NBSIR 77-1282

# Investigation of the Suitability of Light Duty Pipe Hangers for Use in Residential and Care Type Sprinkler Systems

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Center for Fire Research
Institute for Applied Technology
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Final Report

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**Office of Policy Development and Research**
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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*

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CONTENTS

# LIST OF FIGURES

## LIST OF TABLES

INVESTIGATION OF THE SUITABILITY OF LIGHT DUTY PIPE HANGERS FOR USE IN RESIDENTIAL AND CARE TYPE SPRINKLER SYSTEMS

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Abstract

Several sizes of various types of commonly available light duty hangers for pipe, cable and conduit were subjected to load failure tests and while under load to exposure to 70 and 140 pound (31.8 and 63.5 kg, respectively) crib fires. In addition, hangers made from thin strap metal were tested for effect on performance of undersized screws and for benefit obtained from the use of washers. All sizes of the two-hole or two-fastener hangers met the NFPA No. 13 Standard for the Installation of Sprinklers load requirement, while only the nominal 1-1/4 inch size of the one-hole hangers met the requirement. Washers improve the performance of hangers made of thin strap metal.

Key words: Automatic sprinklers; care type occupancies; fire endurance; load failure; pipe hangers; residential occupancies.

## 1. INTRODUCTION

In October 1973, the U.S. Department of Housing and Urban Development (HUD) issued changes to the Minimum Property Standards (MPS) for Multi-family Housing (FHA 2600), [1][1] Housing for the Elderly with Special Consideration for the Handicapped (HUD PG 46) [2], and Nursing Homes (FHA 4514.1) [3]. The changes pertained to fire protection standards for the above occupancy types. Subsequently, these documents were superseded by MPS for Multi-family Housing (4910.1) [4] and MPS for Care Type Housing (4920.1) [5]. Our primary interest in these documents is the requirement for automatic sprinkler installation as follows:

[1] Numbers in brackets refer to literature references at the end of this paper.

(1) In multi-family residential buildings four stories or more in height, an automatic sprinkler protection system must be provided in all corridors, public spaces, service areas and utility areas.

(2) In care type constructions 3 and 4, automatic sprinkler protection must be provided throughout.

(3) In care type constructions 1 and 2, automatic sprinkler protection must be provided in public spaces, in corridors serving patient rooms, and in hazardous areas such as soiled linen rooms, paint shops, storage or workshops involving combustible supplies and in equipment and trash collection rooms.

It is required that the automatic sprinkler systems be installed in accordance with the National Fire Protection Association Standard 13 (NFPA 13), Installation of Automatic Sprinklers [6].

In March 1974, a research project, sponsored by HUD, was initiated at the National Bureau of Standards (NBS) to develop improved design criteria in terms of spacing requirements, water discharge rates, hanger requirements and piping performance criteria for corridor sprinkler systems as required by the MPS's cited above. Water distribution from automatic sprinkler heads was addressed in a previous report [7]. This report contains the results of load failure and fire tests conducted on light duty pipe hangers for use in residential and care type occupancies.

## 2. PURPOSE

Present requirements for pipe hangers for sprinkler systems as outlined in NFPA Standard No. 13 specify that pipe hangers be listed by a nationally recognized testing laboratory such as Underwriters' Laboratories, Inc. (UL) (Standard for Pipe Hanger Equipment for Fire Protection Service, UL 203) [8], or Factory Mutual (FM) (Factory Mutual Approval Standard for Automatic Sprinkler Systems, Class Nos. 1951, 1952, 1953) [9] or certified by a registered professional engineer for the following:

1. Designed to support five times the weight of the water filled pipe plus 250 pounds at each point of piping support.

2. Ferrous materials are used for hanger components.

Both UL and FM require pipe hangers to withstand a short time test load equal to the weight of a 12 to 15-foot (3.7 to 4.6-m) length of Standard Weight Schedule 40 pipe filled with water, (379 pounds (172 kg) for 12 feet of nominal 1 inch pipe), multiplied by a factor of five (5) plus an added load of 250 lb (1112 newtons (N))[2]. The factor of 5 is apparently intended to provide a margin of strength to compensate for inaccuracies in design, imperfections in materials, deficiencies in craftsmanship, and deterioration of the system. The 250 lb (1112 N) additional load is apparently intended to compensate for human abuse during and after installation. The form of human abuse envisioned in the development of the sprinkler hanger standards according to people familiar with the history [10,11] is that of a person supporting his weight on an installed pipe. In addition to the previous loads, UL also imposes a minimum test load of 750 lb (3337 N) on all hangers. The basis for this load which is three times the abuse load is undetermined.

The purposes of this investigation were as follows:

1. to determine the ultimate failure load of installed light-duty pipe hangers typically available through plumbing supply outlet,

2. to determine whether exposure to fire would cause the pipe hangers suspended from combustible structural elements (wood joists) to fail prematurely, causing the sprinkler system to become inoperative prior to expected sprinkler actuation, and

3. to determine realistic excess load factors to be used for the selection of hanger spacing.

Hangers suspended from steel beams or concrete slabs were not considered here since the holding ability in a properly anchored system is considered to be a function of the strength of the hanger alone rather than the complete hanger system including the attachment to the structural element.

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[2] A 1-lb load is regarded as a 1-lb force = 4.45 newton

## 3. TEST FACILITIES

### 3.1. Tensile Test Setup

A screw type tensile-compression machine with a load range selection of 0-10 000 lb (44 480 N) was used to conduct the tensile tests. In each instance a short section of pipe or a substitute of the same diameter was used to transmit the load to the sample hanger uniformly in order to avoid stresses not likely in sprinkler system installations.

### 3.2. Fire Test Facility

A 7 ft 3 in x 7 ft 3 in x 7 ft 6 in (2.2 m x 2.2 m x 2.3 m) high test room lined with asbestos mill board[3] was used to conduct fire testing of the pipe hangers. A nominal "2 x 4" (actual finish size: 1-1/2 in x 3-1/2 in (3.8 cm x 8.9 cm)) piece of lumber[4] simulating a ceiling joist was supported against the ceiling, narrow edge down, by nominal 2 in x 4 in (actual size: 1-1/2 in x 3-1/2 in (3.8 cm x 8.9 cm)) steel studs at opposite walls of the test enclosure. A thermocouple was installed 1 ft (30 cm) out the diagonals from each of the ceiling corners (see figure 1). The thermocouples were connected in parallel to a recorder to obtain an average ceiling temperature.

The fire source used consisted of wood cribs constructed of 22 in (55.9 cm) long nominal 2 in x 4 in lumber as shown in figure 2. The moisture content of the cribs immediately before the tests ranged from 7-1/2 to 10 percent. The average for each crib was determined to be 8 to 9 percent by weight. The weight of each crib before testing was adjusted to 70 $\pm$ 1/2 lb (3.18 $\pm$ 0.2 kg) by the addition or removal of an appropriate length of stick.

### 3.3. Pipe Hangers

A selection of light duty pipe hangers, as shown in figure 3, common to most plumbing supply houses was chosen to give a representative cross-section of commonly available pipe hangers, and included perforated copper banding, one and two hole copper, steel, and galvanized malleable iron straps, and split rings with and without swivel features.

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[3] Canadian Government Spec. No. 34-GP-18

[4] Select Structural No. 1

An effort was made to select designs with implied possible structural weaknesses such as lightness of hanger, dependency on only one retaining screw, or a small hinge as an integral part of the hanger.

Only the nominal 1-1/4 inch one-hole malleable iron strap hanger met Federal specification for pipe hangers and supports WW-H-171D [12]. The steel two-hole strap hangers ranged in thickness from 0.018 inch (0.046 cm) to 0.086 inch (0.218 cm). The copper two-hole strap hangers ranged in thickness from 0.028 inch (0.071 cm) to 0.045 inch (0.114 cm). None of the two-hole strap hangers met Federal specification for metal retaining strap for conduit, pipe and cable FF-S-760a [13].

### 3.4. Fasteners

Since the connections of primary interest in this investigation were those between pipe hangers and wood joists, wood screws were selected as the fasteners and these were sized to support a minimum load of 250 pounds (1112 N). This was the load initially thought to be adequate for residential and care type occupancy applications. In most instances, the diameter of the screw used was as large as the hanger would accommodate up to a maximum of 3/8 inch (0.95 cm) which is a limit for insertion into the short edge of a nominal 2 in x 4 in (actual size 1-1/2 in x 3-1/2 in (3.8 cm x 8.9 cm)) lumber. Guidance in the selection and use of wood screws was obtained from the National Design Specification for Stress-Grade Lumber and Its Fastenings [14], the Wood Handbook [15], and Holding Power of Wood Screws [16].

Several of the strap hangers made of light gage steel or copper were fastened with screws one size smaller than the maximum size they could accommodate for the purpose of exploring the effect on performance of hanger system strength of screw size. Additionally, several hangers tested were fastened with the maximum size screw plus appropriately sized washers for the purpose of exploring the possible benefit of washers. In instances where the screws designed for a 250 pound (1112 N) load pulled out of the wood during testing, additional samples were tested using machine bolts that extended all the way through the nominal 2 in x 4 in wood and included washers and nuts on the top side.

The perforated copper banding was initially fastened to the nominal 2 in x 4 in joist with screws shorter than required by design. The test specimens incorporating washers - and thereby transmitting the greatest load to the wood-screw interface - did not fail at the connections, so additional tests with the correct size screws were not conducted.

All tests incorporated the use of washers (see table 3) except for the following: lightweight strap hanger tests mentioned above, tests incorporating flat head screws mating to countersunk hanger holes, and tests of the 5/8 in (1.6 cm) strap hangers where additional samples of the hangers initially tested were not available.

# 4. TEST METHODS

## 4.1. Tensile Tests

Each of the strap hangers was fastened to the short edge of a nominal 2 in x 4 in joist (actual size 1-1/2 in x 3-1/2 in (3.8 cm x 8.9 cm)). Appropriately sized pilot holes were drilled for each screw and the screw was lubricated with floating white soap to ease insertion. A substitute for a pipe was inserted in each hanger loop as shown in figure 4 and the fastening screws were tightened. The copper banding was attached as shown in figure 5. Each assembly was then positioned in the testing machine and pulled at an elongation rate of 0.05 inch per minute (0.13 cm/min) until continued pulling caused no increase in load.

## 4.2. Fire Tests

For the first test, one wood crib was placed in the burn room. Several hangers were installed on the joist and weights suspended from the hangers as shown in table 2. A test load varying from 75 lb (334 N) to 250 lb (1112 N) was applied to sample hangers through short sections of steel pipe to simulate a sprinkler system suspended from wood joists in a ceiling. The crib was ignited using 100 ml of heptane in a container centered under the crib. The time from ignition of the liquid fuel to failure of the hangers as well as the ceiling temperature at each failure occurrence was recorded. It was noted during the first test that the combustion of one crib did not produce the desired ceiling temperatures of the range of 900-1200 °F (482 to 649 °C), and the decision was made to utilize 2 cribs in all additional fire tests. Both cribs were ignited simultaneously, using 100 ml of heptane each. The time and ceiling temperature for each hanger failure was recorded and is shown in table 2. In the initial test, the crib was allowed to burn out. In subsequent tests, the crib fires were extinguished as soon as failure of the hangers occurred.

# 5. RESULTS

## 5.1. Load Failure Tests

### 5.1.1. Split Ring Hangers

The load failure values (see table 3) obtained for the split-ring hangers for both the nominal 1-inch and the 1-1/4 inch pipe far exceeded the NFPA 13 load requirement. It should be noted that the comparison of hangers in table 4 is based on the highest hanger mode failure and excludes consideration of those data related to fastener failure. Failures were usually by cracking of the beam attachment plate around the threaded hole for the hanger rod. Variation in screw size from No. 12 to No. 14 had no effect on the performance of the hanger.

### 5.1.2. Steel Strap Hangers (2 Hole)

The performance of the nominal 1-1/4 inch and 2 inch two-hole steel strap hangers also far exceeded the NFPA 13 load requirement. These hangers are 11/32 inch wide by 0.024 inch thick (0.87 x 0.06 cm) and 1-1/4 inch wide by 0.086 inch thick (3.18 x 0.22 cm), respectively. One of the nominal 1-1/4 inch hangers broke at the sharp bend near the part that attaches to the building element, and another failed by pulling the screws. The bolt heads broke off in all of the tests of the nominal 2-inch hangers incorporating through-bolts. Through-bolts were used because hangers with lag bolts had failed by the bolts pulling out of the wood.

### 5.1.3. Copper Plated Steel Strap Hangers (2 Hole)

The more lightly constructed nominal 3/4 inch and 1-1/2 inch two-hole copper plated steel strap hangers also met the NFPA 13 load requirement. These hangers are 7/16 inch wide by 0.018 inch thick (1.11 x 0.05 cm) and 3/4 inch wide by 0.034 inch thick (1.91 x 0.09 cm), respectively. The typical failure mode was shear of the hanger around the screw head or washer. The use of washers always resulted in some increase in the average failure load, and the use of undersized screws always resulted in some decrease in the average failure load.

### 5.1.4. Copper Strap Hangers (2 Hole)

The nominal 5/8 inch, 1 inch and 1-1/4 inch two-hole copper strap hangers also met the NFPA 13 load requirement.

These hangers are 3/8 inch wide by 0.032 inch thick (0.95 x 0.08 cm), 1/2 inch wide by 0.028 inch thick and 9/16 inch wide by 0.045 inch thick (1.43 x 0.11 cm), respectively. The performance characteristics of these were the same as the copper plated steel strap hangers.

### 5.1.5. Malleable Iron Strap Hangers (1 Hole)

The nominal 3/4 inch, 1 inch, 1-1/2 inch, and 2 inch one-hole malleable iron strap hangers failed to meet the NFPA 13 load requirement. The design variations are numerous, difficult to describe or draw and are therefore here characterized only by width and thickness both of which are measured in the plane of the top surface through which the fastener passes. The thickness is not uniform being much greater at the edges with a relatively thin webbing in between. These hangers are 13/16 inch wide by 9/32 inch thick (2.06 x 0.71 cm), 27/32 inch wide by 9/32 inch thick (2.14 x 0.71 cm), 1-5/32 inch wide by 11/32 inch thick (2.94 x 0.87 cm), and 1-1/8 inch wide by 5/8 inch thick (2.86 x 1.59 cm), respectively. The load failure values for the nominal 3/4 inch hangers ranged from 80 to 145 lb (346-645 N). The values for the nominal 1-inch hangers ranged from 205 to 225 lb (912-1001 N). The values for the nominal 1-1/2 inch hangers ranged from 300 to 325 lb (1335-1446 N). The values for the nominal 2-inch hangers ranged from 575 to 600 lb (2559-2670 N). The failure mode for each was by uncurling of the strap.

Only the nominal 1-1/4 inch one-hole strap hanger met the NFPA 13 load requirement. This hanger is 25/32 inch wide by 13/32 inch thick (1.98 x 1.03 cm).

### 5.1.6. Perforated Copper Banding

The load failure values for the perforated copper banding when attached without washers to the bottom on the nominal 2 inch x 4 inch (3.8 cm x 8.9 cm) piece of wood ranged from 130 to 210 lb (578-934 N) which is less than the NFPA 13 load requirement. The banding is 3/4 inch (1.91 cm) wide by 0.027 inch (0.07 cm) thick with 11/32 inch (0.87 cm) holes spaced 3/4 inch (1.91 cm) on centers. The failure mode was deformation of the banding at the attachment perforation. When the banding was attached without washers to the side of the nominal 2 inch x 4 inch (3.8 cm x 8.9 cm) joist, higher values ranging from 460 to 510 lb (2047-2270 N) were obtained. The failures were characterized by enlargement of the attachment hole and the subsequent pull-through of the screw.

The addition of steel flat washers to additional samples in both side and bottom attachment configurations resulted in an increased failure load. A substantial strength improvement ranging from 480 to 550 lb (2136-2448 N) was noted in those with the banding attached to the bottom of the nominal 2 inch x 4 inch (3.8 x 8.9 cm) joist. Failure was, in two instances, by shear of the banding at the edge of the washer and, in one instance, by elongation of the banding at a hole located several holes from a connection. A marginal strength improvement ranging from 540 to 580 lb (2403-2581 N) was noted in those tests with the banding attached on the side of the joist. Failure was by elongation of the banding at a hole located several holes from a connection.

As might be expected, hangers incorporating two fasteners performed better than hangers with one fastener. None of the two fastener hangers failed structurally under the NFPA 13 required load but all except the nominal 1-1/4 inch size of the one fastener hangers did.

## 5.2. Fire Tests

Fire test No. 1 showed first, that the ceiling temperatures obtained from the combustion of one 70 lb (31.8 kg) crib did not reach the temperatures that would result from a typical building fire; and second, that the perforated copper banding fails under a load of 75 lb (334 N) due to enlargement of the fastener holes at relatively low temperatures 482 °F (250 °C) (see figure 6).

In fire tests 2 through 4 (figures 7 through 9) failure occurred at times ranging between 9 and 17 minutes when the screws and lag bolts pulled out of the joist after thermal degradation had reduced the amount of wood at the point of attachment of the hanger to the joist. There was no apparent relationship between the amount of load and the failure time and temperature. In each instance, the joist was well involved in flames, and temperatures at the ceiling exceeded 932 °F (500 °C).

In fire test No. 5 (figure 10) a nominal 1-inch diameter section of pipe was suspended from 2 split swivel rings. The 500 lb (227.3 kg) load was evenly distributed along the pipe length. Failure occurred when the hanger rod pulled out of the base plate of one hanger causing the weights to be released. The second hanger was sheared off at the hinges.

Test No. 6 (figure 11) consisted of a similar setup, the difference being that each hanger supported a 250 lb (1112 N) load separately. During the development of the fire it was noted that both weights swayed slightly due to the air currents caused by the fire. Both hangers then sheared at the hinges, at temperatures lower than those expected from the previous tests. Both hanger base plates remained intact, i.e., no separation of rod from base plate or extraction of bolts from the beam occurred. These results can be interpreted as indicating that although this type of hanger is adequate to sustain the minimum required load, it is not adequate to sustain a moment acting through the hinges.

## 6. CONCLUSIONS

The following conclusions are based upon 6 fire endurance tests of 5 types of hangers under load and 96 load failure tests of 6 types of hangers:

1. Fire tests indicate that wood joists supporting the prescribed load of a sprinkler pipe hanger must be exposed to substantial fire for at least nine minutes before thermal degradation of the wood causes release of the fasteners.

2. There was no clear evidence that time to failure under fire exposure was related to load over the range of loads examined (100 to 200 lb).

3. The fact that ceiling temperatures during the fire tests exceeded 932 °F (500 °C) and that the supporting joists were well involved in the combustion process at the time of failure indicates that in situations with exposed hangers, the automatic sprinkler heads would actuate the extinguishing system to control the fire before collapse of the piping support.

4. Commonly available lightly constructed two-hole or two-fastener hangers for pipe, cable, and conduit are suitable for residential and care type sprinkler applications provided that they are properly fastened to the structure.

5. One-hole malleable iron strap hangers generally are not suitable for residential and care type automatic sprinkler applications since four of the five sizes tested failed at less than the NFPA 13 load requirement.

6. Copper is not suitable for use as a structural element of hangers for automatic sprinkler systems that might be exposed to an average ambient air temperature, exceeding 200 °C (the recrystallization or annealing temperature of pure copper metal).

7. The load can be assumed to be distributed evenly between two fasteners on a hanger, and therefore each fastener should be designed to support one-half of the load.

8. Washers are of benefit in every connection of thin strap metal to wood and essential for connection of copper banding to the bottom of joists.

9. Undersized screws reduce the strength of hanger assemblies made of thin strap metal.

10. Except for the nominal 2-inch, one-hole strap hanger and the copper banding used to support a nominal 2-inch pipe, none of the hangers benefit, from the standpoint of meeting the NFPA 13 load requirement, by reduction of hanger spacing below 15 feet.

## 7. GUIDELINES FOR THE SELECTION OF FASTENERS

### 7.1. Fastener Selection

Since the strength of screw connections increases with screw diameter as well as length, the process of selection should begin with a determination of the largest size screw that will pass through the fastener hole in the hanger snugly but without force. Thereafter, the determination of appropriate screw sizes may be made from tables 13, 14, 18, and 19 in the National Design Specification for Stress Grade Lumber [14]. Data in those tables is based on the formulas that follow.

#### 7.1.1. Axially Loaded Wood Screws

Lengths of wood screws loaded axially are determined as follows:

$$l = \frac{L}{nFKG^2D}$$

where $l$ = total length of the screw (inches)

$L$ = load support requirement of the hanger (pounds)

$n$ = number of screws in the hanger connection

$G$ = specific gravity of the wood

$K$ = 2840

$D$ = body diameter of the screw (inches)

$F$ = fraction of threaded part to total length of the screw. (0.667 for wood screws)

This simplifies to the following:

$$l = \frac{L}{1894\ nG^2D}$$

### 7.1.2. Laterally Loaded Wood Screws

The size of wood screws loaded laterally is determined with the following formula:

$$D = \sqrt{\frac{L}{K}}$$

where $K$ = 4800 (wood specific gravities from 0.62 to 0.75)

= 3960 (wood specific gravities from 0.51 to 0.54)

= 3240 (wood specific gravities from 0.42 to 0.48)

= 2520 (wood specific gravities from 0.31 to 0.41)

$L$ = load support requirement of the hanger (pounds)

$D$ = body diameter of the screw (inches)

Laterally loaded screws must be embedded in the wood a distance of 7 times the body diameter of the screw to provide the lateral strength given in the formula.

### 7.1.3. Axially Loaded Lag Bolts

Lengths of lag bolts loaded axially are determined with the following formula:

$$l = \frac{L}{nFKG^{1.5}D^{0.75}}$$

where K = 1800

F = 0.667

This simplifies to the following:

$$l = \frac{L}{1200\ nG^{1.5}D^{0.75}}$$

## 7.2. Pilot Hole Requirements

All connections to wood made with non-self-drilling types of wood screws require appropriately sized pilot holes in order to develop maximum strength. The withdrawal resistance and the lateral support capability of a wood screw is dependent upon the relationship between the diameter of the pilot hole and the root (minor) diameter of the screw. Lateral support capability also is dependent upon the relationship between the diameter of the pilot hole and the body, shank or major diameter of the screw. Unfortunately, standards for wood screws do not specify the dimension of the root (minor) diameter. The wood screw manufacturing industry has established the practice of making the root diameter 67 percent of the body diameter. From this estimate of the root diameter, the pilot hole sizes can be determined based on the following rules provided by the National Design Specification and given here in tables 6 and 7 for woods commonly used in building construction (specific gravities of 0.64 and less).

For axial loading:

1. For wood specific gravities greater than 0.65, the lead hole should approximate 90 percent of the root diameter.

2. For wood specific gravities less than 0.64, the lead hole should approximate 70 percent of the root diameter.

For lateral loading:

1. For wood specific gravities greater than 0.65, the lead hole receiving the shank should approximate the diameter of the shank, and that receiving the threaded portion, should approximate the root diameter.

2. For wood specific gravities less than 0.64, the part of the hole receiving the shank should approximate 7/8 of the diameter of the shank and that for the threaded portion should approximate 7/8 of the root diameter.

### 7.3. Self-Drilling and Tapping Screws

Recent innovations by certain screw manufacturers are the self-drilling and tapping screws. The existence of these types of wood fasteners was not discovered until after the experimental work was completed and therefore none were used in these tests. Research by others on the holding power of these fasteners shows promise for their use for hanger attachment [17,18]. If these fasteners can be used without the requirement for pilot holes as reported, a great saving in installation time can be realized and the dependence on good craftsmanship can be considerably reduced.

## 8. ACKNOWLEDGMENTS

The authors are grateful to Mr. Klaus Wahle who did the groundwork to initiate this investigation and under whose direction the fire tests were conducted. Mr. John Grimes and Mr. Richard Zile also are to be acknowledged for attention to detail during the fabrication and testing of the numerous load test samples. The efforts of Josephine Ledford, Phyllis Martin, and Clare Metzel all of whom lent a hand at typing the several revisions are appreciated.

## 9. REFERENCES

[1] Minimum Property Standards for Multi-family Housing, FHA 2600, General Revision No. M-23, Department of Housing and Urban Development, Federal Housing Administration, Washington, D.C. (Oct. 1973).

[2] Minimum Property Standards, Housing for the Elderly with Special Consideration for the Handicapped, HUD PG 46, General Revision No. E-3, Department of Housing and Urban Development, Federal Housing Administration, Washington, D.C. (Oct. 1973).

[3] Minimum Property Standards for Nursing Homes, FHA 4514, Change No. 5, Department of Housing and Urban Development, Federal Housing Administration, Washington, D.C. (Oct. 1973).

[4] Minimum Property Standards for Multi-family Housing, Volume 2, 4910.1, Department of Housing and Urban Development, Federal Housing Administration, Washington, D.C. (1973).

[5] Minimum Property Standards for Care-Type Housing, Volume 3, 4920.1, Department of Housing and Urban Development, Federal Housing Administration, Washington, D.C. (1973).

[6] Installation of Automatic Sprinkler Systems, NFPA No. 13, National Fire Protection Association, Boston, MA (1976 Revision).

[7] Custer, R.L.P. and Wahle, K., Distribution of Water Through a Vertical Plane from Automatic Sprinkler Heads, Nat. Bur. Stand. (U.S.), NBSIR 75-920 (December 1975). NTIS Order No. PB 248913; $4.00.

[8] Standard for Pipe Hanger Equipment for Fire Protection Service, UL 203, Underwriters' Laboratories, Inc., Northbrook, IL.

[9] Factory Mutual Approval Standard, Pipe Hanger Components for Automatic Sprinkler Systems, Class Nos. 1951, 1952, 1953 (January 1975), Factory Mutual Research, Norwood, MA.

[10] Personal Communication with Miles R. Suchomel, Underwriters' Laboratories, Inc.

[11] Personal Communication with William Testa, Grinnell Fire Protection Systems, Inc., Chairman of NFPA 13, Chapter 3 Subcommittee.

[12] Federal Specification for Pipe Hangers and Supports, WW-H-171D (October 19, 1970).

[13] Federal Specification for Strap, Retaining (Metal for Conduit, Pipe, and Cable) FF-S-760a, April 30, 1964, and Amendment 2, August 26, 1966.

[14] National Design Specification for Stress-Grade Lumber and Its Fastenings, National Forest Products Association, Technical Services Division, Washington, D.C. (1973).

[15] Wood Handbook: Wood as an Engineering Material, U.S. Department of Agriculture Handbook 72 (Revision 1974). GPO/$7.85.

[16] Holding Power of Wood Screws, I. J. Fairchild, Technological Paper No. 319, National Bureau of Standards.

[17] Stern, E. G., Wood Screws for Building Construction and Wood Products Assembly, Wood Research Laboratory, Virginia Polytechnic Institute, Bulletin No. 39 (May 1959).

[18] Wilkinson, T. L. and Laatch, T. R., Lateral and Withdrawal Resistance of Tapping Screws in Three Densities of Wood, Forest Products Journal, Vol. 20, No. 7 (July 1970).

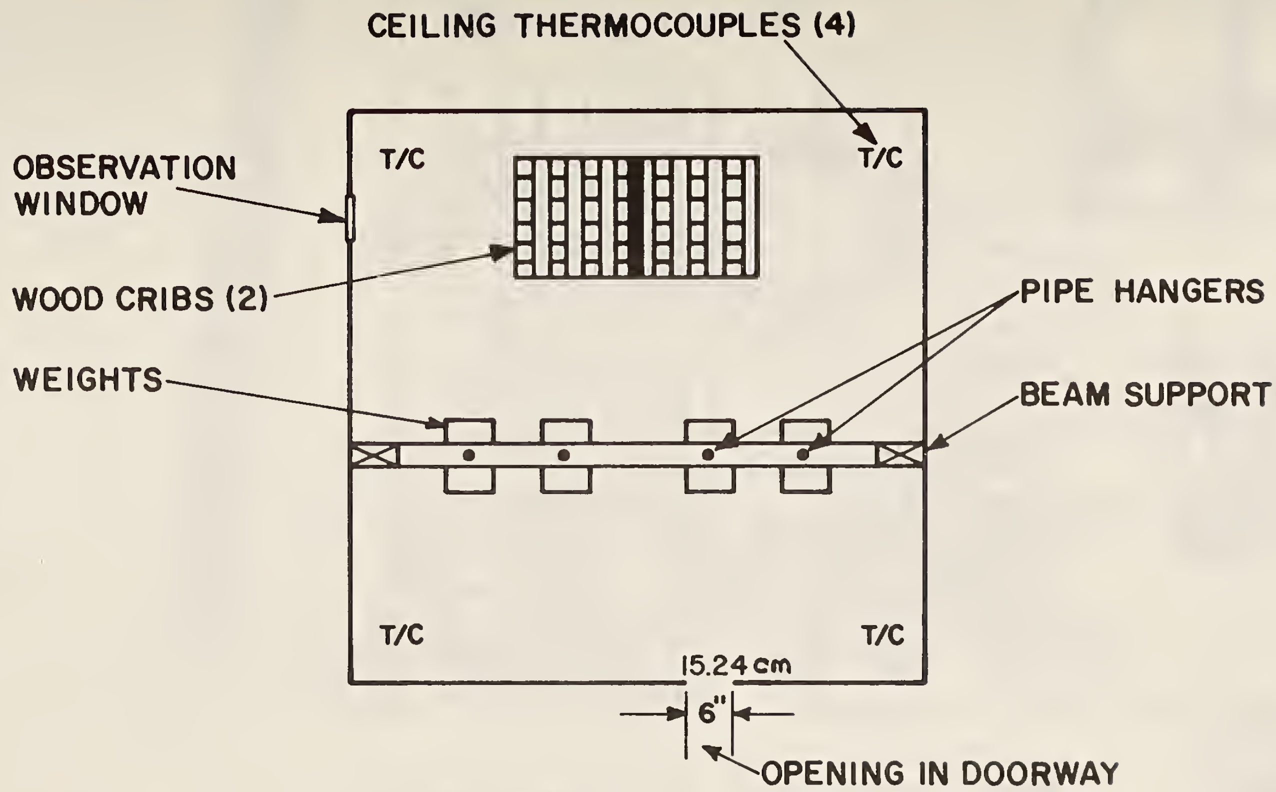


Figure 1. Plan View of the Burn-Room Configuration

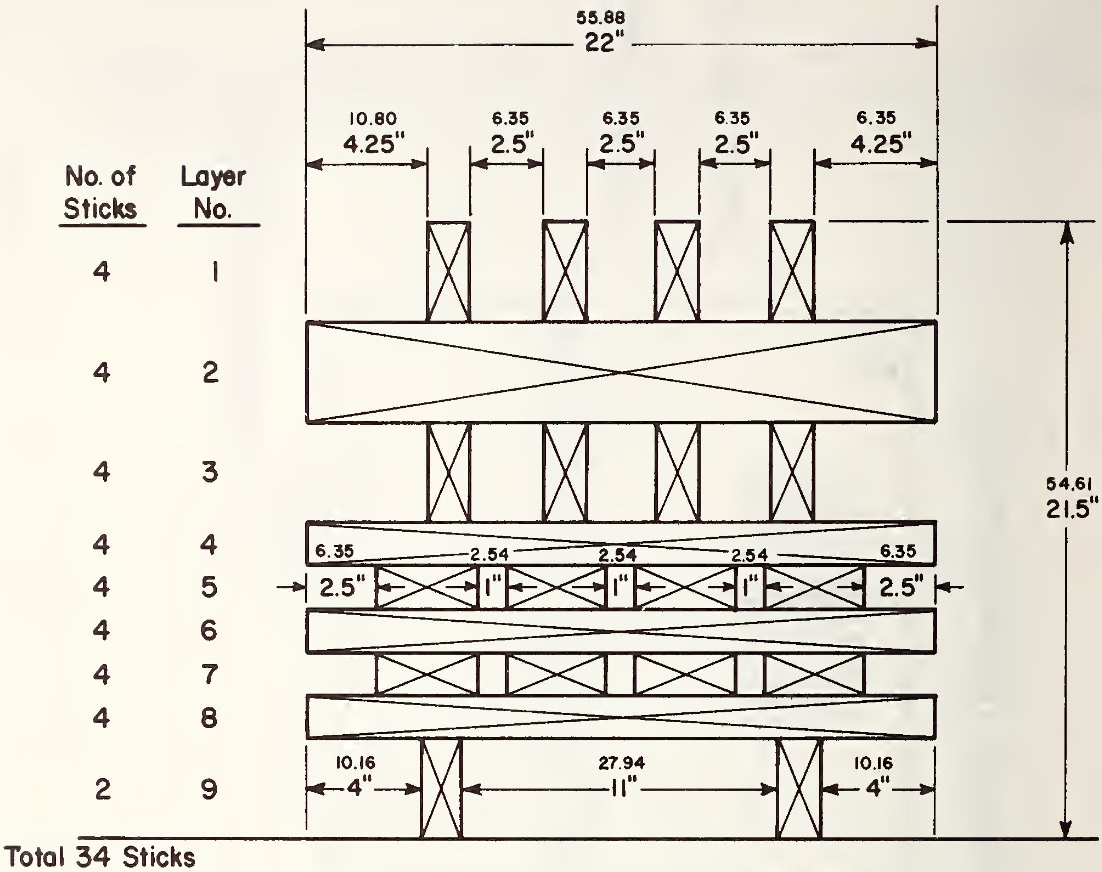


Figure 2. Wood Crib Assembly

Note: The numerals above the English dimensions are metric equivalents in centimeters.

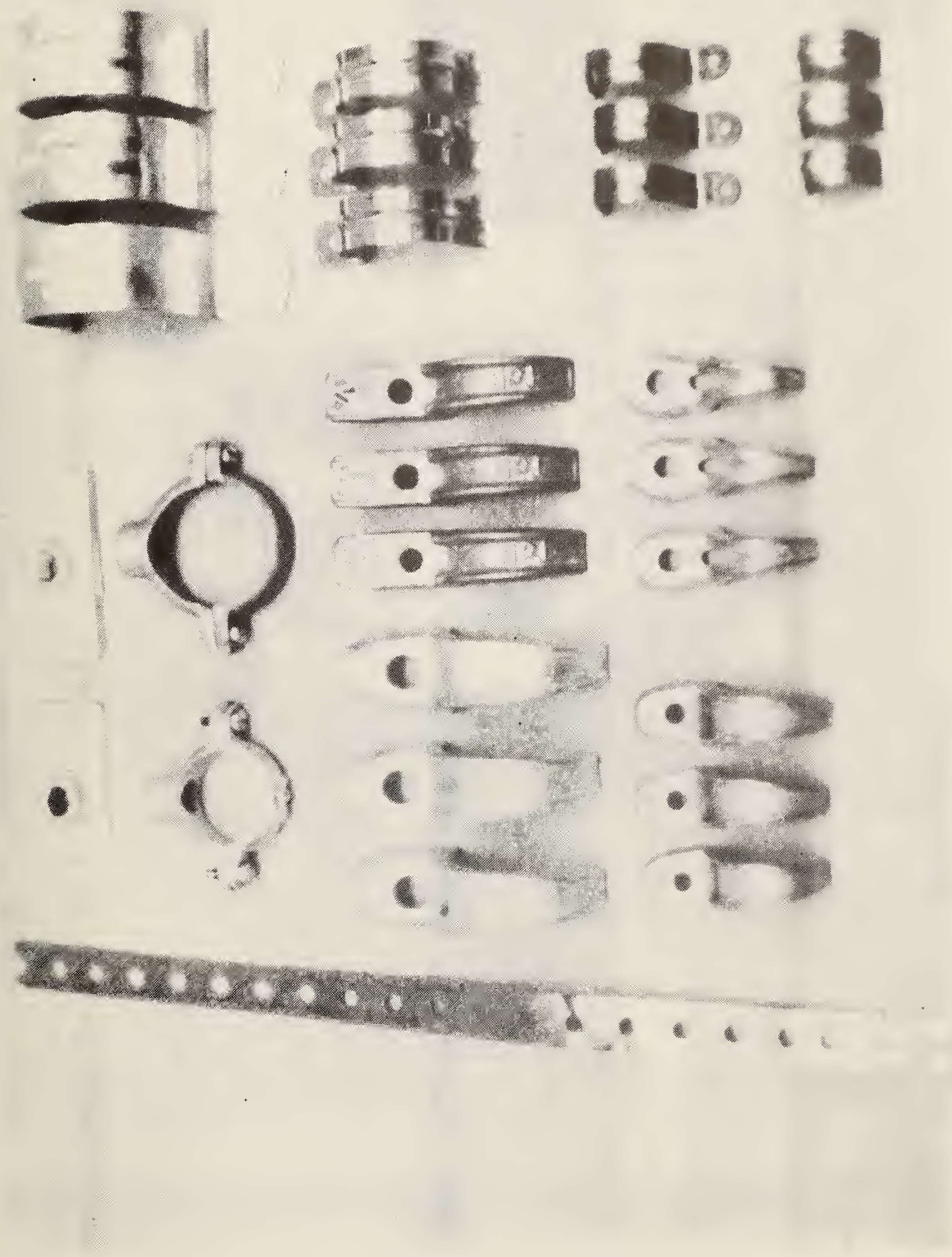

Figure 3. Display of Types of Hangers Tested

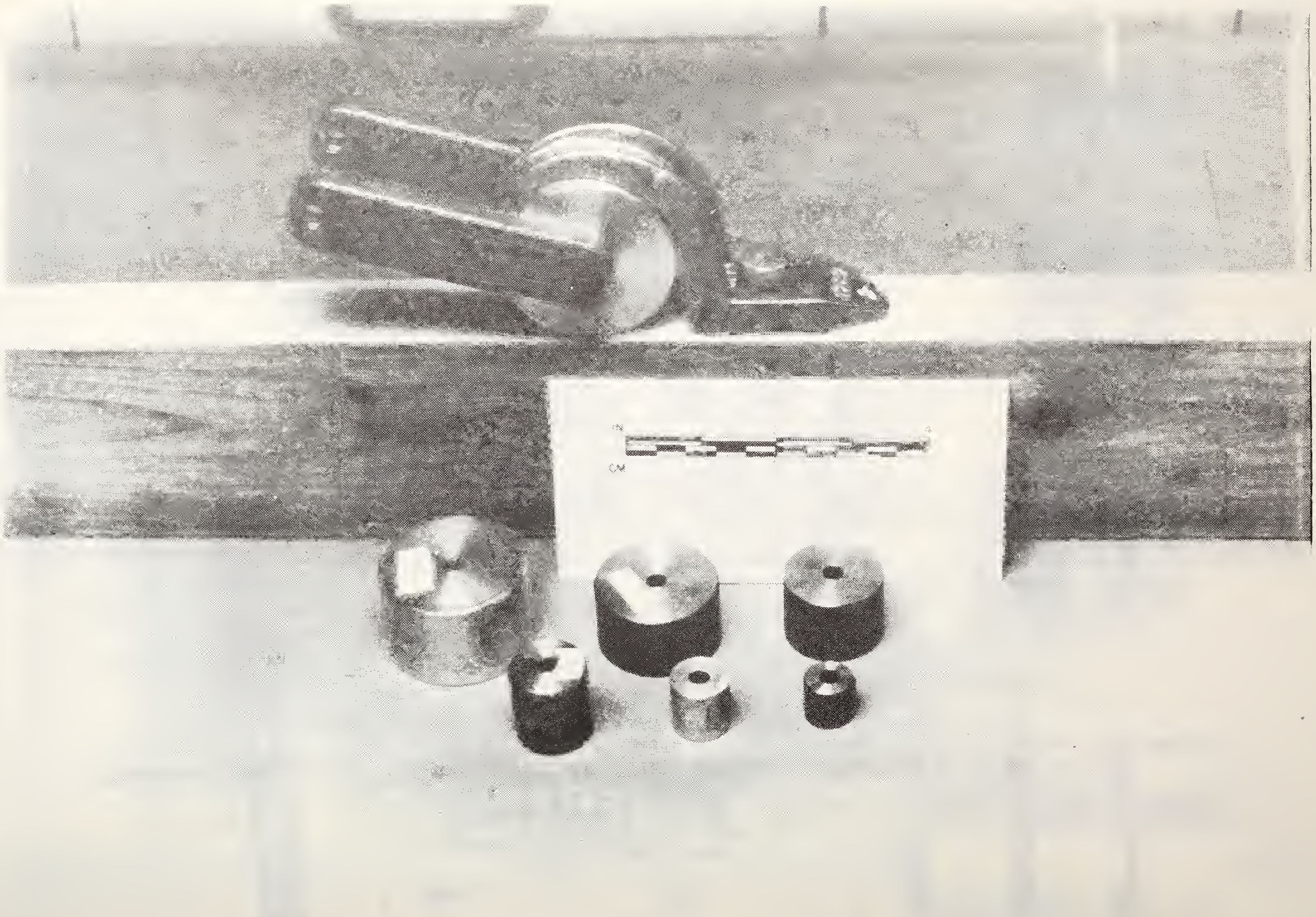

Figure 4. Strap Hanger Connection to Wood Joist

Note: During tests the linkage was normal to the joist and the assembly was inverted from that shown in picture.

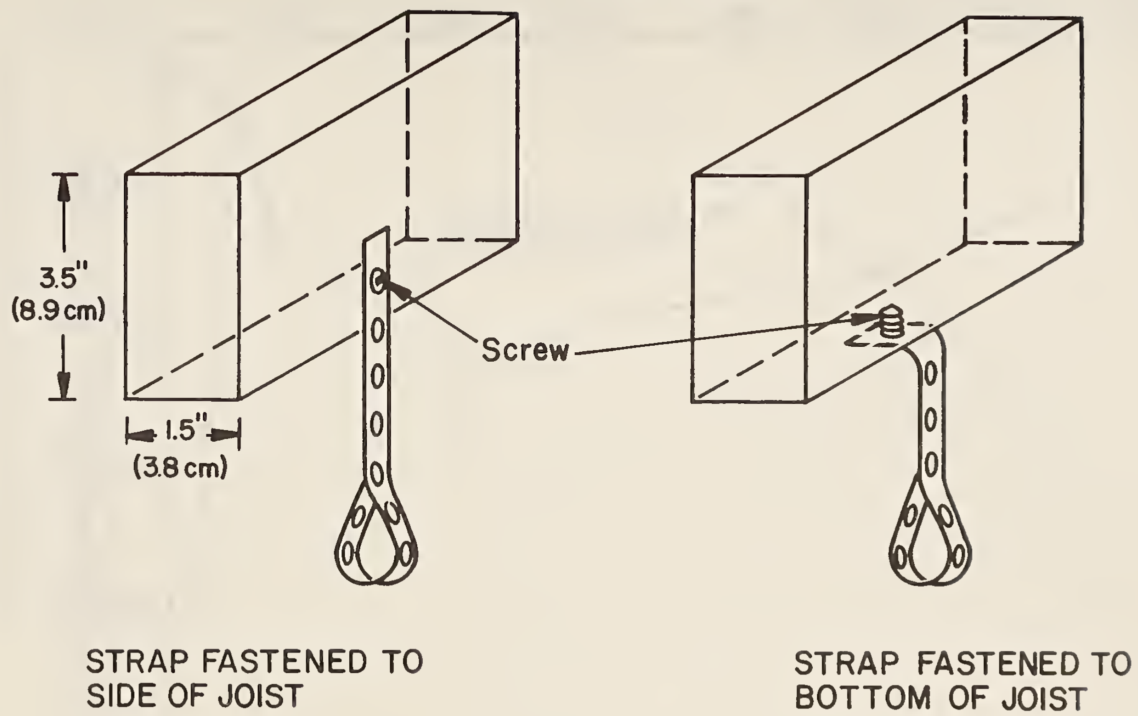


Figure 5. Copper Banding Connections to Wood Joist

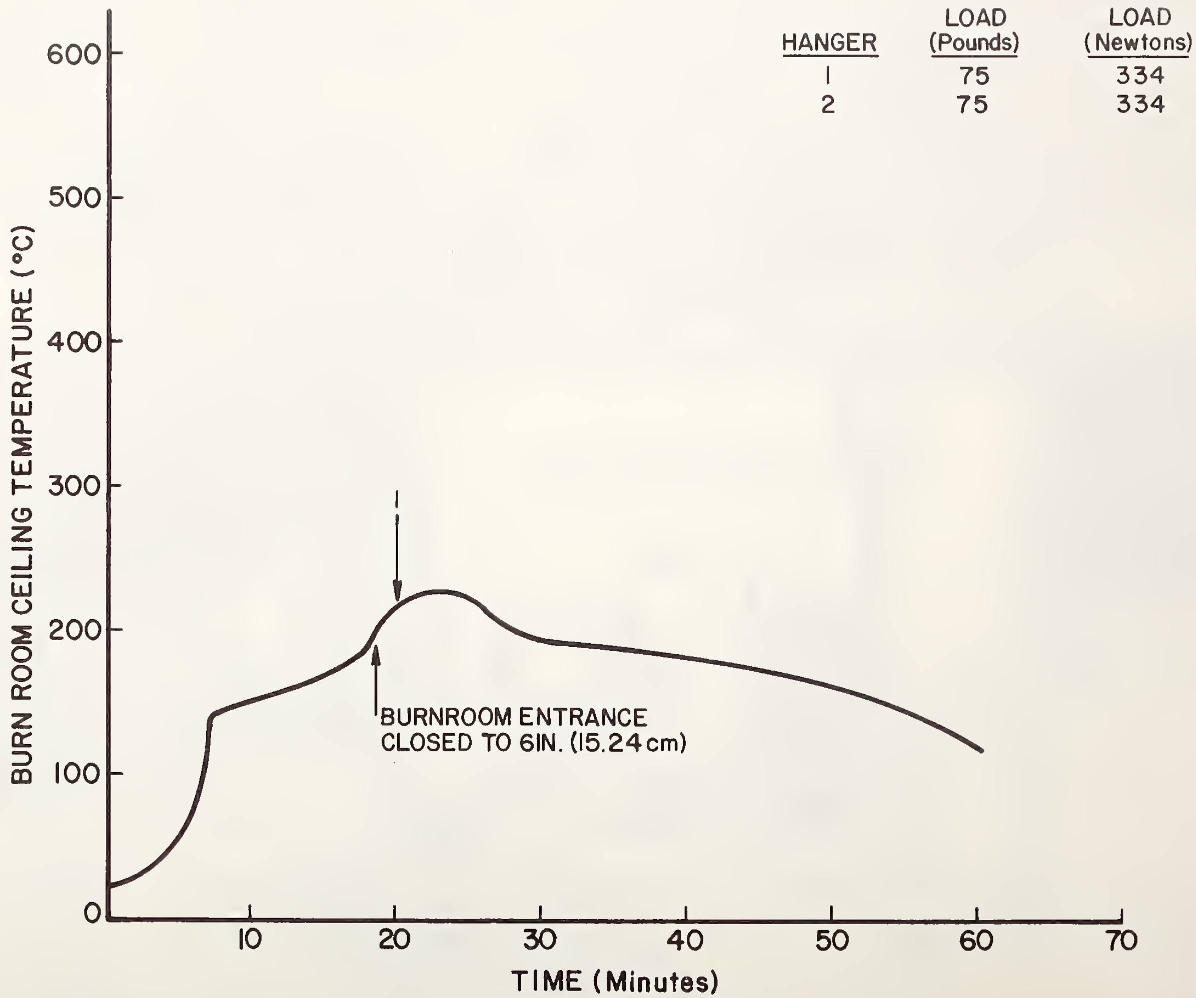


Figure 6. Temperature versus Time Graph of Fire Test Number 1
Note: Numbered arrow on graph marks the time given in table 2 at which the numbered hanger failure occurred.

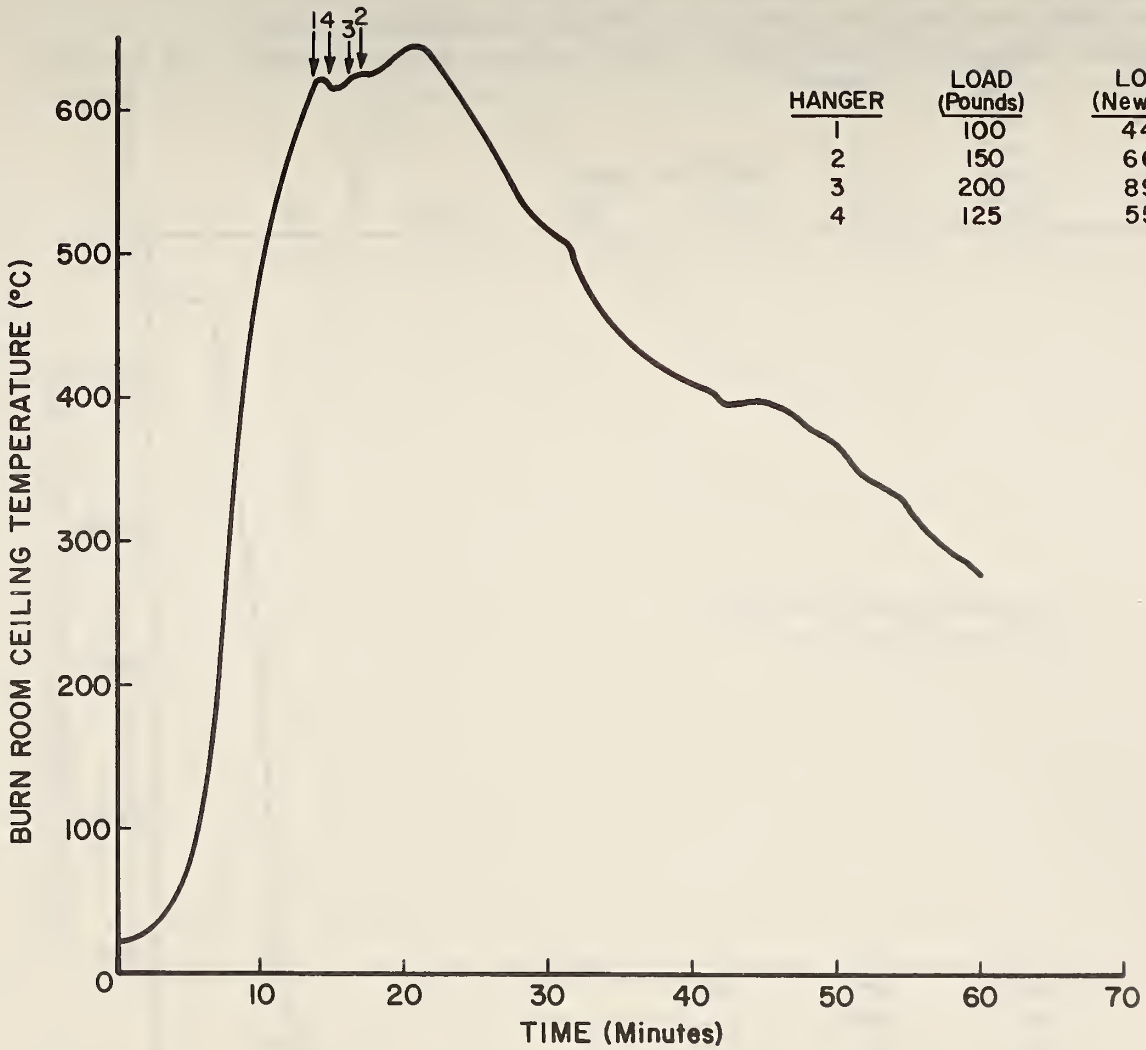


Figure 7. Temperature versus Time Graph of Fire Test Number 2
Note: Numbered arrow on graph marks the time given in table 2 at which the numbered hanger failure occurred.

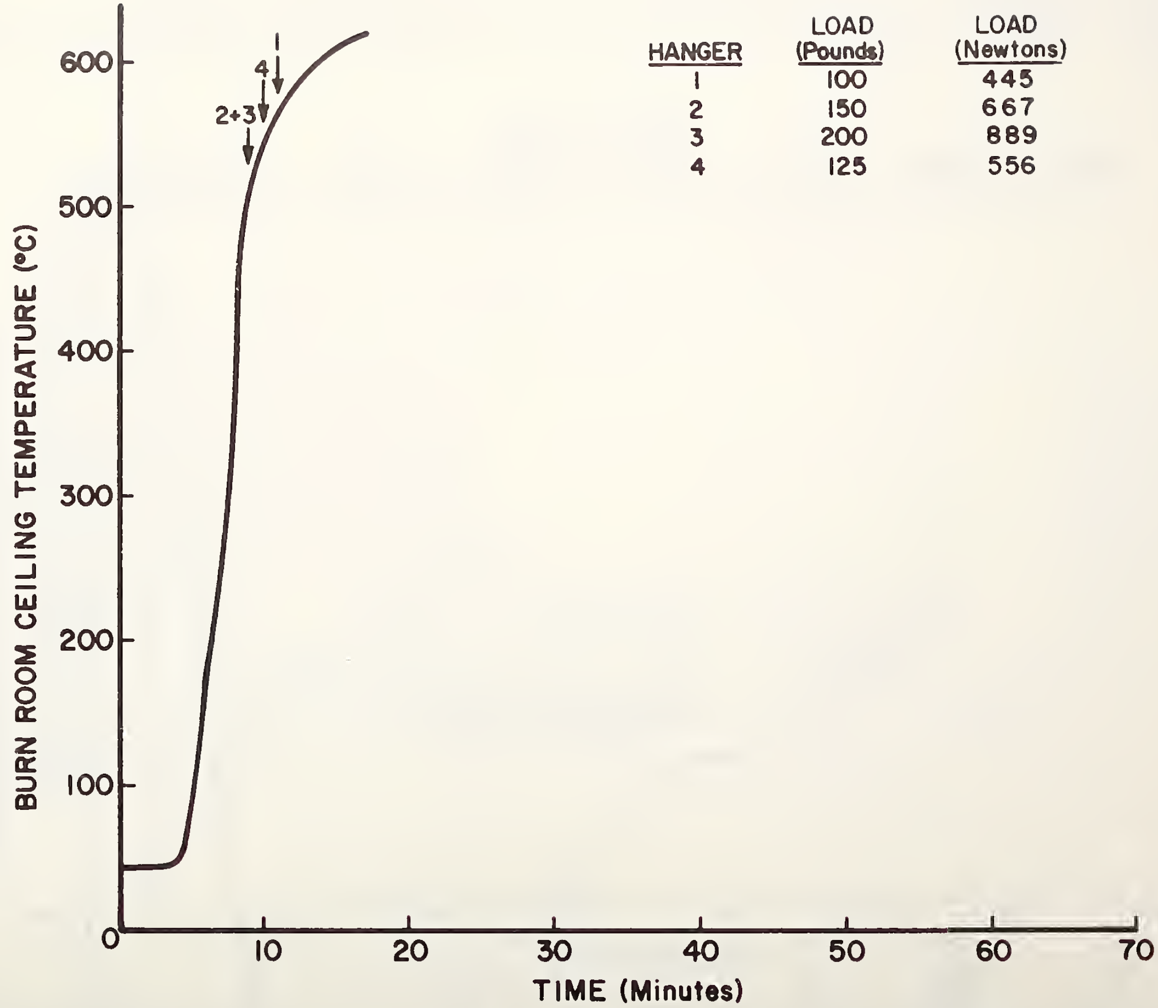


Figure 8. Temperature versus Time Graph of Fire Test Number 3
Note: Numbered arrow on graph marks the time given in table 2 at which the numbered hanger failure occurred.

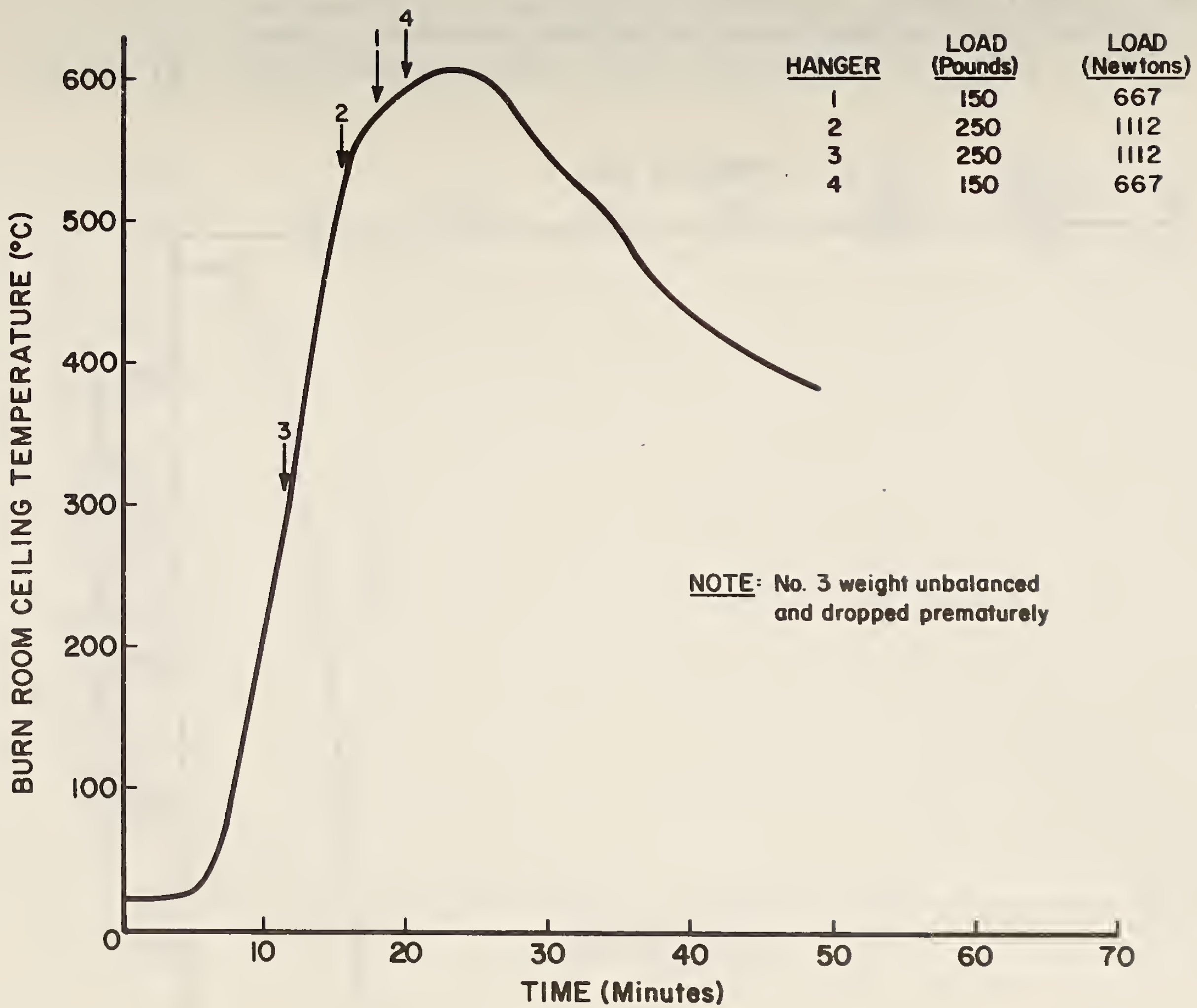


Figure 9. Temperature versus Time Graph of Fire Test Number 4
Note: Numbered arrow on graph marks the time given in table 2 at which the numbered hanger failure occurred.

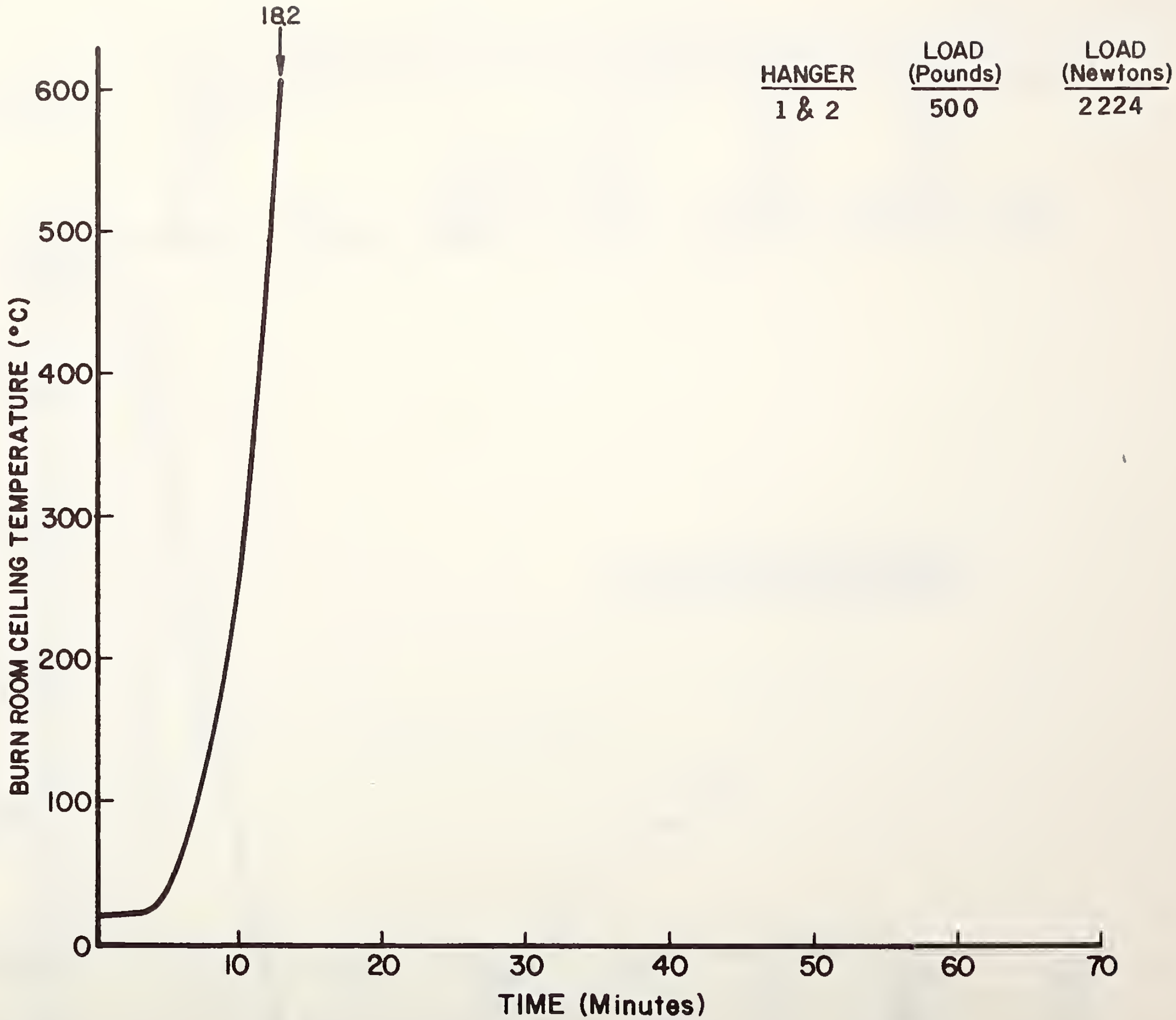


Figure 10. Temperature versus Time Graph of Fire Test Number 5
Note: Numbered arrow on graph marks the time given in table 2 at which the numbered hanger failure occurred.

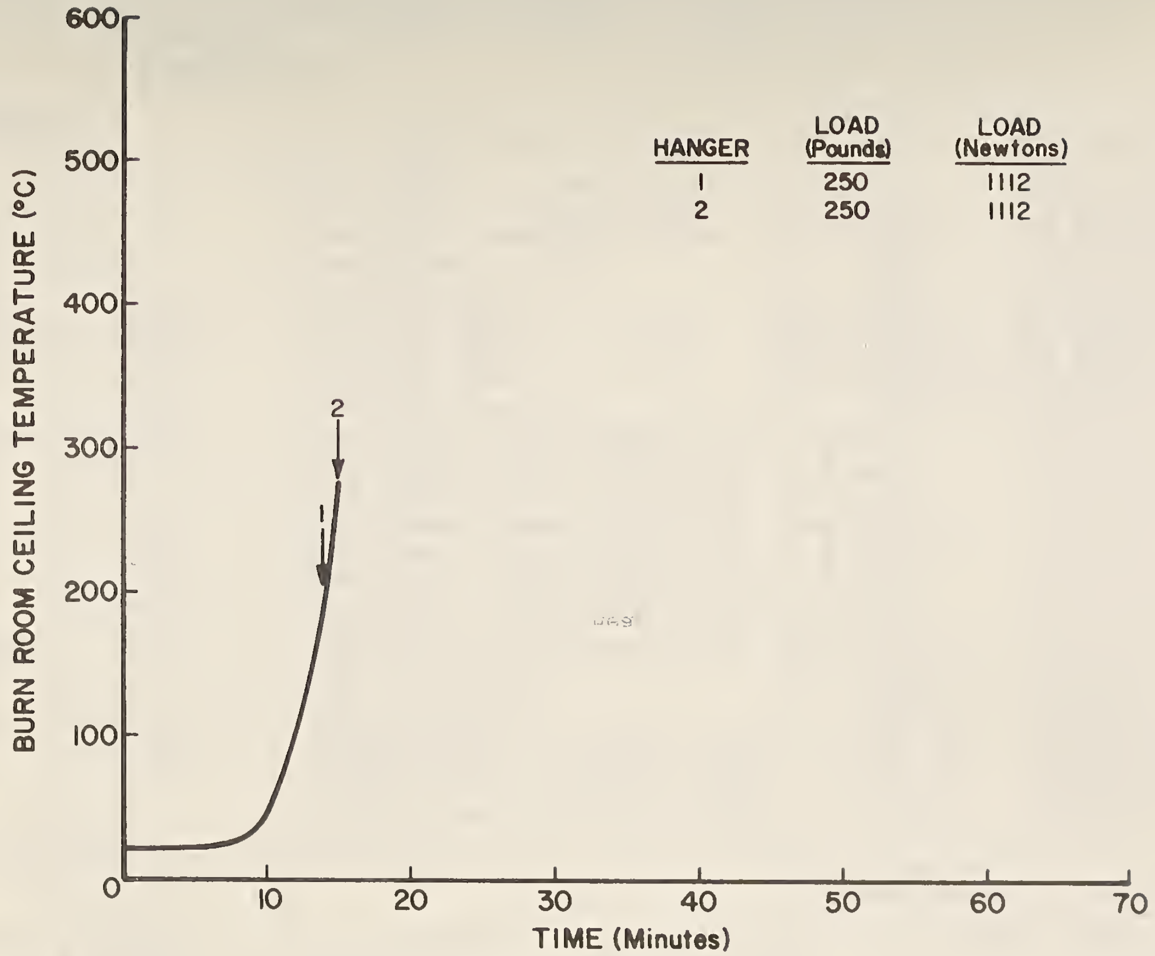


Figure 11. Temperature versus Time Graph of Fire Test Number 6
Note: Numbered arrow on graph marks the time given in table 2 at which the numbered hanger failure occurred.

Table 1. Pipe Hanger Summary

| Hanger | | Fastener | | | |
|---|---|---|---|---|---|
| Type | Nominal Pipe Size (in) | Type | Size (diameter x length) Number/inches (x inches) | (in) | (cm) |
| Split Ring | 1 | Tapping Screw, Flat Head, Steel | # 14x1-1/2 | 0.242x1.50 | 0.615x3.81 |
| | 1 | Tapping screw, Flat Head, Steel | # 12x1-3/4 | 0.216x1.75 | 0.549x4.44 |
| | 1-1/4 | Tapping Screw, Flat Head, Steel | # 14x1-1/2 | 0.242x1.50 | 0.615x3.81 |
| | 1-1/4 | Tapping Screw, Flat Head, Steel | # 12x1-3/4 | 0.216x1.75 | 0.549x4.44 |
| Strap, 2 Hole Galv. Steel | 1-1/4 | Lag Bolt, Steel | 1/4x1-1/2* | 0.250x1.50 | 0.635x3.81 |
| | 2 | Lag Bolt, Steel | 5/16x1* | 0.3125x1.00 | 0.794x2.54 |
| | 2 | Machine Bolt, Steel | 5/16x4* | 0.3125x4.00 | 0.794x10.16 |
| Strap 2, Hole Copper Plt. Steel | 3/4 | Wood, Screw, Round Head, Steel | # 10x2† | 0.190x2.00 | 0.483x5.08 |
| | 3/4 | Wood, Screw, Round Head, Steel | # 9x2 | 0.177x2.00 | 0.450x5.08 |
| | 1-1/2 | Wood, Screw, Round Head, Steel | # 10x2† | 0.190x2.00 | 0.483x5.08 |
| | 1-1/2 | Wood, Screw, Round Head, Steel | # 9x2 | 0.177x2.00 | 0.450x5.08 |
| Strap, 2 Hole Copper | 5/8 | Wood, Screw, Round Head, Steel | # 7x2-1/2 | 0.151x2.50 | 0.384x6.35 |
| | 5/8 | Wood, Screw, Round Head, Steel | # 6x2-1/2 | 0.138x2.50 | 0.351x6.35 |
| | 1 | Wood, Screw, Round Head, Steel | # 10x2† | 0.190x2.00 | 0.483x5.08 |
| | 1 | Wood, Screw, Round Head, Steel | # 9x2 | 0.177x2.00 | 0.450x5.08 |
| | 1-1/4 | Wood, Screw, Round Head, Steel | # 10x2† | 0.190x2.00 | 0.483x5.08 |
| | 1-1/4 | Wood, Screw, Round Head, Steel | # 9x2 | 0.177x2.00 | 0.450x5.08 |
| Strap, 1 Hole Galv. MI** | 3/4 | Lag Bolt, Steel | 1/4x2-1/2* | 0.250x2.50 | 0.635x6.35 |
| | 1 | Lag Bolt, Steel | 1/4x2-1/2* | 0.250x2.50 | 0.635x6.35 |
| | 1-1/4 | Machine Bolt, Steel | 5/16x4* | 0.3125x4.00 | 0.794x10.16 |
| | 1-1/2 | Lag Bolt, Steel | 5/16x2* | 0.3125x2.50 | 0.794x6.35 |
| | 1-1/2 | Lag Bolt, Steel | 3/8x2* | 0.375x2.00 | 0.953x5.08 |
| | 2 | Lag Bolt, Steel | 3/8x2* | 0.375x2.00 | 0.953x5.08 |
| | 2 | Machine Bolt, Steel | 3/8x4* | 0.375x4.00 | 0.953x10.16 |
| Banding Perforated Copper | | Wood Screw, Round Head, Brass | # 12x7/8 | 0.216x0.87 | 0.549x2.22 |
| | | Wood Screw, Flat Head, Steel | # 12x3/4* | 0.216x0.75 | 0.549x1.90 |
| | | Wood Screw, Flat Head, Steel | # 12x2* | 0.216x2.00 | 0.549x5.08 |

* All tests incorporated washers

** Malleable iron

† Three tests incorporated washers and three did not

Table 2. Fire Tests

| Test No. | Heat Source | Hanger Type | Hanger Nominal Pipe Size (in) | Fastener Type | Fastener Size (in) | Fastener Size (cm) | Load (lbs) | Load (N) | Failure Temperature (°F) | Failure Temperature (°C) | Failure Time (min:s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1-70 lb (31.75 kg) Crib | Perforated Copper Banding | | Wood Screw, Round Head, Brass | #12x7/8 | 549x2.22 | 75 | 334 | 419 | 215 | 20:00 |
| | | Strap, 2 Hole, Copper | 3/4 | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | 75 | 334 | No Failure | | No Failure |
| 2 | 2-70 lb (31.75 kg) Cribs | Strap, 1 Hole Galv MI* Cribs | 1-1/4 | Lag Bolt, Steel | 1/4x2 | .635x5.08 | 100 | 445 | 1139 | 615 | 13:45 |
| | | | 1-1/4 | Lag Bolt, Steel | 1/4x2 | .635x5.08 | 150 | 667 | 1130 | 610 | 14:45 |
| | | | 1-1/4 | Lag Bolt, Steel | 1/4x2 | .635x5.08 | 200 | 890 | 1115 | 624 | 16:10 |
| | | | 1-1/4 | Lag Bolt, Steel | 1/4x2 | .635x5.08 | 125 | 556 | 1115 | 624 | 17:00 |
| 3 | 2-70 lb (31.75 kg) Cribs | Strap, 2 Hole Galv. MI | 1-1/4* | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | 150 | 667 | 932 | 500 | 9:00 |
| | | | 1-1/4* | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | 200 | 889 | 932 | 500 | 9:00 |
| | | | 1-1/4* | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | 125 | 556 | 1015 | 546 | 9:45 |
| | | | 1-1/4* | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | 100 | 445 | 1015 | 546 | 9:46 |
| 4 | 2-70 lb (31.75 kg) Cribs | Strap, 1 Hole, Galv. MI | 1-1/2 | Lag Bolt, Steel | 1/4x3 | .635x7.62 | 250 | 1112 | 531 | 277 | 11:30 |
| | | | 1-1/2 | Lag Bolt, Steel | 1/4x3 | .635x7.62 | 250 | 1112 | 995 | 535 | 15:50 |
| | | Split, Swivel Ring | 1-1/2 | Wood Screw, Flat Head, Steel | #12x2-1/2 | .549x6.35 | 150 | 667 | 1065 | 574 | 18:00 |
| | | | 1-1/2 | Wood Screw, Flat Head, Steel | #12x2-1/2 | .549x6.35 | 150 | 667 | 1101 | 594 | 20:00 |
| 5 | 2-70 lb (31.75 kg) Cribs | Split, Swivel Ring** | 2 | Wood Screw, Flat Head, Steel | #12x2-1/2 | .549x6.35 | 500 | 2224 | 1126 | 608 | 12:39 |
| 6 | 2-70 lb (31.75 kg) Cribs | Split, Swivel Ring | 1 | Wood Screw, Flat Head, Steel | #12x2-1/2 | .549x6.35 | 250 | 1112 | 356 | 180 | 13:40 |
| | | | 1 | Wood Screw, Flat Head, Steel | #12x2-1/2 | .549x6.35 | 250 | 1112 | 500 | 260 | 14:50 |

* MI is an abbreviation for Malleable Iron.

** 1 in (2.54 cm) diameter pipe, 7 ft (2.13 m) long suspended between hangers spaced 5 ft (1.52 m) apart with load uniformly distributed on pipe.

Table 3. Load Failure Tests

| Hanger Type | Hanger Nominal Pipe Size (in) | Fastener Type | Fastener Size (in) | Fastener Size (cm) | Washer | Load (lbs) | Load (N) | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| Split Ring | 1 | Tapping Screw, Flat Head, Steel | #14x1-1/2 | .615x3.81 | No | 1495 | 6653 | Attachment Plate Broke, Clamp Cracked |
| Split Ring | 1 | Tapping Screw, Flat Head, Steel | #14x1-1/2 | .615x3.81 | No | 1295 | 5763 | Attachment Plate Cracked at Neck |
| Split Ring | 1 | Tapping Screw, Flat Head, Steel | #12x1-3/4 | .549x4.44 | No | 1520 | 6764 | Attachment Plate Cracked at Neck |
| Split Ring | 1 | Tapping Screw, Flat Head, Steel | #12x1-3/4 | .549x4.44 | No | 1345 | 5985 | Attachment Plate Cracked at Neck |
| Split Ring | 1-1/4 | Tapping Screw, Flat Head, Steel | #14x1-1/2 | .615x3.81 | No | 1460 | 6497 | Screws Pulled |
| Split Ring | 1-1/4 | Tapping Screw, Flat Head, Steel | #14x1-1/2 | .615x3.81 | No | 1400 | 6230 | Screws Pulled |
| Split Ring | 1-1/4 | Tapping Screw, Flat Head, Steel | #14x1-1/2 | .615x3.81 | No | 1400 | 6230 | Screws Pulled |
| Split Ring | 1-1/4 | Tapping Screw, Flat Head, Steel | #12x1-3/4 | .549x4.44 | No | 1440 | 6408 | Attachment Plate Cracked |
| Split Ring | 1-1/4 | Tapping Screw, Flat Head, Steel | #12x1-3/4 | .549x4.44 | No | 1550 | 6898 | Attachment Plate Cracked |
| Split Ring | 1-1/4 | Tapping Screw, Flat Head, Steel | #12x1-3/4 | .549x4.44 | No | 1510 | 6720 | Attachment Plate Cracked |
| Strap, 2 Hole Steel | 1-1/4 | Lag Bolt, Steel | 1/4x1-1/2 | .635x3.81 | Yes | 1500 | 6675 | |
| Strap, 2 Hole Steel | 1-1/4 | Lag Bolt, Steel | 1/4x1-1/2 | .635x3.81 | Yes | 1170 | 5206 | Screw Pulled |
| Strap, 2 Hole Steel | 1-1/4 | Lag Bolt, Steel | 1/4x1-1/2 | .635x3.81 | Yes | 1530 | 6808 | Broke at Bend |
| Strap, 2 Hole Steel | 2 | Lag Bolt, Steel | 5/16x1 | .794x2.54 | Yes | 685 | 3048 | Screw Pulled |
| Strap, 2 Hole Steel | 2 | Lag Bolt, Steel | 5/16x1 | .794x2.54 | Yes | 1195 | 5318 | Screw Pulled |
| Strap, 2 Hole Steel | 2 | Lag Bolt, Steel | 5/16x1 | .794x2.54 | Yes | 1175 | 5229 | Screw Pulled |
| Strap, 2 Hole Steel | 2 | Machine Bolt, Steel | 5/16x4 | .794x10.16 | Yes | 2835 | 12 616 | Bolt Head Broke Off |
| Strap, 2 Hole Steel | 2 | Machine Bolt, Steel | 5/16x4 | .794x10.16 | Yes | 3050 | 13 572 | Bolt Head Broke Off |
| Strap, 2 Hole Steel | 2 | Machine Bolt, Steel | 5/16x4 | .794x10.16 | Yes | 2790 | 12 415 | Bolt Head Broke Off |

Table 3. Load Failure Tests (continued)

| Hanger | | Fastener | | | Washer | Load | | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| Type | Nominal Pipe Size (in) | Type | Size | | | | | |
| | | | (in) | (cm) | | (lbs) | (N) | |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 290 | 1290 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 405 | 1802 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 280 | 1246 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 400 | 1780 | Strap Sheared At Edge of Washer |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 420 | 1869 | Strap Sheared At Edge of Washer |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 300 | 1335 | Strap Sheared At Edge of Washer |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 250 | 1112 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 320 | 1424 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 3/4 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 360 | 1602 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 820 | 3649 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 1020 | 4539 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 995 | 4428 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 1030 | 4584 | Screw Head Pulled Off |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 985 | 4383 | Strap Sheared At Edge of Washer |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 1115 | 4962 | Strap Sheared At Edge of Washer |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 1000 | 4450 | Screw Pulled Thru Strap Hole |
| Strap, 2 Hole Copper Plated Steel | 1-1/2 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 1080 | 4806 | Screw Pulled Thru Strap Hole |

Table 3. Load Failure Tests (continued)

| Hanger | | Fastener | | | Washer | Load | | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| Type | Nominal Pipe Size (in) | Type | Size (in) | Size (cm) | | (lbs) | (N) | |
| Strap, 2 Hole Copper | 5/8 | Wood Screw, Round Head, Steel | #7x2-1/2 | .384x6.35 | No | 435 | 1936 | Strap Broke At Screw Hole |
| Strap, 2 Hole Copper | 5/8 | Wood Screw, Round Head, Steel | #7x2-1/2 | .384x6.35 | No | 490 | 2180 | Strap Broke At Screw Hole |
| Strap, 2 Hole Copper | 5/8 | Wood Screw, Round Head, Steel | #7x2-1/2 | .384x6.35 | No | 550 | 2448 | Strap Broke At Screw Hole |
| Strap, 2 Hole Copper | 5/8 | Wood Screw, Round Head, Steel | #6x2-1/2 | .351x6.35 | No | 390 | 1736 | Strap Broke At Screw Hole |
| Strap, 2 Hole Copper | 5/8 | Wood Screw, Round Head, Steel | #6x2-1/2 | .351x6.35 | No | 380 | 1691 | Strap Broke At Screw Hole |
| Strap, 2 Hole Copper | 5/8 | Wood Screw, Round Head, Steel | #6x2-1/2 | .351x6.35 | No | 290 | 1290 | Strap Broke At Screw Hole |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 460 | 2047 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #10x2 | .483.5.08 | No | 505 | 2247 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 425 | 1891 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #10x2 | .483.5.08 | Yes | 580 | 2581 | Strap Sheared Around Washer |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 540 | 2403 | Strap Sheared Around Washer |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 575 | 2559 | Strap Sheared Around Washer |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 500 | 2225 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 525 | 2336 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 600 | 2670 | Strap Sheared Around Screw Head |

Table 3. Load Failure Tests (continued)

| Hanger | | Fastener | | | Washer | Load | | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| Type | Nominal Pipe Size (in) | Type | Size (in) | Size (cm) | | (lbs) | (N) | |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 405 | 1802 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 480 | 2136 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | No | 355 | 1580 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 535 | 2381 | Strap Sheared Around Washer |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 540 | 2403 | Strap Sheared Around Washer |
| Strap. 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #10x2 | .483x5.08 | Yes | 505 | 2247 | Strap Sheared Around Washer |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 375 | 1669 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | 440 | 1958 | Strap Sheared Around Screw Head |
| Strap, 2 Hole Copper | 1-1/4 | Wood Screw, Round Head, Steel | #9x2 | .450x5.08 | No | | | |
| Strap, 1 Hole MI* | 3/4 | Lag Bolt, Steel | 1/4x2-1/2 | .635x6.35 | Yes | 145 | 645 | Strap Uncurled |
| Strap, 1 Hole MI* | 3/4 | Lag Bolt, Steel | 1/4x2-1/2 | .635x6.35 | Yes | 140 | 623 | Strap Uncurled |
| Strap, 1 Hole MI* | 3/4 | Lag Bolt, Steel | 1/4x2-1/2 | .635x6.35 | Yes | 80 | 356 | Strap Uncurled and Cracked |
| Strap, 1 Hole MI | 1 | Lag Bolt, Steel | 1/4x2-1/2 | .635x6.35 | Yes | 205 | 912 | Strap Uncurled and Cracked |
| Strap, 1 Hole MI | 1 | Lag Bolt, Steel | 1/4x2-1/2 | .635x6.35 | Yes | 220 | 979 | Strap Uncurled and Cracked |
| Strap, 1 Hole MI | 1 | Lag Bolt, Steel | 1/4x2-1/2 | .635x6.35 | Yes | 225 | 1001 | Strap Uncurled and Cracked |
| Strap, 1 Hole MI | 1-1/4 | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 505 | 2247 | Screw Pulled |
| Strap, 1 Hole MI | 1-1/4 | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 435 | 1936 | Screw Pulled |
| Strap, 1 Hole MI | 1-1/4 | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 485 | 2158 | Screw Pulled |
| Strap, 1 Hole MI | 1-1/4 | Machine Bolt, Steel | 5/16x4 | .794x10.16 | Yes | 590 | 2626 | Strap Uncurled |
| Strap, 1 Hole MI | 1-1/4 | Machine Bolt, Steel | 5/16x4 | .794x10.16 | Yes | 520 | 2314 | Strap Uncurled |
| Strap, 1 Hole MI | 1-1/4 | Machine Bolt, Steel | 5/16x4 | .794x10.16 | Yes | 510 | 2270 | Strap Uncurled |

* Abbreviation for Malleable Iron.

Table 3. Load Failure Tests (continued)

| Hanger Type | Hanger Nominal Pipe Size (in) | Fastener Type | Fastener Size (in) | Fastener Size (cm) | Washer | Load (lbs) | Load (N) | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| Strap, 1 Hole MI* | 1-1/2 | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 300 | 1335 | Strap Uncurled |
| Strap, 1 Hole MI | 1-1/2 | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 325 | 1446 | Strap Uncurled |
| Strap, 1 Hole MI | 1-1/2 | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 315 | 1402 | Strap Uncurled and Cracked |
| Strap, 1 Hole MI | 1-1/2 | Lag Bolt, Steel | 5/16x2 | .794x5.08 | Yes | 285 | 1268 | Screw Pulled |
| Strap, 1 Hole MI | 1-1/2 | Lag Bolt, Steel | 5/16x2 | .794x5.08 | Yes | 315 | 1402 | Screw Pulled |
| Strap, 1 Hole MI | 1-1/2 | Lag Bolt, Steel | 5/16x2 | .794x5.08 | Yes | 355 | 1580 | Screw Pulled and Strap Uncurled |
| Strap, 1 Hole MI | | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 420 | 1869 | Screw Pulled |
| Strap, 1 Hole MI | | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 445 | 1980 | Screw Pulled |
| Strap, 1 Hole MI | | Lag Bolt, Steel | 3/8x2 | .953x5.08 | Yes | 350 | 1558 | Screw Pulled |
| Strap, 1 Hole MI | | Machine Bolt, Steel | 3/8x4 | .953x10.16 | Yes | 600 | 2670 | Strap Uncurled |
| Strap, 1 Hole MI | | Machine Bolt, Steel | 3/8x4 | .953x10.16 | Yes | 575 | 2559 | Strap Uncurled |
| Strap, 1 Hole MI | | Machine Bolt, Steel | 3/8x4 | .953x10.16 | Yes | 590 | 2626 | Strap Uncurled |
| Banding, Perforated** Copper, 3/4" wide | | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | No | 460 | 2047 | Banding Broke at Screw |
| Banding, Perforated** Copper, 3/4" wide | | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | No | 480 | 2136 | Banding Broke at Screw |
| Banding, Perforated** Copper, 3/4" wide | | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | No | 510 | 2270 | Banding Broke at Screw |
| Banding, Perforated† Copper, 3/4" wide | | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | No | 210 | 934 | Screw Pulled Thru Banding Hole |
| Banding, Perforated† Copper, 3/4" wide | | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | No | 130 | 578 | Screw Pulled Thru Banding Hole |
| Banding, Perforated† Copper, 3/4" wide | | Wood Screw, Round Head, Brass | #12x7/8 | .549x2.22 | No | 170 | 756 | Screw Pulled Thru Banding Hole |
| Banding, Perforated** Copper, 3/4" wide | | Wood Screw, Flat Head, Steel | #12x3/4 | .549x1.91 | Yes | 580 | 2581 | Banding Broke at a Hole near center |
| Banding, Perforated** Copper, 3/4" wide | | Wood Screw, Flat Head, Steel | #12x3/4 | .549x1.91 | Yes | 560 | 2492 | Banding Broke at a Hole near center |
| Banding, Perforated** Copper, 3/4" wide | | Wood Screw, Flat Head, Steel | #12x3/4 | .549x1.91 | Yes | 540 | 2403 | Banding Broke at a Hole near center |

* MT is an abbreviation for Malleable Iron.

** Attached to side of beam (see figure 9).

† Attached to bottom of beam (see figure 9).

Table 3. Load Failure Tests (continued)

| Hanger | | Fastener | | | Washer | Load | | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| Type | Nominal Pipe Size (in) | Type | Size (in) | Size (cm) | | (lbs) | (N) | |
| Banding Perforated† Copper, 3/4" wide | | Wood Screw, Flat Head, Steel | #12x2 | .549x5.08 | Yes | 550 | 2448 | Banding Sheared Around Washer |
| Banding Perforated† Copper, 3/4" wide | | Wood Screw, Flat Head, Steel | #12x2 | .549x5.08 | Yes | 480 | 2136 | Banding Broke 2 Holes from Fastener |
| Banding Perforated† Copper, 3/4" wide | | Wood Screw, Flat Head, Steel | #12x2 | .549x5.08 | Yes | 510 | 2270 | Banding Sheared Around Washer |

† Attached to bottom of beam (see figure 9).

Table 4. Excess Load Factors (Strap Fasteners)*

| Hanger Type | Nominal Pipe Size (in) | 5[Weight (Pipe+Water)] + 250 by Hanger Spacing** 6 ft (lbs) | (1.83m) (N) | 12 ft (lbs) | (3.66m) (N) | 15 ft (lbs) | (4.57m) (N) | Average Failure Load† (lbs) | (N) | Excess Load Factor* by Hanger Spacing 6 ft(1.83m) | 12 ft(3.66m) | 15 ft(4.57m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Steel Pipe | | | | | | |
| Split Ring | 1 | 314.8 | 1400.2 | 379.3 | 1687.1 | 411.7 | 1831.2 | 1469 | 6534.1 | 4.7 | 3.9 | 3.6 |
| | 1-1/4 | 341.8 | 1520.3 | 433.4 | 1927.8 | 479.2 | 2131.5 | 1500 | 6672.0 | 4.4 | 3.5 | 3.1 |
| Strap, 2-Hole | 1-1/4 | 341.8 | 1520.3 | 433.4 | 1927.8 | 479.2 | 2131.5 | 1515 | 6738.7 | 4.4 | 3.5 | 3.2 |
| Galv. Steel | 2 | 409.8 | 1822.8 | 569.7 | 2534.0 | 649.6 | 2889.4 | 2892 | 12863.6 | 7.1 | 5.1 | 4.5 |
| Strap, 1-Hole | 3/4 | 292.8 | 1302.4 | 335.7 | 1493.2 | 357.2 | 1588.8 | 122 | 542.7 | 0.4 | 0.4 | 0.3 |
| Galv. | 1 | 314.8 | 1400.2 | 379.3 | 1687.1 | 411.7 | 1831.2 | 217 | 965.2 | 0.7 | 0.6 | 0.5 |
| Mall. Iron | 1-1/4 | 341.8 | 1520.3 | 433.4 | 1927.8 | 479.2 | 2131.5 | 540 | 2401.9 | 1.6 | 1.2 | 1.1 |
| | 1-1/2 | 363.0 | 1614.6 | 476.1 | 2117.7 | 532.6 | 2369.0 | 313 | 1392.2 | 0.9 | 0.6 | 0.6 |
| | 2 | 409.8 | 1822.8 | 569.7 | 2534.0 | 649.6 | 2889.4 | 588 | 2615.4 | 1.4 | 1.0 | 0.9 |
| | | | | | | Copper Pipe | | | | | | |
| Strap, 2-Hole | 3/4 | 270.0 | 1201.0 | 290.1 | 1290.4 | 300.1 | 1334.8 | 373 | 1659.1 | 1.4 | 1.3 | 1.2 |
| Cop. Pltd. Steel | 1-1/2 | 307.3 | 1366.9 | 364.6 | 1621.7 | 393.3 | 1749.4 | 1043 | 4639.3 | 3.4 | 2.9 | 2.7 |
| Strap, 2-Hole | 5/8 | 265.5 | 1180.9 | 280.8 | 1249.0 | 288.5 | 1283.2 | 492 | 2188.4 | 1.9 | 1.8 | 1.7 |
| Copper | 1 | 280.5 | 1247.7 | 310.8 | 1382.4 | 325.9 | 1449.6 | 565 | 2513.1 | 2.0 | 1.8 | 1.7 |
| | 1-1/4 | 792.8 | 1302.4 | 335.7 | 1493.2 | 357.2 | 1588.8 | 527 | 2344.1 | 1.8 | 1.6 | 1.5 |

* Ratio of † to **.

** NFPA 13 Load supporting requirement disregarding the spacing requirement. The NFPA 13 Load requirement is based on the weight of 12 feet of water filled pipe 1-1/4 inches in diameter or smaller or 15 feet of water filled pipe 1-1/2 inches in diameter or larger, times 5 plus 250 pounds.

† Highest average hanger mode failure load.

Table 5. Excess Load Factors (Copper Banding)*

| Nominal Pipe Size (in) | Excess Load Factors | | | | | |
|---|---|---|---|---|---|---|
| | Side Attachment** | | | Bottom Attachment† | | |
| | 6 ft (1.83m) | 12 ft (3.66m) | 15 ft (4.57m) | 6 ft (1.83m) | 12 ft (3.66m) | 15 ft (4.57m) |
| Steel Pipe | | | | | | |
| 3/4 | 1.9 | 1.7 | 1.6 | 1.8 | 1.5 | 1.4 |
| 1 | 1.8 | 1.5 | 1.4 | 1.6 | 1.4 | 1.2 |
| 1-1/4 | 1.6 | 1.3 | 1.2 | 1.5 | 1.2 | 1.1 |
| 1-1/2 | 1.5 | 1.2 | 1.1 | 1.4 | 1.1 | 1.0 |
| 2 | 1.4 | 1.0 | 0.9 | 1.3 | 0.9 | 0.8 |
| Copper Pipe | | | | | | |
| 3/4 | 2.1 | 1.9 | 1.9 | 1.9 | 1.8 | 1.7 |
| 5/8 | 2.1 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 |
| 1 | 2.0 | 1.8 | 1.7 | 1.8 | 1.7 | 1.6 |
| 1-1/4 | 1.9 | 1.7 | 1.6 | 1.8 | 1.5 | 1.4 |
| 1-1/2 | 1.8 | 1.5 | 1.4 | 1.7 | 1.4 | 1.3 |

* Ratio of 2 or 3 to NFPA load requirement disregarding the spacing requirement.
** Average failure load for side attachment = 560.0 lb.
† Average failure load for bottom attachment = 513.3 lb.

Table 6. Pilot Hole Sizes (Axial Loading)

| Screw Size No. | Body Diameter (in) | Estimated Root Diameter (in) | 70% Root Diameter (in) | Nearest Drill Size (in) | Nearest Drill No. |
|---|---|---|---|---|---|
| 6 | 0.138 | 0.092 | 0.064 | 0.635 | 52 |
| 7 | 0.151 | 0.101 | 0.071 | 0.0700 | 50 |
| 8 | 0.164 | 0.109 | 0.077 | 0.0760 | 48 |
| 9 | 0.177 | 0.118 | 0.083 | 0.0820 | 45 |
| 10 | 0.190 | 0.127 | 0.089 | 0.0890 | 43 |
| 12 | 0.216 | 0.144 | 0.101 | 0.1015 | 38 |
| 14 | 0.242 | 0.161 | 0.113 | 0.1130 | 33 |
| 16 | 0.268 | 0.179 | 0.125 | 0.1285 | 30 |
| 18 | 0.294 | 0.196 | 0.137 | 0.1360 | 29 |
| 20 | 0.320 | 0.213 | 0.149 | 0.1495 | 25 |
| 24 | 0.372 | 0.248 | 0.174 | 0.1730 | 17 |

Table 7. Pilot Hole Sizes (Lateral Loading)

| Screw Size | Body Diameter (in) | Estimated Root Diameter (in) | 7/8 Root Diameter (in) | Near Drill Size (in) | Thread Drill No. | 7/8 Body Diameter (in) | Near Drill Size (in) | Body Drill No. |
|---|---|---|---|---|---|---|---|---|
| 6 | 0.138 | 0.092 | 0.081 | 0.0810 | 46 | 0.121 | 0.1200 | 31 |
| 7 | 0.151 | 0.101 | 0.088 | 0.0890 | 43 | 0.132 | 0.1285 | 30 |
| 8 | 0.164 | 0.109 | 0.095 | 0.0960 | 41 | 0.144 | 0.1440 | 27 |
| 9 | 0.177 | 0.118 | 0.103 | 0.1040 | 37 | 0.155 | 0.1540 | 23 |
| 10 | 0.190 | 0.127 | 0.111 | 0.1110 | 34 | 0.166 | 0.1660 | 19 |
| 12 | 0.216 | 0.144 | 0.126 | 0.1285 | 30 | 0.189 | 0.1890 | 12 |
| 14 | 0.242 | 0.161 | 0.141 | 0.1405 | 28 | 0.212 | 0.2130 | 3 |
| 16 | 0.268 | 0.179 | 0.156 | 0.1570 | 22 | 0.235 | 0.2340 | A |
| 18 | 0.294 | 0.196 | 0.172 | 0.1730 | 17 | 0.257 | 0.2570 | F |
| 20 | 0.320 | 0.213 | 0.187 | 0.1850 | 13 | 0.280 | 0.2810 | K |
| 24 | 0.372 | 0.248 | 0.217 | 0.2130 | 3 | 0.326 | 0.3230 | P |

NBS-114A (REV. 7-73)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET | 1. PUBLICATION OR REPORT NO. NBSIR 77-1282 | 2. Gov't Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|
| 4. TITLE AND SUBTITLE Investigation of the Suitability of Light Duty Pipe Hangers for Use in Residential and Care Type Sprinkler Systems | | | 5. Publication Date October 1977 |
| | | | 6. Performing Organization Code |
| 7. AUTHOR(S) Warren D. Hayes, Jr. and Richard L. P. Custer | | | 8. Performing Organ. Report No. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234 | | | 10. Project/Task/Work Unit No. 4928671 |
| | | | 11. Contract/Grant No. |
| 12. Sponsoring Organization Name and Complete Address (Street, City, State, ZIP) Division of Energy, Building Technology and Stds. Office of Policy Devlpment and Research, U.S. Dept. of Housing and Urban Development Washington, D.C. 20410 | | | 13. Type of Report & Period Covered Final Report |
| | | | 14. Sponsoring Agency Code |

15. SUPPLEMENTARY NOTES

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

Several sizes of various types of commonly available light duty hangers for pipe, cable and conduit were subjected to load failure tests and while under load to exposure to 70 to 140 pound (31.8 and 63.5 kg, respectively) crib fires. In addition, hangers made from thin strap metal were tested for effect on performance of undersized screws and for benefit obtained from the use of washers. All sizes of the two-hole or two-fastener hangers met the NFPA No. 13 Standard for the Installation of Sprinklers load requirement, while only the nominal 1-1/4 inch size of the one-hole hangers met the requirement. Washers improve the performance of hangers made of thin strap metal.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*) Automatic sprinklers; care type occupancies; fire endurance; load failure; pipe hangers; residential occupancies.

| 18. AVAILABILITY [X] Unlimited | 19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED | 21. NO. OF PAGES 44 |
|---|---|---|
| [ ] For Official Distribution. Do Not Release to NTIS | | |
| [ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13 | 20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED | 22. Price $4.50 |
| [X] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151 | | |

USCOMM-DC 29042-P74