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

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### 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 15amp 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 in-service 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 preemptive 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 Massillon, 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 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 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 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:

7 The wiring is in good condition; and

7 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.

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