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# RESIDENTIAL CONSTRUCTION IN BOSTON AT THE TIME OF THE CAPE ANN EARTHQUAKE OF 1755

by

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supervised by
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THE 1755 CAPE ANN EARTHQUAKE

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16. Abstract (Limit: 200 words)

This study is concerned with determining seismic risk in New England to encourage more appropriate earthquake building regulations. For this purpose, the strength of ground shaking caused by the Cape Ann, Massachusetts earthquake of 1755 is examined through a detailed study of earthquake resistance of existing buildings at that time. Residential buildings, representative of those existing in 1755, are divided into type and location in the city of Boston. By understanding construction techniques, materials, and structural systems of these buildings, and by estimating seismic effects on the buildings from damage reports, a more accurate estimation of ground shaking strength can be determined. This survey covers each house type in a separate chapter which includes (1) a brief history of the area; (2) an estimate of the number of houses of that type existing in 1755; (3) location; (4) a summary chart of the masses of each part of the house; (5) details of construction; and (6) drawings. Mass calculations are found in the appendices.

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Damage assessment
New England
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Cape Ann Earthquake of 1755
Boston

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# CHAPTER I - INTRODUCTION

The purpose of this entire project is to determine more accurately the strength of ground shaking caused by the Cape Ann, Massachusetts earthquake of 1755. This will be accomplished through a detailed study of the earthquake resistance of buildings that existed at the time of the earthquake. It is hoped that this research will lead to a greatly improved confidence in estimates for seismic risk in New England.

The Cape Ann earthquake has played a major role in determining seismic risk in the Northeast and design for critical facilities such as nuclear power plants and earth dams located in the East. A better understanding of the seismicity of New England will encourage more appropriate seismic building regulations.

There were no earthquake recording devices in 1755. There are, however, two catagories of information which we hope to use together to determine the strength of the ground shaking. The first category is damage reports. Those compiled by Weston Geophysical Research, Inc. are especially helpful. The second category is building construction and technique.

An in-depth study is being conducted of several types of buildings representative of those in existance in 1755. Along with the Society for the Preservation of New England Antiquities, attempts have been made to reconstruct which types of houses were present, how many there were of each type and in what part of Boston they were located. Figure 1

1. North End
2. Downtown
3. Suburbs - Residential Area

1. Shipbuilders, craftsmen
   craftsmen had shops on first floors
   of homes
2. Shopkeepers, craftsmen, taverns
   craftsmen had shops on first floors
   of homes
3. residences

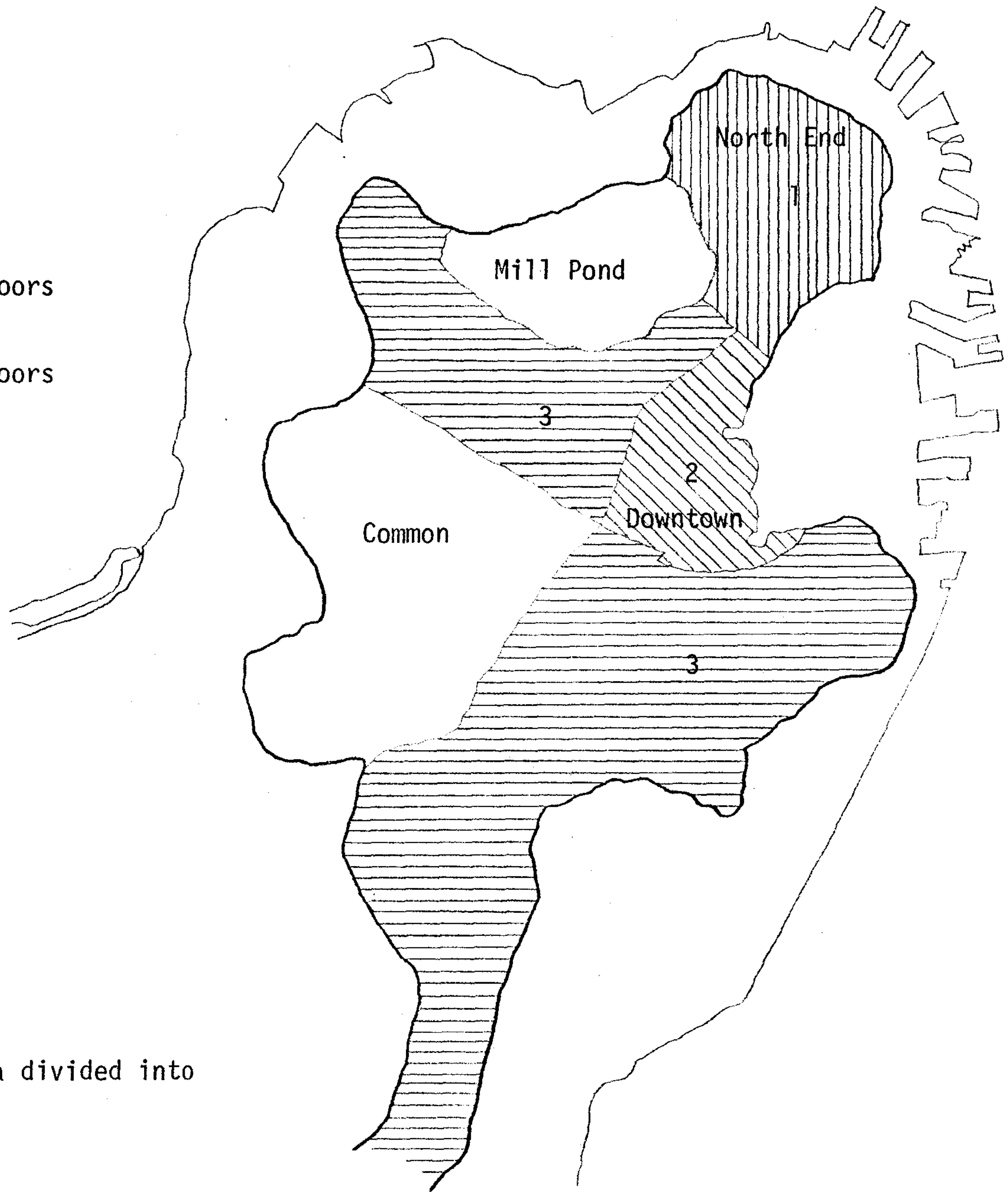



Figure 1. The Shawmut Peninsula divided into Three Regions

shows Boston divided into three separate regions and describes differences between these regions. Figure 2 estimates how many of each building type were located in each region. Figure 3 briefly describes each building type.

By first understanding the construction techniques, materials and structural systems of these representative buildings and second by estimating the effect of the earthquake on the buildings from the damage reports, it will be possible to make a more accurate estimation of the strength of the ground shaking.

Following a brief history of the area, each house type will be covered in a separate chapter. Each chapter will begin with an estimate of how many houses of that type existed and where they were located. There will also be a summary chart of the masses of each part of the house. The chapter will go into details of construction of such areas as foundation, framing system, walls, roof, chimney, etc., with attention paid to sizes of members and types of connections. Drawings will accompany each chapter. Mass calculations can be found in the appendices at the end of the report.

Figure 2. Breakdown of Houses by Number and Percent

| | AREA 1 DOWNTOWN | AREA 2 NORTH END | AREA 3 RESIDENTIAL | TOTAL # | TOTAL % |
|---|---|---|---|---|---|
| TYPE 1 - HEAVY TIMBER FRAME | 5.25% (210) 15% of Area 1 | 13.65% (546) 39% of Area 2 | 20.1% (804) 67% of Area 3 | 1560 | 39% |
| TYPE 2 - BRICK BEARING WALLS | 27.65% (1106) 79% of Area 1 | 14% (560) 40% of Area 2 | 4.5% (180) 15% of Area 3 | 1846 | 46.15% |
| TYPE 3 - BRICK END WALL | 0.35% (14) 1% of Area 1 | 0.35% (14) 1% of Area 2 | 0.3% (12) 1% of Area 3 | 40 | 1% |
| TYPE 4 - EARLY GEORGIAN (timber) | 1.75% (70) 5% of Area 1 | 7% (280) 20% of Area 2 | 5.1% (204) 17% of Area 3 | 554 | 13.85% |
| TOTAL # OF HOUSES | 1400 | 1400 | 1200 | 4000 | |
| TOTAL PERCENT | 35% | 35% | 30% | | 100% |

Figure 3. Building Types Description

TYPE 1 - HEAVY TIMBER FRAME

Heavy timbers, brick chimneys, lime and clay mortar, fieldstone foundations, interior plank partitions, two to three stories, gabled or gambrel roof, mortise and tenon and dovetail joints, clapboards ( or shakes), brick nogging laid in clay and/or sheathing, diamond pane casement windows or double hung sash windows, some covered with roughcast.

a) Garrison
b) New England Large
C) Salt-box

TYPE 2 - BRICK BEARING WALL

12" thick brick bearing walls, souble hung sash windows, fieldstone foundations, interior plank partitions, two or three stories, one or two rooms deep, gabled, gambrel, or hipped roof, brick chimneys, wooden floor beams and joists which frame into brick walls.

TYPE 3 - BRICK END WALL

End walls brick, usually with chimneys built into end walls, wooden front and rear walls, clapboards, souble hung sash windows, central front-to-back hall, interior plank partitions, 2 to 3 stories, 1 or 2 rooms deep.

TYPE 4 - EARLY GEORGIAN (timber)

Lighter timbers than the heavy timber frame house type, brick chimneys - either end chimneys or two interior, symmetrical chimneys, 2" interior bearing wall partitions, double hung sash windows, one (or two) rooms deep, Hipped roof (or gambrel), symmetrical window arrangement, central front-to-back hall.

## CHAPTER 2 - BRIEF HISTORY

The center of downtown Boston for most of this century has been the central shopping district. Jordan Marsh, Filene's and several other popular retail stores can be found at the corner of Summer and Washington Streets. Recently, however, this center has been shifted about a quarter of a mile north just past the Old State House to the Faneuil Hall-Quincy Market Area. This was the center of town known to the Bostonian of the first half of the eighteenth century and was known more commonly as Dock Square. Although it is greatly changed now this was the town dock area and the site of the original shoreline of the Shawmut peninsula. The intersection of Summer and Washington Streets, now one of the busiest places in Boston, was at that time only one block away from a pond which served as the town watering place for cattle.

Thanks to men like John Bonner, a mapmaker of the eighteenth century, we have extremely accurate records of the physical layout of the town of Boston. Bonner produced a fine map of the town of Boston in 1722. Several other updated maps were released afterwards, in 1725, 1733, 1739, 1743 and 1769. These maps are extremely handy in noticing the growth and change in Boston before and after 1755. "These maps are particularly helpful in graphically delineating the many gabled, connected structures by means of sketch elevations of buildings along each street as well as the free-standing public and mercantile edifices. While the building representations are not to be taken too literally, the density of development with row structures surrounding the area of Clarke's or North

Square and the increased encroachment of the filled land and wharves along the waterfront into the Town Dock and Harbor is apparent."[1] It is significant to know which structures were founded on filled land as these are more suseptible to damage during ground shaking.

The 1743 edition of Bonner's map shows several changes from the 1722 version. Faneuil Hall is shown in the Town Dock built partially on filled land. The wharves are shown to have been extended out farther into the Harbor, with Long Wharf extending out about 2600 feet, and showing a row of warehouses on the north side.

Bonner's map of 1769 "with the many Additional Buildings and New Streets" shows very little change from the 1743 version. The same conclusion can be drawn from "A Plan of the Town of Boston in New England with its Environs" by Henry Pelham. This 1777 map shows that no significant changes had taken place in Boston since the time of the 1755 earthquake.

Other maps of the late 18th century and early 19th century are available and are helpful in showing any changes in the rate of growth. It is also worth noting that many pre-1755 buildings are still existing on post-1755 maps and no major reconstructions occured in any areas (that might have been due to ground motion damage).

A few maps were made in the 19th centruy which are reconstructions pf pre-1755 Boston such as the "Map of the Town of Boston 1676", by Samuel C. Clough, c. 1880's. These maps are believed to be fairly accurate and provide additional insight to the physical character of Boston.

Another important source of information about the character of Boston in the early 17th century are drawings. There are some excellent perspectives of the waterfront (especially the Long Wharf area) by William Burgess and Paul Revere. For example, in Price's 1743 edition of Burgess' "A Southeast View of ye Great Town of Boston...", we can pick out several meaningful details; the types and density of buildings, what sort of roofs they had, etc.

From these maps and perspectives we can also see that many of the buildings, expecially in the Town Dock and North Square areas, were not rectilinear but rather conformed to the irregular lots on which they were constructed. There exists today several sketches of individual houses, public buildings and streets. These provide more specific information about the structures of the period. Many of these drawings are included in books like James H. Stark's Antique Views of the Town of Boston and Reverend Edward G. Porter's Rambles in Old Boston.

The wooden structures range from single room, one story houses to three story houses with gambrel roofs and dormers to Georgian "mansions" with hip roofs like the Shirley-Eustis house in Roxbury. Sketches of masonry houses include two and three story structures with double-hung sash windows, belt courses in the brick, some with gambrel roofs and some with hipped roofs. Many of these masonry structures were row houses and shared party walls, but some were free standing such as the mansions of the well-to-do like the 3 story Faneuil-Phillips house or the Thomas and John Hancock House both on Beacon Street.

From these maps and pictures, along with town records, deeds, newspapers, letters and diaries of the period it is possible for us to draw a fairly accurate picture of the town of Boston in the first half of the eighteenth century.

The original size of the town amounted to about half of what makes up Boston today. The Shawmut Peninsula, as it was called, was connected to the mainland only by a small isthmus, now the site of Washington Street. By 1755 the actual shape of the land had barely been altered since the time of the first settlers. Although large parts of the shoreline had been wharfed out and Mill Pond and Mill Creek had been created, no major filling had occurred. The Tramount, or the three hills of Boston, rose high above the growing town at its feet and was sparsely populated.

Detailed census were not taken prior to 1790, but a fairly accurate estimate of the population may be made. James Bonner, on his map of 1722 estimates the population at 12,000, while in 1743 he estimates 20,000. William Price on "A Southeast View of Ye Great Town of Boston..." also estimates the population at 20,000. "... another source puts the population at the same date as only 16,382 and a second one as late as 1760 actually records a decline in the population to 15,613."[2]

Daniel Neil, in 1719, says about Boston that it "... was 'well paved', had forty-two streets, thirty-six lanes, and twenty-two alleys... Neil records that three thousand houses stood in the town."[3]

Bonner, on his maps, estimates the number of houses at 4000 in 1743. Some years earlier, on his map of 1722, he gives the number of houses as 3000, of which 1000, or 1/3, are brick and the remaining 2/3 are of timber construction. "William Price, in his 1743 edition of Burgess' view of Boston, in the same apparent ratio of 'one third brick, the rest of timber and stone'".[4] The use of stone was minimal. All stone used for building was imported and foundations were constructed of field-stone.

More and more buildings were constructed with brick as time went on, largely due to the almost uncontrolable fires that wiped out large areas at once. A brief history of fires is given in Appendix A. From the study of fires we can deduce some important facts, particularly about the ages of certain buildings or areas in the town. For example, we know that the 1711 fire burned down a lot of the area around the Cornhill and King Street intersection. Therefore, we can say that in 1755 this area was made up of relatively new buildings. In other parts of the city there remained buildings which were much older, such as in the North End or in the South End.

The North End was heavily populated, especially by merchants who had their dwellings, warehouses and wharves in close proximity, and by ship builders who similarly enjoyed the convenience of living close to their yards.[5] The North End was further transversed by people from other parts of town wishing to get to Charlestown or the North by way of the ferry from the North End across the Charles River.

Other occupations held by the townspeople were carpenter, mason, tailor and other tradespersons. There were many shopkeepers in the neighborhood of Cornhill (now Washington Street) who kept shop on the first floor of their homes. Further away in the South End many people were farmers, but most of the homes on the Shawmut peninsula had at least a small garden if not some fruit trees.

We notice the urban character of Boston from the start. In 1642, Robert Nash, a butcher, was asked to remove his garbage from his yard and find somewhere else to slaughter his beasts as the smells were offensive to the townspeople. There are also references in the town records to the unrestrained movements of goats and hogs.

Thus, there can be no doubt that Boston was a thriving maritime community. With an estimated 16,000 - 20,000 inhabitants, upwards of 40 wharves, more than a dozen shipyards and over six ropewalks, it was one of the largest towns in British North America.

## CHAPTER 3 - BUILDING TYPE 1

The type 1 house is the heavy timber frame house. The prototype presented in this chapter is modeled after the Paul Revere House in the North End, Boston, shown in figure 4 as it stands today. Commonly constructed between 1640 and 1710, this was a popular style throughout New England. In Boston, the heavy timber frame house appeared in all three areas designated in the introduction.

In Area 1, downtown, about 15% of the houses (~210) were of type 1 construction at the time of the 1755 earthquake. Although many more may have existed earlier in the century, by 1755 many had been destroyed by fire or taken down to be replaced by some other style.

In Area 2, the North End, 39% (~550) of the houseswere of heavy timber frame construction. The percentage is higher here because there were less fires in the North End in the late seventeenth and early eighteenth centuries than there were downtown. Hence many more of the type 1 houses survived. The Paul Revere House is a prime example.

In Area 3, the outlying areas of the Shawmut peninsula, there was a greater percentage of heavy timber frame houses. Approximately 800, of 67% of Area 3 was of this type. It is possible that construction of these timber houses continued many years later in the more rural area than in the urban area. Also, when one house caught fire in Area 3, not being in close proximity to very many other houses, the fire could not do as much damage as a fire downtown. Or perhaps the

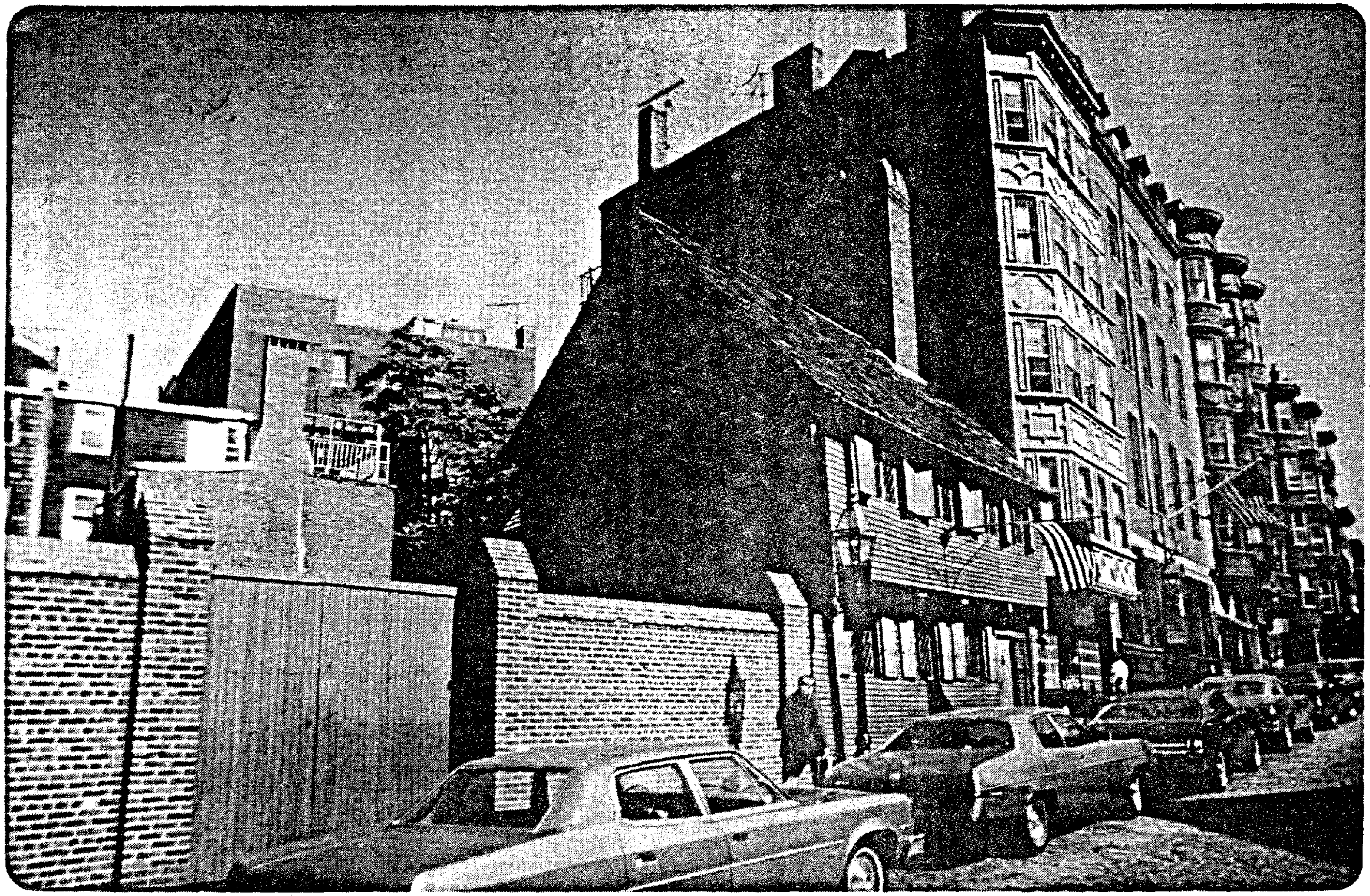


Figure 4. Paul Revere House, North Square, Boston

suitability of type 1 houses to rural life accounts for this high concentration.

The type 1 house can be broken down into seven basic parts:

1. the foundation
2. the braced framing system
3. the flooring system
4. the walls
5. the roofing system
6. interior partitions
7. the chimney

1. The Foundation

The heavy timber frame house that could have been found in 1755 Boston usually had a fieldstone foundation about two feet thick on all four sides, as can be seen in figures 5 and 6. It projected about six feet into the ground.

"Cellars were common and used as a storage space for vegetables and other bulk foods. Cellars were never built under lean-to additions. Sometimes they were built under the main part of the house, but mostly just under the hall, from which a steep staiway descended into it. The cellar was low, with a dirt floor, and the walls were invariably of fieldstones, laid up dry or with clay and later lime mortar. On the outside the foundation was barely visible, since the house sat low on the ground."[6]

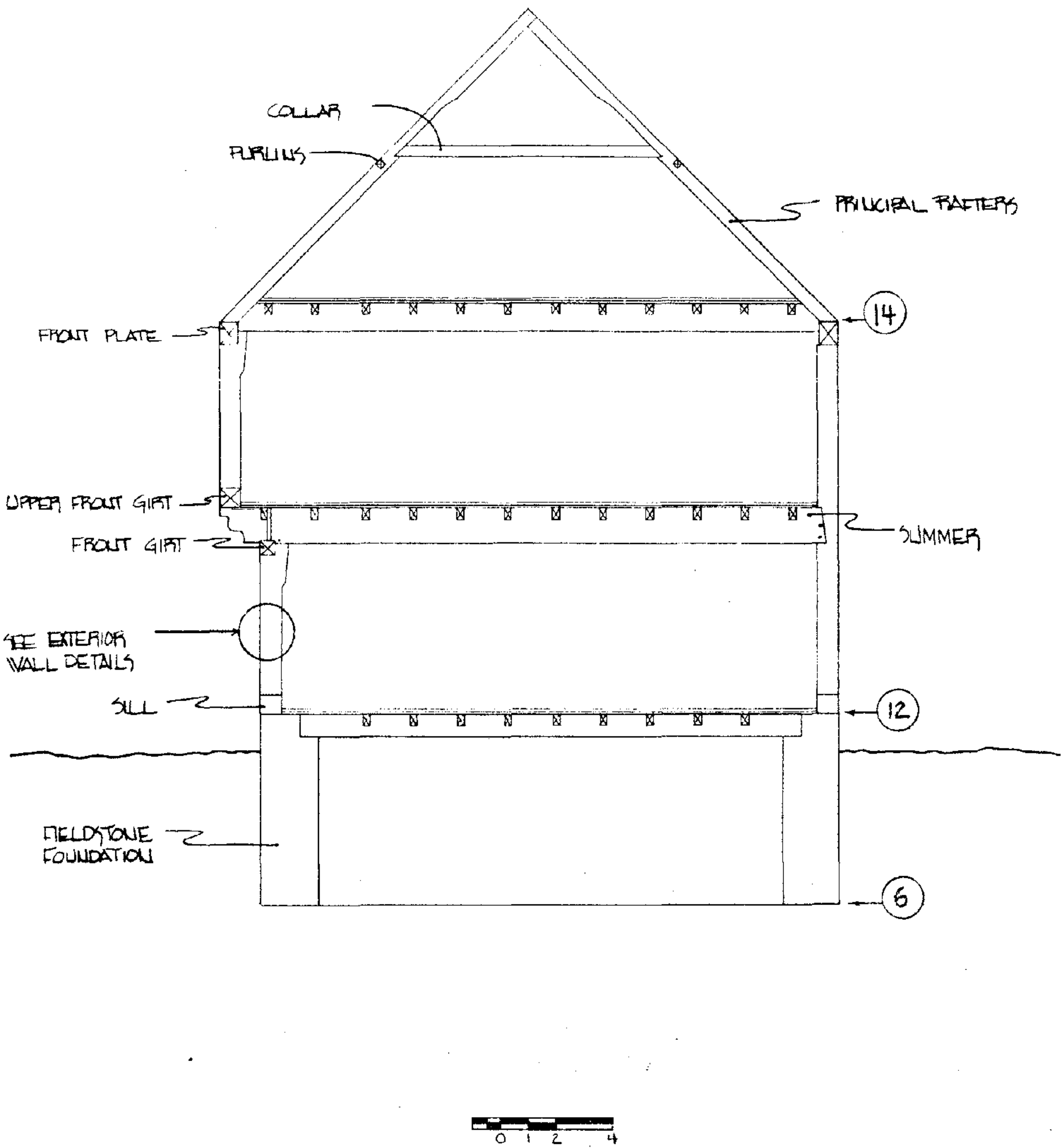



Figure 5. Type 1 - Cross section

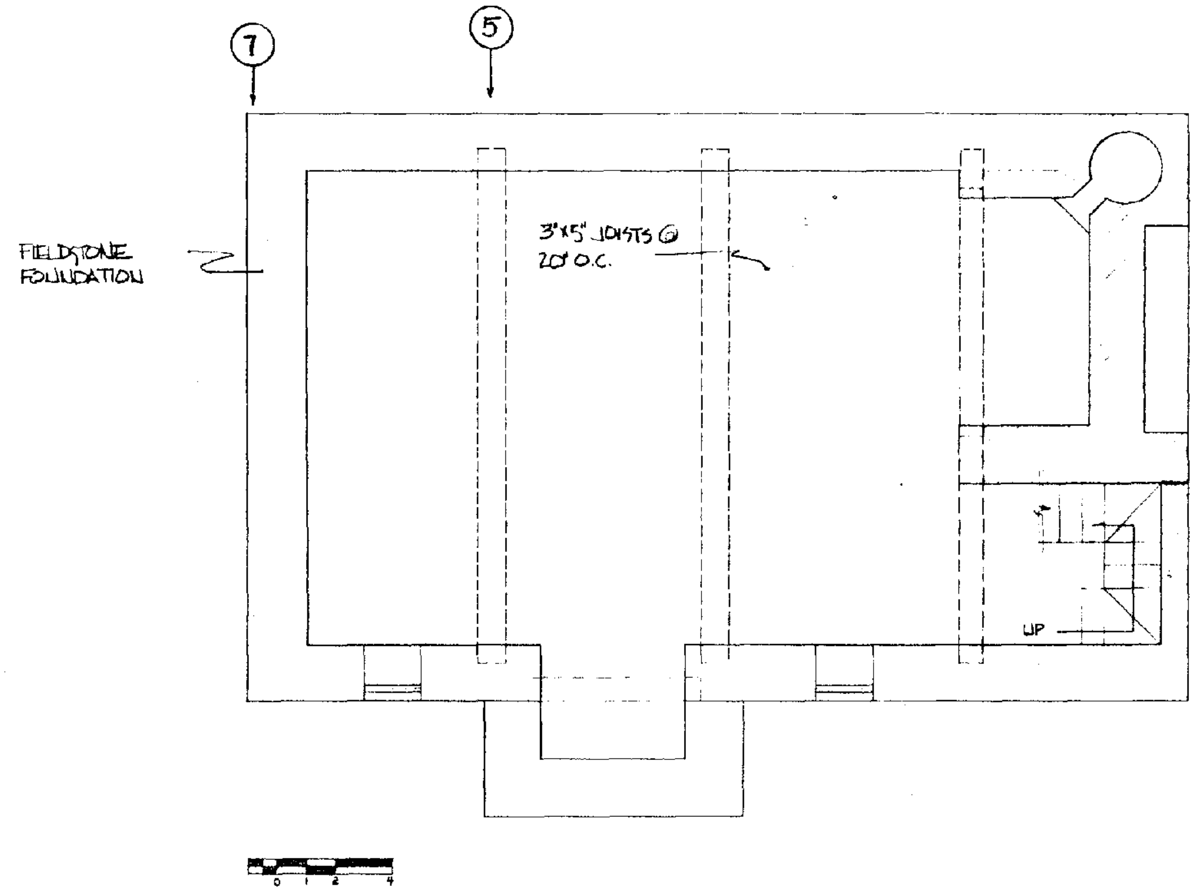



Figure 6. Type 1 - Basement Plan

2. The Framing System

Characteristic of the typical Colonial wood frame house was the use of heavy medieval framing. These massive timbers were made of oak, hand hewn with ax and adze and joined with amazing skill. Oak was used because it was sturdy and lasting: the timbers were of huge size because they often had to carry a heavy load of clay or brick nogging within the walls, and the cutting away of so much wood at the notched joints required added thickness.[7]

Seven kinds of framing timbers were employed in the Colonial house and their particular uses and names have remained standard in most American buildings for more than two centuries.[8]

SILLS: The sills rested on top of the foundation walls and carried the rest of the frame. They were good sized beams, joined securely at the corners.

POSTS: The posts were the main vertical supports. Usually there were eight of them, those near the central chimney being called 'chimney posts', the others 'corner posts'. Posts were often widened at the top to carry the weight of the crosswise girts.

GIRTS: The girts were the main horizontal supports carrying the second floor. They were mortised into the posts, and known, according to location, as 'front girts', 'rear girts', and 'end girts'. Those connecting the chimney posts from front to back were known as 'chimney girts'.

BRACES: Diagonal braces against wind loads were often employed. They spanned upper or lower corners and the small wall studs were cut to fit them.

SUMMER BEAMS: The summer was a heavy beam spanning the middle of a large room. It ran from front girt to rear girt or from end girt to chimney girt. It served as a support for the floor joists for the next story. One of the biggest beams in the whole house, it was laid flatwise. The joint between the summer and the girt was almost always a shouldered dovetail, so designed so that the summer could not be pulled or pushed out of place.

JOISTS: Joists were smaller beams that carried the floorboards. They ran from summer beam to rear girt and from summer to front girt, or from summer to summer and summer to end girt as in the type 1 house. The joists which carried the first floor were usually just logs which had been flattened at the top. Being in the cellar they were out of sight.

PLATES: The plates were horizontal timbers at the top of the posts on which the rafters rested. The four main crosswise timbers at this level were called the upper end girts and upper chimney girts, and they served as ties to hold the front and back walls of the house together against the outward thrust of rafters.

The type 1 house was a braced frame house. Two foot by six foot braces ran from the sills or girts up to about the middle of the posts as can be seen in figure 7. Sometimes the bracing ran from the posts to the girts above.

It is also interesting to note that in this entire braced frame not one nail is used.

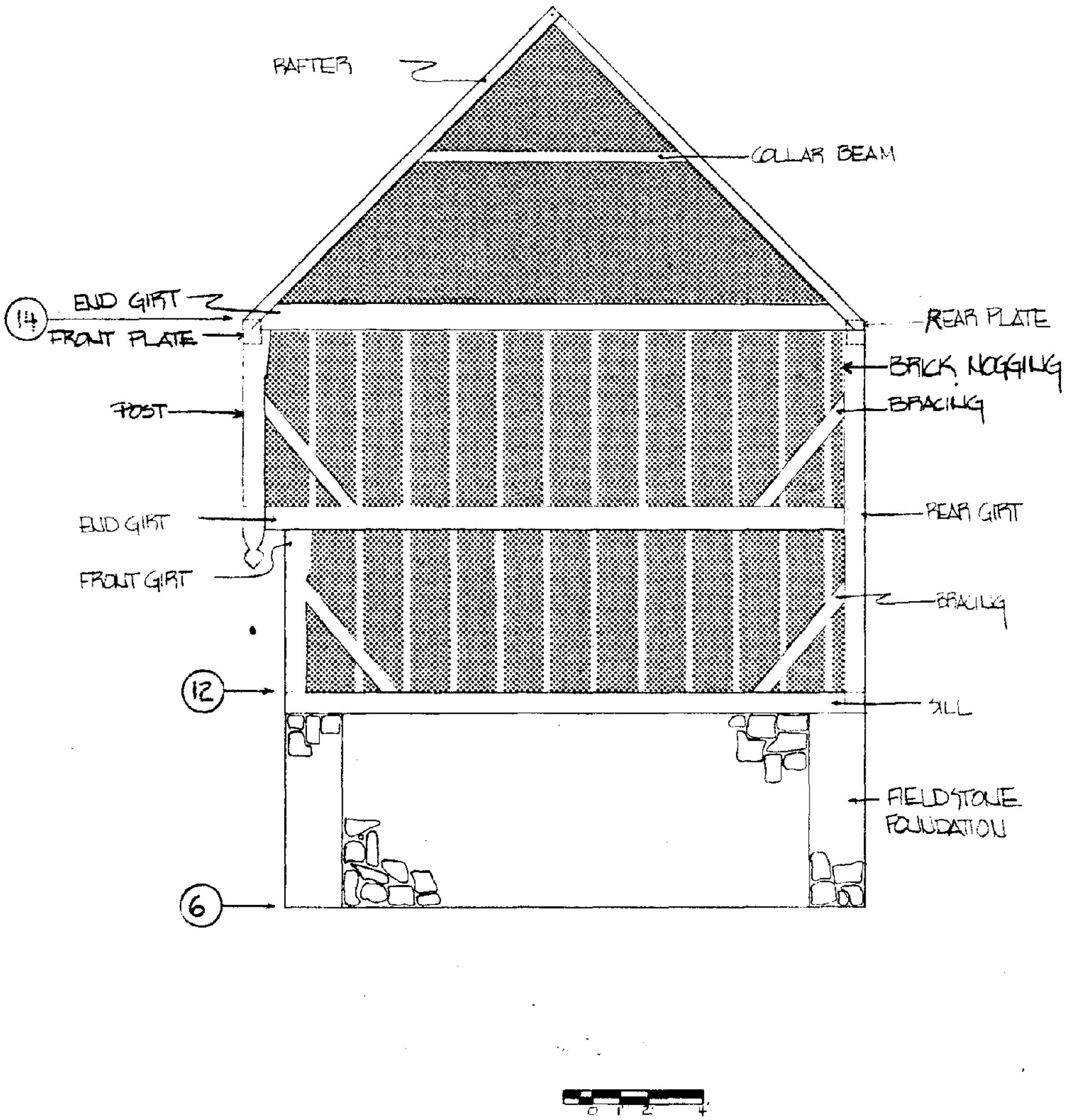



Figure 7. Type 1 - Section of End Wall

Floor beans rested in pockets in the foundation walls. These beams were about 8" across by 10" deep. Sills, usually 8" or 9" square, were placed atop the foundation walls. This relationship can be seen more clearly in figure 5.

The vertical columns supporting the horizontal members were called posts. Posts were usually about 9" square at the base and mortise and tenoned, as discussed below, into the sill. Sometimes the posts ran continuously up to the eaves. In other houses the posts of the second story were mortise and tenoned into the girts.

Most of the joints in a colonial frame are varieties of the mortise and tenon. The tenon, or flange, fits into the mortise, or socket; a hole is bored through the whole joint and a rounded wooden pin, known as the treenail (pronounced 'trunnel') runs through the joint to secure it.[9] Mortise and tenon joints can be seen in figure 8 and a version of the offset pin is shown in figure 9.

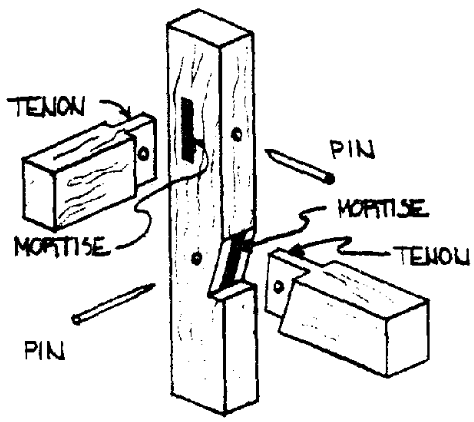



Figure 8. Mortise and Tenon Joint

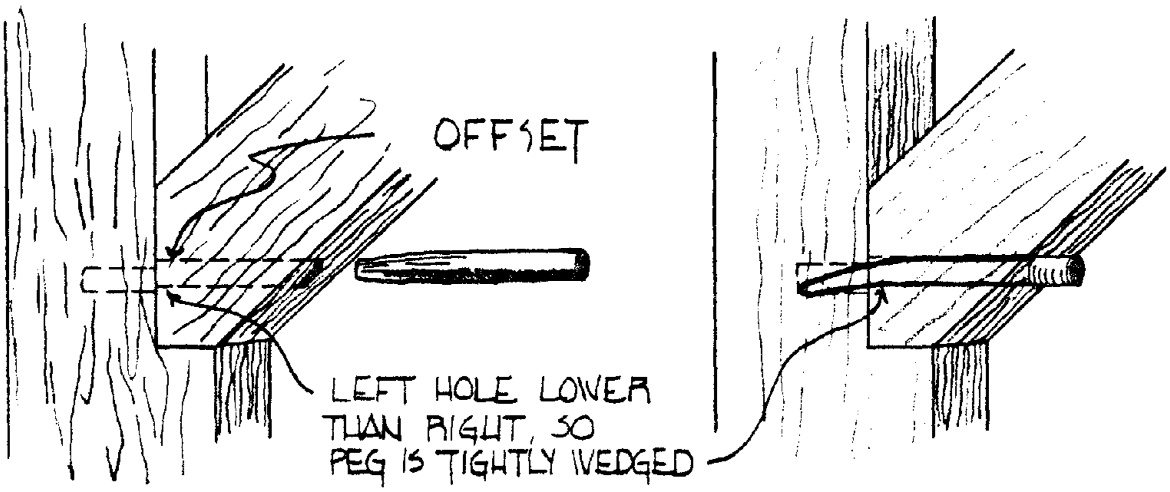



Figure 9. The Offset Pin

Posts often widened at the top to 9" x 12". In this case, shown in figure 10, they were refered to as gunstock posts or musket stock posts. A type 1, or garrison house such as the Paul Revere House, has two different kinds of posts. The posts at the back of the house run the full two stories and do not widen at the top, as can be seen in figure 5.

The posts at the front of the house are not continuous. On the first floor the post mortises into the sill and is about 9" x 9". The second story posts are mortised into the upper front girt where they are 9" x 9" and widen at the top to 9" x 12", where they reach the front plate, girts and summers. Obviously where there is an overhang the posts cannot be continuous.

The overhang, or 'jetty' was a common feature on the garrison type house. Three types of overhangs can be seen in figure 11.

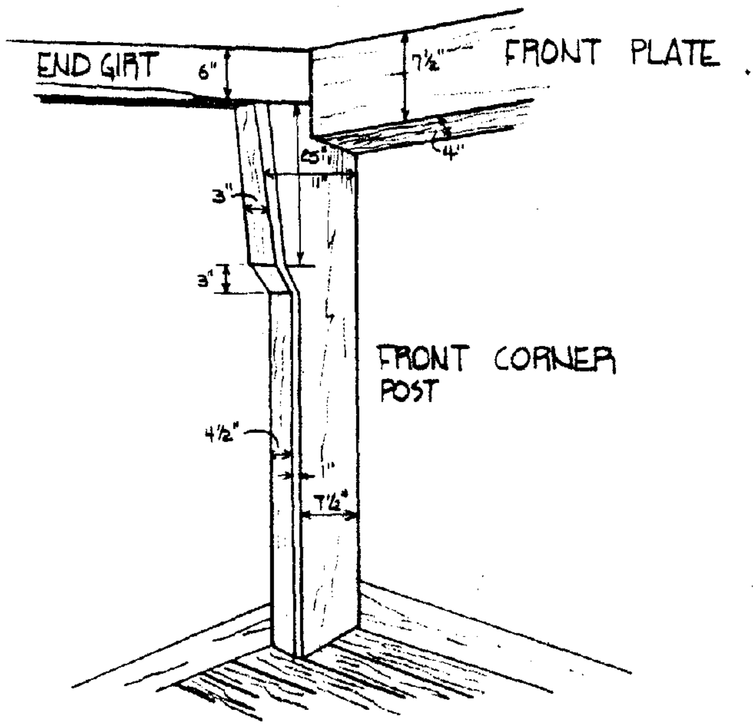



Figure 10. Often Colonial Posts Widened at the Top

The overhang may be either framed or hewn and was not usually more than eighteen inches. In a framed overhang the posts in each story are separate pieces of timber. In a hewn overhang the upper part of a single post which runs through two stories projects beyond the lower part, and a bracket, hewn out of the post itself, marks the amount of the projection at the second floor. Often in a framed overhang, where the second story post hung down below the girts, the bottom of the post was carved into a pendant, or 'pendil'.

There are four suggestions for the reason for the overhang. The first one suggests a defense against the Indians, but this is highly

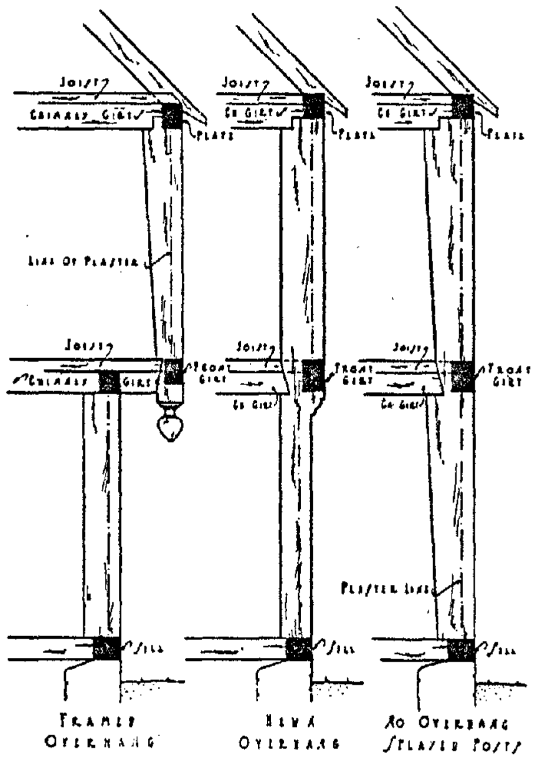



Figure 11. Three Types of Overhangs

unlikely. One reason is because the overhang almost never occured on all four sides of a house, it usually ran just across the front of a house, sometimes just at the ends, and the Indians were hardly polite enough to attack only on the guarded side. Nor were there trap doors, and thus would have offered more protection to the attackers than the defenders. Also this feature originated in England, where there were no Indians.

The confusion has probably arisen here because of a failure to distinguish between houses and blockhouses: the later were intended for security against the Indians, and they had a defensive overhang on all four sides.

A second suggestion is that since land values were so high, the overhanging second story increased usable space, however it is used in isolated farmhouses as well as the North End.

A third suggestion is that it was a technical matter of framing: separate posts for the two stories were stronger than one long post weakened at the middle by a triple joint for the insertion of the necessary three horizontal girts.

A fourth suggestion is that people simply liked the looks of the overhang.

* * *

The girts, summers and plates were the main horizontal beams in the house. Figure 12 shows the girts and summers overhead by dashed lines. The type 1 house had three girts on the first floor and three girts on the second floor. These girts were usually 8" across by 10"

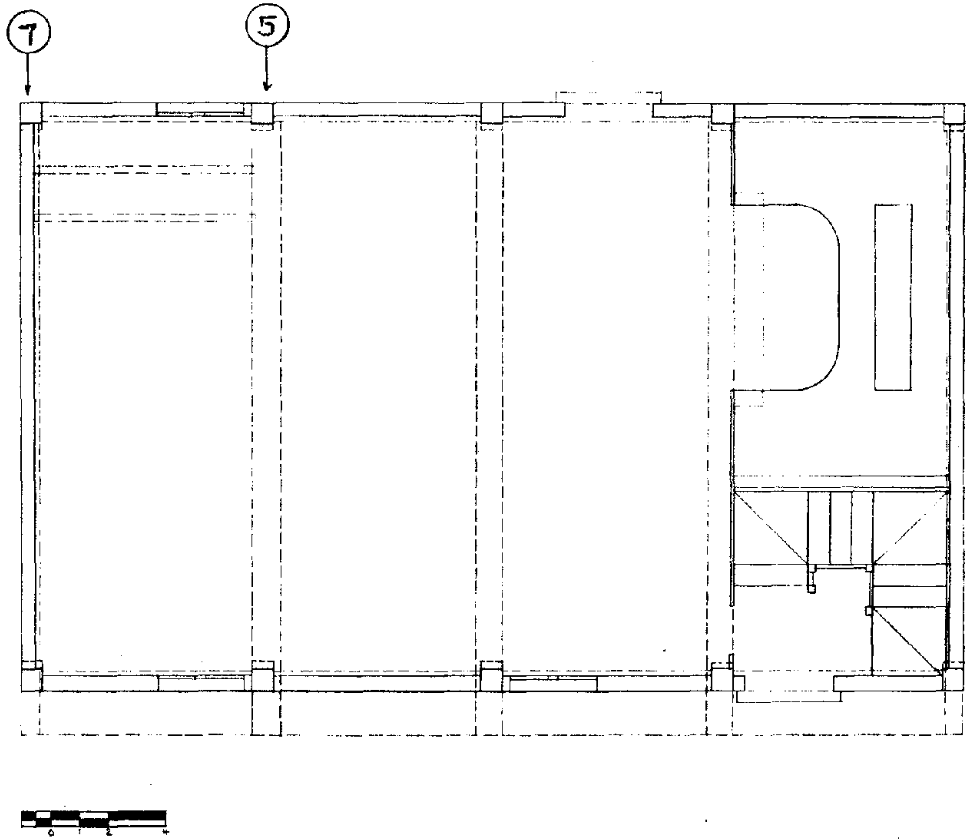



Figure 12. Type 1 - First Floor Plan

deep, but there were exceptions. For instance, the chimney girt in the Paul Revere house is larger than this. On top of the first floor posts were the end girts, chimney girt, front girt and rear girt. These were all mortise and tenoned into the posts. Since the rear posts ran continuously up through the second floor, the end girts and chimney girts were mortised into a notched section of the posts just below the second floor level.

Two summer beams also connected to the girts at this level. The joint between the summer and the girts was almost always a shouldered dovetail. Figure 13 shows how it was designed so that the summer could not be pulled or pushed out of place. The summer ran parallel to the end girt and chimney girts and was the largest beam in the house. First floor summers in the type 1 house were 12" x 15". Second story summers were also very large, about 10" x 12", but smaller than their downstairs counterparts.

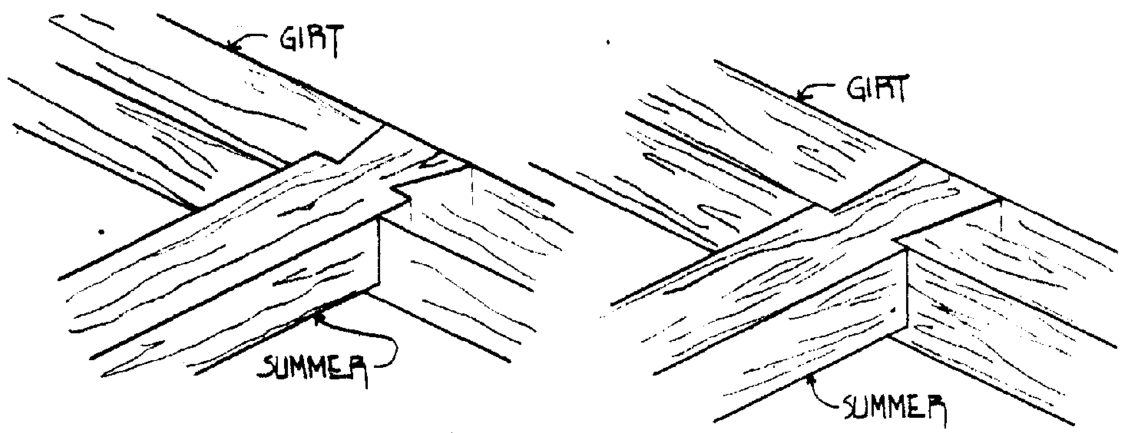



Figure 13. Shouldered Dovetail and Plain Dovetail Joints

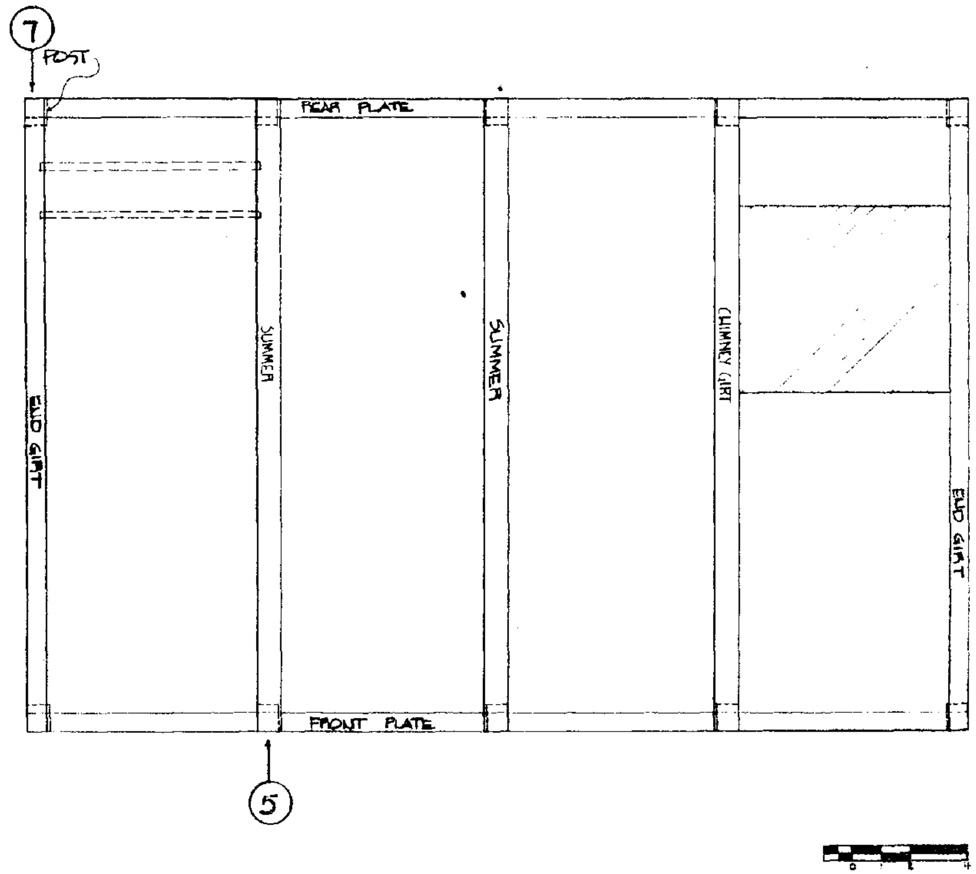



Figure 14. Type 1 - Attic Framing Plan

Above the second story posts were the upper end girts, upper chimney girt and second story summers directly above the first floor girts and summers. These are shown in figure 14 which is the attic framing plan or the framing which lies directly below the attic floorboards. The posts below are shown here as dashed lines. At the front and back of the structure were the front plate and the rear plate. The plates were 8" x 10" as were the second story girts. As previously mentioned, the upstairs summers were 10" x 12".

* * *

The roof of a type 1 house was a gabled or pitched roof shown in figure 15.

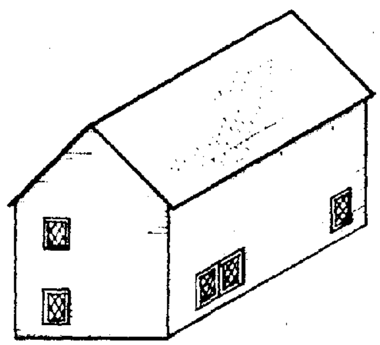


Figure 15. Gabled or Pitched Roof

Three major roofing members were used:

RAFTERS: The beams supporting the roof.

PURLINS: These were the horizontal beams set between the principal rafters at one or more levels between the plate and the peak of the roof.

COLLARS: A collar was a small beam in the garret that tied two rafters together, thus bracing them, usually just above head level.

The roofing system was very symmetrical. The rafters peaked in the center at the ridgeline at about a 45 degree angle. The two kinds of rafters that were employed are shown in figure 16. Principal rafters came up directly on top of each post. These rafters were 6" x 6" and mortised into the front and rear plates. In between these principal rafters were 3" x 3" horizontal members called purlins. These were located midway between the plate and the ridgeline. They were also mortise and tenoned into place.

Between the principal rafters and parallel to them were the smaller common rafters. Usually three of them were placed between the larger rafters. The common rafters were 3" x 3" and ran from the plates to the ridgeline. It is interesting to note that there was no ridgepole which ran the entire length of the house. The rafters met in a mortise and tenon joint at the ridgeline as shown in figure 17.

3. The Flooring System

The flooring system consisted of the joists, the oak flooring and the subflooring. Three inch by five inch joists about 20" on center framed into the floor beams. The girts and summers of one room hold the joists for the floor above. Due to the rigidity of an oak beam, joists were tusk-tenoned into one end and simply dropped into place at the other end. Figure 18 shows a tusk-tenoned joint.

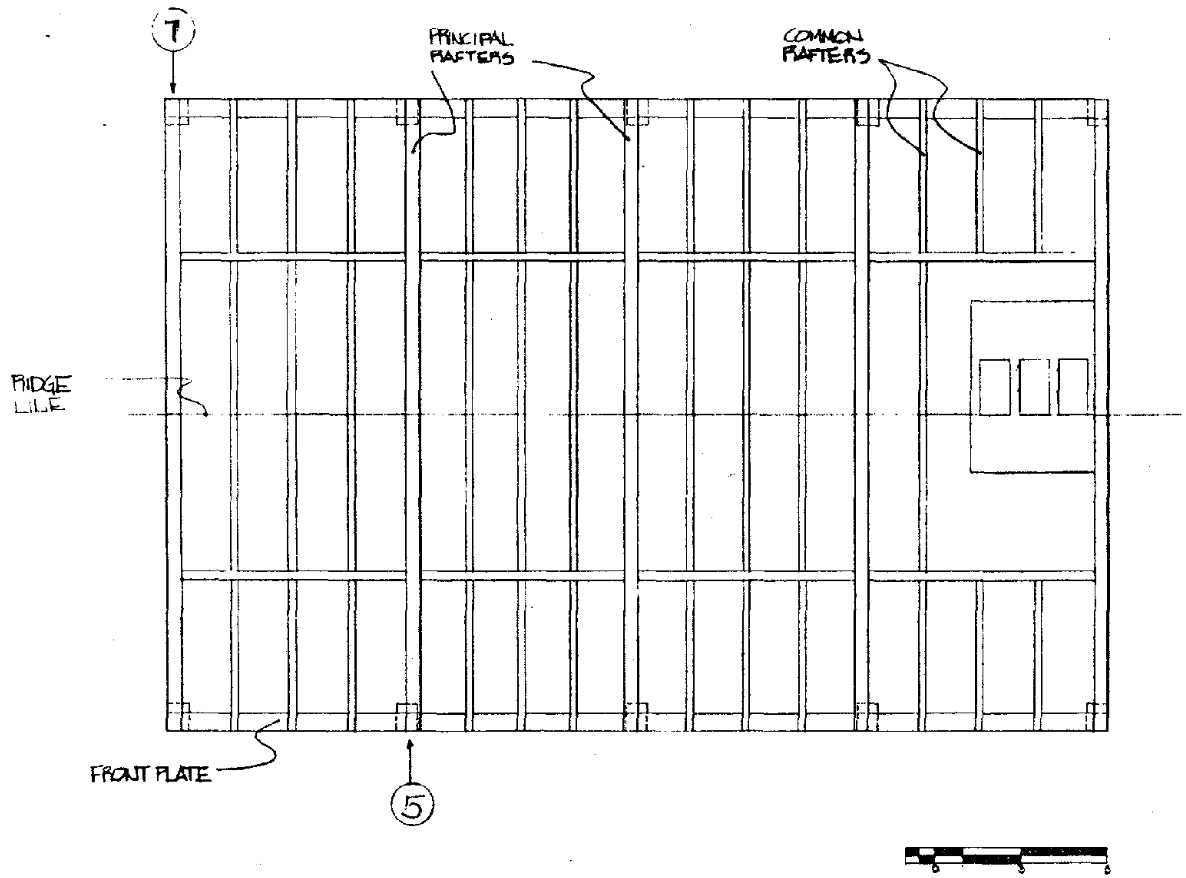



Figure 16. Type 1 - Roof Framing Plan

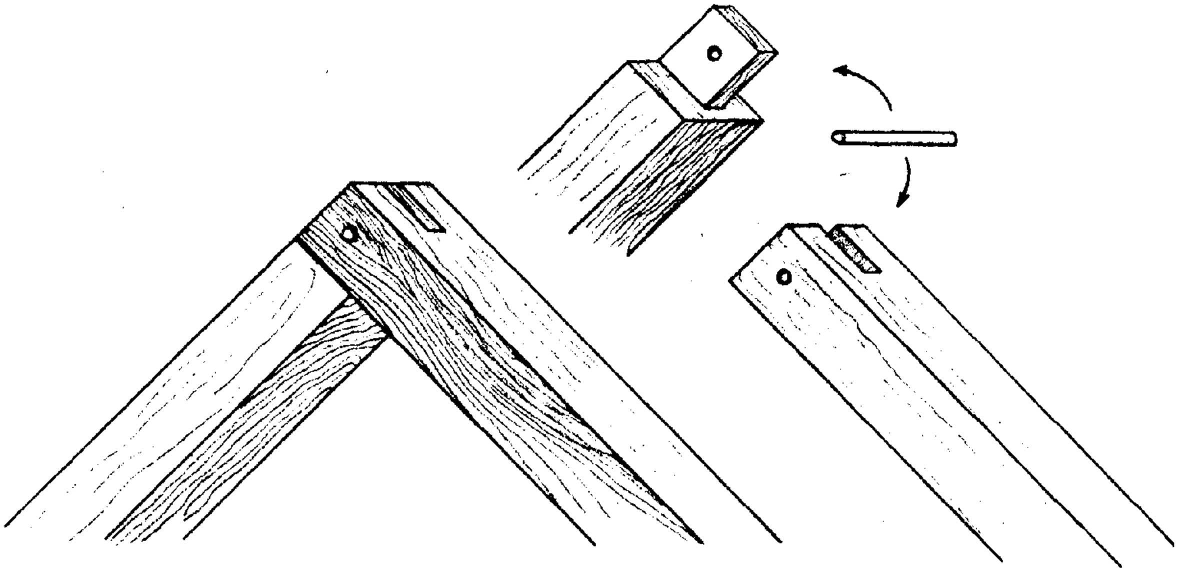


Figure 17. Mortise and Tenon in Rafters, No Ridgepole

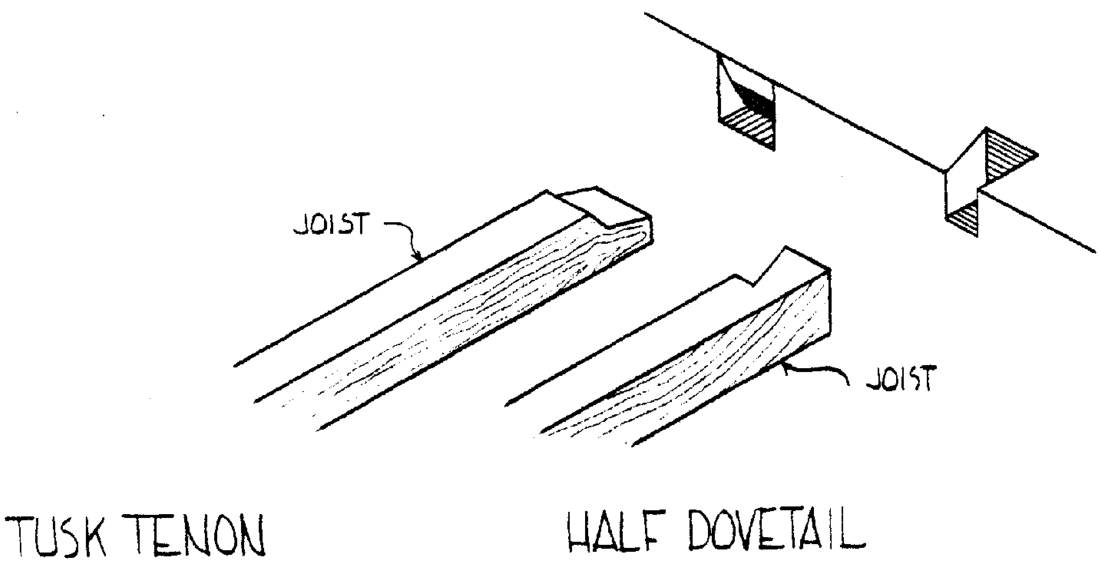



Figure 18. Framing Details - Joists

Later houses of this style have the ground floor joists framing into the sill, with the tops of the sills and the joists flush.

Floor boards were placed on top of the joists. Two layers of flooring were used. Wooden planks, usually of oak, 16" - 20" wide and 1" thick ran perpendicular to the joists. It is interesting to note that both the flooring and the subflooring ran in the same direction. Today many openings are noticable in old floors and one can look from one story through to the second story. Figure 19 shows how the floorboards were halved together at the joints.

Figure 19. Floorboards

4. The Walls

The walls were a very interesting part of the type 1 house. There are several possibilities. Three common cross sections will be discussed here and are shown in figure 20. First it can be stated that all these wall sections had studs. Oak members, 3" x 3", ran from sill to girt between the posts, and were spaced about 20" on center.

The first type of wall detail is with brick nogging. Bricks were laid up flat in clay mortar or mud between the studs. The exterior of

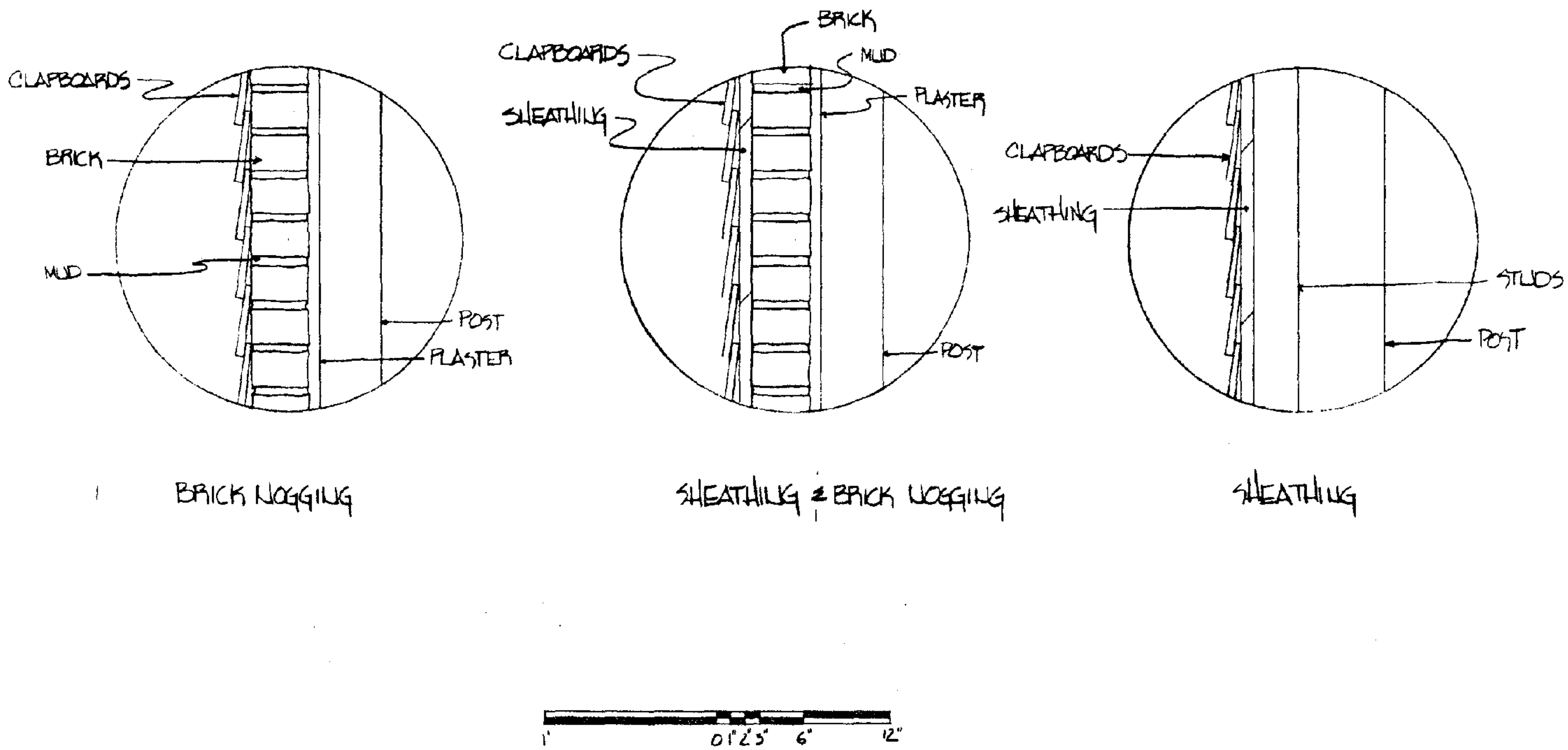



Figure 20. Type 1 - Exterior Wall Details

the wall was then clapboarded. Clapboards, usually of white pine, were 6" wide and overlapped each other an inch to keep out the weather. They were 1/2" at the top and thickened to approximately 3/4" at the base. Clapboards were 3 or 4 studlengths long and were nailed to the studs. Here we see one of the only uses of nails in the type 1 house.

The interior of the wall consisted of 1" of lath and plaster over the brick and studs.

Another type of wall detail is the sheathing and brick nogging detail. Early Americans learned that planks of wood nailed under the clapboards provided a better insulated house than one with brick nogging alone. Consequently, walls were laid up with brick and lath and plastered on the interior. However, before the clapboards were put on, oak boards about 12" wide, 1" thick and beveled on top and bottom were nailed to the studs. The clapboards were then nailed to the sheathing boards.

The third type of wall detail is the sheathihg detail. This wall section occurred when the colonists realized that the sheathing alone was sufficient insulation. The brick nogging was not necessary.

5. The Roofing System

Over the framing system of rafters and purlins, were the roofboards and the shingles. Figure 21 shows a cross section of the roofing system where it touches the chimney. The roofboards provided insulation and a nailing base for the shingles. The horizontal roofboards were about 1" thick and 12" - 16" wide. They were very

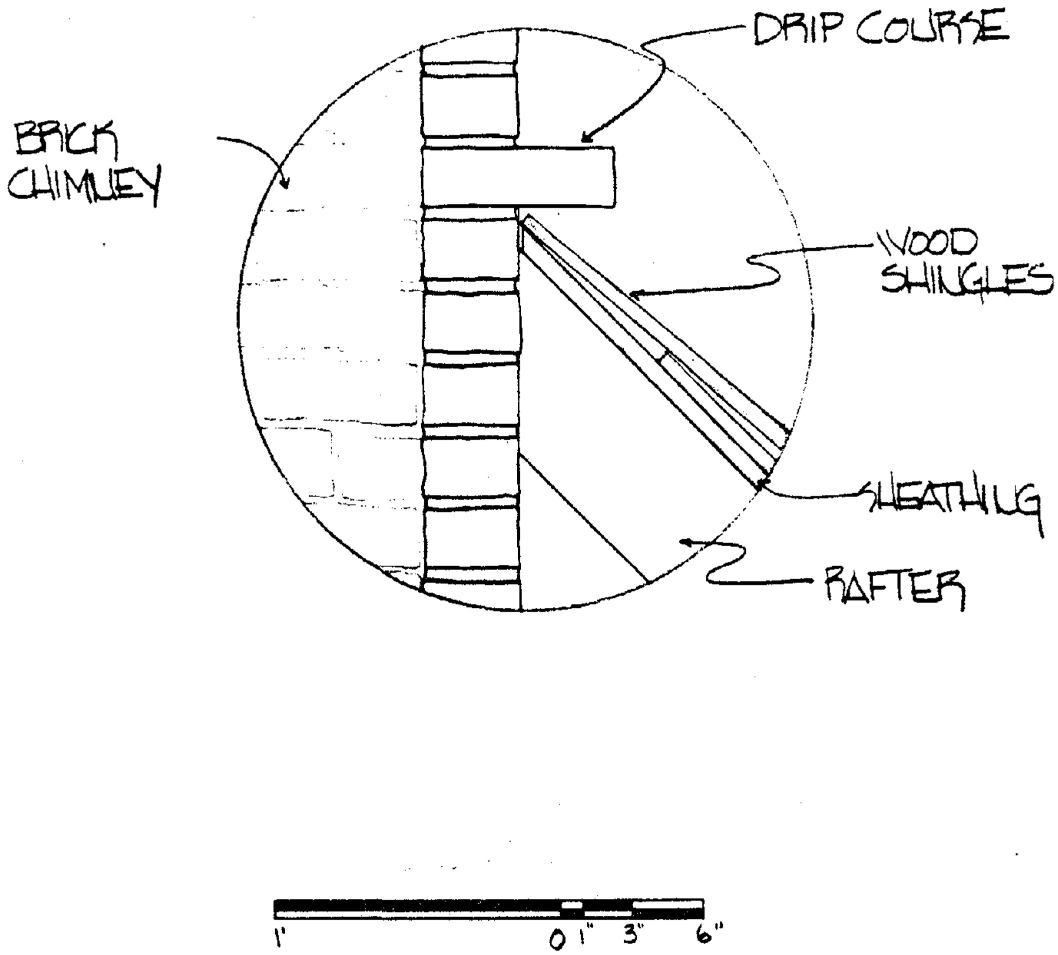



Figure 21. Type 1 - Roof-chimney detail

often rejects from the floorboards, because they had knotholes or were badly split.

Wood shingles were nailed to the sheathing, just as the sheathing was nailed to the rafters and purlins. The shingles were usually of white pine, the same material as the clapboards, noted for its weathering properties. Shingles were 1/2" to 3/4" thick, 8" - 10" wide and from 16" to 3 feet long. The exposure, or 'weather', varies from 8" to 10".

6. Interior Patitions

Non-load bearing interior partitions can be found in front of the fireplace on the first and second floors and between the stairway and the main room on the first and second floors. This can be seen in figure 12. Interior partitions were vertical oak planks, 2" thick and 12" - 16" wide. The doors to the hall and to the hall chamber were cut into the partition wall.

7. The Chimney

The chimney in the type 1 house was a massive brick structure which provided warmth, light and heat for cooking. Figure 22 shows a type 1 brick chimney. From the grade level where its dimensions were 12' x 7'6", it tapered up to a height of approximately 30', where its 4' x 6' summit was one wythe thick. This chimney held three fireplaces. Figure 23 shows the fireplace plans. The basement fireplace was 4' x 8' and 5' high, the first floor fireplace 3' x 8' and 5' high and the second floor fireplace was 2'6" x 4' and 3' high. These fireplaces,

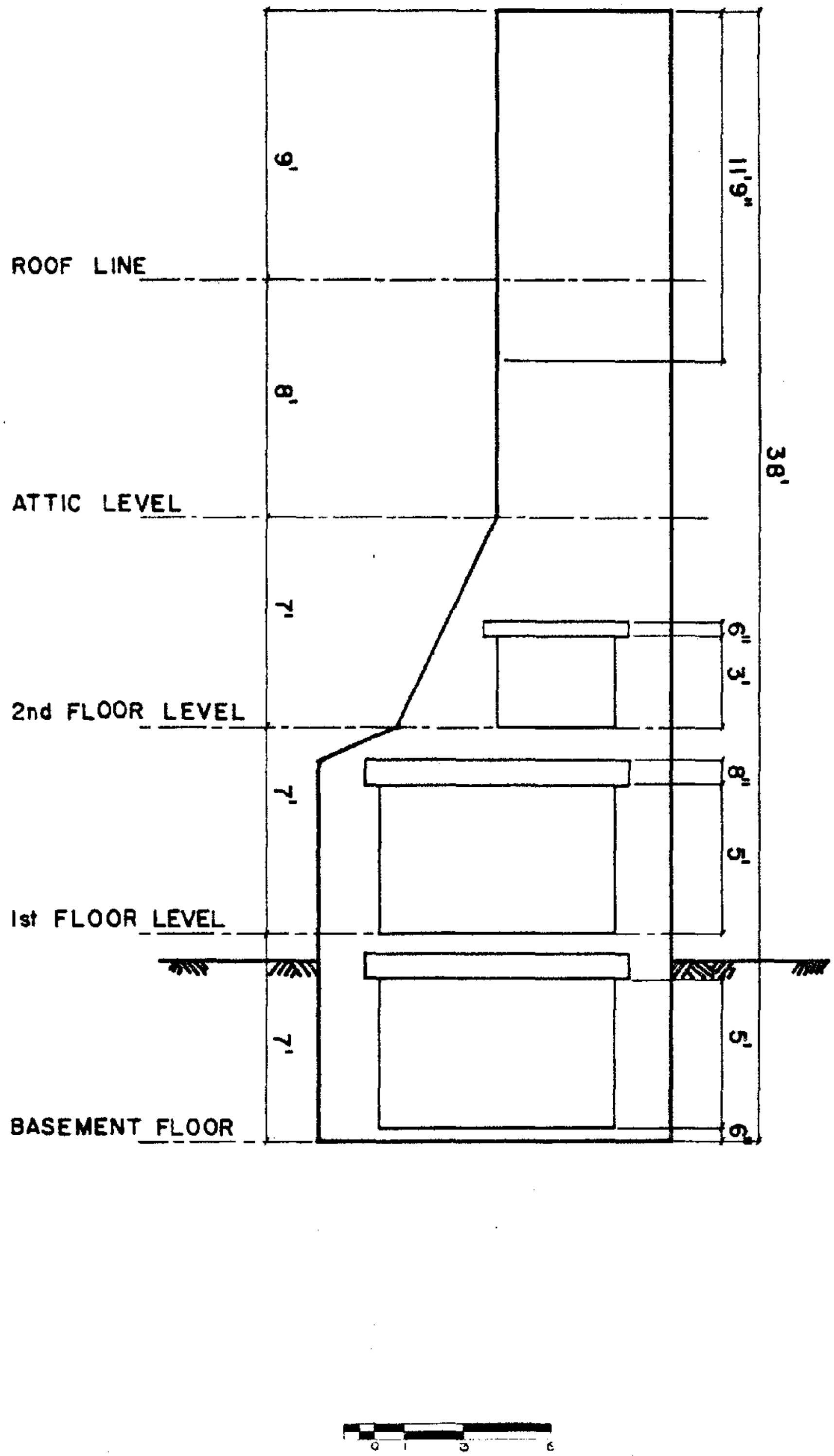



Figure 22. Type 1 - Brick Chimney

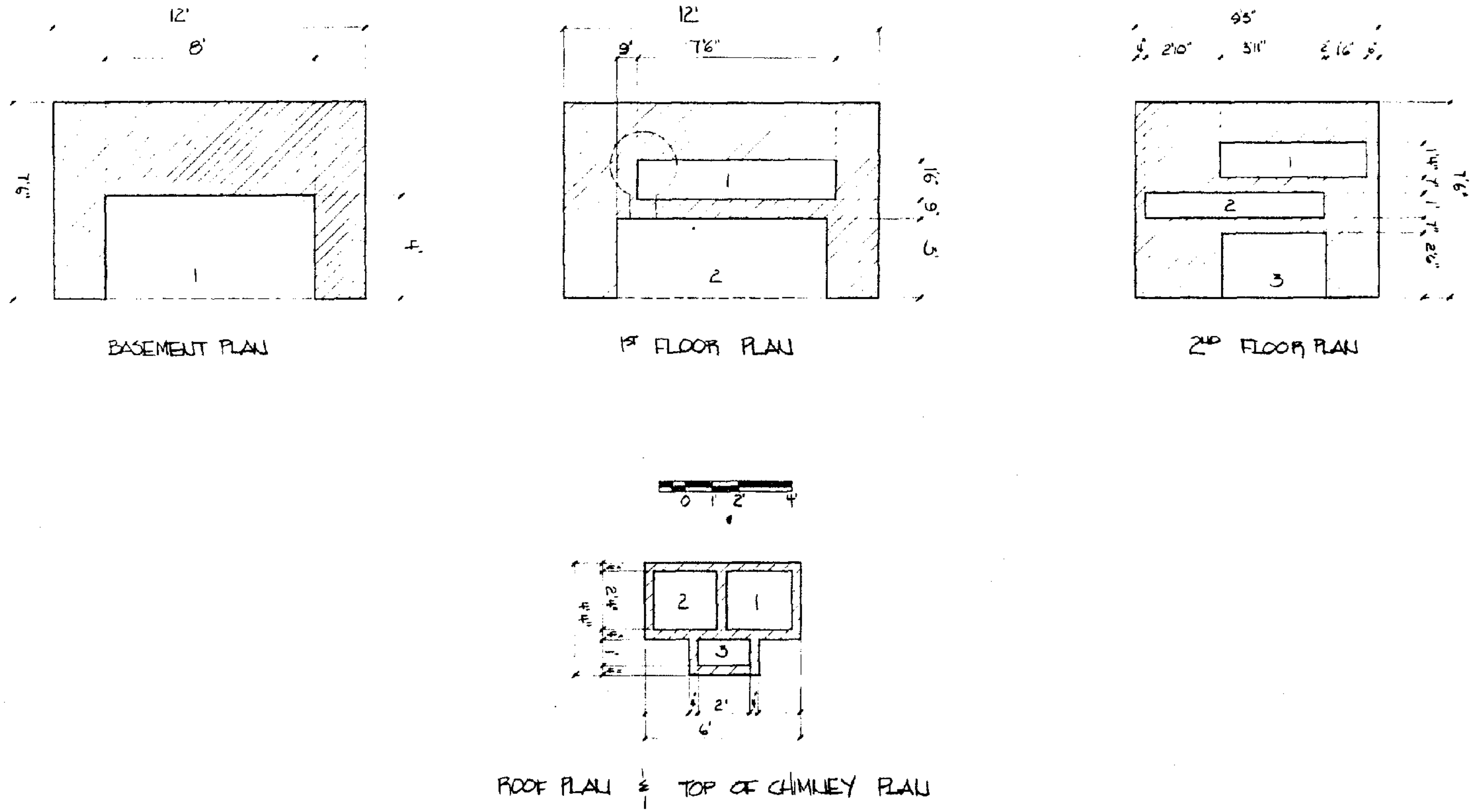



Figure 23. Type 1 - Chimney Plans

especially the larger ones were very inefficient and lost about 5/6 of their heat up the flue. The first floor fireplace was usually used for cooking and therefore had an oven at its back. This oven was basically a 25" - 30" diameter hemisphere.

In some cases, in extremely urban areas, the basement fireplace was the kitchen fireplace. Other alternatives for the basement include a solid brick or rubble base below grade for use as storage.

The flues, shown in figure 24, narrowed as they approached the top of the chimney and the brick around the top of the flues was one wythe thick. This can also be seen in figure 25, the chimney section.

Where the roof met the chimney a course of brick protruded out over the connection. This was the colonists form of flashing. The extended bricks were known as the drip course which is shown in figure 21. Lime mortar was certainly used above the roofline. Below the roofline less durable lime mortar or mud was used.

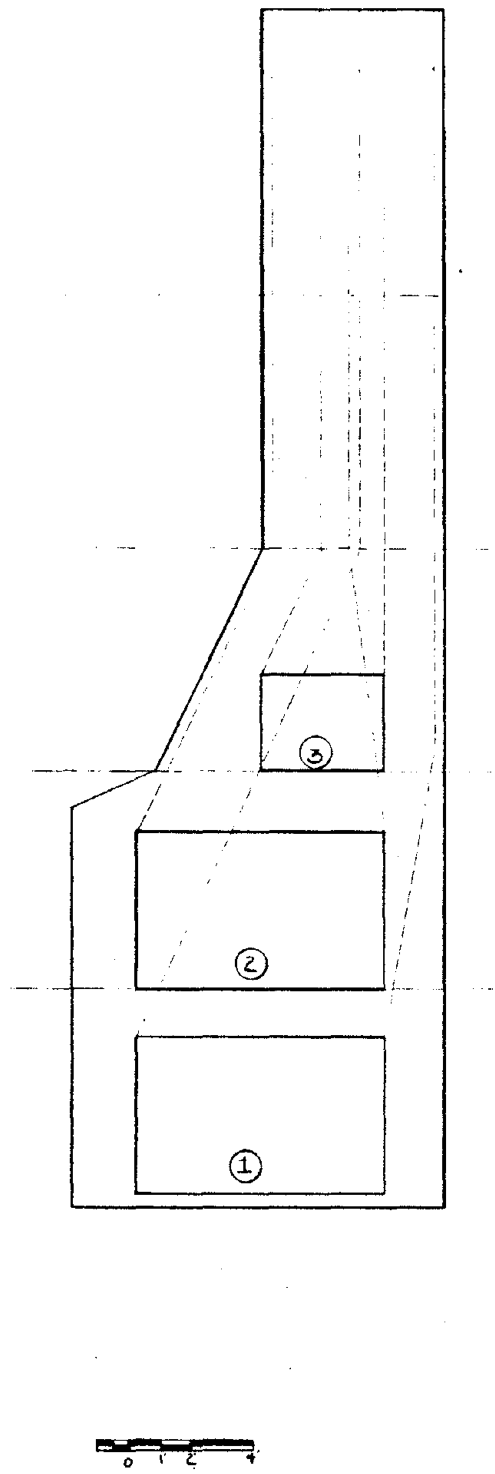



Figure 24. Type 1 - Flue Diagram

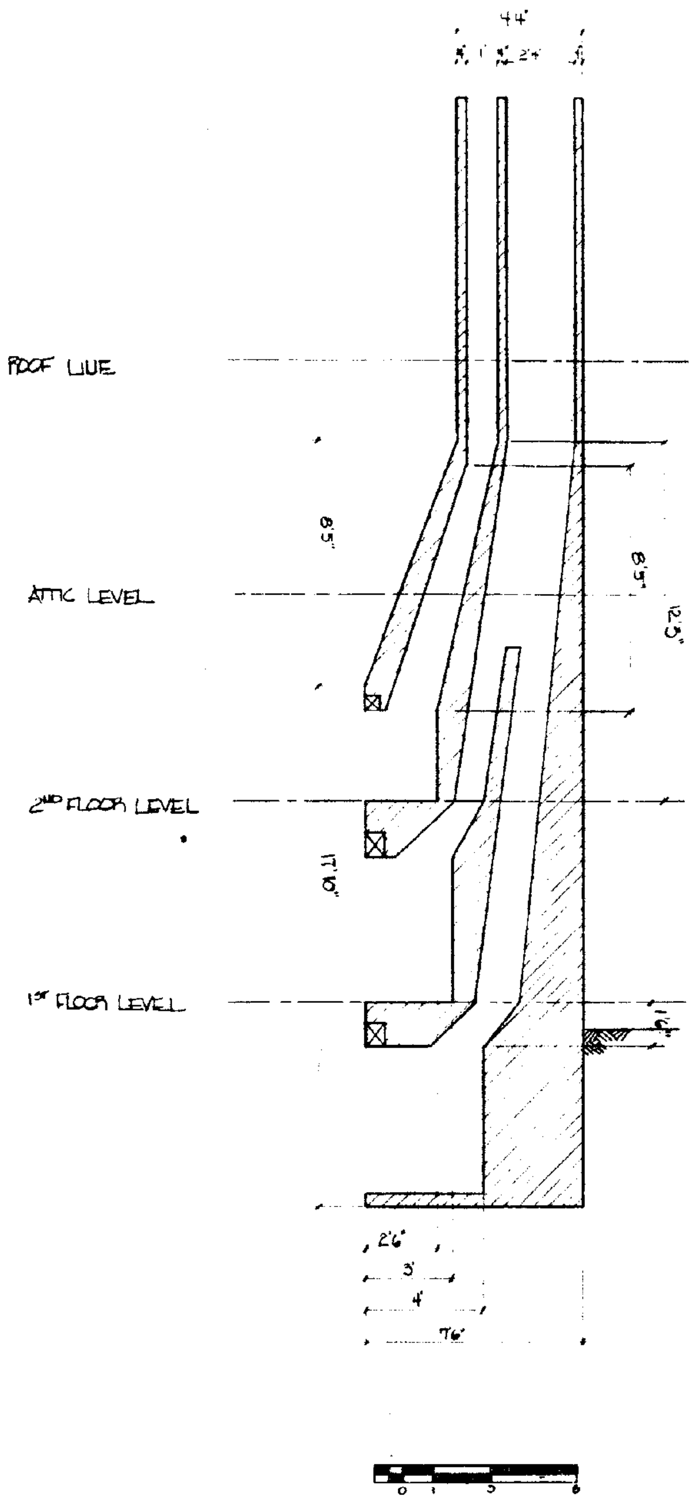



Figure 25. Type 1 - Chimney Section

## MASS CALCULATIONS

Based on typical weights of construction materials used, masses for each type of house have been calculated. This enables us to compare masses of different types and to compare the same type with different wall systems. The following table shows weights used for materials.

| | |
|---|---|
| WHITE OAK | 45 lbs./cu.ft. |
| BRICK & MORTAR | 105 lbs./cu.ft. |
| PLASTER | 120 lbs./cu.ft. |
| WHITE PINE | 28 lbs./cu.ft. |

What follows is a cover sheet including the weights of each system in the house and a total for the whole house. A similar cover sheet will be provided for each house type.

## MASSING CALCULATIONS - TYPE 1

| TYPE OF MATERIAL | WEIGHT OF MATERIAL IN HOUSE |
|---|---|
| 1. Wood Framing | 21.2 kips |
| 2. Chimney | 71 kips |
| 3. Flooring (oak) | 43.5 kips |
| 4. Interior Partitions (oak) | 0.875 kips |
| 5. Roof | 9.26 kips |
| 6. Walls | |
| Type A | 23.8 kips |
| Type B | 64.5 kips |
| Type C | 69.4 kips |
| TOTAL WEIGHT OF HOUSE | |
| with wall type A | 170 kips |
| with wall type B | 210 kips |
| with wall type C | 215 kips |

BUILDING TYPE 1A

The type 1A house is a heavy timber frame house with a lean-to addition. The lean-to could be built with the house from the start and called an original lean-to, or added later. Figure 26 shows the plan of a type 1A house. Figure 27 shows the frame of an original lean-to house, the Whipple-Matthews House in Hamilton, Massachusetts.[10] The Whipple-Matthews House is shown in figure 28. This style of house has the same materials and methods of construction as the type 1. The addition on the back, or the lean-to, consists of three rooms. The middle room is the kitchen, which has its own fireplace. Two smaller side rooms are formed by plank partitions. On one side is a room called a buttery and on the other is a borning room.

Not only does type 1A have a lean-to, but its chimney is central and it has symmetrical rooms on either side. There are two rooms on the first floor in the main part of the house and there are two chamber rooms on the second floor.

The Chimney

The type 1A chimney although larger is about the same height as the type 1. It has some additional fireplaces however. It is basically a doubled type 1 that is pushed out in back to add a kitchen chimney. Figure 29 shows two chimney sections and figure 30 shows two chimney elevations.

Figure 31 shows the chimney plans. The first and second floor

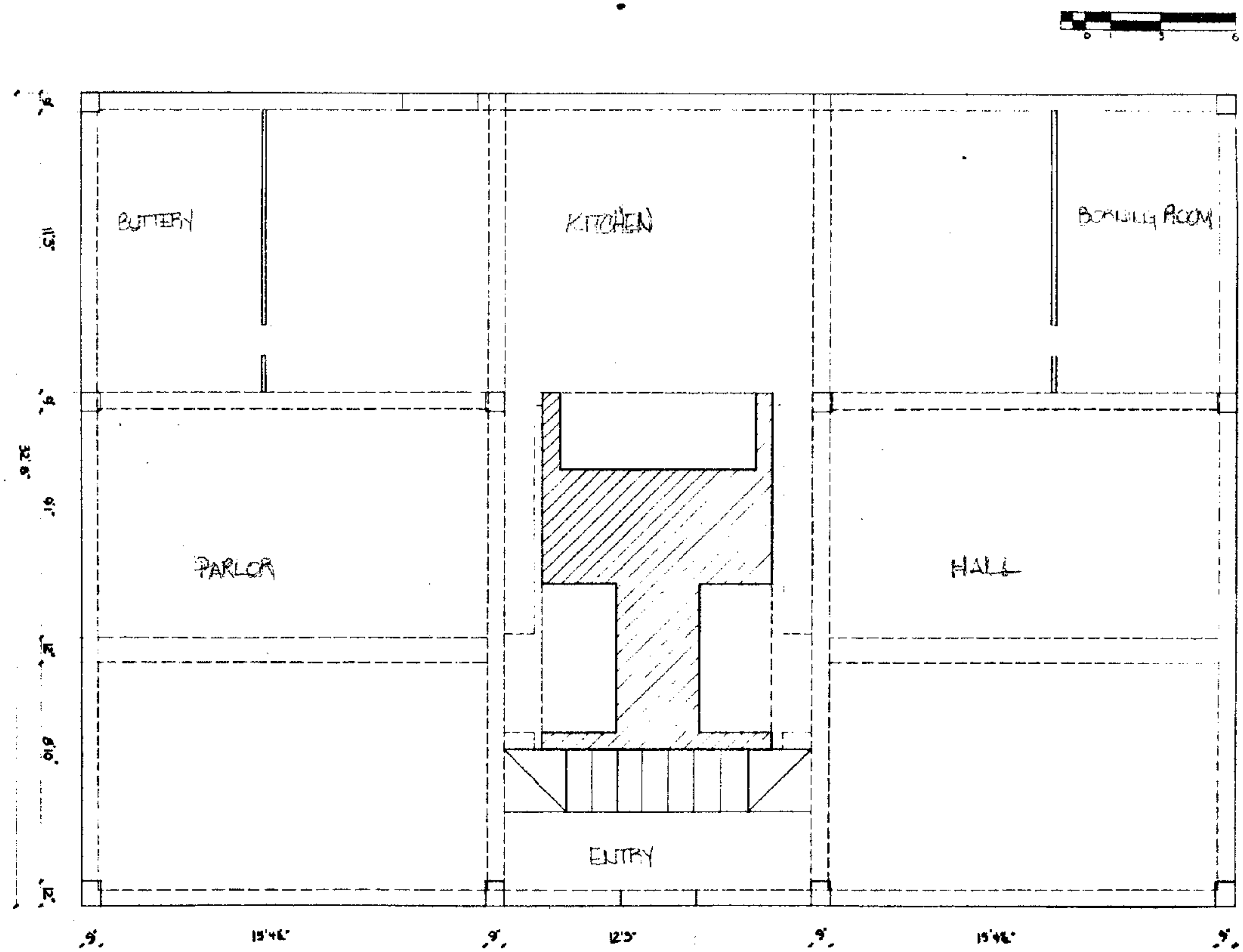



Figure 26. Type 1A - First Floor Plan

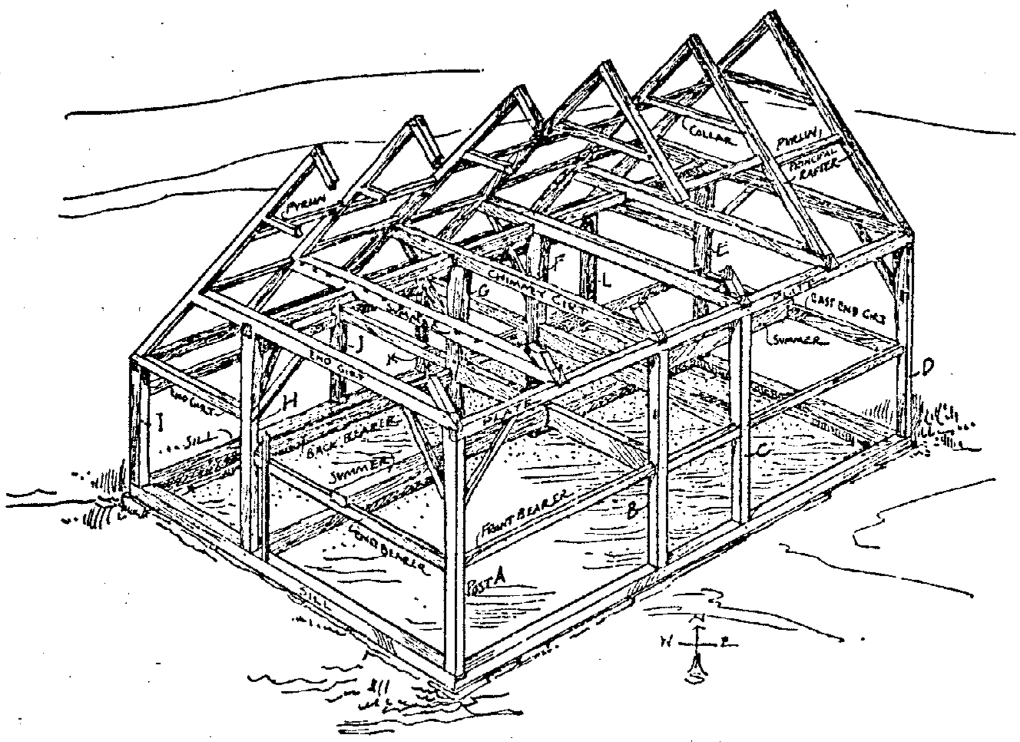



Figure 27. Frame of an Original Lean-to House

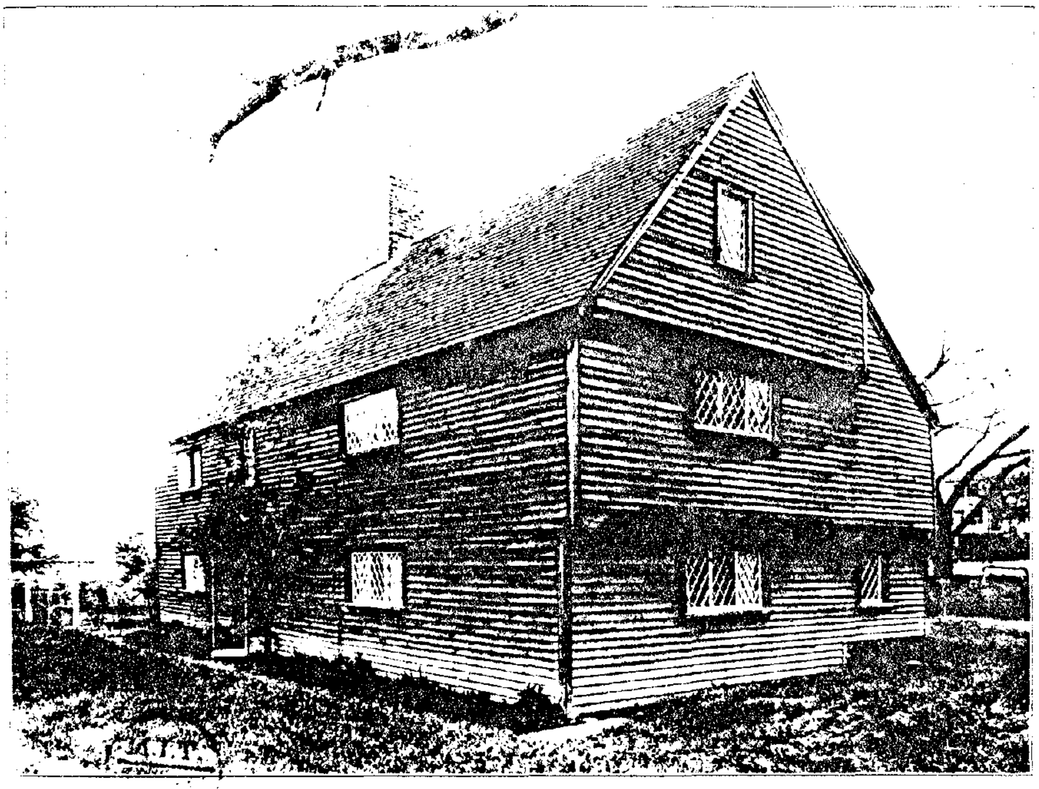


Figure 28. Whipple Matthews House, Hamilton, Mass.

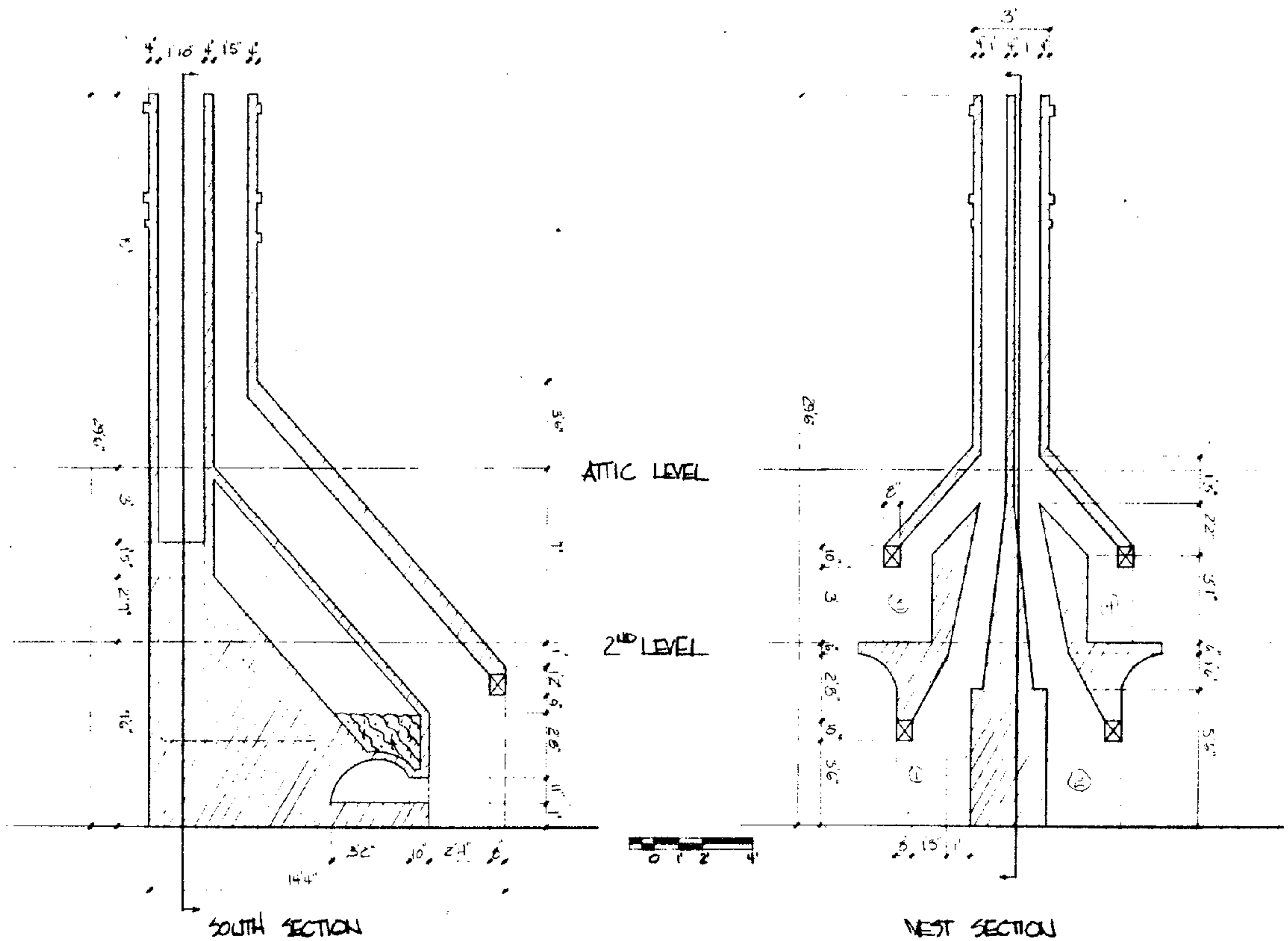



Figure 29. Type 1A - South Section and West Section of Chimney

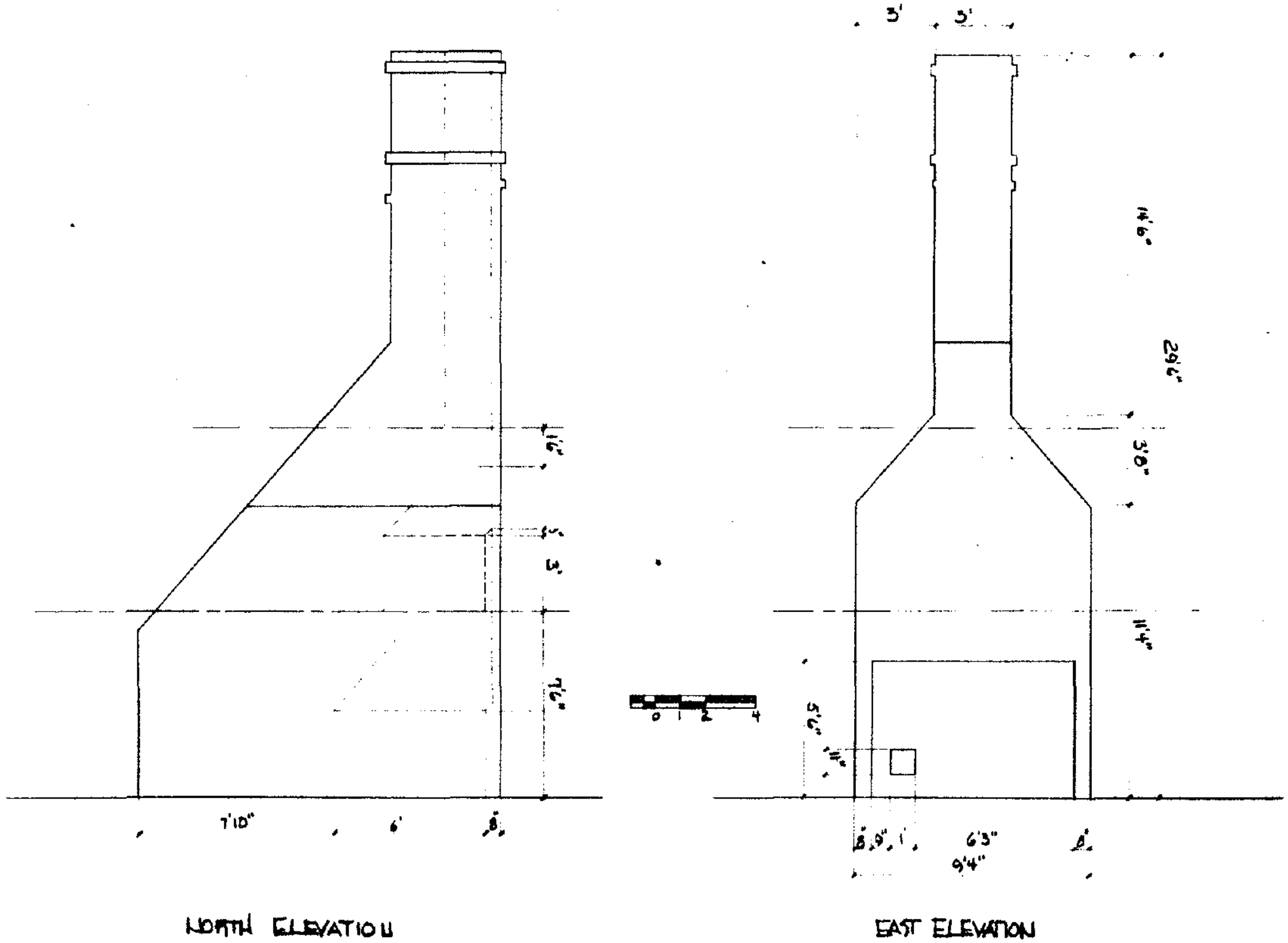



Figure 30. Type 1A - North Elevation and East Elevation of Chimney

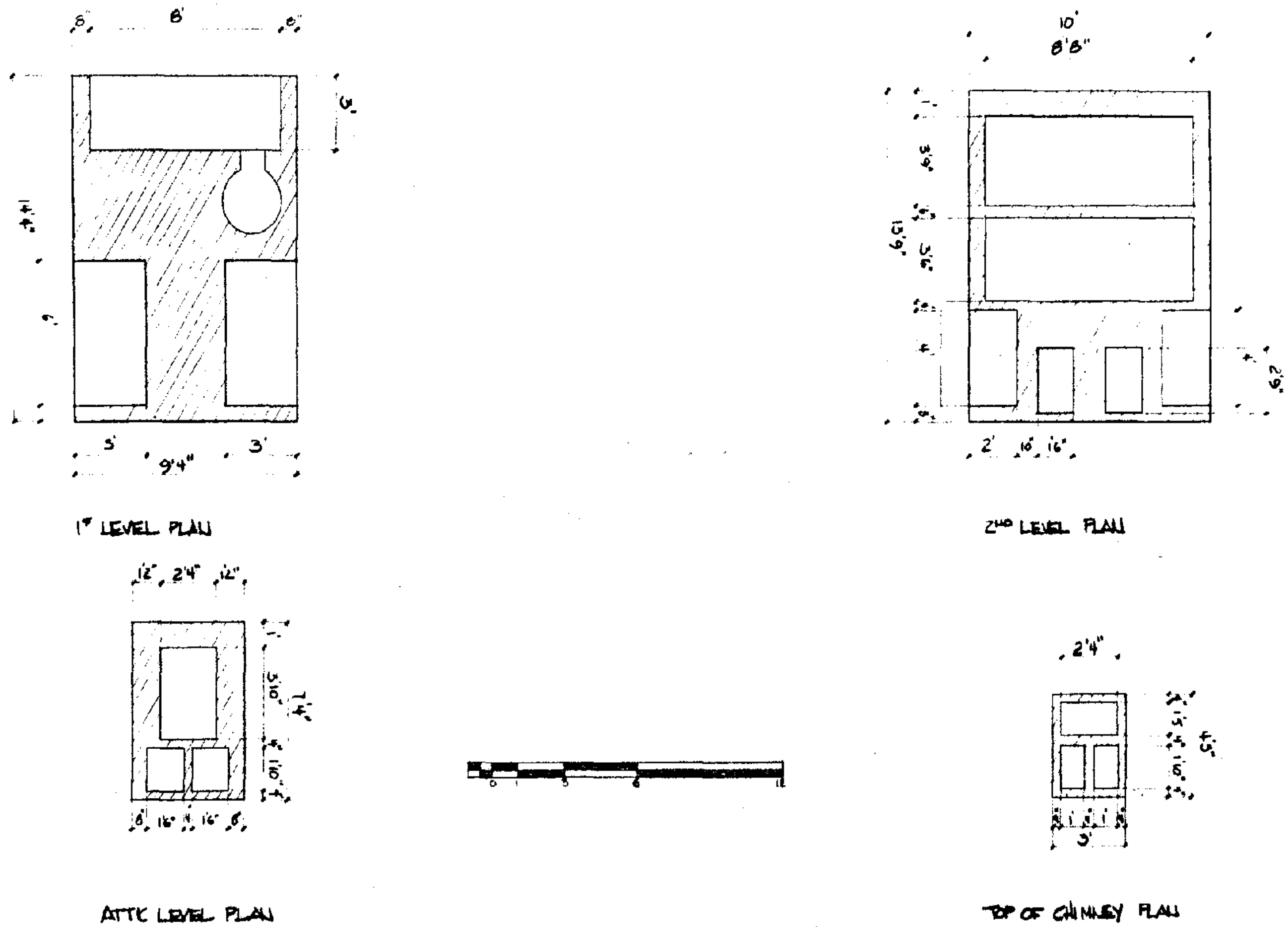


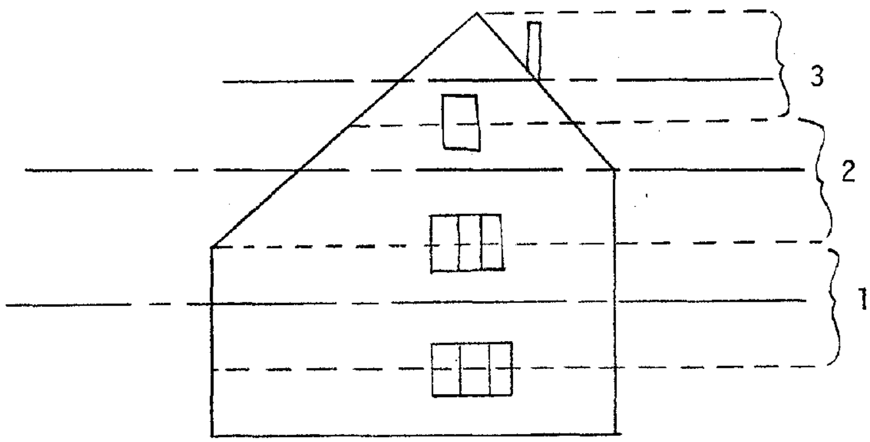

Figure 31. Type 1A - Chimney Plans

fireplaces on either side are symmetrical. The fireplaces on the first floor are 3' x 6' and 3'6" high. Their flues continue up behind the second floor fireplaces which are 2' x 4' and 3' high. Each first floor fireplace's flue and the smaller one above it continue up and become one flue at just about the attic floor level. These two flues, each encased by one wythe of brick, continue up to the top of the chimney. They are met by the flue from the kitchen chimney which comes up behind the first two flues. The base of the chimney is 14'4" x 9'4" and it tapers up to 3' x 4'3" at the top.

## MASSING CALCULATIONS - TYPE 1A

| TYPE OF MATERIAL | WEIGHT OF MATERIAL IN HOUSE |
|---|---|
| 1. Wood Framing | 28.7 kips |
| 2. Chimney | 86.1 kips |
| 3. Flooring | 75.2 kips |
| 4. Interior Partitions | 6.3 kips |
| 5. Roof | 15.9 kips |
| 6. Walls | |
| Type A | 28 kips |
| Type B | 76.1 kips |
| Type C | 81.8 kips |
| TOTAL WEIGHT OF HOUSE | |
| with wall type A | 240.2 kips |
| with wall type B | 288.3 kips |
| with wall type C | 294 kips |

## MASS DISTRIBUTION - TYPE 1A




| | Framing | Flooring & Subflooring | Interior Partitions | Walls | Roof | TOTAL |
|---|---|---|---|---|---|---|
| 1. Second floor connection | | | | | | |
| WALL A | 9.8 | 17.1 | 2.7 | 12.9 | 0 | 42.5kips |
| WALL C | 9.8 | 17.1 | 2.7 | 37.6 | 0 | 67.2kips |
| 2. Attic floor connection | | | | | | |
| WALL A | 8.8 | 13.8 | 1.8 | 6.1 | 4.7 | 35.2kips |
| WALL C | 8.8 | 13.8 | 1.8 | 17.8 | 4.7 | 46.9kips |
| 3. Chimney connection | | | | | | |
| WALL A | 3.2 | 0 | 0 | 2.5 | 9.6 | 15.3kips |
| WALL C | 3.2 | 0 | 0 | 7.3 | 9.6 | 20.1kips |

## CHAPTER 4 - BUILDING TYPE 2

The type 2 house is the masonry bearing wall house. It is modeled after the Pierce-Hichborn House in the North End, Boston. This type of masonry house was commonly constructed between 1700 and 1725 and is usually referred to as the Late Colonial or Early Georgian type. Although the Early Georgian house was at first an expression of wealth, it soon became a common type in Boston, especially downtown and in the North End. The Georgian is typified by its symmetry and its balanced facade, a requirement that took precedence over interior arrangement. Chimneys began to migrate from the center of the houses to the walls. The natural thing to do, and the most economical, then was to incorporate chimneys into brick bearing walls.

The type 2 masonry house has two rooms per floor, each with its own fireplace, and a central hallway running from front to back. In Area 1, downtown, and Area 2, the North End, type 2 often became a unit of row housing sharing one or two of its brick bearing walls with another house next to it. However sometimes it stood alone. A later version of this house had four rooms per floor, each with a fireplace, also located in the masonry end walls. This type was more likely to stand alone and was found mor frequently in the residential Area 3 than in the more densely populated sections of the town.

Roughly 80% (1100) of the buildings downtown, Area 1, were of masonry construction at the time of the 1755 earthquake. Forty percent (~560) of the buildings in the North End were of masonry construction.

Type 2 buildings were not as common in the outlying areas of the town. Only about 5% of the Area 3 buildings were masonry. This is only about 180 houses which more than likely were owned by the wealthier townspeople.

The type 2 house can be broken down into its basic parts which will then be discussed in greater detail:

1. the foundation
2. the brick bearing walls (mortar, bricks, sizes, bonding)
3. the chimneys
4. wooden framing members and the flooring system
5. interior partitions
6. the roofing system

1. The Foundation

The foundation does not differ from that of the type 1 house. It was a fieldstone and clay foundation about 21" thick on all four sides. It projected 5-1/2' into the ground as canbe seen in figure 32. Typically some broader, flatter fieldstones were chosen to top off the others, upon which a one foot thick brick wall began, the mortar now turning to a lime mortar.

2. The Brick Bearing Walls (mortar, bricks, sizes, bonding)

The basic unit of the masonry walls is the single brick, shown in figure 33. Although in one house it is highly likely that each brick is a slightly different size than the one next to it, for the purposes of this study the average size brick is used throughout the house with average size mortar joints. The typical brick is 2-1/4" high, 3-1/4"

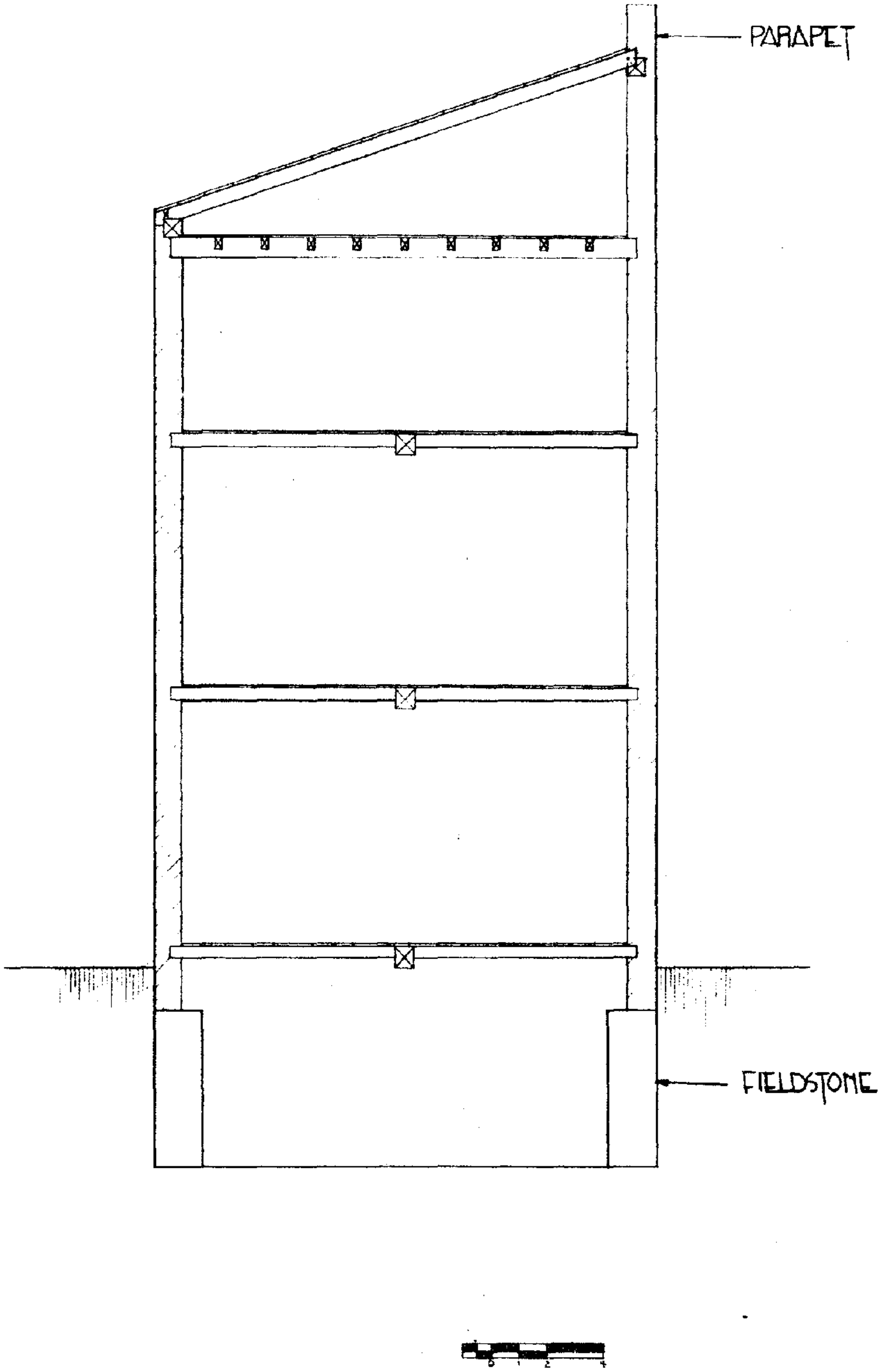



Figure 32. Type 2 - Section

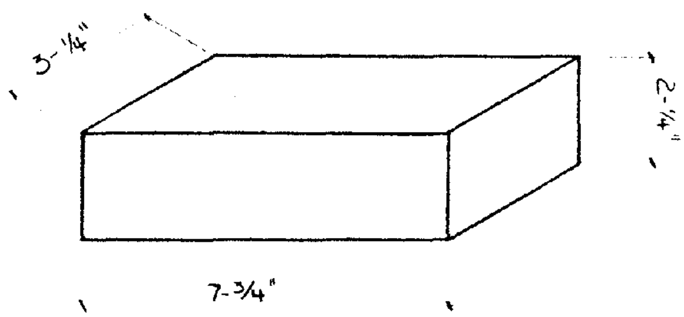



Figure 33. Type 2 - Typical Brick

wide with 3/8" vertical mortar joints. Its length is 7-3/4" with 1/4" horizontal mortar joints.

The bond used in all four walls of the Type 2 House is a common bond. Figure 34 and 35 pictures of the Hichborn House, show this bond, consisting of a header course and then three stretcher courses repeated from the bottom of the wall to the top. Figure 36 shows the brickwork where two perpendicular walls meet. Shown in Figure 37 are two stylistic elements. The horizontal belt courses marking interior levels and the treatment of window arches, both characteristic of the first quarter of the eighteenth century, but not of particular importance to this study. The bond used in the chimney was a running bond which is simply stretcher course upon stretcher course. This also occurred in the hearths.

Mortar

It is difficult to say what type of mortar was generally used at this time. Certainly the colonists had progressed farther than mud and straw. Probably the method of obtaining lime from turning shells was obsolete, also. Many sources indicate that lime was readily available at this time.[11] However, some will say that it was not or even if it was no one was using it in an efficient way. That is to say that by making mortar with the wrong process, the lime could not bond as strongly as it would have with a better mortar-making process.[12]

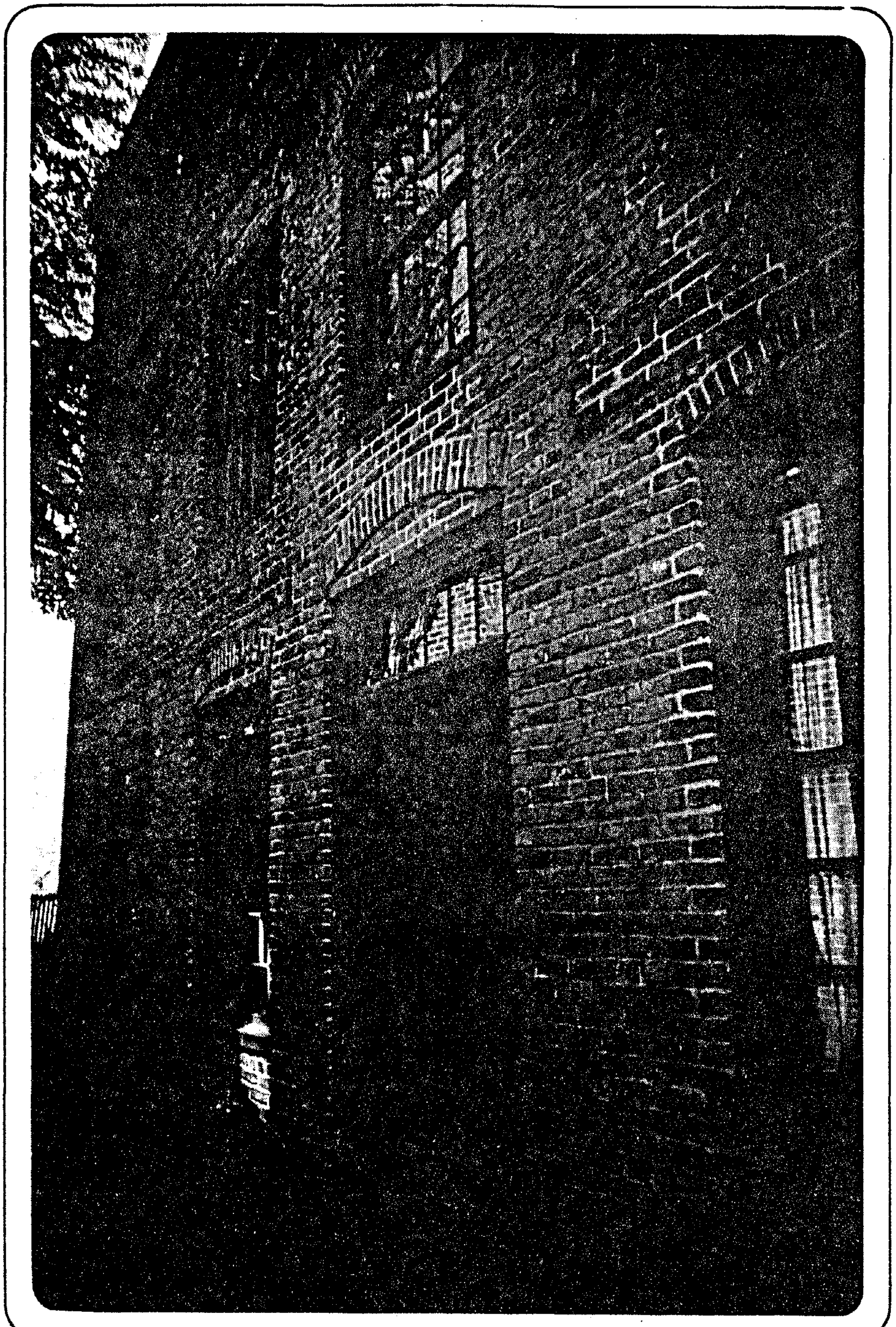


Figure 34. Hichborn House, North End, Boston

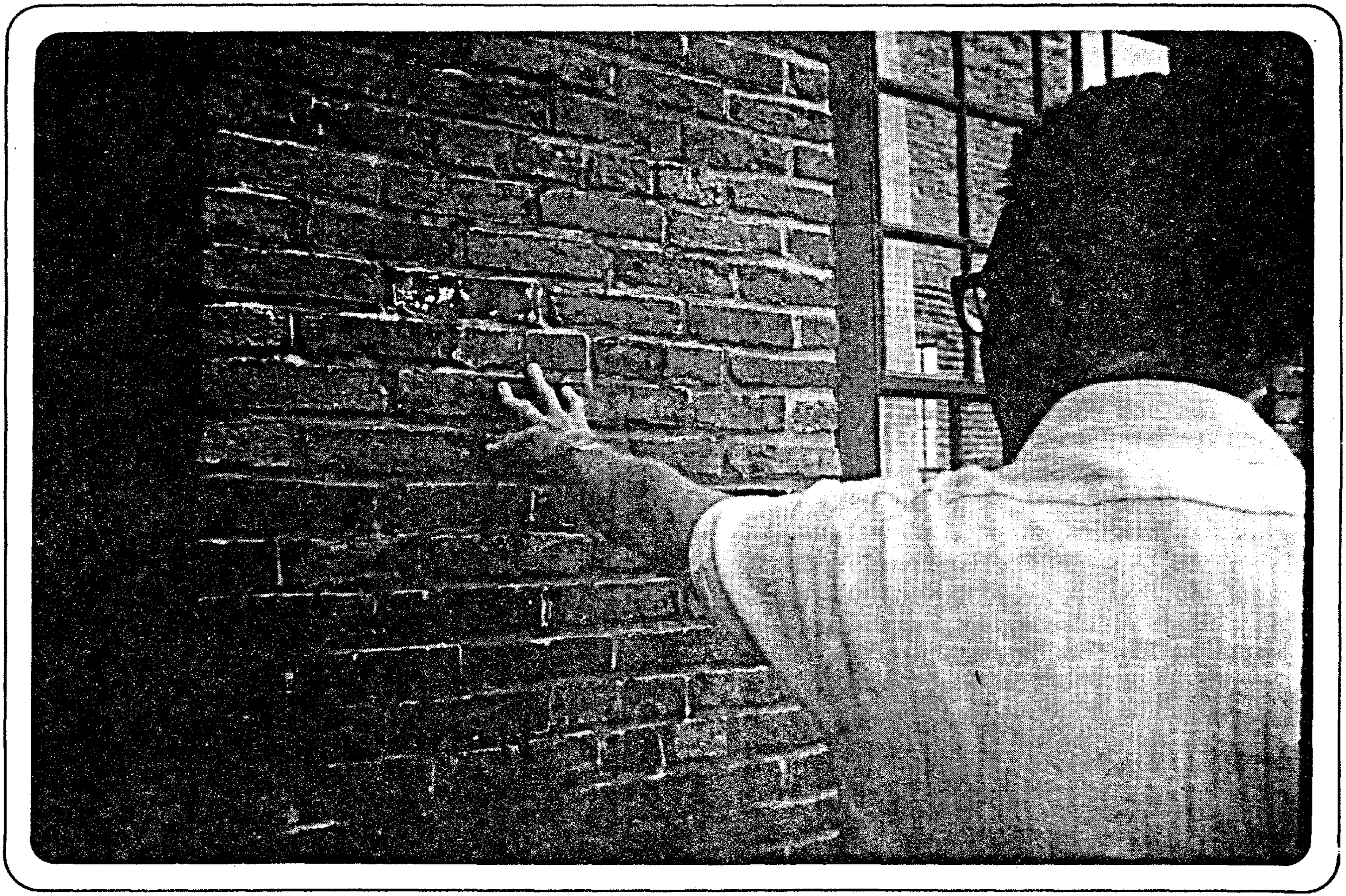


Figure 35. Hichborn House, North End, Boston

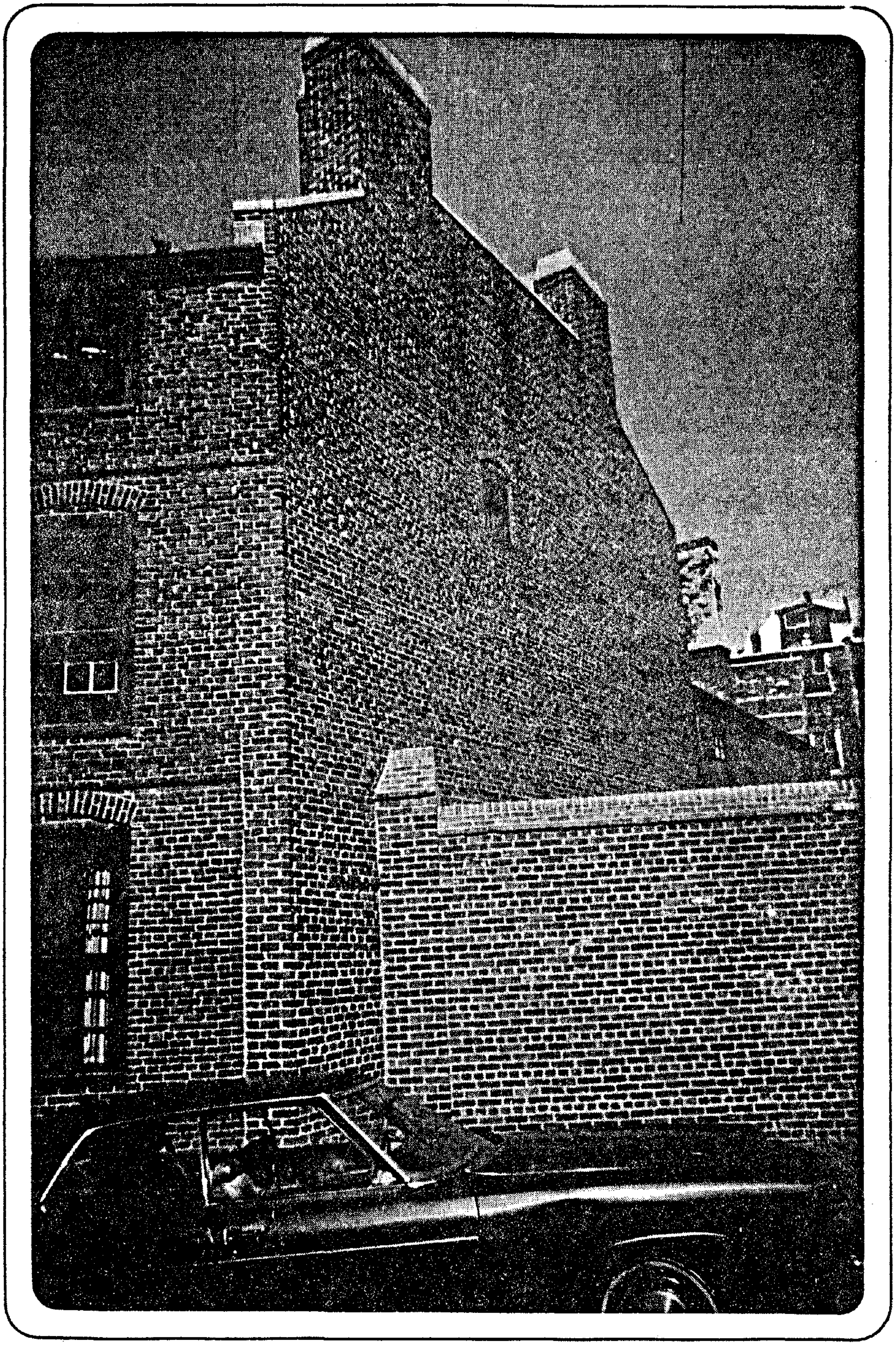


Figure 36. Hichborn House, North End, Boston

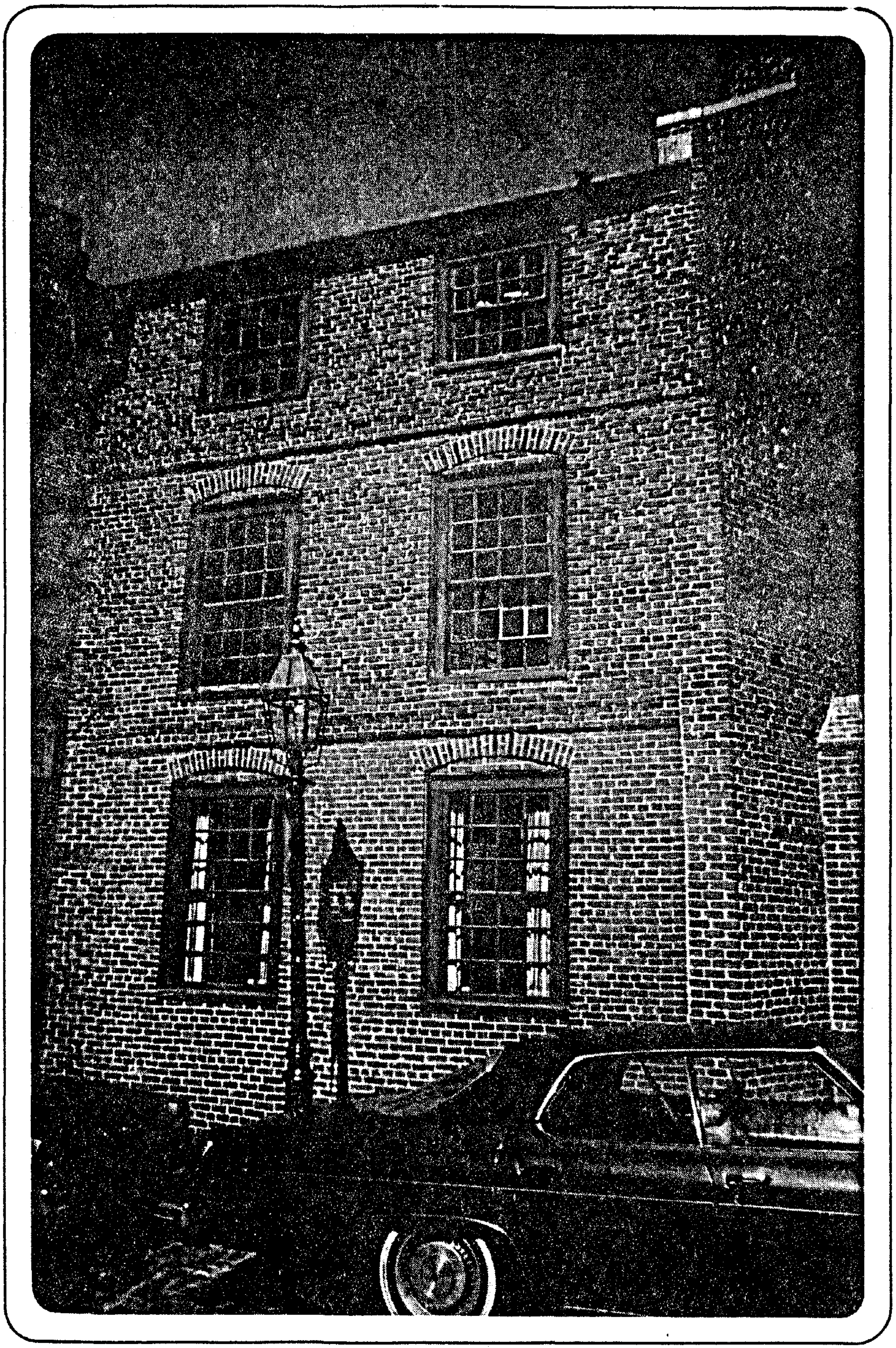


Figure 37. Hichborn House, North End, Boston

Some information on mortar content is available. For instance, mortar analysis from a basement wall in the Baldwin House at Branford, Connecticut (pre-1650) gives the following proportions:

| | |
|---|---|
| "Silica (sand | 30.14 |
| Lime Carbonate | 51.44 |
| Clay | 3.70 |
| Iron Oxide | 4.10 |
| Organic | 10.10 |
| | 99.48 |

"Sample also contains traces of calcium hydroxide and of magnesium carbonates."[13]

Probably the best description of brick making is the following passage by Thomas Dawes a brickmaker, who, although writing the article in the latter part of the 18th century, describes in great detail the "tried & true" methods of masonry probably used in the first half of the 18th century.[14]

## 4.b BRICKS AND MORTAR IN EIGHTEENTH CENTURY BOSTON

Boston Magazine    Athenaeum

April 1784 By Thomas Dawes, bricklayer - architect

pp. 219-20 "On Making Bricks" "Z" "Boston, April, 1784"

Two sorts of bricks:
1. Sand bricks, for arches, fascias, etc.
2. Common red brick

Particulars on latter:
1. Heaped in spring for rain and dew=mortar
2. Put in moulds
3. "Turned out" on floor and dried
4. Piled up in kiln
5. Burnt and made ready for sale

Results are 3 types: 1. Cherry red
2. Clinkers - hard burned, glazed ends
3. Soft - "chimney bricks" little burned

100,000 bricks in kiln -

law of commonwealth regulates size of bricks 8"x4"x2" after burning inferior: mould not pressed, oversize, honeycombed, smaller o. clay dug in fall, lay in body all winter, tempered in spring by oxen treading (less well prepared by laborers turning over and over, too much water) "small sort commonly made"

if brick walls built in fall were covered following winter improvements in bond, strength - sometimes washed out when green.

"On Making Mortar" p.432-3 "Z"

... "observations upon the mortar generally used by the bricklayers in this metropolis and the neighborhood of it."

... most commonly made with any sort of lime and sand purchased at the cheapest rate and easily come at."

... mixed hastily together without being properly incorporated

... too new or too old for purpose of cementing with proper strength. Good limestone in several parts of state "That in the county of Lincoln at St. Georges has the preference."

... the sooner used, the better - "age will weaken it and the air will slack it, however close the casks may be into which it is put."

"Sand

... should be carefully attended to: that which is a grey color and free from filth, will make the brightest mortar and is the best for outside work." "The sand should be of sharp grit, and its particles like very small stones, and may be got at the islands in this harbor.

... after it has been washed with rain and exposed to the sun and air it becomes fresh and equal to any pit sand;"

... one cart load and a half of this sand is sufficient for one hogshead of stone or quick lime containing one hundred gallons."

"Mortar for Outside work

...take one third of a hogshead of lime and a half a cart load of sand"

...put sand on "floor of rough boards making a circle of say six of eight feet in diameter and put the lime in the center, the throw water on in such quantities as to set it a slaking, but not so much as to drown the lime."

"On Making Mortar"

..."As the lime begins to open and smoke throw on alternately the sand from the outer circle of bed, and repeated quantities of water keeping in as much as possible the smoke and steam; that the fine particles of flour of the lime may not fly off (incorporate as soon as possible) in a week or ten days you will find a kind of sweating in the mortar, somewhat like a fermentation, it is their in the best state for adhering to the stone or brick and will continue in this state sufficient time for use. This kind of mortar for more than thirty years continues in the joint, as firm and hard as the stone and brick. In brick work made of any such mortar, I have known it difficult to get a nail of any sort into the joint. Mortar made of fine sand in which are particles of clay and dirt answers very well for chimneys, filling of walls, and inside work not exposed to the weather."

...Bricks in the hot months are exceeding thirsty, more especially if they are carted from the kiln immediately to the work without having received any rain or dew

..."if laid in this state... poor bond results...wetting recommended keep dry in wet months... do not allow freezing.1764 building" ... "as good brickwork as any in metropolis" had bricks "taken out of kiln in Brookline" built in winter, mortar "used Hot" lime slaked with hot water.

3. The Chimneys

The chimney in the type 2 house was a large brick structure. It differed from the type 1 chimney by being somewhat smaller but more importantly by being incorporated into the brick bearing wall. Two identical chimneys occur in the type 2 house, both in the rear wall.

During construction the wall and the chimney probably rose together. As in the type 1 house the six fireplaces provided light, warmth and heat for cooking. Figures 38 through 41 show the chimney in plan, section and elevation.

Each of the six rooms has its own fireplace. Three fireplaces will be described in detail, with the understanding that there is a mirror image on the other side of the house. The dimensions of the chimney at the first floor level are 5-1/2' deep by 7'4" wide. This includes the hearth which is 21" deep brick laid in a running bond as is the rest of the chimney structure as previously mentioned. The first floor hearth is supported by the chimney base, also 5'6" deep by 7'4" wide, which consists of a large arch made of brick. This basement arch, shown in figures 39, 40 and 41 was used mainly for storage. As in the type 1 house this chimney base could alternatively be solid brick or a basement fireplace.

The dimensions of the first floor fireplace are 3'10" deep by 6' wide. An elementary smoke shelf can be seen in chimney section, figure 39, and this occurs in each fireplace. The second story fireplace is 2'5" deep by 3'10" wide. Its hearth is 14-1/2" deep, laid in running bond and supported by a brick corbel as seen in the corbel detail, figure 42. It can be seen that the joists mortise and tenon into the header which in turn touches the edge of the corbel. The flooring is laid over the joists and the header and also touches the brick corbel. The header is the only wooden member of the joist

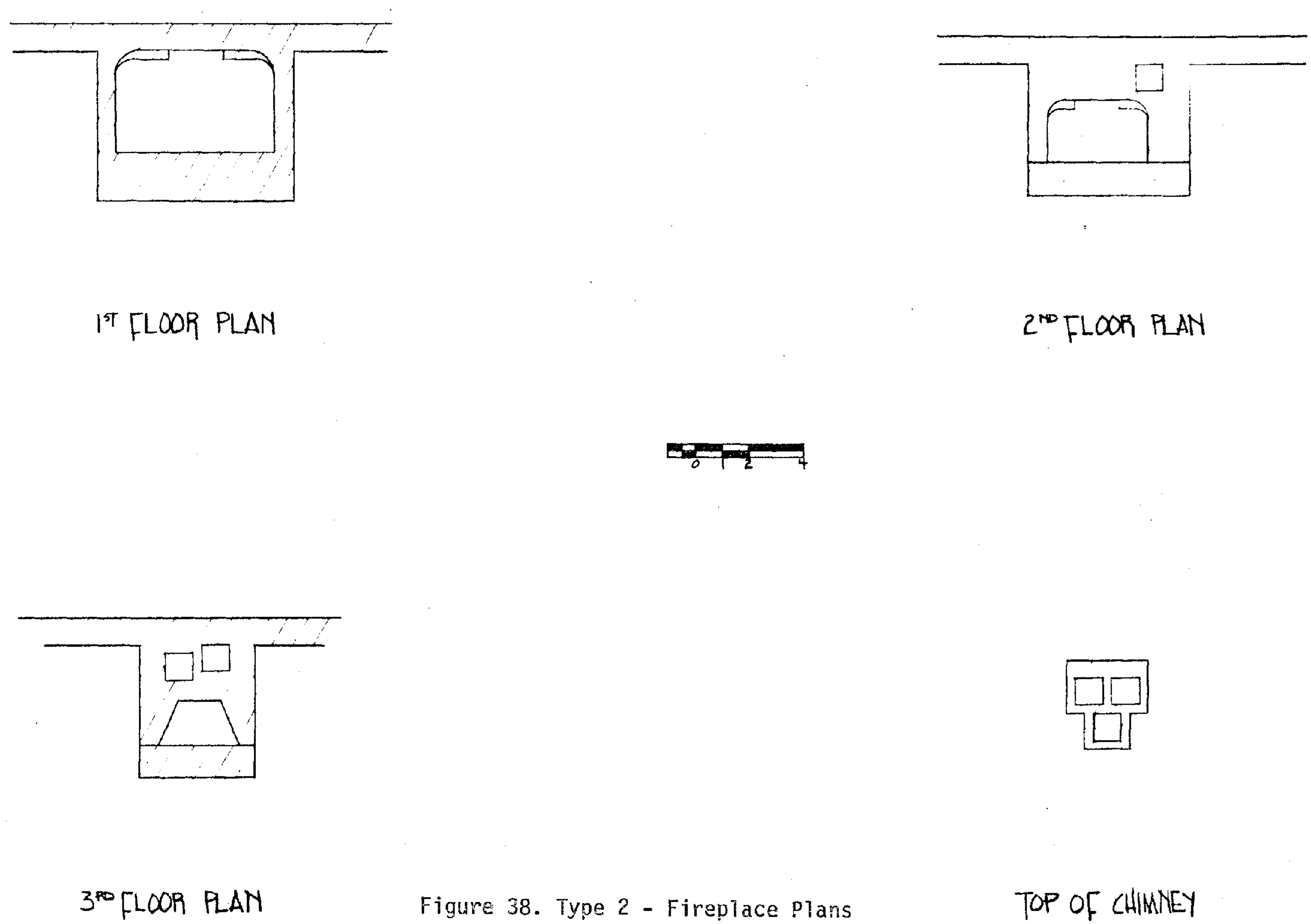



Figure 38. Type 2 - Fireplace Plans

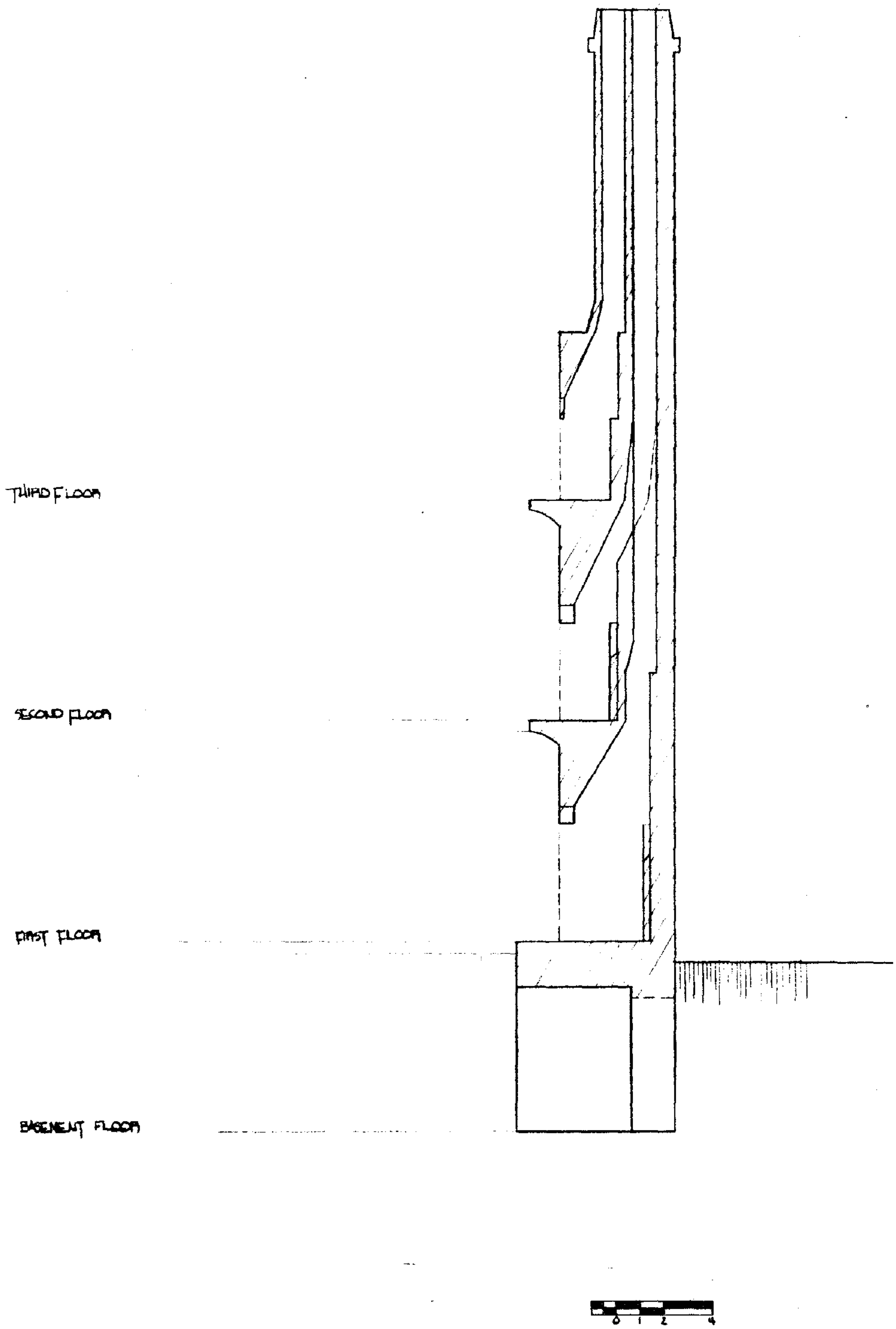


Figure 39. Type 2 - Chimney Section

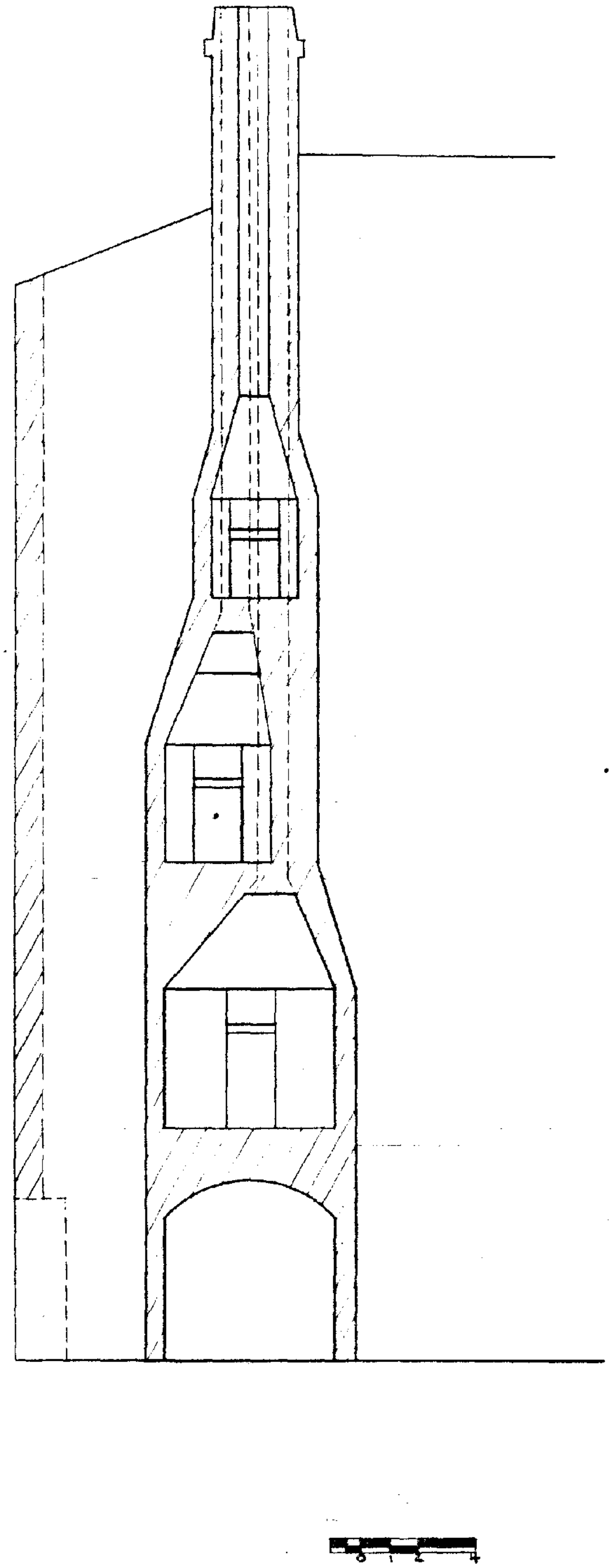



Figure 40. Type 2 - Chimney Section

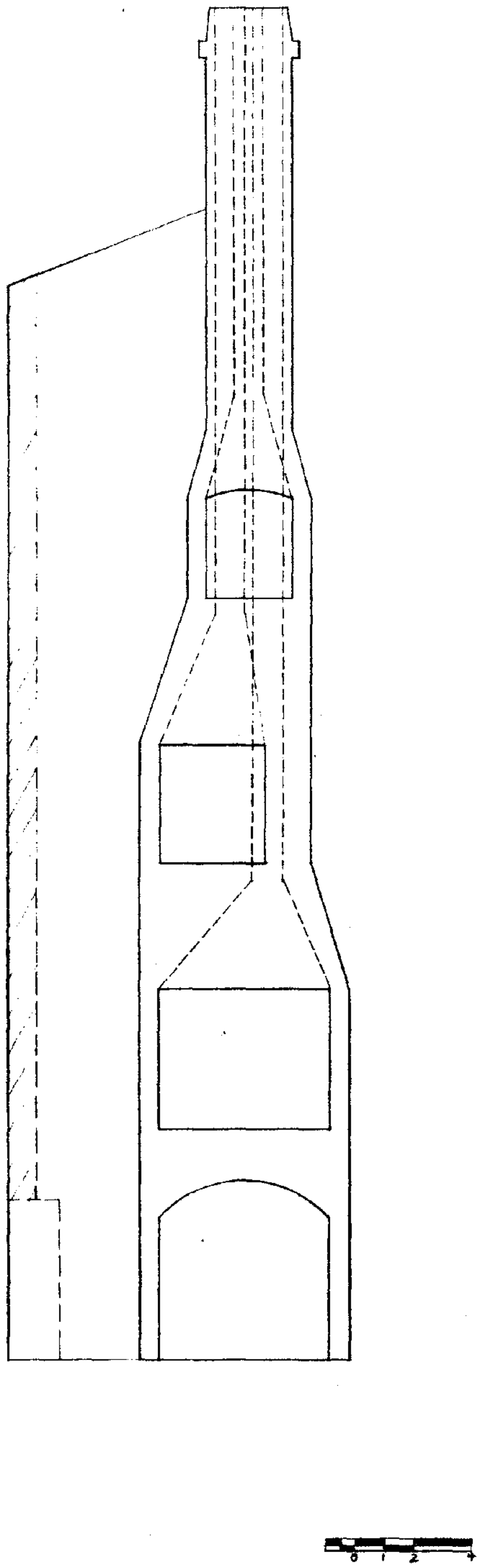


Figure 41. Type 2 - Flue Diagram

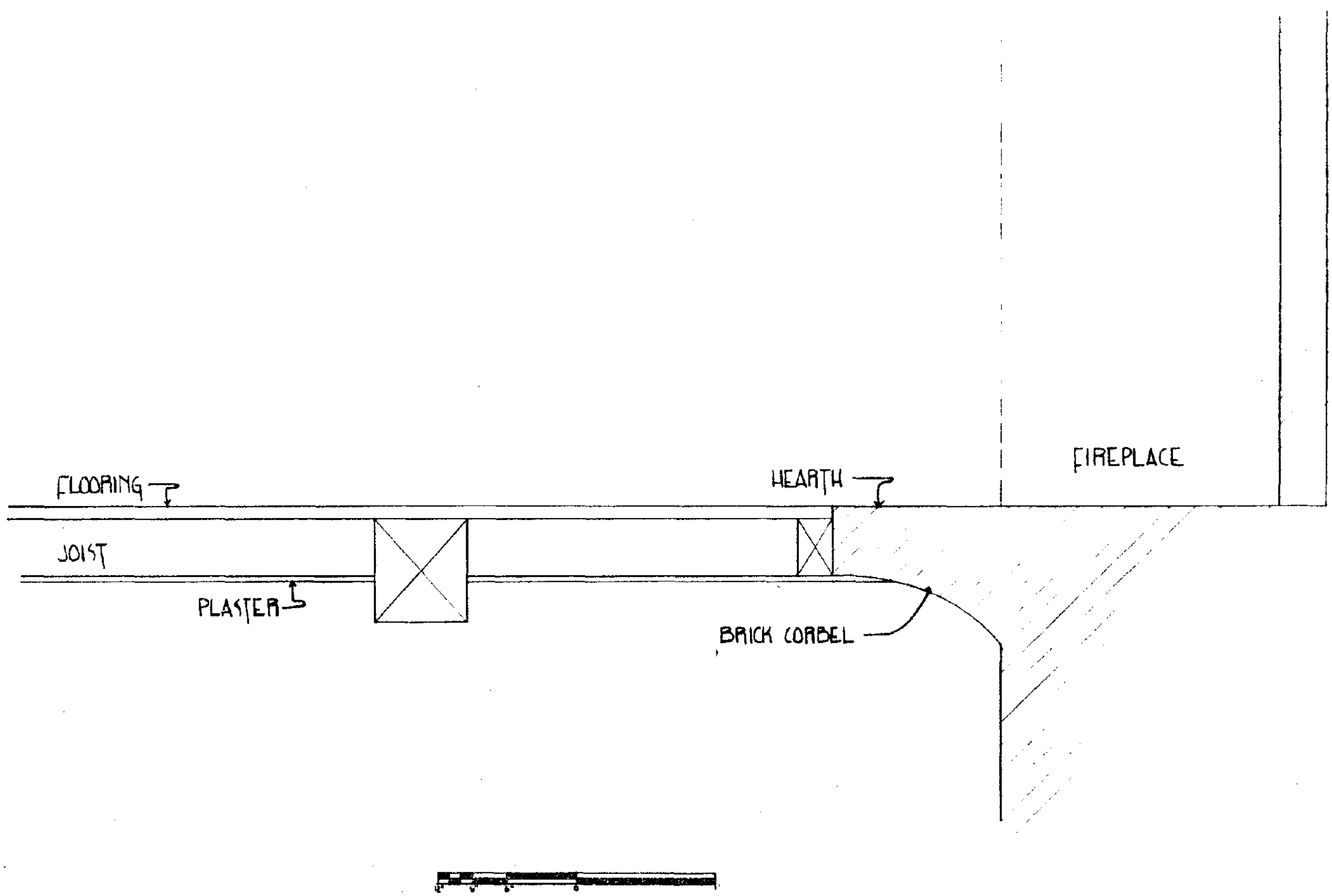



Figure 42. Type 2 - Corbel Detail

system which necessarily touches the chimney. It is framed between two joists on either side of the chimney which do not come in contact with any of the bricks of the chimney.

A plan of the chimney at the third floor level shows the chimney to be 4'4" wide by 5' deep. Again the hearth is 14'6" deep and is supported by a corbel. The fireplace itself is 1'9" deep, 3' wide at the front, sloping in to 1'6" at the back.

The flue from the third floor fireplace comes up in front of the flues from the first and second floor fireplaces which rise side by side at the back of the chimney. The flues taper to 1' x 1' at the top, with one wythe of brick built around them.

The total height of the chimney from the bottom of its base to the top of its flues is 46'. Thirty-nine feet of this is above grade. The rear wall of the house extends up over the roof line about 1-1/2'. Five feet of the chimney-top extends above this parapet wall.

4. Wooden Framing Members and the Flooring System

The type 2 flooring system was much the same as the type 1 flooring system and is shown in figures 43 through 46. One major difference was that the summers (beams spanning the middle of rooms) and the girts (beams on either side of the central hallway) fit into pockets anywhere from 2" - 4" deep when they made the connection to a brick bearing wall. On the other hand, when a summer met a girt a dovetail joint was used. Summers and girts were 8" deep by 9" wide oak beams.

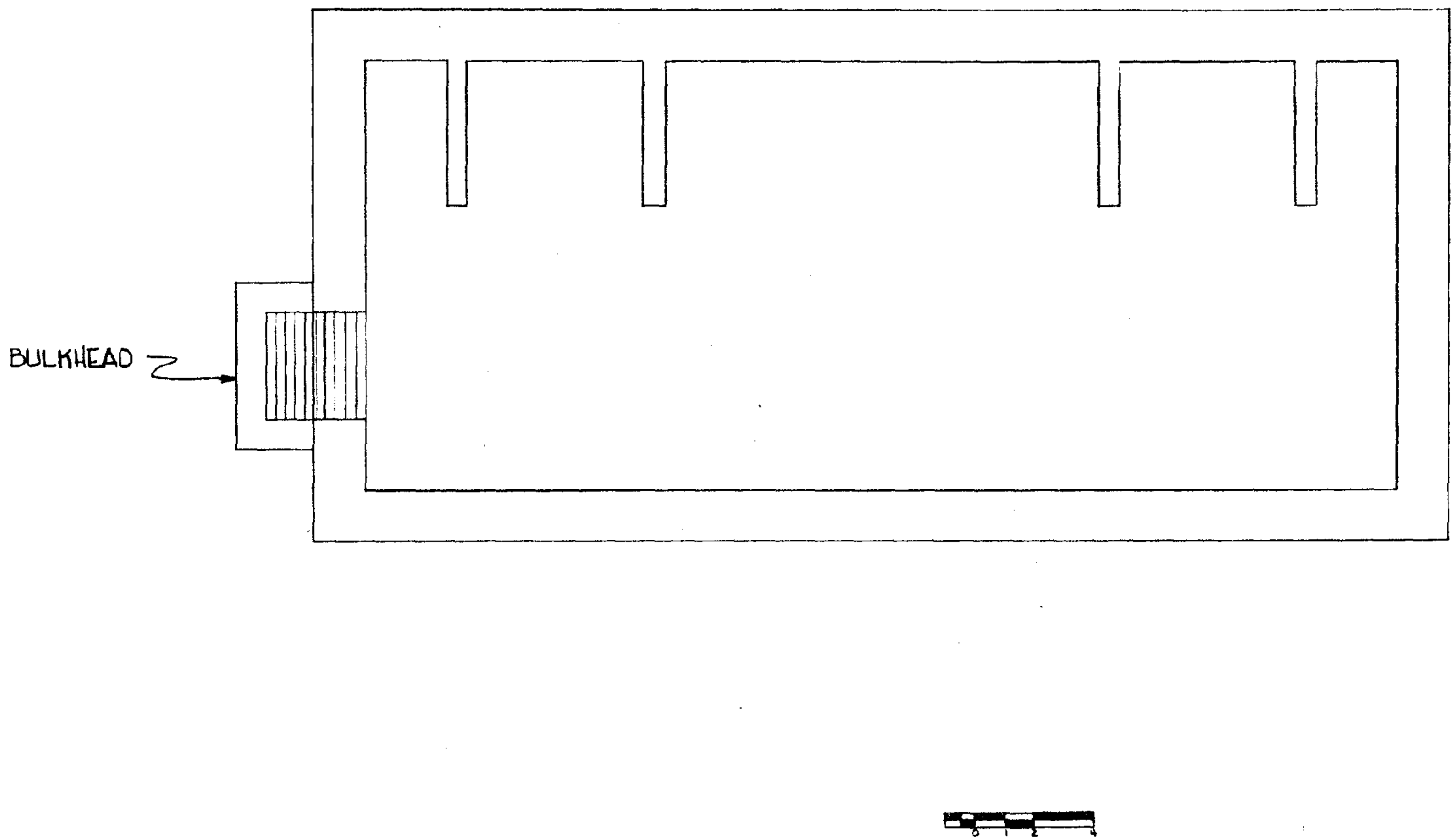



Figure 43. Type 2 - Basement Plan

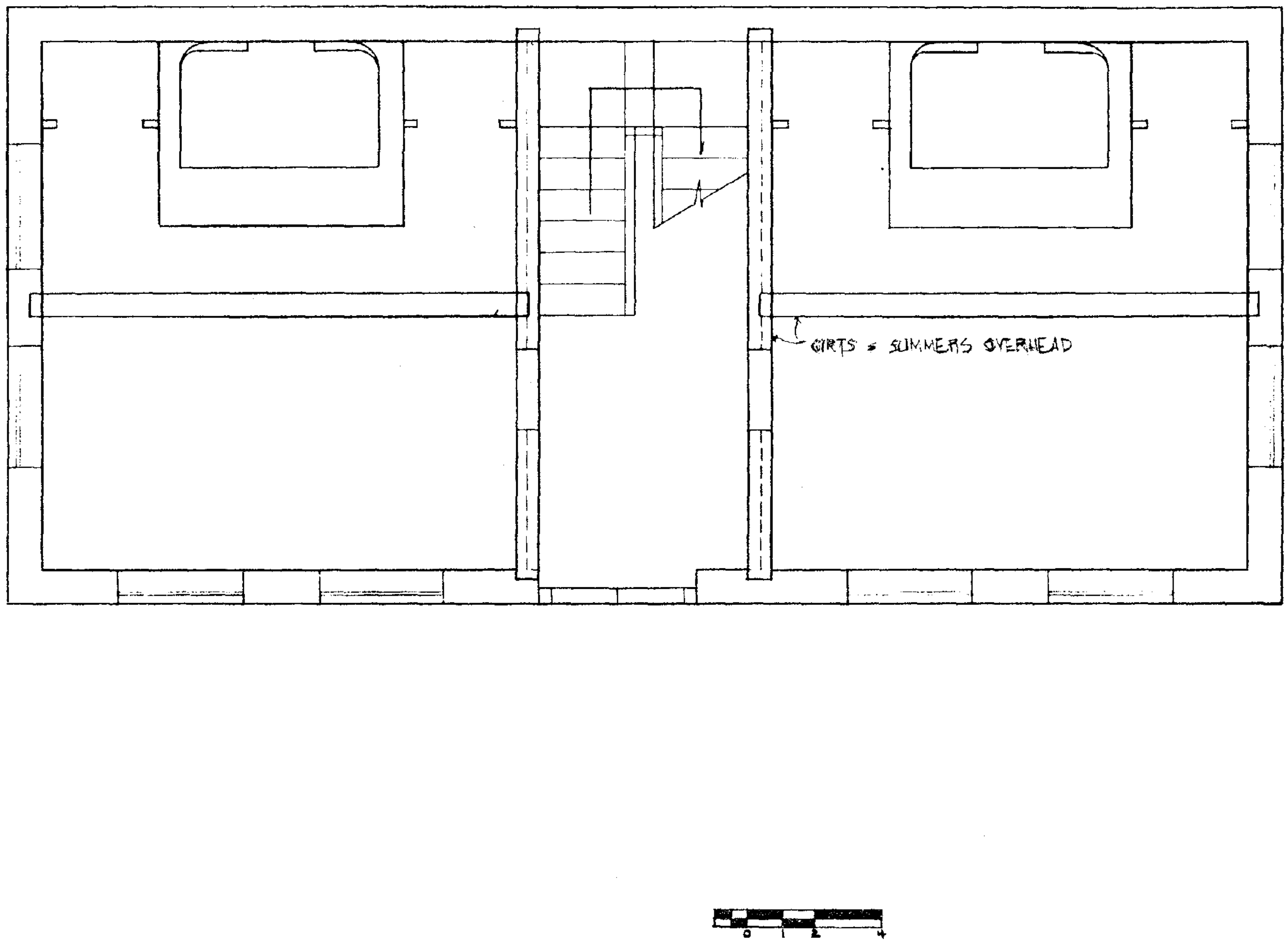



Figure 44. Type 2 - First Floor Plan

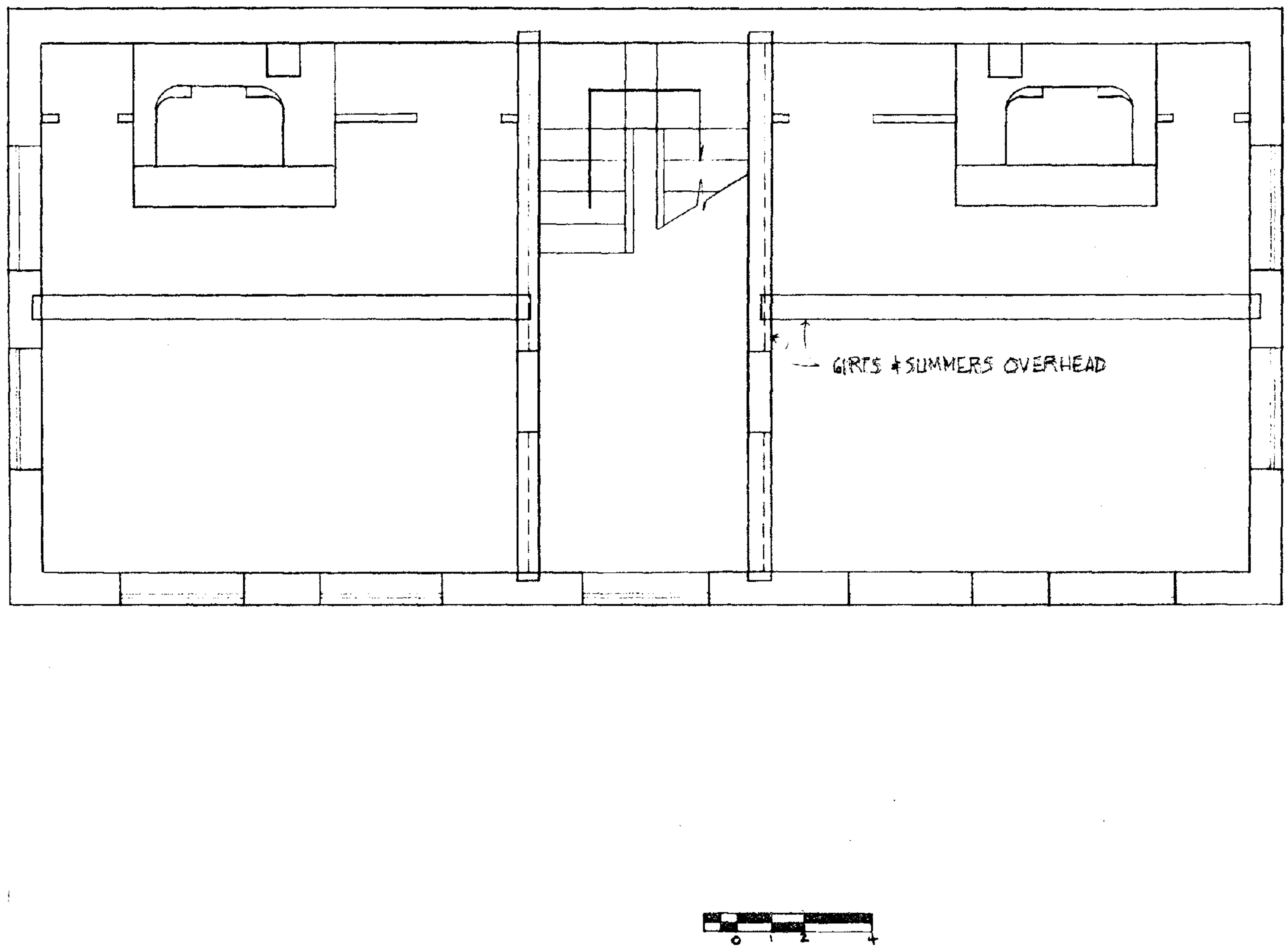



Figure 45. Type 2 - Second Floor Plan

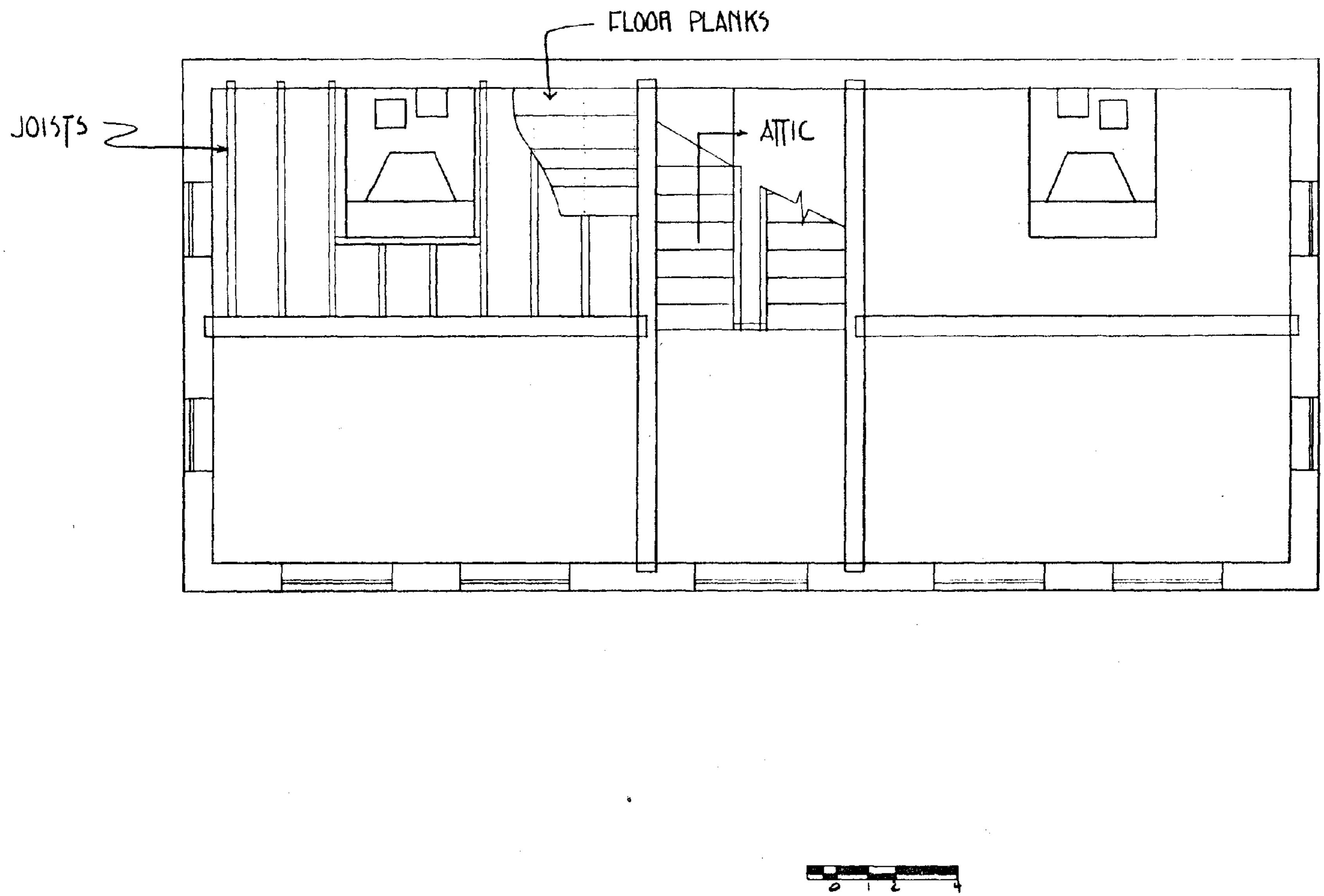



Figure 46. Type 2 - Third Floor Plan

The next part of the flooring system were the joists. Typically 3" wide by 5" deep and made of oak, they ran from the summer to the masonry wall (or from summer to summer, as is the case in the attic floor framing plan). They too fit into pockets in the brick walls and were then most likely dropped into place in the summer in a half dovetail joint as previously shown in figure 18.

Oak floorboards were then placed on top of the joists as shown in figure 46. These boards were 1" thick and anywhere from 9" - 22" wide and figure 47 shows how they were joined by means of a spline. The spline, a separate piece of wood fit into grooves at the ends of the floorboards. Nails, probably hand-wrought, were used to fasten the planks to the joists. Most frequently a plank will be fastened to a specific joist with three nails, one along the centerline of the plank and the other two at a distance of 1/4" from either side. However a 9" board could sometimes have just two nails at each joist and a 22" board could sometimes have four.

5. Interior Partitions

Interior partitions can be found on each of the three main floors beneath the girts, separating the hallway from each to the two side rooms. They are vertical oak planks 2" thick and 12" - 16" wide. A common method of construction was to mortise and tenon them to the girt above, swing them into their vertical position and nail them at the bottom. Another method used a joint called a 'rabbit' at the top which is one continuous groove, and then nailed them at the bottom.

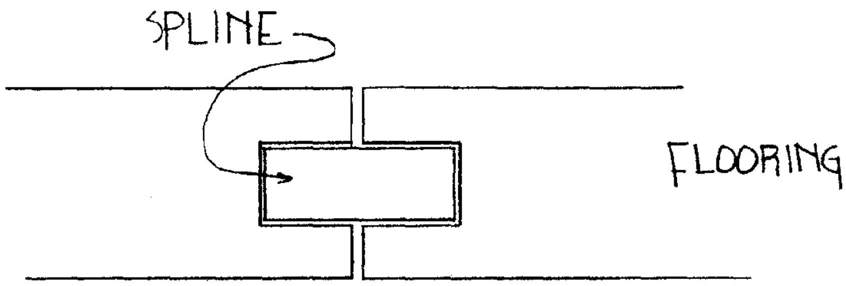



Figure 47. Type 2 - Spline

Both sides of the plank were then plastered, making a partition wall 4" thick.

6. The Roofing System

The type 2 house has a hipped roof. Its main members are two hip rafters, two principal rafters, several common rafters and plates. All rafters and plates are made of oak and cross sections vary from 6-1/2" deep by 7-1/2" wide hips to 6" deep by 5" wide principals to 5" deep by 3" wide commons to 8" x 8" plates. The type 2 section, figure 32, shows the connections of the rafters, plates and the top of the brick wall, seen in plan in figure 48. At the top, the rafter fits into the brick wall in a 4" deep pocket. Before it reaches the pocket it notches into the plate. The plate itself is resting on a ledge formed by the first two wythes on the interior side of the parapet wall. In the front of the house the rafter also notches into a plate then continues over it, extending out to the far edge of the brick wall. This is the way in which the hip rafters, the principal rafters and the rafters between the principals frame into the house. The roof framing plan, figure 49, then indicates how the remaining common rafters frame into the rest of the roof.

At the lower ends they connect to the brick wall and the plate in the same fashion as the others. At the other end they fit into pockets in the hip rafter. These pockets are still visible in the hip rafters of the Hichborn House which survived the fire. There does not seem to be any indication of a pinned or tenoned joint. It seems

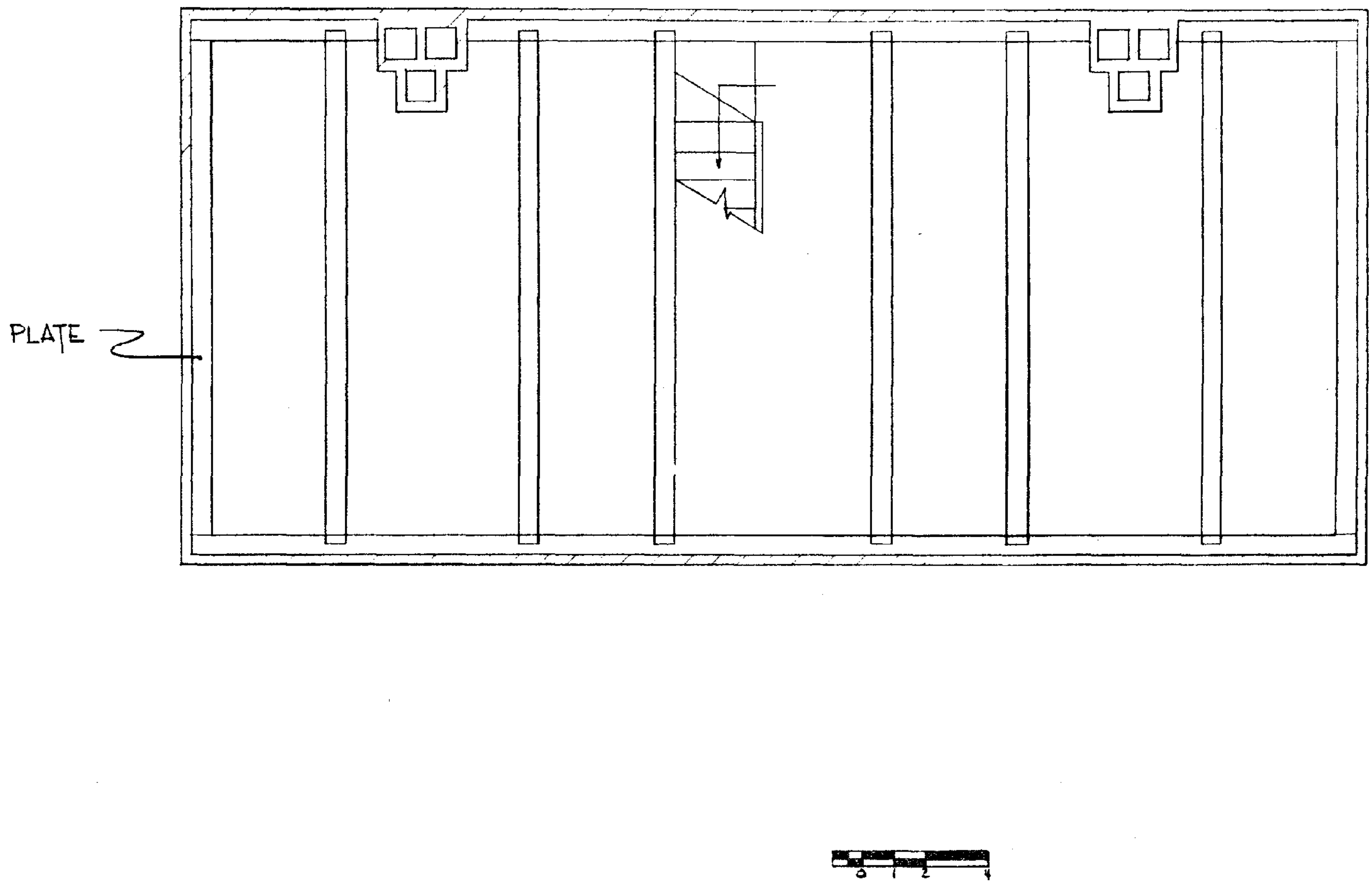



Figure 48. Type 2 - Attic Framing Plan

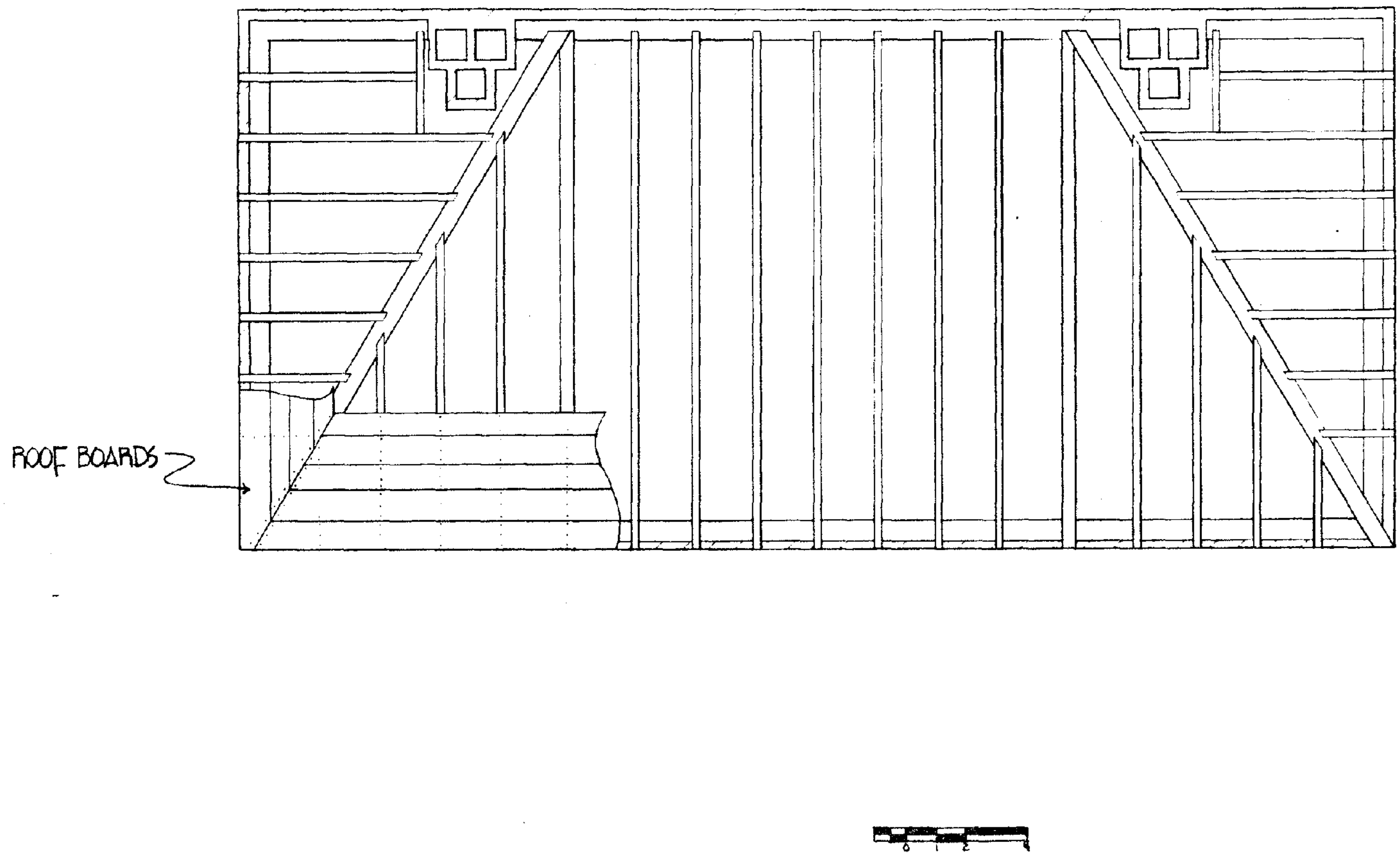



Figure 49. Type 2 - Roof Framing Plan

the rafters just slipped into the hip rafter slots.

Roof boards were then butted up against one another over the rafters and nailed into place as shown in figure 49. These were 1" thick boards, 9" - 22" wide, much the same as the type 1 house.

MASSING CALCULATIONS - TYPE 2

| TYPE OF MATERIAL | WEIGHT OF MATERIAL IN HOUSE |
| --- | --- |
| 1. Wood Framing | 8.8 kips |
| 2. Brick Walls | 305.2 kips |
| 3. Chimneys | 102.3 kips |
| 4. Flooring | 26.5 kips |
| 5. Interior Partitions | 2.4 kips |
| 6. Roof | 5.8 kips |
| TOTAL WEIGHT OF HOUSE | 451 kips |

## CHAPTER 5 - VARIATIONS

Although the houses already mentioned were common types, there were also several popular wariations which occurred. A certain type of plan could have been seen with different roof forms, and constructed of different materials. For example, a four room per floor, two story house could be found before 1755 in Boston with either a hipped roof, a gambrel roof or a gabled roof. It could be constructed of either brick, timber or a combination of brick end walls and timber walls front and back. Often the particular combination of plan, roof and materials can be helpful in dating a house.

This chapter will briefly cover two variations common to Boston at the time of the 1755 earthquake. The first is a roof form known as the gambrel roof. The second is a house where front and rear timber walls were used with brick end walls.

### A. The Gambrel Roof

A roof form common in 1755 Boston was the Gambrel roof. This timber roof was used with brick and timber buildings alike. Gambrels were frequently found on the 2 story, four rooms per floor type plan. Two types of gambrels can be seen in figures 50 and 51. The gambrel is a roof with two slopes, steep in the lower portion above the eaves, much less steep in the upper portion between the change in slope and the ridge. Figure 50 shows the more familiar type of gambrel.[15] Figure 51 shows the earlier gambrel roof of the Peter Tufts House in Medford, Mass.[16] Figure 52 shows the roof framing for

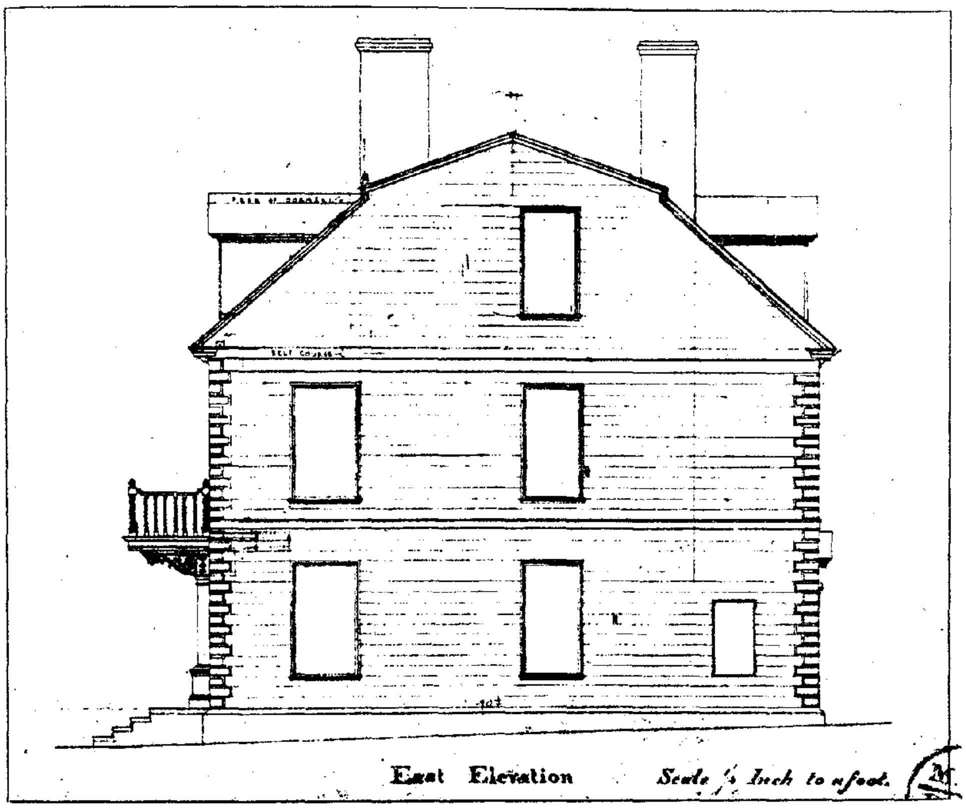



Figure 50. Hancock House

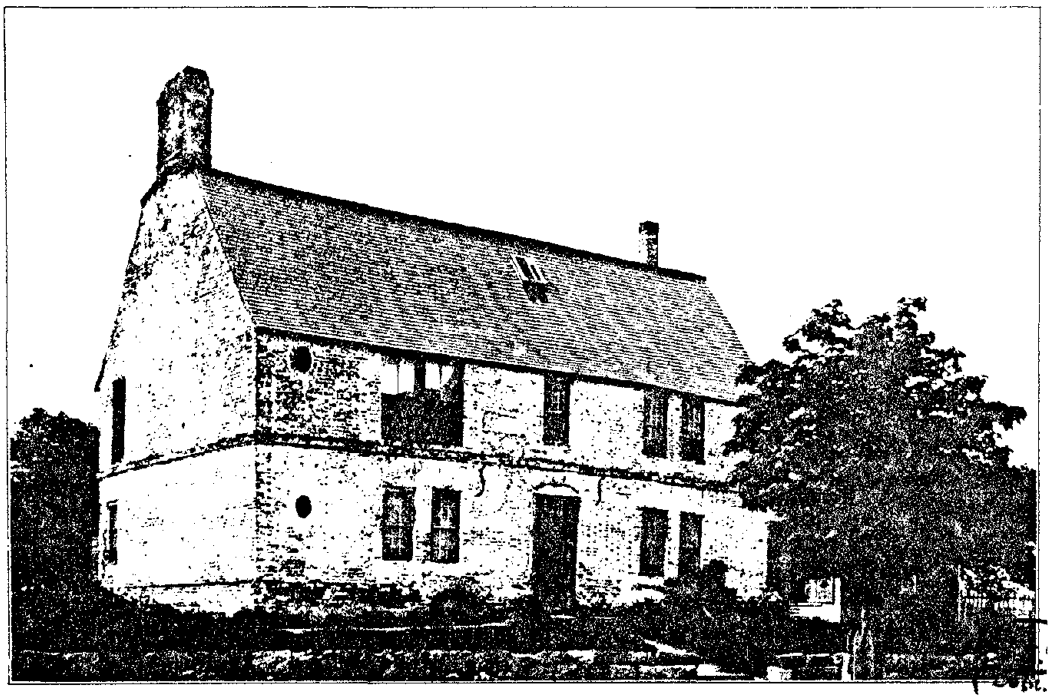


Figure 51. Peter Tufts House

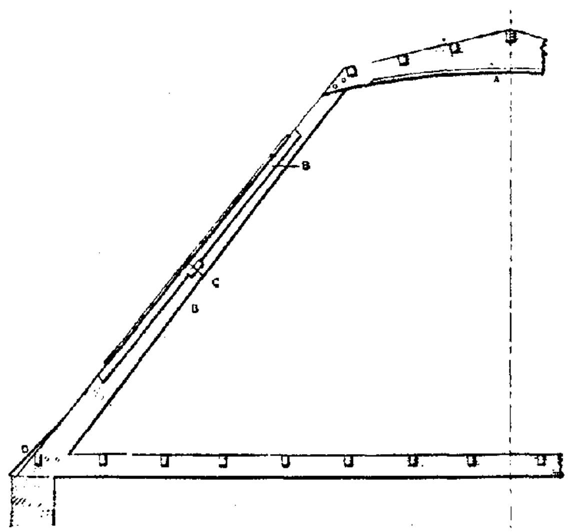


Figure 52. Roof Framing, Tufts House

the Tufts House.[17]

What has happened in this early form of gambrel is the main slopes of the steep gabled roof have been truncated. It has been suggested that the form originated from the desire to reduce the height of the medieval roof, especially over buildings of a double file of rooms.[18]

The gambrel roof was long supposed to have been introduced to America by the Dutch, but it did not appear on Dutch houses until the eighteenth century, It was used in New England long before that.[19] The advantages to the gambrel roof are apparent. It is economical because it saves material and uses shorter rafter lengths. It also provides a spacious attic with adequate headroom.

The gambrel was introduced to New England in the last quarter of the seventeenth century. The Peter Tufts House with its early gambrel was built in 1765. There are numerous other examples in the following decades. The gambrel became increasingly popular throughout the first three quarters of the eighteenth century in New England.

The framing of the roof is shown in figure 53. Two sets of rafters are shown with purlins running between at the change of angle level. The purlins are supported by purlin posts which are in turn supported by the girts. As in previous roofing systems no ridgepole is used. The purlins, however, in this example are continuous from post to post.

The word gambrel probably has a derivation from Old Norman-French. It appears as early as 1715 in the London-Gazette, an

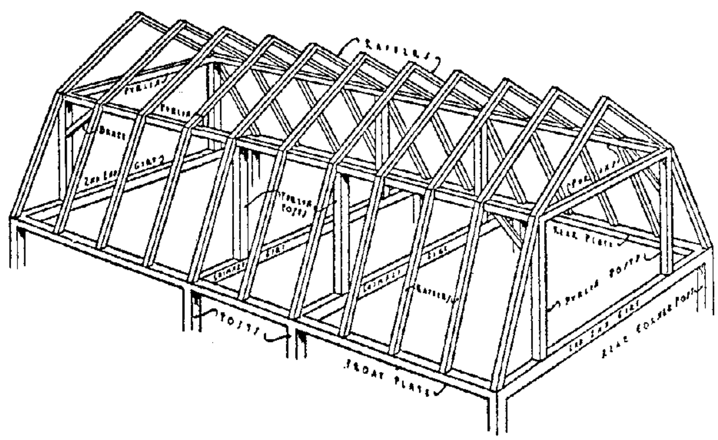



Figure 53. Typical Gambrel Framing

official publication, referring to the joint in the upper part of a horse's hind leg. By analogy, the double slope of the gambrel roof obtained its name, and the word appears in American books in that sense from the middle of the 19th century. The classical example occurs in Wendell Holmes' 'Autocrat of the Breakfast Table'(Chapter XII):[20]

> Know Old Cambridge? Hope you do.-
> Born there? Don't say so. I was, too.
> (Born in a house with a gambrel roof,-
> Standing still, if you must have proof.-
> 'Gambrel'? - 'Gambrel'? - Let me beg
> You'll look at a horse's hinder leg, -
> first great angle above the hoof, -
> That's the gambrel; hence gambrel-roof.)

B. Type 3 - Brick End Wall House

The type 3 house is the brick end wall house. This type has four rooms per floor, 2 stories and an attic. It also xould have been found in 1755 Boston with 2 rooms per floor or with 3 stories. Typically it had a gambrel or hipped roof. It is a Georgian style house as can be seen in the symmetry of its facade shown in figure 54, the Short House, Newbury, Mass.

The type 3 house was also quite symmetrical in plan. A typical plan of a type 3 residence can be seen in figure 55. The four rooms on the first floor are balanced around a central hallway which runs front to back. Each room is cut off from its neighboring room and the hallway by interior partition walls. These walls were usually wood planks and plaster. The front and rear walls of the house were of timber construction much like the construction of type 1 and 1A.

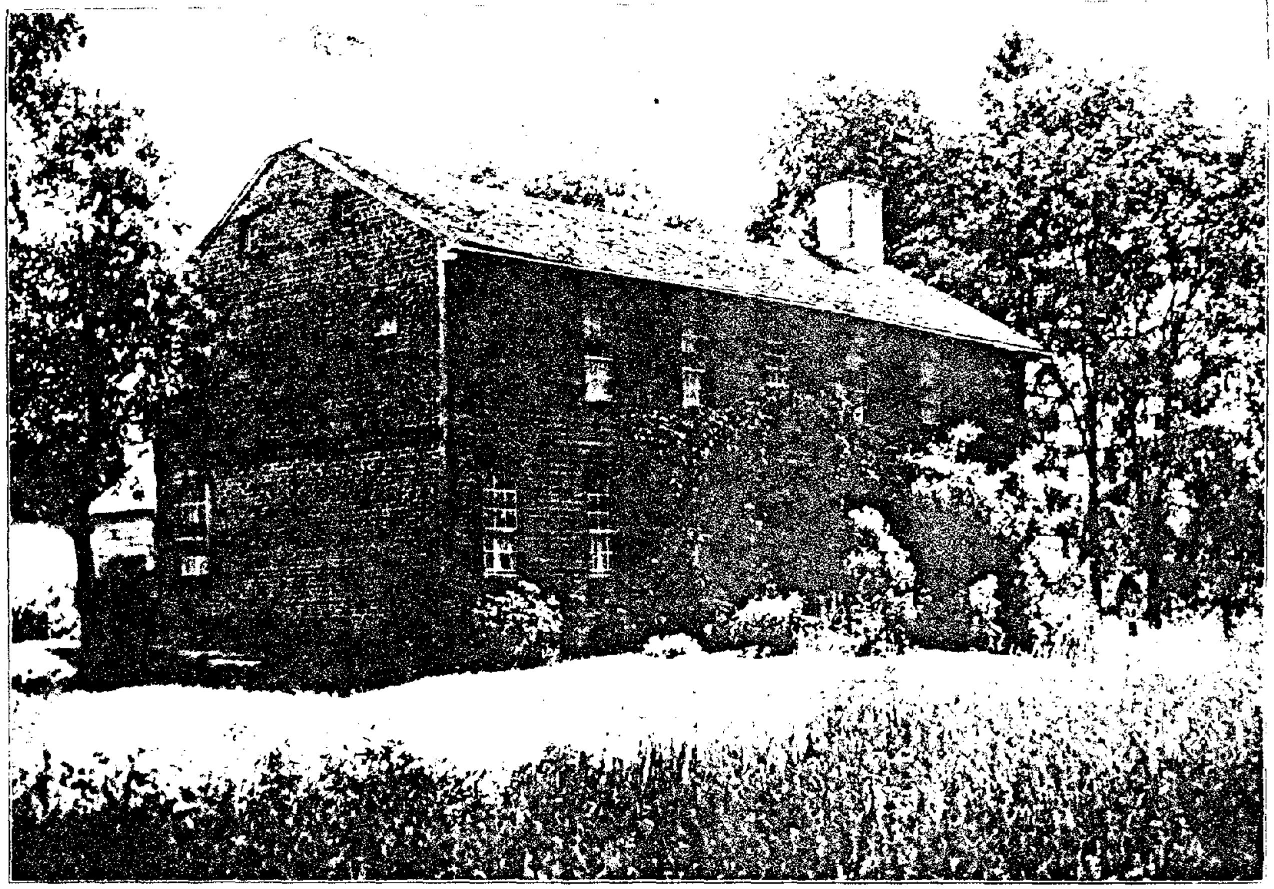


Figure 54. Short House, Newbury, Mass.

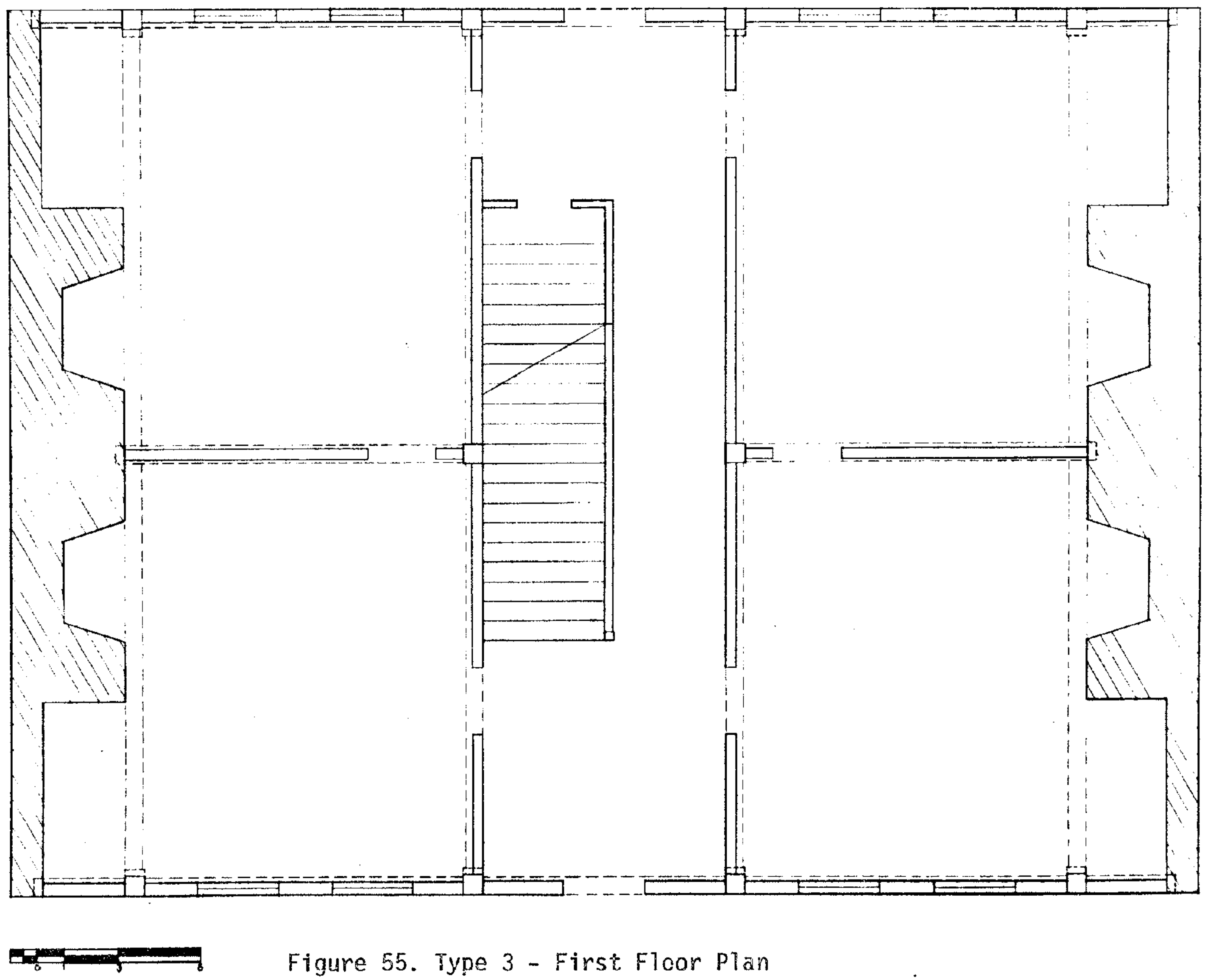


Figure 55. Type 3 - First Floor Plan

Posts supported girts and plates, and the exterior was clapboarded.

The end walls were of masonry construction. Each end wall held the two chimneys for the two rooms on its side of the house. These shimneys were a part of the end wall in the same way that the chimneys in the type 2 house were a part of the end wall. The wall without the chimney portion was three wythes thick. The chimneys continued up with them for a while.

The girts and plates from the front and rear walls sat in pockets in the brick end walls, much the same as the type 2 house. Alcoves were formed in the four corners of the plan between the chimney and the timber frame wass and these often became closets.

Although this type of house was not great in number in Boston, it is of significance to this study because of its brick end walls, particularly its gable ends. Accounts of the 1755 earthquake from newspapers and diaries of the time mention damage to gable ends. "The Gable Ends of several brick buildings, perhaps of 12 to 15, are thrown down; I mean from the Roofs of the Houses to the Eaves..."[21]

# CHAPTER 6 - CONCLUSION

This report has attempted to provide a basis for further study of the strength and effects of the 1755 earthquake in the Boston area. With careful diagrams and descriptions it has described the predominant architectural types and the most common building construction techniques of the period. Type 1 portrays the heavy timber frame house, type 2 the typical masonry house. Chapter 5 suggests common variations. But by no means is this report all inclusive. There did exist other types and many variations but time and dependable source material were limiting factors.

It is also important to remember that this report depicts buildings as they were built, not the condition they were in in 1755. Age, maintenance, and quality of construction all affect a building's reaction to an earthquake.

This report is intended to be used in conjunction with damage reports of the period. Hopefully it can then be determined, with further research, what type of earthquake it would take to match the damage descriptions with respect to the house types discussed in this report. In this way it may be possible to make a more accurate estimation of the strength of the ground shaking in 1755 in the Boston area.

## APPENDIX A: FIRES[22]

Fire was a major problem for the Bostonians. Each time a major disaster occurred, steps were taken to prevent that disaster (if possible) from happening again.

A study of fires in Boston helps us to determine what types of houses were present before a fire, what they were made of, how many were burned and what areas of town were destroyed. These facts are usually well documented by the people of the time. Here we can also see by the laws that were passed, what types of structures were put up after the fire.

On March 26, 1631, a thatched house belonging to a Mr. Thomas Sharp burned down because of a defective wooden chimney. Th town then passed a law prohibiting wooden chimneys in thatched houses. This was the first step taken in building for fire.

The first chimneys were laid up of 'splinters' of wood in log cabin style. They filled the gaps with mud and smeared the inside with clay. These crude chimneys continued to be in use for a long time, especially in the poorer sort of houses. The common house with a lean-to plan often had up to five fireplaces, all built into a central stack which sometimes measured as much as 10 - 12 feet.

Colonial documents make reference to the office of 'Chimney-viewer'. Chimney-viewers were appointed to inspect the chimneys of all houses every three months in summer and every six weeks in winter, to see that they were kept clean, well daubed with clay, or the masonry sound. It was an important function in the early days of wood and clay chimneys and thatched roofs, as the safety of the community depended largely on this form of fire prevention.

Many fires occured after Mr. Sharp's, but the first one called the 'Great Fire' occured in April of 1653. It destroyed eight housesin the State and Washington Street area. The inhabitants called a town meeting and ordered that everyone provide themselves with long ladders that would reach to the ridge of the house, also that they have a twelve foot pole with a good large swab at the end of it for damping out sparks that might land on the roofs. They constructed a town resevoir to be used in case of fire and in 1654 Joseph Jenks devised the first fire engine for Boston.

The next major fire occured in December, 1676, when a tailor's apprentice fell asleep at his work and left his candle burning. A strong southeast wind helped the flames along and within four hours nearly fifty houses were in ashes. A sudden downpour of rain, said Samuel Sewall, checked 'the (otherwise) masterless flames'.

Some of the streets in the burned out district (the North End) were straightened out by the town after this fire. The inhabitants also ordered a fire engine from England and a Thomas Atkins, carpenter was put in charge managing this engine, and choosing assistants, whom the town promised to pay for their work.

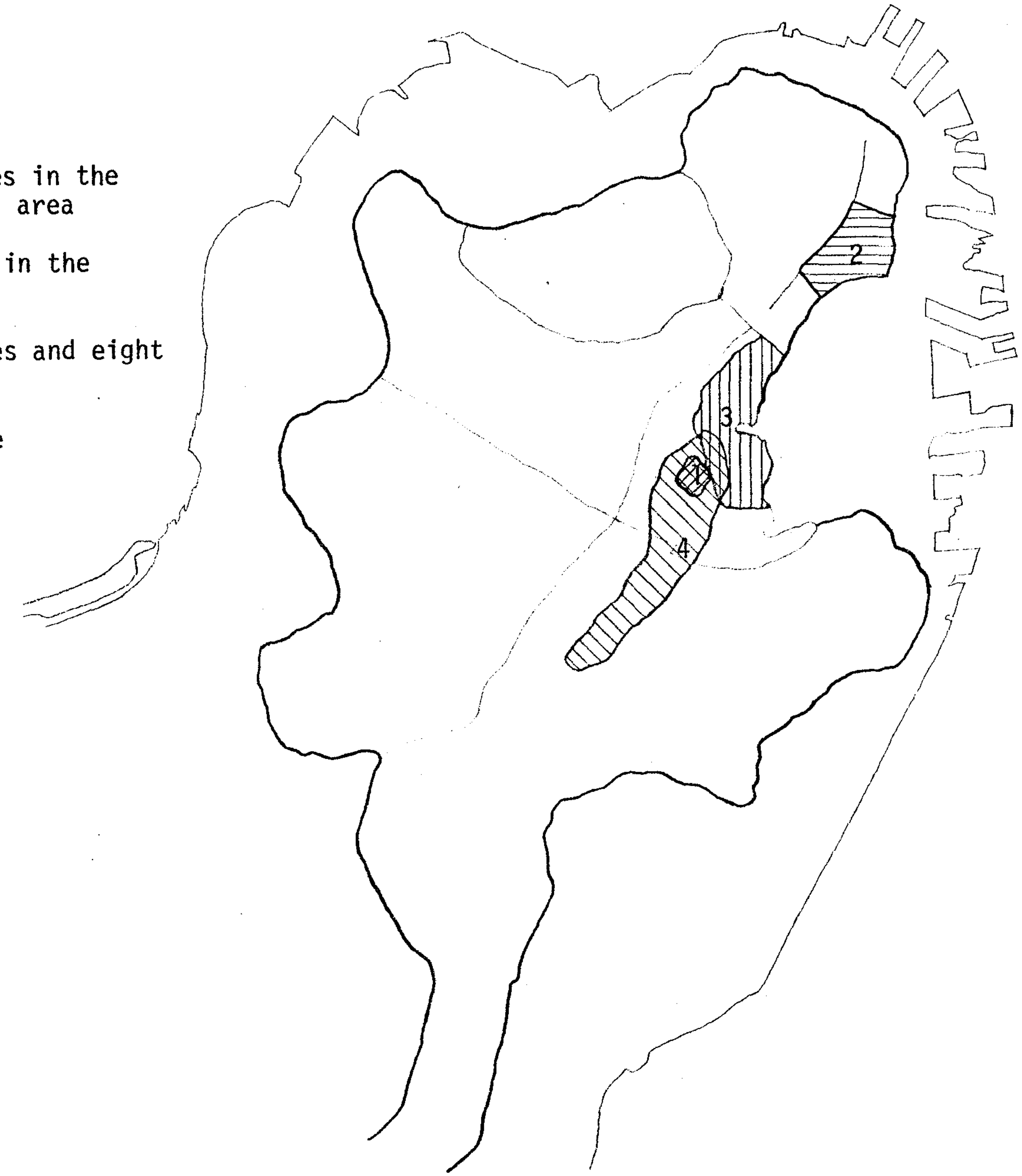
A rash of fires followed and on August 18, 1679, a fire developed at which the 'firemen' and their little engine were helpless. The fire had started at a tavern ' The Sign of the Three Mariners'

1. 1653 - Destroyed 8 houses in the State and Washington St. area

2. 1676 - Nearly 50 houses in the North End

3. 1679 - Seventy warehouses and eight dwellings near the dock

4. 1711 - 100 houses in the Cornhill area



near the dock and within 12 hours seventy warehouses and eight dwellings were in ruins.

After the 1679 fire, the town ruled that only stone or brick buildings could be built in Boston. Later, certain small buildings were exempted, such as privies.

On the evening of October 13, 1711, a Scottish woman, picking oakum while drunk, was too slow to smother sparks falling on the stuff from a nearby fire. Soon her tenement was burning rapidly out of control, and flames sprang from building to building on Cornhill (now Washington St.) The next morning, in this most densely settled and wealthiest part of town about 100 house were burned to the ground. Rubble from the burned areas was used to fill up Long Wharf which was being built at that time.

# APPENDIX B: MASS CALCULATIONS FOR TYPE I

## ① VOLUME OF WOOD FRAMING

### Ⓐ SILLS (oak)

FRONT & BACK - 32'9" LONG
2 END SILLS - 19'2" LONG
CROSS SECTION IS 9" x 9"

$$\frac{2\left[(32' \times 12'' + 9'') \times 9'' \times 9''\right] + 2\left[(19' \times 12'' + 2'') \times 9'' \times 9''\right]}{1728 \text{ cu. in.}}$$

$$= (63,666 + 37,260)/1728 = \underline{\underline{58.4 \text{ cu. ft.}}}$$

### Ⓑ POSTS (oak)

I. (4) REAR POSTS - 9" x 9" x 12'3"

$$\frac{4\left[(12' \times 12'' + 3'') \times 9'' \times 9''\right]}{1728 \text{ cu. in.}} = 27.56 \text{ CU. FT.}$$

II. FRONT POSTS - (4) BOTTOM 9" x 9" x 4' } 1ST FLOOR
(4) TOP 1'9" x 10½" x 9"

(4) BOTTOM 6' x 9" x 9" } 2ND FLOOR
(4) TOP 1'9" x 10½" x 9"

①Ⓑ① FRONT POSTS (con't.)

$$\frac{4\left[9''\times 9''\times(4'\times 12'')\right] + 4\left[(1'\times 12''+9'')\times 10.5''\times 9''\right]}{1728 \text{ cu. in.}} = 13.6 \text{ cu.ft.}$$

and

$$\frac{4\left[(6'\times 12'')\times 9''\times 9''\right] + \left[(1'\times 12''+9'')\times 10.5''\times 9''\right]4}{1728 \text{ cu.in.}} = 18.1 \text{ cu.ft.}$$

TOTAL POSTS = 59.3 cu. ft.

Ⓒ GIRTS (oak)

I. (2) END GIRTS - 20'9" LONG, 8"x10" CROSS SECTION
II. (2) UPPER END GIRTS - 21' LONG, 8"x10" CROSS SECTION
III. FRONT GIRT - (4) 7'3" PIECES, 6"x6" SECTION
IV. REAR GIRT - (4) 7'3" PIECES, 8"x10" SECTION
V. UPPER FRONT GIRT, (4) 7'3" PIECES, 9"x9" SECTION

I & II. $$\frac{2\left[(20'\times 12''+9'')\times 8''\times 10''\right] + 2\left[(21'\times 12'')\times 8''\times 10''\right]}{1728 \text{ cu.in.}} = 47.2 \text{ cu.ft.}$$

and

III & IV. $$\frac{4\left[(7'\times 12''+3'')\times 6''\times 6''\right] + 4\left[(7'\times 12''+3'')\times 8''\times 10''\right]}{1728 \text{ cu.in.}} = 23.4 \text{ cu.ft.}$$

① Ⓒ V. GIRTS (con't.)

$$\frac{4[(7' \times 12'' \times 3'') \times 9'' \times 9'']}{1728 \text{ cu.in.}} = 16.3 \text{ cu.ft.}$$

TOTAL GIRTS = 86.9 cu.ft.

Ⓓ SUMMERS (oak)

I. (3) BASEMENT - 8" x 10" x 18' LONG
II. (3) FIRST FLOOR - 12" x 15" x 21'6" LONG
III (3) SECOND FLOOR - 10" x 12" x 21' LONG

$$\frac{3(18' \times 12'' \times 8'' \times 10'') + 3((21' \times 12'' + 6'') \times 12'' \times 15'') + 3(21' \times 12'' \times 10'')}{1728 \text{ cu.in.}} = 163.1 \text{ cu.ft.}$$

## (E) PLATES (oak)

I. FRONT PLATE - 8"x10" x 32'9"
II. REAR PLATE - 8"x10" x 32'9"

$$\frac{2\left[(32' \times 12" + 9") \times 8" \times 10"\right]}{1728 \text{ cu. in.}} = \underline{\underline{36.4 \text{ cu. ft.}}}$$

## (F) ROOFING SYSTEM (oak)

I. (10) PRINCIPAL RAFTERS - 6"x6"x15'6"
II. (22) COMMON RAFTERS - 3"x3"x15'3"
III. (8) PURLINS - 3"x3" x 7'6"
IV. (5) COLLAR BEAMS - 3"x5" x 9'

I. & II. $$\frac{10\left[(15' \times 12" + 6") \times 6" \times 6"\right] + 22\left[(15' \times 12" + 3") \times 3" \times 3"\right]}{1728 \text{ cu. in.}} = 59.7 \text{ cu. ft.}$$

III. & IV. $$\frac{8\left[(7' \times 12" + 6") \times 3" \times 3"\right] + 5\left[(9' \times 12") \times 3" \times 5"\right]}{1728 \text{ cu. in.}} = 8.4 \text{ cu. ft.}$$

<u>TOTAL ROOFING SYSTEM = 68.1 cu. ft.</u>

⑨ STUDS (oak)

3" x 3" x 7'3" LONG

EACH END WALL HAS 23 STUDS

$$\frac{23[(7' \times 12" + 3") \times 3" \times 3"]}{1728 \text{ cu.in.}} = 10.42 \text{ cu.ft.}$$

FRONT & BACK WALLS HAVE 32 STUDS EACH

$$\frac{32[(7' \times 12" + 3") \times 3" \times 3"]}{1728 \text{ cu.in.}} = 14.5 \text{ cu.ft.}$$

TOTAL STUDS = 49.84 cu.ft.

AREA IN SQ. FT.

FLOORING & SUBFLOORING

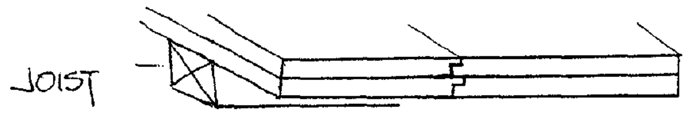
I. 1ST FL. AREA – (31'6" x 19'3") – (4' x 2½') – (8' x 2½') – (12' x 7'6")
= 490.54 SQ.FT.

II. ATTIC FL. AREA – (31'6" x 21') – (7'6" x 9'3") = 660.1 SQ.FT.

III 2ND FL. AREA – (31'6" x 21') – (3' x 6') – (1'4" x 2'8") = 640 SQ.FT.

TOTAL FLOORING & SUBFLOORING = 3581.28#

② FLOORING (BOARDS & JOISTS)(OAK)



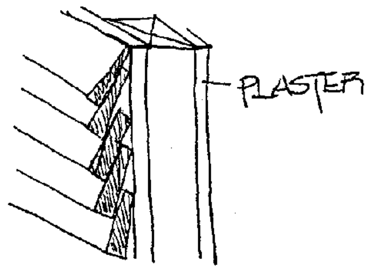

VOLUME: $\frac{(1" \times 12" \times 12") + (1" \times 12" \times 12") + (3" \times 5" \times 12")}{1728 \text{ cu. in.}} = .27 \text{ cu. ft.}$
OF 1#

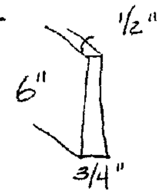
③ INTERIOR PARTITIONS – (oak)

12" x 12" x 2" / 1728 cu. in. = 0.17 cu. ft. VOLUME OF 1#

## (4) WALL (VOLUMES OF 1#)

(A)




SHEATHING WALL DETAIL

I. STUD - $(3'' \times 3'' \times 12'') / (1728 \text{ cu.in.}) = 0.0625$ cu.ft.

II. SHEATHING - $(1'' \times 12'' \times 12'') / (1728 \text{ cu.in}) = 0.083$ cu.ft.

III. CLAPBOARDS $[2[\frac{1}{2}(\frac{1}{2}'' + \frac{3}{4}'')6''] [12''] + (\frac{1}{2}'')(1'')(12'')] / 1728 = .056$ cu.ft

IV. PLASTER - $(12'' \times 12'' \times 1'') / 1728$ cu.in. $= 0.083$ cu.ft.

(B) BRICK NOGGING WALL DETAIL

I. PLASTER - $(12'' \times 12'' \times 1'') / 1728$ cu.in. $= 0.083$ cu.ft.

II. BRICK NOGGING $(12'' \times 12'' \times 4'') / 1728$ cu.in. $= 0.33$ cu.ft.

III. CLAPBOARDS - $2[\frac{1}{2}(\frac{1}{2}'' \times \frac{3}{4}'')6''][12''] + (\frac{1}{2}'')(1'')(12'')] / 1728 = .056$ cu.ft.

IV. STUDS - .0625 cu.ft.

(C) SHEATHING & BRICK NOGGING WALL DETAIL

I. PLASTER - 0.083 cu.ft.

II. BRICK NOGGING - 0.33 cu.ft.

III SHEATHING - 0.083 cu.ft.

IV. CLAPBOARDS - 0.056 cu.ft.

V. STUD - 0.0625 cu.ft.

## (5) ROOF

1 SQ. FT. OF ROOF WITHOUT RAFTERS IS:

SHEATHING (OAK) - $(12" \times 12" \times 1") / 1728$ cu. in. = 0.083 cu. ft.

SHINGLES (PINE) - $\dfrac{2[12" \times 3/4" \times 12"] + [4" \times 12" \times 3/4"] + [8" \times 12" \times 3/4"]}{1728 \text{ cu.in.}} = 0.1875 \text{ ft.}^3$

AMOUNT OF SQ. FT. OF PARTS OF HOUSE

ROOF

$\dfrac{2[15'9" \times 32'8"]}{144 \text{ sq. in.}} = 1029$ SQ. FT.

WALLS

I. END WALLS - $[(20'9" \times 6') + (6' \times 19')] = 238.5$ #

II. FRONT WALL - $\dfrac{(31'6" \times 12')}{144} = 378$ #

TOTAL - 1233 #

WINDOWS

3 WINOWS 3'x3' (1ST FLOOR) - 9# x 3' = 27#

4 WINDOWS 3'x3' (2ND FLOOR) - 9# x 4' = 36#

2 DOORS 3'x6' - 18# x 2 = 36#

SQ. FT. OF OPENINGS TO BE SUBTRACTED FROM WALL AREA 99#

1233# - 99# = **1134#**

INTERIOR PARTITIONS

(OVER CHIMNEY & BETWEEN CHAMBER & STAIRWAY ON 1ST & 2ND FLOORS)

1ST FLOOR $(3'+3')(2' \text{ high}) + 5' \times 6' = 42^{\#}$

2ND FLOOR $(10')(4' \text{ high}) + 5' \times 6' = 70^{\#}$

TOTAL INTERIOR PARTITIONS = $112^{\#}$

## WEIGHT OF A TYPE 1 HOUSE

① WOOD FRAMING

$1173.34 \text{ cu.ft.} \times \frac{45 \text{ lbs}}{\text{cu.ft.}} = 52{,}800 \text{ lbs} = 52.8 \text{ Kips}$

② OAK FLOORING

$.27 \text{ cu.ft.} \times 45 \text{ lbs/cu.ft.} = 12.15 \text{ lbs in } 1^{\#}$

$12.15 \frac{\text{lbs}}{\text{ft}^2} \times 3581.28^{\#} = 43.5 \text{ Kips}$

③ INTERIOR PARTITIONS

.17 cu.ft. x 45 lbs/cu.ft. = 7.65 lbs, in 1#

7.65 lbs/ft.² x 112 ft² = 856.8 lbs = 0.857 Kips

④ ROOF pine .1875 cu.ft. x 28 lbs/cu.ft. = 5.25 lbs.

oak .083 cu.ft. x 45 lbs/cu.ft. = 3.735 lbs

9 lbs/ft² x 1029 ft² = 9.26 Kips

⑤ WALL Ⓐ 0.1455 x 45 lbs/cu.ft. = 6.5 lbs.

0.056 x 28 lbs/cu.ft. = 1.6 lbs.

0.083 cu.ft. x 120 lbs/cu.ft. = 10 lbs

18.1 lbs/ft² x 1134# = 20.5 Kips

Ⓑ 0.0625 x 45 lbs/cu.ft. = 2.8 lbs. oak

0.056 x 28 lbs./cu.ft. = 1.6 lbs pine

0.33 x 105 lbs./cu.ft. = 34.7 lbs. brick & mortar

0.083 x 120 lbs/cu.ft. = 10.0 lbs plaster

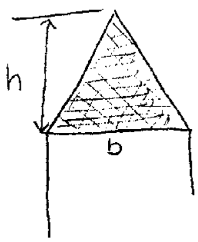
49.1 lbs. in 1#

49.1 lbs./ft.² x 1134# = 55.7 Kips

(c) 0.1455 cu.ft x 45 lbs/cu.ft. = 6.5 lbs oak
0.056 cu.ft. x 28 lbs/cu.ft. = 1.6 lbs pine
0.33 cu.ft. x 105 lbs/cu.ft. = 34.7 lbs brick & mortar
0.083 cu.ft. x 120 lbs/cu.ft. = 10 lbs plaster
52.8 lbs in 1#

$52.8 \frac{lbs}{ft^2} \times 1134\# = 59.9$ Kips

(6) END WALLS OF ATTIC (2)




h = 9½' = 114"
b = 19' = 228"
A = 90#

TOTAL AREA = 180#

$\bar{w}$ WALL A - $180\# \times 18.1 \frac{lbs}{ft^2} = 3.3$ Kips

$\bar{w}$ WALL B - $180\# \times 49.1 \frac{lbs}{ft^2} = 8.8$ Kips

$\bar{w}$ WALL C - $180\# \times 52.8 \frac{lbs}{ft^2} = 9.5$ Kips

(7) CHIMNEY - 71 Kips (CALCULATED BY ALAN HO, RESEARCH ASSISTANT ON PROJECT)

# WEIGHT OF A TYPE 1 HOUSE

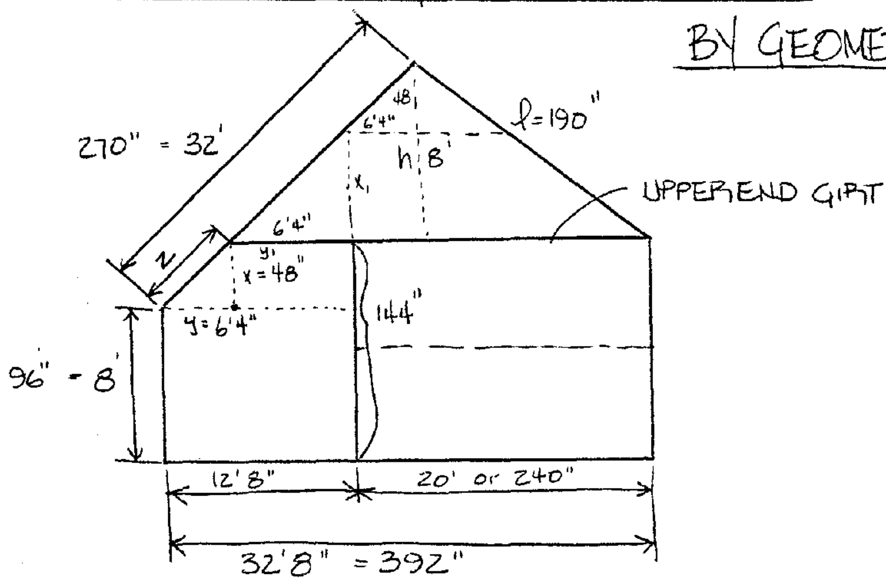
| TYPE OF MATERIAL | TOTAL VOLUME (in cu.ft.) | TOTAL WEIGHT | VOL. OF A 1# SECT. | WT. OF A 1# SECT. | AMT OF # IN HOUSE | WEIGHT OF MATERIAL IN HOUSE |
|---|---|---|---|---|---|---|
| ① WOOD FRAMING | 472.2 | 21.2$^k$ | | | | 21.2 KIPS |
| ② CHIMNEY | | | | | | 71 KIPS |
| ③ FLOORING (oak) | | | .27 cu.ft. | 12.15 lbs. | 3581.28 | 43.5 KIPS |
| ④ INT. PART. (oak) | | | .17 cu.ft. | 7.65 lbs | 112# | .875 Kips |
| ⑤ ROOF | | | pine-.1875<br>oak-.083 | 9 lbs | 1029# | 9.26 KIPS |
| ⑥ WALL | | | A B C | A-18.1 lbs. | 1134# | A - 20.5 KIPS |
| oak | | | .15 .06 .15 | B-49.1 lbs. | | B - 55.7 KIPS |
| pine | | | .06 .06 .06 | C-52.8 lbs | | C - 59.9 KIPS |
| brick | | | 0 .33 .33 | | | |
| plaster | | | .08 .08 .08 | | | |
| ⑦ END WALLS OF ATTIC | | | | A-18.1<br>B-49.1<br>C-52.8 | 180# | A - 3.3 KIPS<br>B - 8.8 KIPS<br>C - 9.5 KIPS |

TOTAL WEIGHT OF HOUSE A-170$^k$; B-210$^k$; C-215$^k$

# APPENDIX C: MASS CALCULATIONS FOR TYPE IA

TT

BY GEOMETRY




① $x = 48''$, $\therefore x_1 = 48''$

② $y$ and $y_1$ are $\sim 6'4''$

③ upper end girt is $\sim 20' + 6'4'' = 316''$

④ $z = \sqrt{(6'4'')^2 + (48'')^2} = 90'' = 7'6''$

$3z = 22'6'' = 270''$

⑤ $h = 8'$, $240' - 6'4'' = 164''$

⑥ $\ell = \sqrt{164^2 + 96^2} = 190'' = 15'10''$

## ① VOLUME OF WOOD FRAMING

### Ⓐ SILLS (oak)

I. FRONT & BACK 45'6" = 546"

II. (2) ENDS - 32' 8" or 392"

III (2) INTERIOR SILLS - 15'4" or 184"

$$2(546")(9"\times9")+2(392")(9"\times9")+2(184")(9"\times9")=105.2 \text{ cu.ft.}$$

### Ⓑ POSTS (oak)

I. REAR POSTS - 9"x9"x 12'3" or 9"x9"x147"

$$4(81 \text{ sq.in.} \times 147") = 27.56 \text{ cu.ft.}$$

$$1728 \text{ cu.in.}$$

II. FRONT POSTS (see Type 1) = 31.7 cu.ft.

III. LEAN-TO POSTS - 9"x9" x 8' = 9"x9" x 96'

$$4(81 \text{ sq.in.} \times 96")/1728 \text{ cu.in.} = 18 \text{ cu.ft.}$$

**TOTAL POSTS = 77.26 cu.ft.**

## © GIRTS (oak)

I. FRONT GIRTS – (8"x10")(44'6") = (80)(534) = 24.7 cu. ft.

II. (2) END GIRTS – 2(8"x10")(18'10") = 2(80)(226") = (10.5)2 = 21 cu. ft.

III. (2) CHIMNEY GIRTS – 18'10" long – 2(226"x80) = 21 cu. ft.

IV. REAR GIRT – (15'4")(2) or (368" x 80 sq. in.) = 17 cu. ft.

V. (4) LEAN-TO END GIRTS (2 INTERIOR) – (11'3") – 4(135" x 8" x 10") = 25 cu. ft.

VI. LEAN TO REAR GIRT – 2(15'4") + (12'3") or (515" x 8" x 10") = 23.8 cu. ft.

VII. (2) UPPER-END GIRTS – 2 (316" x 8" x 10") = 29.3 cu. ft.

VIII. (2) UPPER-CHIMNEY GIRTS – 2(316" x 8" x 10") = 29.3 cu. ft.

TOTAL GIRTS = 191.1 cu. ft.

## (D) PLATES

I. FRONT PLATE – 46' x 8" x 10" = 25.6 cu. ft.

II. REAR PLATE – 46' x 8" x 10" = 25.6 cu. ft.

III. LEAN-TO PLATE – 46' x 8" x 10" = 25.6 cu. ft.

TOTAL PLATES = 76.8 cu. ft.

Ⓔ SUMMERS (oak)

I. (2) FIRST-FLOOR SUMMERS
(15'6") x 12" x 15" = 19.4 cu.ft.

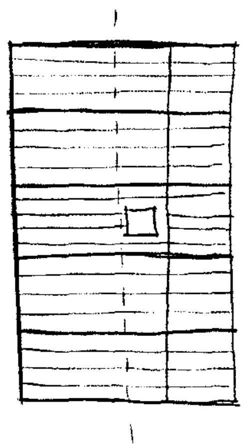
II. (2) SECOND-FLOOR SUMMERS
(26'4") x 10" x 12" = 20 cu.ft.

TOTAL SUMMERS = 78.8 cu.ft.

Ⓕ ROOFING SYSTEM

I. (6) FRONT PRINCIPAL RAFTERS (6" x 6" x 190")
II. (6) REAR PRINCIPAL RAFTERS (6" x 6" x 270")
III. (3) SETS OF PURLINS (43' of each set) (3" x 3" x 516")
IV. (15) FRONT COMMON RAFTERS (3" x 3" x )
V. (16) REAR COMMON RAFTERS (3" x 3" x 264")
VI. (6) COLLAR BEAMS (13' x 3" x 5")

I. 23.8 cu.ft.
II. 33.8 cu.ft.
III. 8 cu.ft.
IV. 14.6 cu.ft.
V. 22 cu.ft.
VI. 8 cu.ft.



TOTAL ROOFING SYSTEM = 110.2 cu.ft.

TOTAL VOLUME OF WOOD FRAMING = 639.4 cu. ft.

AMOUNT OF SQ. FT. IN HOUSE

FLOORING

I. FIRST FLOOR AREA (374"x534") - 19264 sq. in. = 1253 #

II. SECOND FLOOR AREA (227"x534) - 19800 = 704.3 #

III. ATTIC FLOOR AREA (316"x534") - 4928 = 1137.6 #

TOTAL FLOORING & SUBFLOORING = 6189.8 #

AMOUNT OF SQ. FT. OF PARTS OF HOUSE

ROOF (46'x190") + (46'x270") = 1763 sq. ft.

WALLS

I. END WALLS - 379.2 # each

II. FRONT WALL $\frac{480" \times 144"}{144 \text{ s.i.}}$ = 480 #, REAR WALL $\frac{480" \times 96"}{144"^2}$ = 320 #

III. END WALLS OF ATTIC - 105.3 #

SOLID WALLS - 1690.6 #

WINDOWS

ATTIC – (2) 1'x3' = 3x2 = 6#

FIRST FLOOR –

(4) 3'x3' = 9x4 = 36#

(2) 1'x3' = 3x2 = 6#

(2) 3'x3' = 9x2 = 18#

(2) 3'x6' DOORS = 18x2 = 36#

SECOND FLOOR –

(4) 3'x3' = 9x4 = 36#

(1) 1'x3' = 3x1 = 3#

141# OF OPENINGS IN WALL

TOTAL SQ.FT. OF WALL AREA MINUS OPENINGS –

1690.6
– 141
1549.6#

INTERIOR PARTITIONS

I. FIRST FLOOR – (37'2"x6')+2(9'x7')+(3'x6')2+ 2(14'x3'6") = 446#

II. SECOND FLOOR – (43'x6')+2(3'x14')+2(3'x6') = 378#

TOTAL INTERIOR PARTITIONS = 824#

CHIMNEY (ESTIMATED BY PARTS) = height x area or average area of part

| | | | |
|---|---|---|---|
| ①-Ⓧ | $4.33' \times 68.8^{\#}$ | 297.9 cu.ft. | 31,280 lbs. |
| Ⓧ-② | $1.17' \times \frac{(68.8^{\#}+60.7^{\#})}{2}$ | 75.8 cu.ft. | 7,955 lbs. |
| ②-③ | $2' \times \frac{(60.7^{\#}+50.5^{\#})}{2}$ | 111 cu.ft. | 11,676 lbs. |
| ③-④ | $3.58' \times \frac{(50.5^{\#}+33.3^{\#})}{2}$ | 150 cu.ft. | 15,750 lbs. |
| ④-⑤ | $2.17' \times \frac{(33.3^{\#}+23.6^{\#})}{2}$ | 61.7 cu.ft. | 6,482 lbs. |
| ⑤-⑥ | $1.25' \times \frac{(23.6^{\#}+19.7^{\#})}{2}$ | 27 cu.ft. | 2,842 lbs. |
| ⑥-⑨ | $.92' \times \frac{(19.7^{\#}+5.8^{\#})}{2}$ | 11.7 cu.ft. | 1,232 lbs. |
| ⑨-top | $14.58' \times 5.8^{\#}$ | 84.6 cu.ft. | 8,879 lbs. |
| | | 819.7 cu.ft. | 86,096 lbs. |

TOTAL WEIGHT OF CHIMNEY = 86.1 Kips

# WEIGHT OF A TYPE 1A HOUSE

FRAMING - 639.4 cu.ft. x 45 lbs/cu.ft. = 28.7 Kips

FLOORING - $12.15 \frac{lbs}{ft^2} \times 6189.8^{\#} = 75.2$ Kips

INTERIOR PARTITIONS - $7.65 \frac{lbs}{ft^2} \times 824^{\#} = 6.3$ Kips

ROOF - $9 \frac{lbs.}{ft^2} \times 1763^{\#} = 15.9$ Kips

WALL- (A) $18.1 \frac{lbs}{ft^2} \times 1549.6^{\#} = 28$ Kips

(B) $49.1 \frac{lbs.}{ft^2} \times 1549.6^{\#} = 76.1$ Kips

(C) $52.8 \frac{lbs.}{ft^2} \times 1549.6^{\#} = 81.8$ Kips

WEIGHT OF A TYPE 1A HOUSE

| TYPE OF MATERIAL | TOTAL VOLUME (in cu.ft.) | TOTAL WEIGHT | VOL. OF A 1# SECT. | WT OF A 1# SECT | AMT. OF # IN HOUSE | WEIGHT OF MATERIAL IN HOUSE |
|---|---|---|---|---|---|---|
| ① WOOD FRAMING | 639.4 | | | | | 28.7$^{K}$ |
| ② CHIMNEY | 819.7 | | | | | 86.1$^{K}$ |
| ③ FLOORING (oak) | | | .27 cu.ft. | 12.15 lbs. | 6189.8# | 75.2$^{K}$ |
| ④ INT. PART. (oak) | | | .17 ft$^{3}$. | 7.65 lbs. | 824# | 6.3$^{K}$ |
| ⑤ ROOF | | | pine-.1875<br>oak-.083 | 9 lbs. | 1763# | 15.9$^{K}$ |
| ⑥ WALL | | | A B C | A-18.1 lbs | 1549.6# | A-28$^{K}$ |
| oak | — | — | .15 .06 .15 | B-49.1 lbs. | | B-76.1$^{K}$ |
| pine | — | — | .06 .06 .06 | C-52.8 lbs | | C-81.8$^{K}$ |
| brick | — | — | 0 .33 .33 | | | |
| plaster | — | — | .08 .08 .08 | | | |

TOTAL WEIGHT OF HOUSE - A-240.2$^{K}$; B-288.3$^{K}$; C-294.0$^{K}$

# APPENDIX D: MASS DISTRIBUTION FOR TYPE 1A

## PART 1 - MASS OF HOUSE ACTING AROUND 2ND FL. LEVEL

① I. $\frac{1}{2}$ (REAR POSTS) = 13.78 cu.ft.
$\frac{1}{2}$ (FRONT POSTS) = 15.85 cu.ft.
$\frac{5}{8}$ (LEAN-TO POSTS) = 11.25 cu.ft.

II. FRONT GIRT = 24.7 cu.ft.
END GIRTS = 21 cu.ft.
CHIMNEY GIRTS = 21 cu.ft.
REAR GIRT = 17 cu.ft.
(4) LEAN-TO GIRTS = 25 cu.ft.
LEAN-TO REAR GIRT = 23.8 cu.ft.

III. LEAN-TO PLATE = 25.6 cu.ft.

IV. SUMMERS = 19.4 cu.ft.

TOTAL VOLUME OF FRAMING = 218.38 cu.ft.

$218.38 \text{ cu.ft.} \times 45 \frac{\text{lbs}}{\text{ft}^3} = 9.8 \text{ kips}$

② FLOORING & SUBFLOORING

$2^{ND}$ FLOOR AREA 704.3#

$2(704.3\#) \times 12.15 \text{ lbs/ft}^2 = 17.1 \text{ Kips}$ - WEIGHT OF FLOOR

③ INTERIOR PARTITIONS

1ST FLOOR - (372" x 3') + 2(14' x 3'6") + 2(3' x 6') + 2(9' x 4')
2ND FLOOR - (43 x 3') + 2(3' x 3')
TOTAL - 356.2#

356.2# x 7.65 lbs/ft.² = 2.7 Kips - WEIGHT OF INT. PARTITIONS

④ WALLS

½(END WALLS) = 170#
½(FRONT WALL) = 240#
⅝(LEAN-TO WALL) = 200#
TOTAL = 780#

WINDOWS
½(1ST FL. WINDOWS) + ½(2ND FL. WINDOWS) = 67.5#

WALL A - 712.5# x 18.1 lbs/ft² = 12.9 Kips
WALL C - 712.5# x 52.8 lbs/ft² = 37.6 Kips
} WEIGHT OF WALLS

TOTAL WEIGHT ACTING ABOUT 2ND FLOOR CONNECTION:
W/WALL A = 42.5 Kips
W/WALL C = 67.2 Kips

PART 2 - MASS OF HOUSE ACTING ABOUT ATTIC FL. LEVEL

① I. $\frac{1}{4}$ REAR POSTS = 6.89 cu. ft.
$\frac{1}{4}$ FRONT POSTS = 8.0 "

II. (2) UPPER END GIRTS = 29.3 "
(2) UPPER CHIMNEY GIRTS = 29.3 "

III. FRONT PLATE = 25.6 "
REAR PLATE = 25.6 "

IV. (2) SECOND FLOOR SUMMERS = 40 "

V. ($\frac{1}{4}$) FRONT PRINCIPAL RAFTERS = 5.95 cu. ft.
($\frac{1}{3}$) REAR PRINCIPAL RAFTERS = 11.3 "
1 SET PURLINS = 2.7 "
(16 x $\frac{1}{4}$) COMMON RAFTERS = 3.6 "
(16 x $\frac{1}{3}$) REAR COMMON RAFTERS = 7.3 "

TOTAL VOLUME OF FRAMING = 195.55 cu. ft.
195.55 x 45 lbs/cu. ft. = 8.8$^K$ - WEIGHT OF FRAMING

② FLOORING & SUBFLOORING
ATTIC FLOOR AREA 1137.6$^\#$
1136.6$^\#$ x 12.15 lbs/ft.$^2$ = 13.8 Kips
- WEIGHT OF FLOORING

③ INTERIOR PARTITIONS

2ND FLOOR (43'x3') + 2(3'x14') + 2(3'x3') = 231#

231# x 7.65 lbs/sq. ft. = 1.8 Kips

④ WALLS

2 (1/4 END WALLS) = 170#

2 (1/3 END ATTIC WALLS) = 70.2#

1/4 (FRONT WALL) = 120#

TOTAL - 360.2#

WINDOWS

1/2 (2ND FLOOR) + 1/2 (ATTIC WINDOWS) = 22.5#

360.2# - 22.5# = 337.7# - WALL AREA MINUS OPENINGS

W/WALL A - 337.7# x 18.1 lbs./ft.² = 6.1 KIPS - WT. OF WALLS

W/WALL C - 337.7# x 52.8 lbs/ft² = 17.8 KIPS "

⑤ ROOF (1/4)(46' x 190") + (1/3)(46' x 270") = 527.1#

527.1# x 9 lbs/ft.² = 4.7 KIPS - WT. OF ROOF

TOTAL WEIGHT ACTING ABOUT ATTIC FLOOR CONNECTION:

W/WALL A: 35.2 KIPS

W/WALL C: 46.9 KIPS

PART 3 - MASS OF HOUSE AROUND CHIMNEY CONNECTION

I. $(\frac{3}{4})$ FRONT PRINCIPAL RAFTERS = 17.85 cu.ft.
$(\frac{1}{2})$ REAR PRINCIPAL RAFTERS = 16.9 cu.ft.
(2) sets PURLINS = 5.4 cu.ft.
$(14 \times \frac{3}{4})$ FRONT COMMON RAFTERS = 10.95 cu.ft.
$(16 \times \frac{1}{2})$ REAR COMMON RAFTERS = 11 cu.ft.
(6) COLLARS = 8 cu.ft.

TOTAL VOLUME OF WOOD FRAMING = 70.1 cu.ft.

70.1 cu.ft. x 45 lbs/cu.ft. = 3.2 Kips - WEIGHT OF FRAMING

② FLOORING - $\phi$
③ INTERIOR PARTITIONS - $\phi$

④ WALLS 2 $(\frac{2}{3}$ ATTIC END WALLS) = 140.4#
- WINDOWS - (3#) - 3.0#
137.4#

W/WALL A - 137.4# x 18.1 lbs/ft.² = 2.5 KIPS
W/WALL C - 137.4# x 52.8 lbs/ft.² = 7.3 KIPS
} WT. OF WALLS

⑤ ROOF

$$\left(\tfrac{3}{4}\right)(46' \times 190'') + \tfrac{1}{2}(46' \times 270'') = 1063.8^{\#}$$

$$1063.8^{\#} \times 9\ \text{lbs/ft}^2 = \underline{9.6\ \text{KIPS}}$$

TOTAL WEIGHT ACTING ABOUT CHIMNEY CONNECTION

W/ WALL A = 15.3 KIPS

W/ WALL C = 20.1 KIPS

## APPENDIX E: MASS CALCULATIONS FOR TYPE 2



### ① VOLUME OF WOOD FRAMING

#### Ⓐ GIRTS

6 ( 16.5' x 8" x 9" ) = (8.25 cu. ft.)6 = **49.5 cu. ft.**

#### Ⓑ SUMMERS

I. 6(14.75' x 8" x 9") = 7.375 x 6 = 44.25

II. 6(16.5' x 8" x 9") = 49.5 cu. ft.

TOTAL - 93.75 cu. ft.

#### Ⓒ ROOFING

I. PLATES

37.5' x 8" x 8" = 1.39 cu. ft.

31.5' x 8" x 8" = 1.17 cu. ft.

TOTAL - 2.56 cu. ft.

II. PRINCIPAL RAFTERS - 2(17' x 6" x 5") = 7.1 cu. ft.

III. HIP " - 2(20' x 6.5" x 7.5") = 13.5 cu. ft.

IV. COMMON " - 7(17' x 5" x 3") = 12.4 cu. ft.

V. COMMON " - 2(13.5' x 5" x 3") = 2.8 cu. ft.

VI. COMMON " - 2(10' x 5" x 3") = 2.1 cu. ft.

VII. COMMON " - 2(7' x 5" x 3") = 1.5 cu. ft.

VIII. COMMON " - 2(3.5' x 5" x 3") = 0.7 cu. ft.

IX. COMMON " - 2(2.5' x 5" x 3") = 0.5 cu. ft.

X. COMMON " - 2(3.5' x 5" x 3") = 0.7 cu. ft.

XI. COMMON " - 2( 5' x 5" x 3") = 1.0 cu. ft.

XII. COMMON RAFTERS - 4(6' x 3" x 5") = 2.5 cu. ft.
XIII. COMMON " - 2(7' x 3" x 5") = 1.5 cu. ft.
XIV. COMMON " - 2(8' x 3" x 5") = 1.7 cu. ft
XV. COMMON " - 2(3.5' x 3" x 5") = 0.7 cu. ft.

TOTAL = 48.7 cu. ft.

TOTAL ROOFING = 51.26 cu. ft.

Ⓓ VOLUME OF BRICK WALLS

FRONT (38' x 1' x 27.5') = 1045 cu. ft.
BACK (38' x 1' x 35.5') = 1349 cu. ft.
2(16' x 1' x 27.5') + 2(½ x 16' x 6.5' x 1') = 984 cu. ft.

TOTAL - 3378 cu. ft.

WINDOWS
1ST FLOOR - 8(3.75' x 5' x 1') = 150 cu. ft.
2ND FLOOR - 9(3.75' x 5' x 1') = 168.75 cu. ft.
3RD FLOOR - 9(3.75' x 3.75' x 1') = 126.6 cu. ft.
DOOR - (3.75' x 7' x 1') = 26.25 cu. ft.

= 471.6 cu. ft. OF OPENINGS

TOTAL VOLUME OF BRICK WALLS 3378 - 471.6 = 2906.4 $ft^3$

AMOUNT OF SQ. FT. IN HOUSE

FOUR FLOORS (1, 2, 3 & ATTIC)

$$4[(36' \times 16') - \underset{\text{STAIRWELL}}{30^{\#}}] = 2184^{\#}$$

SQ. FT. OF ROOF

$$(17' \times 17') + 2[\tfrac{1}{2}(17' \times 10.5')] + 2[\tfrac{1}{2}(10.5' \times 17')] = 646^{\#}$$

INTERIOR PARTITIONS

$$2[(16' \times 8.5') - \underset{\text{DOOR}}{(3' \times 7')}] + 1[(16' \times 6') - (3' \times 6')] = 308^{\#}$$

WEIGHTS OF 1# SECTION OF FLOORING, INTERIOR PARTITIONS & ROOF SAME AS TYPE 1.

# CHIMNEY AREAS (CROSS SECTIONAL) AT DIFFERENT LEVELS

① (7.5' x 5.75') - (4' x 6') = 19.1#

② SAME = 19.1#

③  ~ (6.5' x 5') - 1# = 29#



④ 29# - (2.5' x 3.75') = 19.6#

⑤ SAME AS 4 = 19.6#

⑥ (4.3' x 3.75') - 2# = 14.1#
(2# = FLUES)

⑦ 14.1# - $\left[\frac{(1.75' + 3')1.75'}{2}\right]$ = 9.9#

⑧ SAME AS 7 = 9.9#

⑨ (3' x 2') + (1.3' x 1.75) - 3# = 5.3#
(3# = FLUES)

CUBIC FEET OF CHIMNEY BY PART

① → ② $19.1^{\#} \times 4.75' =$ 90.7 cu. ft.

② → ③ $\left[\frac{(19.1^{\#} + 29^{\#})}{2}\right] 3.75' =$ 90.2 cu. ft.

③ → ④ $(.5')(29^{\#}) =$ 14.5 cu. ft.

④ → ⑤ $(19.6^{\#})4' =$ 78.4 cu. ft.

⑤ → ⑥ $\left[\frac{(19.6^{\#} + 14.1^{\#})}{2}\right] \times 4.5' =$ 75.8 cu. ft.

⑥ → ⑦ $(.5')(14.1^{\#}) =$ 7 cu. ft.

⑦ → ⑧ $(3.3')(9.9^{\#}) =$ 32.7 cu. ft.

⑧ → ⑨ $\left[\frac{(9.9^{\#} + 5.3^{\#})}{2}\right] (3.5') =$ 26.6 cu. ft.

⑨ → top $(13.5')(5.3^{\#}) =$ 71.6 cu. ft.

TOTAL CUBIC FEET OF CHIMNEY = 487.5 cu.ft.

BRICK & MORTAR @ 105 lbs/cu.ft.

TWO CHIMNEYS - $2(487.5 \text{ cu.ft.}) \times 105 \frac{\text{lbs}}{\text{cu.ft.}} = 102.3$ Kips

WEIGHT OF A TYPE 2 HOUSE

| TYPE OF MATERIAL | TOTAL VOLUME (IN CU. FT.) | TOTAL WEIGHT | VOL. OF A 1# SECT. | WT. OF A 1# SECT. | AMT. OF # IN HOUSE | WEIGHT OF MATERIAL IN HOUSE |
|---|---|---|---|---|---|---|
| ① WOOD FRAMING | 194.5 | 8.8K | | | | 8.8K |
| ② CHIMNEY | 487.5 x 2 | | | | | 102.3K |
| ③ FLOORING (oak) | | | .27 cuft. | 12.15 lbs. | 2184# | 26.5K |
| ④ INT. PART. (oak) | | | .17 ft³ | 7.65 lbs. | 308# | 2.4K |
| ⑤ ROOF | | | pine-.1875<br>oak-.083 | 9 lbs | 646# | 5.8K |
| ⑥ BRICK WALLS | 2906.4 | 305.2K | | | | 305.2K |

TOTAL WEIGHT OF HOUSE = 451K

## FOOTNOTES

[1]Frederic C. Detwiller, "Demography of Boston in 1755" (unpublished report to M.I.T., Boston, Mass.,1978), p. 7.

[2]Ibid., p. 3.

[3]Ibid., p. 2.

[4]Ibid., p. 3.

[5]Hugh Morrison, Early American Architecture (New York: Oxford University Press, 1952), p. 23.

[6]Ibid, p. 24.

[7]Ibid., p. 22.

[8]Ibid., p. 24.

[9]Ibid., p. 23.

[10]Norman M. Isham, Early American Houses (New York: Da Capo Press, 1967), p. 25.

[11]Paul B. Jenison, "The Availibility of Lime and Masonry Construction in New England: 1630 - 1733," Old-Time New England, Vol. LXVII, Nos. 1-2, (July-December, 1976), pp. 21-26.

[12]1893 Architect and Builder News

[13]Isham and Brown, Early Connecticut Houses

[14]Detwiller, insert between pp. 65 and 66.

[15]Fiske Kimball, Domestic Architecture of the American Colonies and of the Early Republic (New York: Charles Scribner's Sons, 1922), p. 85.

[16]Ibid., p. 46.

[17]Ibid., p. 47.

[18]Ibid., p. 45.

[19]Morrison, P. 37.

[20]Martin S. Briggs, The Homes of the Pilgrim Fathers in England and America (1620-1685) (London and New York: Oxford University Press, 1932), p. 165.

[21]Weston Geophysical Research, Inc. "Historical Seismicity of New England" (unpublished report, December 1976, Revision 1, March, 1977), p. 127.

[22]From a book entitled Boston Observed, by Carl Seaburg.