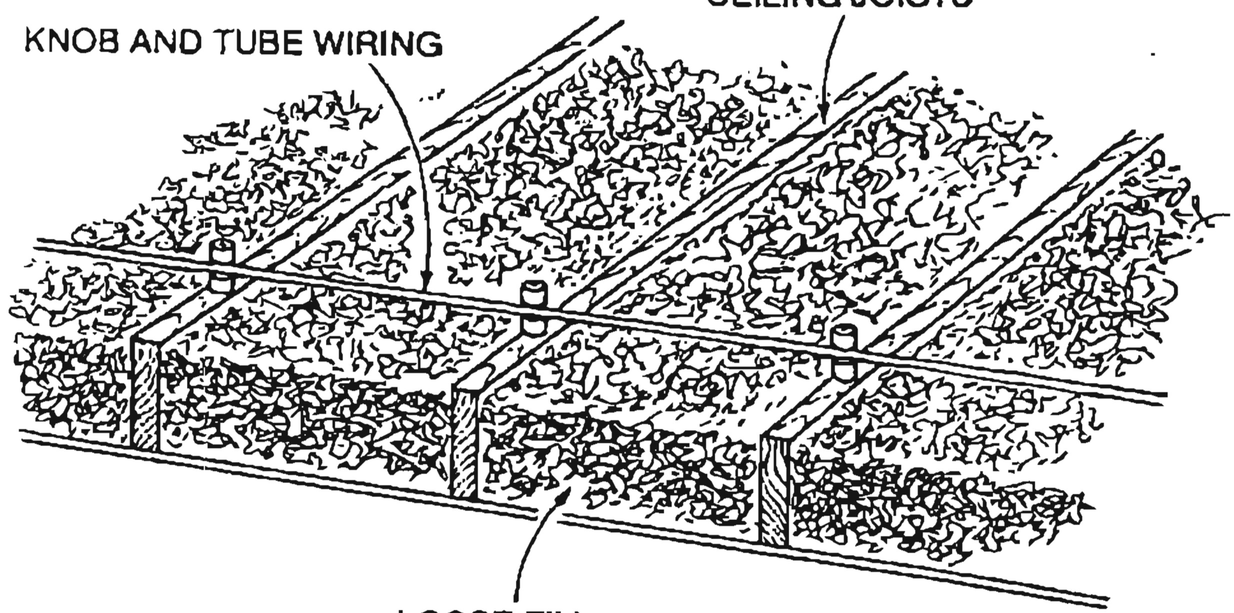
(6) Nothing in this exception will prohibit the authority, having jurisdiction for the enforcement of this code, from requiring permits and inspections for the installation of thermal insulation.

324-5. Conductors.

(a) **Type.** Conductors shall be of a type specified by Article 310.

31. KNOB-AND-TUBE WIRING

- All Insulation
  - When insulation is installed over knob-and-tube wiring, the wiring shall be certified safe as prescribed in the program Policies & Procedures.
  - When program Policies & Procedures allow blocking to be installed to protect knob-and-tube wiring, it shall be installed as prescribed in item 31, pages 7-33 through 7-39.
  - Abandoned knob and tube wiring requires no protection.



Summary of CSD Procedures:
Knob-and-Tube Wiring Survey for Ceiling Insulation

Before ceiling insulation is installed, the Weatherization (Wx) Contractor must hire a licensed (C-10) Electrical Subcontractor to inspect the knob-and-tube wiring and existing overcurrent protection. The following list summarizes the Electrical Subcontractor's responsibilities.

1. Read Section 324-4. of the California Code of Regulations (CCR). Obtain necessary permits and inspections if repair work is done.
2. Inspect the wiring and overcurrent protection to determine the condition of:
   a. the knob-and-tube wiring in the attic (good or deteriorated), and
   b. existing overcurrent protection (proper or improper).
3. If wiring is in *good* condition and proper overcurrent protection is already in place, complete the "Notice of Survey by Electrical Contractor" ("NSBEC") as follows:
   c. Check the applicable boxes in Part (A) indicating the wiring is in good condition: wiring is not deteriorated, there are no improper splices, there is no evidence of improper overcurrent protection, and it is OK to install ceiling insulation.
   d. Sign and date the form, and print firm name and license number.
   e. Get Customer's signature after explaining that the wiring is safe as-is and the existing fuses/breakers will remain. If a change in usage habits is recommended (e.g., change where some appliances are plugged in), explain to the Customer what to do and why.
   f. Give the "NSBEC" original to the Wx Contractor. Copies go to: 1) Occupant (and the Landlord if a rental), 2) Electrical Subcontractor's file, and 3) the Building Department.
4. If wiring is in *good* condition but proper overcurrent protection is *not* already in place, complete the "Notice of Survey by Electrical Contractor" as follows:
   a. *After obtaining Wx Contractor's approval and occupant's agreement*, obtain all required permits, and install proper overcurrent protection (breakers or Type_S fuses).
   b. *Before doing any alterations*, get Occupant's signature *after explaining* that the new fuses/breakers, if a lower amperage than previously used, may cause nuisance tripping in affected circuits unless usage habits are changed (e.g., fewer appliances plugged into one circuit). *The Occupant must understand this and sign the form.*
   c. Check the applicable boxes in Part (A) indicating the wiring *was* in poor condition, but it was *brought up to acceptable condition* by installing proper overcurrent protection, and it is now OK to install ceiling insulation.
   d. Sign and date the form, and print firm name and license number.
   e. Give the "NSBEC" original to the Wx Contractor. Copies go to: 1) Occupant (and the Landlord if a rental), 2) Electrical Subcontractor's file, and 3) the Building Department.
5. If wiring is in *poor* condition and *not* suitable to be brought up to acceptable standards, complete the "Notice of Survey by Electrical Contractor" as follows:
   a. Check the applicable boxes in Part (B) showing why wiring cannot feasibly be brought up to acceptable standards.
   b. Sign and date the form, and print firm name and license number.
   c. Electrician (or Wx Contractor) should explain the "NSBEC" findings to the Owner or Landlord and get his signature. This will verify he has been advised of wiring condition.
   d. "NSBEC" original to Wx Contractor; copies to: 1) Owner/Landlord, and 2) Subcontractor.

9. KNOB-AND-TUBE WIRING POLICY

Contractors may insulate attics, walls and floors in homes containing knob-and-tube wiring if the wiring is certified as safe by a licensed electrical (C-10) subcontractor or, in the case of attic insulation, it is protected as prescribed in the WIS.

9.1. Attic with Knob-and -Tube Wiring

Ceiling insulation may be installed only if the requirements of this section are met.

9.1.1. Insulation Options

An attic containing knob-and-tube wiring may be insulated using either of the following options:

9.1.1.1. Encapsulation

Knob-and-tube wiring may be surrounded and covered (encapsulated) by insulation provided the knob-and-tube wiring has been inspected and certified as safe by a C-10 contractor as prescribed below. This is the recommended option because it provides 100% coverage of the attic floor.

9.1.1.2. Blocking

An attic containing knob-and-tube wiring may be insulated without obtaining C-10 contractor certification provided the wiring is not encapsulated and is protected as prescribed in Section 7, Item 31 of the Conventional Home WIS.

9.1.2. Electrical (C-10) Contractor Certification

For each C-10 subcontractor utilized, the following documentation shall be maintained in the weatherization contractor's office:

1) A copy of the electrical subcontractor's current active C-10 license.
2) Name, address, and telephone number of the subcontractor.
3) Evidence of the subcontractor's insurance (General, Auto Liability, Workmen's Compensation). Coverage must conform to existing CSD contractual requirements.

9.1.3. Wiring Inspection and Certification of Safety

An electrical inspection completed by a licensed C-10 electrical subcontractor shall include the subcontractor's personal inspection and observation that verifies one of the following:

a) All existing knob-and-tube wiring in the area intended to be insulated is in good condition with:
   - no evidence of deterioration,

- no improper connections or splices, and
- no evidence of improper overcurrent protection.

b) The knob-and-tube wiring was in poor condition (unsafe) and was brought up to acceptable standards by installing:
   - a new service panel with breakers, or
   - tamperproof overcurrent protection, or
   - other required repairs.

Results of the inspection shall be recorded in a "Notice of Survey by Electrical Contractor" (see Appendix A) obtained from CSD. After the wiring has been certified as safe, insulation may be installed over it.

9.1.4. Wiring Not Certified Safe

The contractor shall not insulate over knob-and-tube wiring surveyed by the electrical (C-10) subcontractor if it is not suitable to be brought up to acceptable standards due to any of the following conditions:

- Evidence of deterioration.
- Improper overcurrent protection.
- Improper connections or splices.

In these cases, the owner/occupant of the building shall be advised ***that repairs exceed the scope of the weatherization program***. CSD programs will not provide repairs beyond simple overcurrent protection devices.

9.1.5. Notice of Survey by Electrical Contractor

The "Notice of Survey by Electrical Contractor" shall be signed by the client before overcurrent protection is installed.

Copies of the form will be distributed as follows:

a) The original copy will be stored in the client file.
b) A photocopy will be attached to the invoice.
c) The second copy will be left with the client after the inspection.
d) A photocopy of the original will be posted in the attic next to a warning placard (see Appendix A) where it will be visible to persons entering the attic. If there is more than one attic entrance, posting of the "Notice of Survey" shall be at the primary entrance (the warning placard is posted at each entrance).
e) The third copy will be retained by the C-10 contractor, who is responsible for providing a photocopy of the certification to the local code enforcement agency.

9.1.6. Ceiling Insulation Procedures

9.1.6.1. Overcurrent Protection Already in Place

If the unit is inspected by the electrical (C-10) subcontractor and certified in good condition and suitable for the installation of insulation, as outlined below (and implemented as in Article 324-4 of the National Electrical Code, as amended in Part 3, Title 24 of the California Code of Regulations "Insulation Around Knob-and-Tube Wiring"), the contractor shall:

a) Install noncombustible insulation only.

b) Use only noncombustible barriers.

c) Place a copy of the Warning Placard near each openable entrance to the attic ***(including any that are temporarily obstructed by furniture, stored items, etc.)***, in a location where it will be observed by persons entering the attic.

d) The warning placard shall be CSD-issued or a clear reproduction of the copy contained in Appendix A.

9.1.6.2. New Overcurrent Protection Devices Installed

If only proper overcurrent protection is required to bring the knob-and-tube wiring up to an acceptable standards, the electrical subcontractor may install new overcurrent protection if:

a) The owner/occupant has been advised and has signed acknowledgment that the existing appliances and electrical uses may cause current interruption and nuisance, and

b) The new devices to be installed are of the tamperproof overcurrent protection type.

Insulation may be installed, covering and enveloping the wiring, after the tamperproof overcurrent protection has been installed and the unit is certified as safe by the C-10 contractor.

9.2. Walls with Knob-and-Tube Wiring

Wall insulation may be installed only if the knob-and-tube wiring has been certified as safe by a licensed electrical (C-10) subcontractor.

The Inspection, certification and installation procedures for attic insulation shall apply to wall insulation with the following exception: a "Notice of Survey by Electrical Contractor" form shall be given to the customer but there is no requirement to post one in the dwelling.

9.3. Floors with Knob-and Tube Wiring

Insulation may be installed only if the knob-and-tube wiring has been certified as safe by a licensed electrical (C-10) subcontractor.

The inspection, certification and installation procedures for attic insulation shall apply to floor insulation with the following exception: A "Notice of Survey by Electrical Contractor" form shall be given to the customer but there is no requirement to post one in the dwelling.

9.4. Reimbursement for C-10 Contractor Services

CSD-administered programs will provide reimbursement for the services of a C-10 electrical contractor, subject to the following limitations.

a) Reimbursement shall be limited to the cost of inspection of the wiring system, issuance of a Notice of Survey by Electrical Contractor, and installation of simple overcurrent protection (e.g., "S" type fuses).

b) Costs for applicable services shall be itemized and billed in the Minor Envelope Repair category.

An invoice from the C-10 contractor stating the itemized costs of services rendered shall be attached to the "Notice of Survey" in the client's file.

California Department of Community Services and Development

Notice of Survey by Electrical Contractor

This is a verification that the existing knob-and-tube wiring was surveyed at this address:

Number ______ Street ______ City ______ Zip ______

The existing wiring was found to be :

(A)

- ☐ In good condition with:
  - ☐ No evidence of deterioration
  - ☐ No improper connections or splices
  - ☐ No evidence of improper overcurrent protection

OR

- ☐ In poor condition and was brought up to acceptable standards by:
  - ☐ Installing tamperproof overcurrent protection with fuses
  - ☐ Installing new service panel with breakers
  - ☐ Other ______

THEREFORE,

The following area(s) have been approved for the installation of Insulation:

- ☐ Ceiling
- ☐ Walls
- ☐ Floor

AND

A copy of this certification will be filed with the local code-enforcement agency.

(B)

- ☐ In poor condition and not suitable to be brought up to acceptable standards because of:
  - ☐ Evidence of deterioration
  - ☐ Evidence of improper connections or splices
  - ☐ Evidence of improper overcurrent protection
  - ☐ Other ______

A copy of this survey will be furnished to the owner or occupant. The accompanying invoice states the cost of this survey and related services.

Date ______ X ______ Contractor Signature

License Number ______ Firm Name ______

NOTICE TO CUSTOMER: This electrical survey is required before your ceiling, wall, or floor can be insulated under the CSD-administered weatherization programs.

You are advised that if tamperproof overcurrent protection devices are installed to protect the wiring system, your electrical usage habits may require modification to avoid nuisance tripping of the fuses. Prior to installing overcurrent protection, the electrical contractor performing this survey is required to explain the difficulties you may experience after the devices are installed.

I CERTIFY THAT I HAVE READ AND UNDERSTAND THIS NOTICE:

Date ______ X ______ Customer Signature

CAUTION!

There are concealed electrical wires which could cause electrocution!

ELECTRICAL INSPECTION REPORT

CLIENT ______________________ Knob & Tube
ADDRESS ______________________ Romex

A. General:
   1. General conditions of wiring (checked wiring around electrical panel, attic and/or under floor): ______________________
   2. Integrity of wire insulation, (checked wiring around electrical panel, attic and/or under floor): ______________________

B. Adequacy of house wiring based on current load:
   1. Have the circuits been located and identified at the service panel? ____________
   2. Are circuits presently overloaded? ____________
   3. Have the knob and tube circuits to be covered been protected with a 15 amp circuit breaker? ____________

C. Certification: (check one only)
   ________ Only ceiling area approved for insulation
   ________ Only walls approved for insulation
   ________ Both ceiling and walls approved for insulation
   ________ Insulation not approved for ceiling or attic

Knob and tube wiring was found in the following locations:

Ceilings   Walls   Both

Number of "S" fuses installed ______
Number of breakers installed ______
Is existing knob and tube on a 15 amp circuit? ______
Additional comments or work performed: ______________________
____
____

The above information accurately represents my findings during the pre-weatherization electrical inspection.

____________ ____________
Date of Insp. Inspector

Knob and tube wiring is in acceptable condition for coverage by loose-fill insulation in walls? Yes _____ No _____
Knob and tube wiring is in acceptable condition for coverage by loose-fill insulation in attic? Yes _____ No _____

Down-fusing done:
Number of 15 amp "S" type fuses or circuit breakers installed? ________
Down-fusing not done:
Number of 15 amp fuses or breakers existing? ________
Knob and tube wiring not in service? ________

Sample of Seattle City Light and Department of Human Resources form used by journeymen electricia to certify that wiring in a home with knob and tube wiring is safe to be insulated (ie, insulation blown over the wiring after it has been down-fused with S-type fuses.

KNOB AND TUBE VERIFICATION

Owner of house: ______________________________

Address of house: ______________________________

Seattle City Light Account # ______________________________

Insulation Contractor ______________________________

Knob & Tube Wiring Present in:		Knob & Tube wiring is in acceptable condition for coverage by loose-fill insulation.		
Attic	Walls		YES	NO
☐	☐	Walls	☐	☐
		Attic	☐	☐

Down-fusing done	Number of 15 amp S type fuses or cicuit breakers installed.	☐
Down-fusing <u>not</u> done	15 amp fuses or breakers existing.	☐
	Knob & tube wiring not in service.	☐

COMMENTS

____

____

____

____

<u>Reported by</u>:

Name of Journeyman Electrician: ______________________________

Business address ______________________________ Phone: ______________

Journeyman Electrician's License No.: ______________________________

______________________________ ______________
Signature of Journeyman Electrician Date

3.3/MM

ELECTRICAL INSPECTION REPORT

Client's Name:______________________ Project #______________

Address:______________________

Home Phone:______________________

Work Phone:______________________

Other Contact(if necessary)______________________

Walls: OK ☐ Not approved : ☐

Floors: OK ☐ Not approved : ☐

Ceilings: OK ☐ Not approved : ☐

Service 200 AMP ______________ 100 AMP ______________

"S" Type Fuses Install Yes ________ No________

Circuit Breakers Installed Yes________ No________

Flying Splices Repaired Yes________ No________

Amount of Splices Repair:______________

Amount of splices needing repair?______________

Other needed repairs and estimate:______________
(Comments from inspector)

____

____

____

Authorization for repair of more than six splices:______________________
(Signature)

Electrical Contractor & Design
Fax: (503) 667-7965

Multnomah County Wx
Fax: 248-3332

Comments from Program Auditor:

____

____

Date Inspected:____________ Inspector:____________ License#____________

Electrical Inspection Report

Client's name ____________________ Job # ____________

Address ____________________ Date inspected ______

Daytime phone ____________________

A. General

1. Verify condition of visible wiring (check wiring around electrical panel, attic, and/or under floor, wall receptacles and switches): ____________

2. Check integrity of visible wire insulation (check wiring around electrical panel, attic, and/or under floor): ____________

3. Identify and locate knob and tube wiring not in service: ____________

4. Live knob and tube wiring found in the following locations
   Ceilings ____________ Walls ____________ Underfloor ____________

B. Adequacy of house wiring based on current load

1. Have the circuits been located and identified at the service panel? ______

2. Are the circuits presently overloaded? ____________

3. Have the involved knob and tube circuits been protected with a 15 amp circuit breaker? ____________ Type "S" fusing? ____________

C. Repairs necessary for insulation coverage

1. Number of 15 amp fuses installed: ____________
2. Number of 15 amp breakers installed: ____________
3. Number of slices repaired: ____________
4. Number of junction boxes/covers installed: ____________
5. Is existing knob and tube on a 15 amp circuit? ____________
6. Number of junction boxes/covers installed: ____________

D. Certification (check one only)

____________ Only ceiling area approved for insulation
____________ Only walls approved for insulation
____________ Only under floor approved for insulation
____________ Ceiling, underfloor, and walls approved for insulation
____________ Insulation not approved for insulation

The above information accurately represents my findings during the pre-weatherization electrical inspection.

Comments: ____________

Date inspected ____________ Inspector ____________ License # ____________

State of Washington Insulation Coverage over Knob and Tube Wiring Amendment to the NEC

On 10/11/90, the state of Washington amended NEC 324-4 as follows:

"The provision of Section 324-4 of the National Electrical Code shall not be construed to prohibit the installation of loose or rolled thermal insulating material in spaces containing existing knob-and-tube wiring provided that all the following conditions are met:

(1) The wiring shall be surveyed by an appropriately licensed electrical contractor who shall certify that the wiring is in good condition with no evidence of improper overcurrent protection, conductor insulation failure or deterioration, and with no improper connections or splices. Repairs, alterations, or extensions of or to the electrical system shall be inspected by an electrical inspector as defined in RCW 19.28.070.

(2) The insulation shall meet class I specifications as identified in the Uniform Building Code, with a flame spread factor of 25 or less as tested using ASTM E8481a. Foam insulation shall not be used with knob-and-tube wiring.

(3) All knob-and-tube circuits shall have overcurrent protection in compliance with the 60 degree C column of Table 310-16 of the National Electrical Code. Overcurrent protection shall be either circuit breakers or Type S fuses. The Type S fuse adapters shall not accept a fuse of an ampacity greater than that permitted in this chapter."

Following on the heels of Washington State's success, the state of Oregon amended the state code in a similar manner:

"The provisions of Section 324-4 shall not be construed to prohibit the installation of loose or rolled thermal insulating material in spaces containing existing knob-and tube wiring provided that all the following conditions are met:

(1) The visible wiring shall be inspected by a certified electrical inspector.

(2) All defects found during the inspection shall be repaired prior to the installation of insulation.

(3) Repairs, alterations or extensions of or to the electrical systems shall be inspected by a certified electrical inspector.

(4) The insulation shall have a flame spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with ASTM E84-87. Foamed in place insulation shall no be used with knob-and-tube wiring.

(5) Exposed splices or connections shall be protected from insulation by installing flame resistant, non-conducting, open top enclosures which provide at least 3 inches, but not

more than 4 inches side clearance, and a vertical clearance of at least 4 inches above the final level of the insulation.

(6) All knob-and-tube circuits shall have overcurrent protection in compliance with the 60 degree C column of Table 310-16 of NFPA 70-1990. Overcurrent protection shall be either circuit breakers or Type S fuses. The Type S fuse adapters shall not accept a fuse of an ampacity greater than that permitted in this chapter."

The states of Nebraska, Massachusetts, and California also amended state codes to allow for insulation around knob-and-tube wiring under specific protocols. With these amendments in hand, it was possible for state weatherization agencies to develop insulation programs that did not violate ruling building codes, and that provided specific documentation of safety procedures when insulating older homes. "Home rule" states (such as Illinois) did not have this course of action available. In these states, ensuring compliance with building codes would require amendments to all local building codes served by weatherization programs, implying dozens, if not hundreds, of local code amendment campaigns.

3. Department Of Energy Policy

Prior to the NEC code change in 1987, the U.S. Department of Energy (DOE) policy on the knob-and-tube issue was stated in a memorandum from Joseph Flynn, director of the Weatherization Assistance Programs. The memorandum, dated July 25, 1983, stated:

"It is believed that insulation can be safely placed over knob-and-tube wiring provided that:

- The wiring is in good condition and
- The circuits do not carry an amperage greater than the ratf3d current for that size wiring.

In all cases, before insulating over knob-and-tube wiring is approved, personnel authorizing work orders or contracts will conduct a thorough inspection of the areas to be insulated and ensure that:

- All wiring to be covered is examined and pronounced safe and in good condition;
- The electrical system has protective devices matched to the wire sizes which discontinue the flow of electrical current when the circuits are overloaded."

The inspector should check to determine if there is evidence of cracked or frayed electrical insulation or exposed conductors. Installers of the insulation should be cautioned to use care not to damage the old wiring as the new insulation is applied.

Installation of type "S" fuses is required infuse boxes in homes where knob-and-tube wiring systems are used. Type "S" fuses ensure against overloading by making it impossible to put in a larger rated fuse. Permission must be obtained from the client to modify the fuse box. If the client does not consent, the insulation cannot be installed.

Subgrantee personnel who authorize work should be aware that in some cases, when older homes have been re-wired, the knob-and-tube system has been left in place. An inspector may see only the abandoned wiring and take appropriate action. Inspectors will verify that knob and tube systems are, in fact, in service before disqualifying homes.

In 1988, following the NEC code change, DOE went through a period of reconsideration of this policy. The policy was formally changed in a memorandum dated July 13, 1988 from Andre W. Van Rest, chief of the Weatherization Assistance Programs Branch. Following acknowledgement of the NEC code change regarding knob-and-tube wiring (KTW), the memorandum states:

> "DOE has allowed installation of insulation over KTW as a weatherization measure only when precautions outlined in our attached memorandum dated July 25, 1983, are taken. These precautions included an examination of the condition of the wiring and the installation of proper electrical protective devices (typically, properly sized type "S" fuses). Although the application of insulation over KTW may raise the operating temperature of the wire, we are unaware of any problems with homes that contain KTW and have been insulated under the Weatherization Assistance Program.
>
> However, we feel that the most prudent course of action is to comply with the requirements of the 1987 NEC. Therefore, effective immediately, all support offices should notify their states that installation of thermal insulation over KTW is no longer permitted. This action does not affect homes already weatherized."

Department of Energy Reaction to NEC Code Change Regarding Insulation Covering Knob and Tube Wiring

In 1988, following the NEC code change, DOE went through a period of reconsideration of this policy. The policy was formally changed in a memorandum dated July 13, 1988 from Andre W. Van Rest, chief of the Weatherization Assistance Programs Branch. Following acknowledgement of the NEC code change regarding knob-and-tube wiring (KTW), the memorandum states:

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However, we feel that the most prudent course of action is to comply with the requirements of the 1987 NEC. Therefore, effective immediately, all support offices should notify their states that installation of thermal insulation over KTW is no longer permitted. This action does not affect homes already weatherized."

The memorandum placed a clear ban on the installation of insulation around knob-and -tube wiring. The policy, however, was short-lived. Prior to September 1988, Mary E. Fowler became the chief of the Weatherization Assistance Programs Branch. In a memorandum of September 7, 1988, she requested input from the support offices regarding this question. In the responses to this request, DOE became aware of the states that were preparing building code modifications to NEC 324-4. In a memorandum of October 21, 1988, examples of these modifications were distributed. As stated in this memorandum:

"These examples are cited because the approach taken by these states conforms to the general WAP policy that jurisdiction in health and safety matters related to program-funded work resides with state and/or local authorities."

The memorandum acknowledged the state and local administration of the NEC, and went on to officially change DOE policy once more:

"In light of the above, the revised DOE-WAP policy on installation of thermal insulation around KTW is that it is the state's responsibility to ensure that such work be in conformance with the applicable codes in the jurisdiction where the work is being performed. Therefore, the KTW guidance issued on July 25, 1983, and on July 13,1988, is superseded by this memo.

Please convey to your WAP grantees: (1) the revised DOE-WAP policy on installing thermal insulation around KTW, as stated in the previous paragraph; (2) the attached information on the 1987 National Electrical Code change related to KTW; (3) the Washington state material if you think it will be helpful in understanding how other States are handling KTW; (4) that those homes which were completed without insulation since July 13, 1988 may now be insulated under the revised policy. The prohibition against re-weatherization found in section 440.18 (e) (2) (i) will not apply to such insulation work and those homes may not be reported as new completions. In addition, each grantee should be advised to check with the appropriate electrical code authorities in its state to determine whether the NEC KTW change has been adopted as is, has been adopted with modifications, or has not been adopted and, therefore, whether any modification in KTW work performed under the WAP is required within the state."

****Amend Part VI to read:

Part VI—Electrical

Replace Part VI, ELECTRICAL to read:

SECTION E-101—ELECTRICAL CODE FOR ONE- AND TWO-FAMILY DWELLINGS ADOPTED

The electrical requirements shall conform to the Electrical Code for One- and Two-Family Dwellings (NFiPA 70A-1990) excerpted from the 1987 National Electrical Code (NFiPA 70-1990) as published by the National Fire Protection Association, which is adopted by reference and made part of this code.

Exceptions:

1. Multifamily metering ORS 455.420.
2. Electric Ignition Pilot for gas appliances from ORS 479.770 and OAR 918-260-300.
3. Article 324-4 of the Oregon Electrical Specialty Code to read as in this Part.
4. Article 422-7 of the Oregon Electrical Specialty Code to read as in this Part.

SECTION E-102—ELECTRIC PILOT IGNITION

OREGON ADMINISTRATIVE RULES CHAPTER 918, DIVISION 260 BUILDING CODES AGENCY

Electric Ignition Pilot

918-260-300 (1) Definition. Central space heating equipment is environmental heating equipment from which heated air is supplied by means of ducts or pipes to rooms and areas other than the rooms or space in which the equipment is located.

(2) **Prohibited Sale of Certain Equipment.** On or after January 1, 1979, no person shall sell or offer for sale in this state any new gas-fired, forced-air central space heating equipment, clothes dryer or domestic range and, on or after January 1, 1981, new gas-fired swimming pool heaters, unless such equipment, heater, dryer or range is equipped with an electric ignition pilot which complies with the applicable standards of the American Gas Association in effect on October 4, 1977, and which standards are adopted by the Agency pursuant to ORS 479.740.

(3) Nothing in this rule shall apply to:
(a) Gas appliances used in recreational vehicles;
(b) Portable gas appliances used for outdoor recreational purposes; or
(c) Gas appliances used in a structure which is not served by electric power.

Note: The federal National Appliance Energy Conservation Act (NAECA) has preempted the State's authority to require electric ignition pilot for gas fired central heating equipment. (Attorney General's Opinion, OP-6439, 2/13/92)

SECTION E-103—ELECTRIC METERS

455.420 Individual electric meters required in multi-residential buildings; exceptions; standards. (1) Each individual dwelling unit in a multifamily residential building constructed after October 4, 1977, shall have installed a separate, individual electrical meter for each such dwelling unit except where a building inspector certified under ORS 455.715 to 455.740 determines that pursuant to standards adopted by the administrator the installation of a single, central electrical meter for all the dwelling units in such building would facilitate an overall reduction in electrical consumption by such units.
(2) For the purpose of carrying out the provisions of subsection (1) of this section, the administrator based on recommendations of the Energy Conservation Board, shall adopt by rule standards for determining whether the installation of a single electrical meter for all dwelling units in a multifamily residential building facilitates an overall reduction in electrical consumption by such units. [formerly 456.763]

SECTION E-104—CONCEALED KNOB-AND TUBE WIRING

Note: Article 90-2, Scope, says this code (NFiPA 70A-1990) only covers the most commonly encountered construction and if it is not found in this code then (NFiPA 70-1990) is referenced.

Article 324 regulates knob-and-tube wiring which is not contained in this code, but is in NFiPA 70-1990. When knob-and-tube wiring is encountered in existing dwellings, Article 324 is used, except that Section 324-4 is further amended to read:

324-4 Uses Not Permitted. Concealed knob-and-tube wiring shall not be used in commercial garages, theaters and similar locations, motion picture studios, hazardous (classified) locations or in the hollow spaces of walls, ceilings and attics when such spaces are insulated by loose, rolled, or foamed in place insulation material that envelopes the conductors.

Exception: The provisions of Section 324-4 shall not be construed to prohibit the installation of loose or rolled thermal insulating material in spaces containing existing knob-and-tube wiring provided that all the following conditions are met:

(1) The visible wiring shall be inspected by a certified electrical inspector.

(2) All defects found during the inspection shall be repaired prior to the installation of insulation.

(3) Repairs, alterations or extensions of or to the electrical systems shall be inspected by a certified electrical inspector.

(4) The insulation shall have a a flame spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with ASTM E84-87. Foamed in place insulation shall not be used with knob-and-tube wiring.

(5) Exposed splices or connections shall be protected from insulation by installing flame resistant, non-conducting, open top enclosures which provide at least 3 inches, but not more than 4 inches side clearance, and a vertical clearance of at least 4 inches above the final level of the insulation.

(6) All knob-and-tube circuits shall have overcurrent protection in compliance with the 60 degree C column of Table 310-16 of NFiPA 70-1990. Overcurrent protection shall be either circuit breakers or Type S fuses. The Type S fuse adapters shall not accept a fuse of an ampacity greater than that permitted in this chapter.

SECTION E-105—HEATING EQUIPMENT WIRING

Amend article 422-7 by adding an new exception to read:

422-7 Central Heating equipment. Central heating equipment other than fixed electric space heating equipment shall be supplied with an individual branch circuit.

Exception No. 1: Auxiliary equipment such as a pump, valve, humidifier, or electrostatic air cleaner directly associated with the heating equipment shall be permitted to be connected to the same branch circuit.

Exception No 2: If the existing equipment is connected to a lighting circuit, the new equipment may be reconnected to that circuit, provided the equipment being installed has an ampere rating of not more than 50% of the branch circuit rating. The branch circuit shall be calculated at 180 VA per outlet as required in Article 210-23(a).

INSERT

Electrical Code for One- and Two-Family Dwellings (NFiPA 70A-1990) after this page.

ELECTRICAL INSPECTION REPORT

Client's Name:______________________ Project #____________

Address:______________________

Home Phone:______________________

Work Phone:______________________

Other Contact(if necessary)______________________________________

Walls: OK ☐ Not approved : ☐

Floors: OK ☐ Not approved : ☐

Ceilings: OK ☐ Not approved : ☐

Service 200 AMP ____________________ 100 AMP ____________________

"S" Type Fuses Install Yes ________ No__________

Circuit Breakers Installed Yes________ No__________

Flying Splices Repaired Yes________ No__________

Amount of Splices Repair:________________

Amount of splices needing repair?______________________________

Other needed repairs and estimate:______________________________
(Comments from inspector)

____

____

____

Authorization for repair of more than six splices:______________________________
(Signature)

Electrical Contractor & Design
Fax: (503) 667-7965

Multnomah County Wx
Fax: 248-3332

Comments from Program Auditor:

____

____

Date Inspected:____________ Inspector:____________ License#____________

Oregon Housing and Community Services
Knob and Tube Policy

KNOB AND TUBE WIRING

1.10 Knob and tube electrical wiring is often found in the walls and attics of older homes. The possibility that insulation may trap heat produced by overloaded knob and tube wiring circuits requires insulation shall be kept 3 inches away from any live knob and tube wiring. Depending on agency policy, Oregon Building Code allows insulation to be installed over, around or in contact with knob and tube wiring if the following conditions are satisfied. (Oregon Building Codes Division, Temporary Rule effective January 1, 1993; Amends Part VI of the 1990 Edition of the Oregon One and Two Family Dwelling Specialty Code). See Appendix AA for sample electrical inspection report.

1.11 An unfaced fiberglass batt of highest R-value possible shall be placed under the knob and tube wiring. If knob and tube wiring exists in an attic space and is known to be dead (verified and documented by a licensed electrician) then the wiring may be covered by insulation.

1.12 A licensed journeyman electrician or a certified electrical inspector shall inspect all visible knob and tube wiring. This includes repairs, alterations or extensions to the electrical system.

A. All defects found during the inspection shall be repaired prior to the installation of insulation.

B. All knob and tube circuits shall have over-current protection in compliance with the 60°C column of Table 310-16 of National Fire Protection Agency (NFiPA) 70-1 990. Over-current protection shall be 15 amp circuit breakers or Type S fuses. The Type S fuse adapters shall not accept a fuse of an imparity greater than that permitted in this chapter.

1.13 Fiberglass and cellulose insulation are acceptable for use in contact with approved knob and tube wiring. Foamed-in place insulation shall not be used with knob and tube wiring.

1.14 Non-soldered exposed splices or connections shall be protected by installing solid flame resistant enclosure, securely attached with at least 3-inch clearance from insulation.

1.15 When existing knob and tube wiring will not be upgraded as required it shall not be covered. Two options are:

A. Insulate below with nothing above. Maintain a minimum 3-inch air space to the sides of the knob and tube wiring.

B. Insulate below and tent or lid with a baffle 3 inches above. Baffle the knob and tube wiring and blow loose fill insulation in the remaining areas of the attic, or install insulation in the attic area (not over the knob and tube wiring). The baffling material shall have a flame spread of 25 or less when tested in accordance with ASTM E-84-80 and be electrically nonconductive.

Bonneville Power Administration (BPA) on Installing Insulation around and over Knob and Tube

And then there's the dilemma you face with your desire to upgrade the insulation in your home. The National Electrical Code decreed in 1987 that it would not permit insulation contact with knob and tube wiring systems, though some jurisdictions still allow it if the wiring is in good condition

NEC 2011 Article 394 Concealed Knob-and-Tube Wiring

394.12 Uses Not Permitted

(5) Hollow spaces of walls, ceilings, and attics where such spaces are insulated by loose, rolled, or foamed-in-place insulating material that envelops the conductors.

The problem is that the average insulation installer does not know or does not care about electrical codes. Combine insulation with wiring protected with breakers larger than originally intended is a disaster waiting to happen.

Below is a copied section of the NEC 2002 containing that rule relating to this subject. Also there is an NEC Handbook commentary directly following that rule of the NEC.

394.12 Uses Not Permitted.
Concealed knob-and-tube wiring shall not be used in the following:
(5) Hollow spaces of walls, ceilings, and attics where such spaces are insulated by loose, rolled, or foamed-in-place insulating material that envelops the conductors

COPIED SECTION OF THE NEC 2002 HANDBOOK COMMENTARY;
Concealed knob-and-tube wiring is designed for use in hollow spaces of walls, ceilings, and attics and utilizes the free air in such spaces for heat dissipation. Weatherization of hollow spaces by blown-in, foamed-in, or rolled insulation prevents the dissipation of heat into the free air space. This will result in higher conductor temperature, which could cause insulation breakdown and possible ignition of the insulation.

In "Retrofitrs We'd Rather Forget" (Jan/Feb '96), you made reference to insulating over knob-and-tube wiring as being a fire hazard. This statement is incorrect.

Legislation was enacted in Washington state to allow insulating over knob-and-tube wiring per Bonneville Power Administration (BPA) specifications. This resulted because there were no documented cases of a fire being caused by knob-and-tube wiring, whether insulation covered it or not. Because the two conductors of knob- and-tube wiring circuits are spaced some distance apart, it is nearly impossible to short out. Even when covered with flammable materials such as wood shavings, the only way you could get a short was if the insulating materials were wet ... then they won't burn, so you couldn't start a fire anyway.
Overheating the wire would be the only method of ignition for knob-and-tube. Nonmetallic I sheathed cable (NMC) such as Romex, on the other hand, can short as well as be overheated, increasing the potential for fire. NMC has started fires, and we insulate over it.
As an extra safety measure, it is a good idea to use Type S fuses or breakers sized properly for the wire size, the same as you would for NMC. An inspection by the Washington State Electrical Inspector and the installation of proper fusing (or breakers) is a requirement when insulating over knob and tube wiring in Washington and where allowed in other northwest states that follow BPA specifications.

394.12 Uses Not Permitted. Concealed knob-and-tube wiring shall not be used in the following:
(5) Hollow spaces of walls, ceilings, and attics where such spaces are insulated by loose, rolled, or foamed-in-place insulating material that envelops the conductors

Exception: The provisions of Section 394.12 shall not be construed to prohibit the installation of loose or rolled thermal insulating materials in spaces containing existing knob-and-tube wiring, provided all the following conditions are met:

(1) The visible wiring shall be inspected by a certified electrical inspector or a general supervising electrician employed by a licensed electrical contractor.

(2) All defects found during the inspection shall be repaired prior to the installation of insulation.

(3) Repairs, alterations or extensions of or to the electrical systems shall be inspected by a certified electrical inspector.

(4) The insulation shall have a flame spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with ASTM E84-91A 2005 Edition. Foamed in place insulation **394.12 Uses Not Permitted.** Concealed knob-and-tube wiring shall not be used in the following:
(5) Hollow spaces of walls, ceilings, and attics where such spaces are insulated by loose, rolled, or foamed-in-place insulating material that envelops the conductors

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(4) The insulation shall have a flame spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with ASTM E84-91A 2005 Edition. Foamed in place insulation

shall not be used with knob-and-tube wiring.

(5) Exposed splices or connections shall be protected from insulation by installing flame resistant, non-conducting, open top enclosures which provide three inches, but not more than four inches side clearances, and a vertical clearance of at least four inches above the final level of the insulation.

(6) All knob-and-tube circuits shall have overcurrent protection in compliance with the 60 degree C column of Table 310-16 of NFPA 70-2008. Overcurrent protection shall be either circuit breakers or type S fuses. The type S fuse adapters shall not accept a fuse of an ampacity greater than permitted in Section 240.53.

CITY OF SAN JOSE

BUILDING DIVISION POLICY

Policy on Inspection of Knob-and-Tube Wiring prior to Installing Insulation

Policy No. NEC 324-4-1-93
Effective: December 12, 1994
Revised: February 10, 1996

Insulation around knob-and-tube wiring is prohibited by Section 324-4 of the National Electric Code. However, the Department of Housing and Community Development of the State of California and the State Building Standards Commission on 2/15/91 adopted an ordinance amending NEC Section 324-4, to provide a safe method by which loose or rolled insulation may be installed in enclosed spaces of homes with knob-and-tube wiring. A copy of the California Electrical Code article is attached. Note that a State licensed electrical contractor (C-10) must provide written certification to the authority having jurisdiction (i.e. the City of San Jose) that the existing wiring is in good condition with no evidence of deterioration or improper over-current protection, and has no improper connections or splices.

This certification shall be submitted to the City of San Jose Building Division in a form similar to the attached example, and must be signed by both the licensed electrical contractor and the customer. If the existing installation is certified to be in good condition, with no evidence of deterioration, improper connections or splices, nor improper over-current protection, no additional permits and/or inspections will be required by the City.

If any repairs, alterations and/or modifications are required to bring the existing wiring into compliance with the above life safety conditions an electrical permit, inspection and approval of the repairs must be obtained from the City of San Jose's Building Division prior to installation of any insulation. All appropriate work shall be permitted in accordance with the current permit fee schedule.

The approved certification letter should be filed in Building Division records by address with the other permit(s). If there are no other permits required, the certification letter shall be dead filed and permanently archived.

Initiated by:
D.J. Doody,
Supervising Electrical Inspector

Approved by:

Chief Building Official

Knobpoli.doc

324-4. Uses Not Permitted. Concealed knob-and-tube wiring shall not be used, in commercial garages, theaters and similar locations, motion picture studios, hazardous (classified) locations or in the hollow spaces or walls, ceilings and attics when such spaces are insulated by loose, rolled, or foamed in place insulating material that envelops the conductors.

Note: Underscored words NOT ADOPTED by State of California.

Exception: This article is not intended to prohibit the installation of insulation where knob-and-tube wiring is present, provided the following are complied with:

(1) The wiring shall be surveyed by an electrical contractor licensed by the State of California. Certification shall be provided by the electrical contractor that the existing wiring is in good condition with no evidence of deterioration or improper over-current protection, and no improper connections or splices. Repairs, alterations or extensions to the electrical system will require permits and inspections by the authority having jurisdiction for the enforcement of this code.

(2) The certification form shall be filed with the authority having jurisdiction for the enforcement of this code and a copy furnished to the property owner.

(3) All accessible areas in the building where insulation has been installed around knob-and-tube wiring shall be posted with a notice, clearly visible, stating that caution is required when entering these areas.

(4) The insulation shall be noncombustible as defined by Section 415(b) of Part 2 of this Title.

(5) The insulation shall not have any electrical conductive material as part of or supporting the insulation material.

(6) Nothing in this exception will prohibit the authority, having jurisdiction for the enforcement of this code, from requiring permits and inspections for the installation of thermal insulation.

324-5. Conductors.

(a) **Type.** Conductors shall be of a type specified by Article 310.

(b) **Ampacity.** The ampacity shall be determined by Section 310-15.

324-6. Conductor supports. Conductors shall be rigidly supported on noncombustible, nonabsorbent insulating materials and shall not contact any other objects. Supports shall be installed as follows: (1) within 6 inches (152mm) of each side of each tap or splice, and (2) at intervals not exceeding 4 1/2 feet (1.37m).

Exception: If it is not practicable to provide supports in dry locations it shall be permissible to fish conductors through hollow spaces if each conductor is individually enclosed in flexible nonmetallic tubing. The tubing shall be in continuous lengths between supports, between boxes, or between a support and a box.

324-7 Tie Wires. Where solid knobs are used, conductors shall be securely tied thereto by tie wires having insulation equivalent to that of the conductor.

324-8. Conductor Clearances. A clearance of not less than 3 inches (76mm) shall be maintained between conductors and of not less than 1 inch (25.4mm) between the conductor and the surface over which it passes.

Exception: Where space is too limited to provide the above minimum clearances, such as at meters, panel boards, outlets, and switch points, the conductors shall be individually enclosed in flexible nonmetallic tubing, which shall be in continuous lengths between the last support or box and the terminal point.

324-9. Through Walls, Floors, Wood Cross Members, etc. Conductors shall comply with Section 320-11 where passing through holes in structural

PG&E ENERGY PARTNERS PROGRAM
NOTICE OF SURVEY BY ELECTRICAL CONTRACTOR

This is a verification that the existing knob-and-tube wiring at:

____

Address City Zip

has been surveyed this date and found to be:

☐ In good condition with:
- ☐ No evidence of deterioration
- ☐ No improper connections or splices
- ☐ No evidence of improper over-current protection

☐ In poor condition and was brought up to acceptable standards by:
- ☐ Installing proper non-tamperable over-current protection
- ☐ Installing a new service panel with breaker
- ☐ Other-Explain: ______________________________

☐ Unable to meet acceptable standards because of:

DESCRIPTION
- ☐ Evidence of deterioration
- ☐ Evidence of improper connections or splices
- ☐ Evidence of improper over-current protection
- ☐ Other-Explain: ______________________________

☐ Estimated cost of repairs described above: ____________________

☐ A copy of this certification will be filed with the local authority having jurisdiction for this code.

Date __________ Print Name ____________________ Signature ____________________

Firm ______________________________ Lic. No. ____________________

Notice to customer: This survey is required before your attic can be weatherized by PG&E's Energy Partners Program, and is in compliance with Article 324-4 of the National Electrical Code, 1990 Edition, Part 3 Title 24, California Code of Regulations.

You are advised that if non-tamperable over-current protection has been installed to protect the wiring system, your electrical usage habits by require modification to avoid nuisance tripping of the fuses. Before installing the devices and certifying the eligibility of your home, the Electrical Contractor performing this survey is required to explain difficulties you may experience.

I CERTIFY THAT I HAVE READ AND UNDERSTAND THE NOTICE ABOVE:

CUSTOMER SIGNATURE ______________________________ DATE ______________

Bonneville Power Administration (BPA) on Installing Insulation around and over Knob and Tube

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NEC 2011 Article 394 Concealed Knob-and-Tube Wiring

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(5) Hollow spaces of walls, ceilings, and attics where such spaces are insulated by loose, rolled, or foamed-in-place insulating material that envelops the conductors.

The problem is that the average insulation installer does not know or does not care about electrical codes. Combine insulation with wiring protected with breakers larger than originally intended is a disaster waiting to happen.

Below is a copied section of the NEC 2002 containing that rule relating to this subject. Also there is an NEC Handbook commentary directly following that rule of the NEC.

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COPIED SECTION OF THE NEC 2002 HANDBOOK COMMENTARY;
Concealed knob-and-tube wiring is designed for use in hollow spaces of walls, ceilings, and attics and utilizes the free air in such spaces for heat dissipation. Weatherization of hollow spaces by blown-in, foamed-in, or rolled insulation prevents the dissipation of heat into the free air space. This will result in higher conductor temperature, which could cause insulation breakdown and possible ignition of the insulation.

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Overheating the wire would be the only method of ignition for knob-and-tube. Nonmetallic I sheathed cable (NMC) such as Romex, on the other hand, can short as well as be overheated, increasing the potential for fire. NMC has started fires, and we insulate over it.

As an extra safety measure, it is a good idea to use Type S fuses or breakers sized properly for the wire size, the same as you would for NMC. An inspection by the Washington State Electrical Inspector and the installation of proper fusing (or breakers) is a requirement when insulating over knob and tube wiring in Washington and where allowed in other northwest states that follow BPA specifications.

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(2) All defects found during the inspection shall be repaired prior to the installation of insulation.

(3) Repairs, alterations or extensions of or to the electrical systems shall be inspected by a certified electrical inspector.

(4) The insulation shall have a flame spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with ASTM E84-91A 2005 Edition. Foamed in place insulation **394.12 Uses Not Permitted.** Concealed knob-and-tube wiring shall not be used in the following:

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(5) Exposed splices or connections shall be protected from insulation by installing flame resistant, non-conducting, open top enclosures which provide three inches, but not more than four inches side clearances, and a vertical clearance of at least four inches above the final level of the insulation.

(6) All knob-and-tube circuits shall have overcurrent protection in compliance with the 60 degree C column of Table 310-16 of NFPA 70-2008. Overcurrent protection shall be either circuit breakers or type S fuses. The type S fuse adapters shall not accept a fuse of an ampacity greater than permitted in Section 240.53.

Knob and Tube Wiring Amendment for Insulation Coverage in the State of California

How Knob-and-Tube Wiring Works:

K&T wiring consists of insulated copper conductors passing through lumber framing drill-holes via protective porcelain insulating tubes. They are supported along their length by nailed-down porcelain knobs. Where wires enter a wiring device, such as a lamp or switch, or were pulled into a wall, they are protected by flexible cloth or rubber insulation called "loom."

Advantages of Knob-and-Tube Wiring:

•K&T wiring has a higher ampacity than wiring systems of the same gauge. The reason for this is that the hot and neutral wires are separated from one another, usually by 4 to 6 inches, which allows the wires to readily dissipate heat into free air.

•K&T wires are less likely than Romex cables to be punctured by nails because K&T wires are held away from the framing.

•The porcelain components have an almost unlimited lifespan.

•The original installation of knob-and-tube wiring is often superior to that of modern Romex wiring. K&T wiring installation requires more skill to install than Romex and, for this reason, unskilled people rarely ever installed it.

Problems Associated with K&T Wiring:

•Unsafe modifications are far more common with K&T wiring than they are with Romex and other modern wiring systems. Part of the reason for this is that K&T is so old that more opportunity has existed for improper modifications.

•The insulation that envelopes the wiring is a fire hazard.

•It tends to stretch and sag over time.

•It lacks a grounding conductor. Grounding conductors reduce the chance of electrical fire and damage to sensitive equipment.

•In older systems, wiring is insulated with varnish and fiber materials that are susceptible to deterioration.

Compared with modern wiring insulation, K&T wiring is less resistant to damage. K&T wiring insulated with cambric and asbestos is not rated for moisture exposure. Older systems contained insulation with additives that may oxidize copper wire. Bending the wires may cause insulation to crack and peel away.

K&T wiring is often spliced with modern wiring incorrectly by amateurs. This is perhaps due to the ease by which K&T wiring is accessed.

Building Insulation:

K&T wiring is designed to dissipate heat into free air, and insulation will disturb this process. Insulation around K&T wires will cause heat to build up, and this creates a fire hazard. The 2008 National Electrical Code (NEC) requires that this wiring system not be covered by insulation. Specifically, it states that this wiring system should not be in hollow spaces of walls, ceilings and attics where such spaces are insulated by loose, rolled or foamed-in-place insulating material that envelops the conductors.

Local jurisdictions may or may not adopt the NEC's requirement. The California Electrical Code, for instance, allows insulation to be in contact with knob-and-tube wiring, provided that certain conditions are met, such as, but not limited to, the following:

•A licensed electrical contractor must certify that the system is safe.

•The certification must be filed with the local building department.

•Accessible areas where insulation covers the wiring must be posted with a warning sign. In some areas, this sign must be in Spanish and English.

•The insulation must be non-combustible and non-conductive.

•Normal requirements for insulation must be met.

KANSAS HOUSING
RESOURCES CORPORATION

PART II

MASTER FILE

2011

Client Health and Safety

The State of Kansas and subgrantees are required to take all reasonable precautions against performing work on homes that will subject workers or clients to health and safety risks. Before beginning work on the residence, the agency must take into consideration the health concerns of each occupant, the condition of the dwelling, and the possible effect of work to be performed on any particular health or medical condition of the occupants. When a person's health is fragile and/or the work activities would constitute a health or safety hazard, the occupants at risk will be required to leave the home during these work activities

9. ***Electrical Issues*** – The two primary energy-related health and safety electrical concerns are insulating homes that contain knob-and-tube wiring and identifying overloaded electrical circuits. Older electric wiring, primarily knob-and-tube wiring, located in a wall cavity or exposed on an attic floor was intended by code to have free air movement to cool the wire when it is carrying an electric current. Laboratory tests have shown that retrofitting thermal insulation around electric wiring can cause it to overheat, resulting in a fire hazard. The October 21, 1988, Weatherization policy guidance on knob-and-tube remains in effect. The policy places responsibility on the State of Kansas to ensure that insulation around knob-and-tube wiring conforms to applicable codes in jurisdictions where the work is being performed.

   In 1987, Section 324 (article 324-4) of the National Electrical Code (NEC) was revised to prohibit the use of concealed knob-and-tube wiring "in the hollow spaces of walls, ceilings and attics when such spaces are insulated by loose or rolled insulating material." Since 1987, NEC added a prohibition against "foamed in-place" insulation as well. While the NEC is a national code, it is not administered and enforced nationally. Building codes are administered on the state, county, or local level but are usually based on one of the national model codes (e.g., BOCA, CABO, UBC), which reference the NEC for electrical requirements.

   Note: Serious electrical hazards exist when gross overloads are present. Should auditors and crews find such existing problems, they should notify the owner. Weatherization measures that involve the installation of new equipment such as air conditioners, heat pumps, or electric water heaters can exacerbate previously marginal overload problems to hazardous levels. The problem should also be noted in the client file. To the extent that these problems prevent adequate weatherization, the agency should consider repairing them on a case-by-case basis.

   Minor electrical repairs are allowed where health or safety of the occupant is at risk. Upgrades and repairs are allowed when necessary to perform specific weatherization measures.

   Minor upgrades and repairs necessary for weatherization measures and where the health or safety of the occupant is at risk are allowed. Must provide sufficient over-current protection prior to insulating over knob-and-tube wiring.

Retrofitting Knob and Tube Wiring
An Investigation into Codes, Assessment, Wiring Practices and Cost

Submitted to and Funded by:
Pennsylvania Department of Community and Economic Development
January 2004

Prepared by:
Weatherization Training Center at Pennsylvania College of Technology
One College Avenue, Williamsport, PA 17701, www.pct.edu/wtc

Principal Investigator and Author: Larry D. Armanda
Project Director and Editor: Bill Van der Meer

Knob and Tube Wiring and the National Electrical Code,
Article 394.12 of the National Electrical Code (NEC) 2002 Handbook discusses "Concealed Knob-and-Tube Wiring, Uses Not Permitted."
"Concealed knob-and-tube wiring is designed for use in hollow spaces of walls, ceilings, and attics and utilizes the free air in such spaces for heat dissipation. Weatherization of hollow spaces by blown-in, foamed-in, or rolled insulation prevents the dissipation of heat into the free air space. This will result in higher conductor temperature, which could cause insulation breakdown and possible ignition of the insulation."
While the NEC is clear about disallowing insulation over K&T wiring, the NEC does not discuss the more serious fire hazards resulting from alterations of the orginal knob and tube wiring. By not insulating these areas, the free air space will offer some protection from overheated splices or connections.

Voltage Drop, Resistance and Heat Generation
Heat is generated in a circuit whenever current flow (amperage) encounters a resistance to the flow. Voltage drop normally occurs when current passes through a wire. A small voltage drop of approximately 1 to 5 % is expected in all electrical circuits. The greater the resistance of a circuit, the greater the voltage drop. Excessive voltage drop can cause excessive heat, creating a concern of the safety of the circuit.
Excessive voltage drop is caused by high resistance in a circuit when:
1. There is a long run of wire of insufficient gauge or size of the wire for the run.
2. The wire size is too small to carry the load.
3. There are point source(s) of high resistance. These include:

• Poor splices
• Corroded connections

High resistance point sources, such as loose or corroded connections, should raise the greatest concern before adding thermal insulation **(see Appendix 2)**. Excessive voltage drop also leads to poor efficiency, wasted energy, higher electric bills and damage to electrical equipment.
The National Electrical Code 2002 article 210-19 (a) FPN 4 ("Fine Print Notes") discusses voltage drop, which states: *"where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation"*

It should be noted that the NEC further defines "Fine Print Notes" as being for informational purposes only. They are not enforceable and are therefore **not** a mandatory rule. Fine Print notes relate to "reasonable efficiency" of electrical equipment and not fire safety.

Pre and post wiring retrofit voltage drop tests were conducted on a cross section of houses that were included in this project. A "Sure Tester 61-151" that simulates a 20 amp load was used. The tests were performed at ceiling light fixtures and wall receptacles before and after rewiring the old knob and tube. The voltage drop readings indicated only slight reductions and were still well above the 5% suggested values. The voltage drop was checked at the service panel, meter base, weatherhead and the utility equipment. As an experiment, a wire was disconnected from the circuit at the panel, which fed the area to be rewired. A temporary cord with a receptacle was then installed to accept the voltage drop tester. This cord was connected directly onto a fuse or breaker. The resulting voltage drop reading was then subtracted from the post rewire readings. All of the houses inspected indicated 2 to 3% voltage drop on the service equipment. Subtracting the service voltage drop from the post voltage drop readings of the interior wiring brought most of the total circuit voltage drop values well below 5%.

References and Resources
Bibliographic References

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