# COPAKE FURNACE
## Copake, New York

**CONDITIONS ASSESSMENT / RECOMMENDATIONS**

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## ***Background***

Copake Blast Iron Furnace was constructed of local limestone, firebrick, brick and mortar for the manufacture and production of cast iron. The existing furnace was constructed in 1872 to replace an earlier furnace. In circa 1890s, it was fitted with a "modern" water cooled hearth[1] and remained in blast until 1903. Supporting structures surrounding the furnace were demolished in the late 1920s or early 1930s and the stacks' face stones were removed by the New York State Parks department to fabricate a nearby road- or brook-side retaining wall. The bosh, hearth and back-up rubble of the stack were left abandoned with no protection or maintenance and yet the furnace has remained standing; a remarkable testimony to its builders. But the ground surrounding the furnace is littered with piles of fallen stones. The furnace is now owned by New York State Office of Parks, Recreation and Historic Preservation and is part of the public recreational facility called Taconic State Park. Park personnel are uncertain of the stability of the furnace.

Carla Cielo, Architectural and Masonry Conservator, and Tom Hitchins, Architect, were asked to assess the condition of the furnace ruins and to study the feasibility of constructing a structure to protect and house the furnace. On May 17, 2004, Carla and Tom measured the site and conducted a systematic inspection of the remains. Victor Rolando, industrial archaeologist and historian provided assistance. The inspection was conducted from the ground.

## ***Terminology***

The masonry structure which surrounds the inner smelting chamber, is called *the stack.* The east, west and south arches are called *tuyere* arches for the air blast nozzle which supplied the blast and was located at the base of these arches. The larger north arch is the *casting arch.* The sides of the stack are named for their orientation and function of the arch, e.g., the east tuyere arch side. The *smelting chamber* is in the center of the stack and is where iron ore was converted to molten iron. The *hearth* is at the base of the smelting chamber, the slanted portion of the smelting chamber directly above the hearth is the *bosh.* The conical firebrick walls above the bosh are known as the *liner* of the smelting chamber. The brick walls between the liner and the stone stack are called the *inwalls*. The *forewall* is the finished, red-brick, exposed face of the inwalls at the inside end of the casting and tuyere arches.

## ***Findings***

<u>*Stack*</u>: The 33-foot high stack was constructed with large ashlar face stones and solidly-bedded back-up rubble of smaller units with random tie stones set in mortar. During its operational period, the furnace was protected within a low-pitched, gable-roofed, frame building. The building was demolished and most of the face stones were removed in the late 1920s or 1930s for reuse as a retaining wall. No photos of the stack as it appeared before the face stones were removed exist. Circa 1935 photographs of the north casting arch and the east tuyere arch sides, depict the furnace

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[1] Personal communications with Mr. Matt Kierstead, Industrial Historian.

as it appeared shortly after the face stones were removed (illustrations 1 and 2). All face stones were removed except for the lower three courses at the arch bases and two base courses elsewhere. The corners of the stack were retained which enables perception of the dimensions of the furnace at its base. The remaining mass of back-up rubble above the courses of face stone are quite irregular and significantly smaller at the top. The rubble appears to taper slightly to the two-thirds height and then drastically steps inward in the top third. There were no fallen stones at the base of the furnace in the circa 1935 photographs.

The stack was photographed in 1973 by Victor Rolando (illustrations 3, 4 and 5). A comparison of the circa 1935 photographs to the 1973 photographs shows a minor amount of additional stone loss, excessive plant growth on the back-up rubble, and a relatively small amount of fallen stonework at the furnace base. The brick lined casting and tuyere arches (see arches below) experienced the greatest amount of deterioration. The site was kept somewhat tidy as a pile of bricks can be seen in the foreground in some of the photographs in front of the casting arch.

Today, a large quantity of fallen stones surround the furnace ruin. The majority of fallen stones are at the southwest and northeast corners and mostly consist of smaller units from the back-up rubble, but larger face stones also exist within the rubble. The southwest and northeast corner stones are missing, apparently pushed out of position by falling backup rubble from above. Plant growth seems to have remained constant since 1973 (probably due to periodic removal). The overall shape of the stack changed; this is particularly evident at the southwest corner where in 1973 the back-up rubble rose with a slight taper to about the two-thirds height of the stack and today the same area appears to have been sheared. Backup rubble may fall unit-by-unit, but more likely, units will fall in a group acting as a stone avalanche taking other stones along its path with it, causing irreversible damage.

Stones that cantilever because of the loss of stonework beneath it are present throughout and pose an on-going threat. If their center of gravity shifts, more collapse is imminent. Few tie stones remain today. Remaining mortar near the exterior surface has little or no strength. The back-up rubble has lasted as long as it has because it was constructed with stone bearing on stone. The mortar simply filled the voids between units and was not structural as in today's masonry. However, there are large areas that appear to be stable.

*Arches:* The tuyere arches are 10-feet wide and are beautifully articulated with five courses of brick with the header end of the bricks facing out. The casting arch is 16-feet wide at its base and was constructed similarly, but with 6 brick courses. The brick arches act as mini independent vaults below the stack. The apex of the brick arches are woven with interlocking units from each side forming a seam at the top of the arches. The brick arches structurally support the back-up rubble of the stack and likely offered some support for the former face stones. The brick arches bear on three courses of face stones and rely on the weight of the stack to keep the arch acting in compression and the cohesive properties of the mortar to maintain a monolithic quality. The brick arches extend to the inwalls of the stack. The finished redbrick forewalls (in front of the inwalls) are under the brick arches and are not integrated with them. The forewalls and the inwalls bear on the iron lintels at each opening. The use of brick arches in furnace construction was employed in United States furnaces beginning by about the 1860s. Earlier furnaces made use of stone arches.

In the late 1920s or early 1930s, when Copake's face stones were removed, the brick casting arch was in very good condition. The finished face of the brick arch was intact, and it extended beyond the back-up rubble to the depth of the former face stones. But as early as 1935, the forewalls at the inside end of the casting arch had begun to deteriorate, and a large area of missing brick can be seen in a c. 1935 photograph of the hearth area (illustration 6). In 1935, the casting arch had two large areas of removed brick and some loss of brickwork in the lower course at the west side (illustration 1), but the east tuyere arch was in perfect condition (illustration 2). The condition of the east and north brick tuyere arches in 1935 is unknown.

The removal of the face stones has adversely affected all four brick arches by exposing the tops of the brickwork to rain and snow. By 1973, the outer bricks had fallen from position and the layers of brick had begun to delaminate. At the casting arch, the fore and inwalls continued to suffer from a loss of brick, and because the back of the brick arches are above the forewalls, the back of the brick arch began to fail. The cast iron lintels which support the in-walls bear on stonework. Thankfully, at the present time, the bearing of the lintels is relatively stable at each arch and the lintels appear to be able to perform their job.

The present condition at each tuyere arch is as follows:

- *Casting arch:* The casting arch has experienced the greatest amount of brick loss of all of the arches. No finished edge remains except for a small section at the northeast corner. There are sections of the arch which have eroded beyond the depth of the back-up rubble. Many of the remaining bricks at the outside face are unstable. A number of loose bricks were noted at the apex of this arch. The fore- and in-walls at the back of this arch are substantially deteriorated. This deterioration has created an instability at the back of the arch.

- *South tuyere arch (facing the stone retaining wall of the charging bridge):* The brick liner at this arch is in fair condition. More brickwork remains at this arch than at the casting arch. The first layer (inward layer) has delaminated indicating that the mortar between the first and second layer has lost its cohesive ability due to the constant exposure to moisture. Most of the finished edges of all five courses are missing with only a small section of finished edge brick remaining at the lower east half. The arch is missing to a depth of several bricks behind the finished course but still stands beyond the stack suggesting that its ability to support the back-up rubble has not been compromised. Many of the bricks of the outside face are loose, unstable and some are displaced. At least 20 bricks are sporadically missing from the first layer indicating a failure of the bedding mortar in those spots. A crack is present at the underside of the arch. A section of displaced bricks was noted near the hot air pipe which passes through the arch.

- *East tuyere arch:* The east tuyere arch has fared better than the other arches. The arch is missing to a depth of several bricks behind the finished course but still stands beyond the stack suggesting that its ability to support the back-up rubble has not been compromised. This arch exhibits the same failures as the south tuyere arch but is in a less advanced state of deterioration. Two courses of liner with finished edge remain at the lower part of the south corner. The bricks surrounding the hot blast pipe appear to be stable. The remaining unfinished edge bricks are somewhat loose and unstable. Two bricks of the first layer are missing.

- *West tuyere arch*: The condition of the west tuyere arch is comparable to that of the south tuyere arch. No finished edge remains. The lower two layers of brick are separating from the arch at the south side. Three bricks of the first layer are missing. The arch appears to have sagged near the forewall indicating that it is possibly delaminating. The brickwork is loose near the hot blast pipe. There is a missing section of about 5 brick courses at the lintel on the north side.

Most of the conditions noted above are the result of rain, snow melt and the associated freeze thaw cycles of winter. Rain water travels through the stack; some of which exits at the arches which were found to be wet on the day of inspection. The bricks that are sporadically missing from the inward layer may be the result of the removal of iron items commonly found within casting and tuyere arches. Two large sections of the west arch and the forewall of the casting arch have been missing prior to 1935 (as per photographic documentation).

*Bosh / Hearth*

Copake's bosh and hearth are free standing; they are not supported by the stack. The bosh consists of a single wythe of fire brick and is encased within cast iron water-cooled panels. Nearly 45% of the bosh remains. Many of the water-cooled panels remain intact.

The stack liner is about 90 to 95% intact. There is a small section of loose and displaced bricks at the top of the stack.

***General Recommendations:***

Taconic State Park personnel have asked for stabilization options in different cost ranges. One option is to *do nothing* - treating the furnace as a temporary part of the landscape allowing nature to take its toll. If nothing is done, the deterioration process outlined above will progress; as more stones fall the pace will likely increase. But, even with this, a good portion of the furnace will likely still be present in fifty years.

In my opinion, the do nothing option should not be considered. The significance of the furnace and its water cooled hearth, both locally and nationally, is far too great to jeopardize. The work that went into this furnace is extraordinary and could not be duplicated today. The water cooled hearth and free-standing bosh are valuable to the understanding of the evolution of smelting technology, and most valuable if preserved in place. Copake blast furnace is good for local tourism, and will benefit researchers, students and people interested in the study of iron production and industrial technology.

The number one line of defense against the ravages of nature is the construction of a roof. Constructing a roof over and above the furnace, will greatly slow down the existing deterioration processes described above. The roof will protect the valuable bosh and hearth and will stop or slow the deterioration of the mortar between the brick units of the arches and the stone units of the stack. A roof may not completely stop deterioration, but the rate of deterioration will decrease, if the roof is properly maintained.

Given the fragile nature of the furnace ruin, and the fact that Copake was roofed in its operational period, we recommend constructing an auxiliary structure over and above the stack as a protective measure to limit further deterioration. During the operational period, the furnace was housed in a timber framed structure. The last known "furnace house" was 54'-5" x 44'-5", had vertical board siding and a gable roof with the gable ends facing north and south. The height of this building was not documented, but from photographs, it appears to have been four stories high. This building adjoined a casting house and a bridge house.

The team of Cielo and Hitchins considered many different building designs to house the furnace ruin. The options fall in two categories: enclosed building and open air pavilion. The benefits and drawbacks of each category of building are discussed below.

*Option 1: Sheathed building similar to the last known operational period furnace house:* The first concept to consider is to build a new enclosed structure that roughly copies the last known building that sheltered the furnace during the operational period and uses materials that are similar to its construction (illustration 7). The vision for this type of structure includes a timber framed structure with corner posts and two intermediate posts per side, a common rafter system supporting a gable roof and vertical board siding supported on horizontal nailers. This concept may be visually pleasing but is inherently problematic.

In order to protect the archeological remains of the operational period building(s), the new building cannot be constructed directly on the old foundations and therefore must be either smaller or larger. In either case, the need for nailers to secure vertical siding will force viewing of the furnace through windows or relatively small openings. It no longer would be possible to photograph the furnace ruin as a recognizable image. A smaller building would bring the exterior walls within about 5 feet of the base of the furnace. Viewing would be greatly hampered and restricted. In both the smaller or the larger building, the intermediate posts would fall within the casting floor and would compromise any future archeology and its interpretation. A building larger than the original would require lateral supports to join the intermediate supports of the front and back walls, and of the side walls. The lateral supports needed in the larger building would detract from the furnace itself.

Lastly, an enclosed building would require a system of ventilation for safe humidity levels. The author has seen rain form from excess condensation within furnace enclosures. To best preserve the original materials, the interior climate should match that of the exterior. This could be accomplished by hinging the siding (vertically) as in a tobacco barn but would require daily opening and closing.

*Option 2: Unsheathed, open-air pavilion:* The second type of structure to consider to shelter the Copake Furnace ruin consists of an unsheathed, open-air pavilion above the furnace (illustration 8). Our vision for this option consists of a hipped roof supported on four braced corner posts with no intermediate posts. Since there would be no siding, there would be no need for nailers and excess secondary structural members. Concentrating the structure on four corners has many advantages. The ruin would be unobstructed for viewing, photographing and future archeology. The ambient climate would not be altered. The open-air pavilion would be less of a maintenance issue than option 1 and less expensive to build. The hipped roof offers less wind resistance. The size of the last known operational period furnace house could be represented with the placement of the corner posts. The scattered stones which have fallen from the stack and surround the ruin can be retained in situ (except at the corners). The roof of the open air pavilion could be cantilevered beyond the posts to adequately shelter and protect the sides of the stack from rain and snow.

The negative aspect of an open air pavilion is security and the need for a fence at the base of the pavilion to restrict unwanted visitors.

Materials for the construction of an open-air pavilion include the following:

- Timber to conform with existing aesthetics of the park.
- Painted steel

Painted steel would require engineering by a licensed engineer and would have a longer life than timber.

Furnaces are constructed on massive dry laid stone foundations. Copake Furnace is 32-foot square at its base. Depending on its size, the dry laid foundation may be able to be used as the footing for either the open air pavilion or the sheathed building. Archeological explorations would be needed to confirm the size of the foundation before working drawings are developed. The size of the furnace footing should be compared to the size of the last known operational period building in the planning stages of the project therefore archaeology should take place in the planning stage of the project.

As stated above, sheltering the furnace under a roof is the best method for stabilization. A well designed structure using quality materials is necessary. Asphalt roofing materials can give 30 to 40 years life; Standing seam stainless steel or copper can give 75 to 100 years life and requires little maintenance.

<u>*Masonry work*</u>

First and foremost we would like to caution park personnel against creating a restored monument. Copake Furnace is most valuable to the study and interpretation of local iron industry as an intact ruin. A lot of interpretive information remains. Any rebuilding other than what is absolutely necessary to prevent short term collapse should be avoided. The Copake Furnace should be appreciated and interpreted as an above ground archaeological research center.

We DO NOT recommend reconstruction which would diminish the value of this resource by mixing new construction with operational period fabric. A large part of the value of Copake Furnace lies in its industrial archeological potential which would be diminished if reconstruction occurred. All stabilization efforts should limit reconstruction to that which is absolutely necessary to prevent further collapse.

The benefits of conserving a ruinous furnace as a ruin and not rebuilding or recreating what is missing, are vast. In its existing state, its entire history, operational as well as its period of abandonment, is recorded and can serve the general public as a back drop to illustrated display text. It allows visitors the ability to utilize their own imagination to recreate that which was lost since the operational period. As mentioned, "as-found" unaltered industrial remains best serve scholars and other enthusiasts who wish to study the technological processes. Un-restored structures are beautiful and illustrate the passage of time and respect the period of abandonment. We recommend considering Copake as an above ground industrial archaeological laboratory - the basis of an industrial archaeological classroom, to be studied and re-studied by future generations.

*Stack*

After the furnace is roofed, a minimal amount of masonry work should be carried out to prevent any additional stones from falling out of position and to insure the safety of viewers. As stated, large areas exist throughout the stack that appear stable and may require no work at all. But there are many areas of the stack that appear precarious.

We recommend re-establishing the integrity of the stack by removing the loose and deteriorated mortar and injecting new mortar without resetting the existing stonework. Add stonework where needed to rectify cantilevered or precarious conditions. The success of this work is dependent on the use of the right mortar for the situation. The wrong mortar can cause further deterioration by trapping moisture within the joints.

Naturally hydraulic lime (NHL) mortar is strongly recommended. Naturally hydraulic lime has good strength and a high permeability rate. NHL was utilized to deep point Oxford Furnace, Oxford, New Jersey and the owner is very pleased with its results. For more information on naturally hydraulic lime please visit valimeworks.com or pennsylvanialimeworks.com or phone *215-536-4482.*

Ordinary bag lime is not recommended. It is typically dolometic, has little strength, and is not weather resistant. It is commonly mixed with Portland Cement to improve its performance but, as determined by laboratory analysis, even a small amount of Portland Cement added to the mix can greatly inhibit permeability.

Masonry work should be kept to a minimum. The mason should have a very delicate hand and should understand that the aim is to not change the existing ruinous appearance or rebuild.

Before work begins, a stone-by-stone inspection should be carried out by members of a masonry conservation team.

*General procedures and guidelines for masonry work for the stack:*

- The awarded contractor should be trained in the use of naturally hydraulic mortar to insure quality of workmanship and reduce the chance of error. The work should be periodically inspected by qualified personnel. The author has worked with DeGruchy masonry in the past and feels that they are very qualified to train the awarded bidder.
  *DeGruchy Masonry, 215-536-4482*

- The architect, masonry conservator and mason should carefully inspect the stack before any work is carried out.

- Photo document the stack prior to any work.

- Areas that are stable require no work and should be left alone.

- Remove small displaced and loose stones that have no effect on the surrounding stonework before work begins to insure the safety of the masons.

- Remove severely deteriorated, lime-based (original) bedding mortar back to sound mortar. Utilize very low pressure air with a ¼-inch diameter stainless steel air hose attachment. Gentle brushing or vacuum methods may be tested. All sound original mortar is to remain. Note: the object is to leave as much original mortar as possible. Joints should be clean and free of efflorescence, dirt and debris prior to any pointing work. Remove moss, lichen, roots, vegetation, and debris from the joints. Do not remove vegetation by pulling on the roots.

- The mason should work in small areas at a time. Work from top to bottom, from scaffolding from above. Follow all applicable OSHA and state safety regulations.

- Deep point joints that require re-pointing in successive lifts. Deep injection techniques such as the use of a fine tip bag to reach deep joints should be employed. DeGruchy masonry can train the mason for this technique. Do not use pressure or other mechanical grouting techniques. Do not use chemical plasticizers to liquify the mortar.

- Do not leave voids behind new pointing work.

- Do not bring pointing mortar out beyond the face of the stones. Keep mortar a minimum of 1-inch behind the face of the unit.

- Loose and/or unstable stones should be stabilized without removal wherever possible to avoid dislodging additional masonry and to maintain original workmanship.

- In some areas, new stonework may be needed to rectify a cantilevered or precarious condition. In these areas rebuild as originally constructed with stone bearing directly on stone (ie. a dry laid wall). Structural mortar joints are NOT acceptable. Mortar is to be utilized to fill the voids between the stones. New joints should match the thickness and profile of the original joints and should not be greater than ½" thick.

- Add new stonework to fill large voids and areas below cantilevered stones and key into the existing and surrounding stonework by overlapping units for minimum 2/3rds bearing.

- Utilize stones found in the direct vicinity of the furnace. Clean stones found on site with a stiff brush and water.

- Newly reset stonework should be indistinguishable from the original and surrounding stonework when viewed from a distance, but distinguishable upon close examination.

- In limited situations loose and displaced stones may be reset. This is not the preferred method of stabilization and should be avoided if possible. Do not remove more than one loose stone at a time. If a stone is removed for safety reasons, it should be reset immediately.

*Arches*

As with the stack, the condition of the arches is the result of constant exposure to moisture. A roof will greatly benefit the arches. The brick arches are important to the stability of the stack. As such, their structural integrity is important. Bricks that are very loose at the outer face should be removed. Inject an NHL grout between the delaminated courses. The application of low pressure bracing to secure grouted areas should be tested. Bricks should only be reset where absolutely necessary to insure the ability of the arch to act in compression and should be considered for resetting on a case by case basis prior to contracting the work. Use NHL mortar for all work as recommended above. Do not repoint the arches. Develop a plan to monitor the arches after the work is complete.

The arches should retain their patina of age. Mold, efflorescence and dirt, should be retained.

*Bosh and hearth*

The integrity of Copake's water- cooled hearth is remarkable and should be cherished as one of the site's greatest resources. The water-cooled hearth and bosh contribute to the understanding of the evolution of smelting technology in North America. They are rare survivors. The author knows of no others remaining today from this period. At many other sites, the bosh and hearth were either removed for safety reasons or desecrated with modern construction intending to "restore" missing components. The result of such "restorations" is often a detriment to future scholarly study and detracts from the accuracy of the remains. The water cooled hearth and free-standing bosh are most valuable if stabilized with no intervention.

Constructing a roof above and around the furnace is the best means to preserve the bosh and hearth. The displaced brick work at the top of the stack liner may be able to be pushed back into position by hand. Beyond this, no masonry work should take place in the bosh and hearth area. They should remain as found, and naturally weathered and as constructed by our forefathers. Any stabilization rebuilding would detract from the original resource.

Access should be limited to professionals and scholars.

*Conclusions*

As stated, Copake Furnace is in a good state of preservation considering the degree of weather exposure. Copake Furance is significant locally, is important for New York State's heritage and contributes to the understanding of nineteenth century iron production in the nation. The on going threat of future collapse warrants swift action. We recommend the construction of a hipped roof structure to shelter and protect the sides of the furnace. A roof should be constructed as soon as possible.

# PHOTOGRAPHS

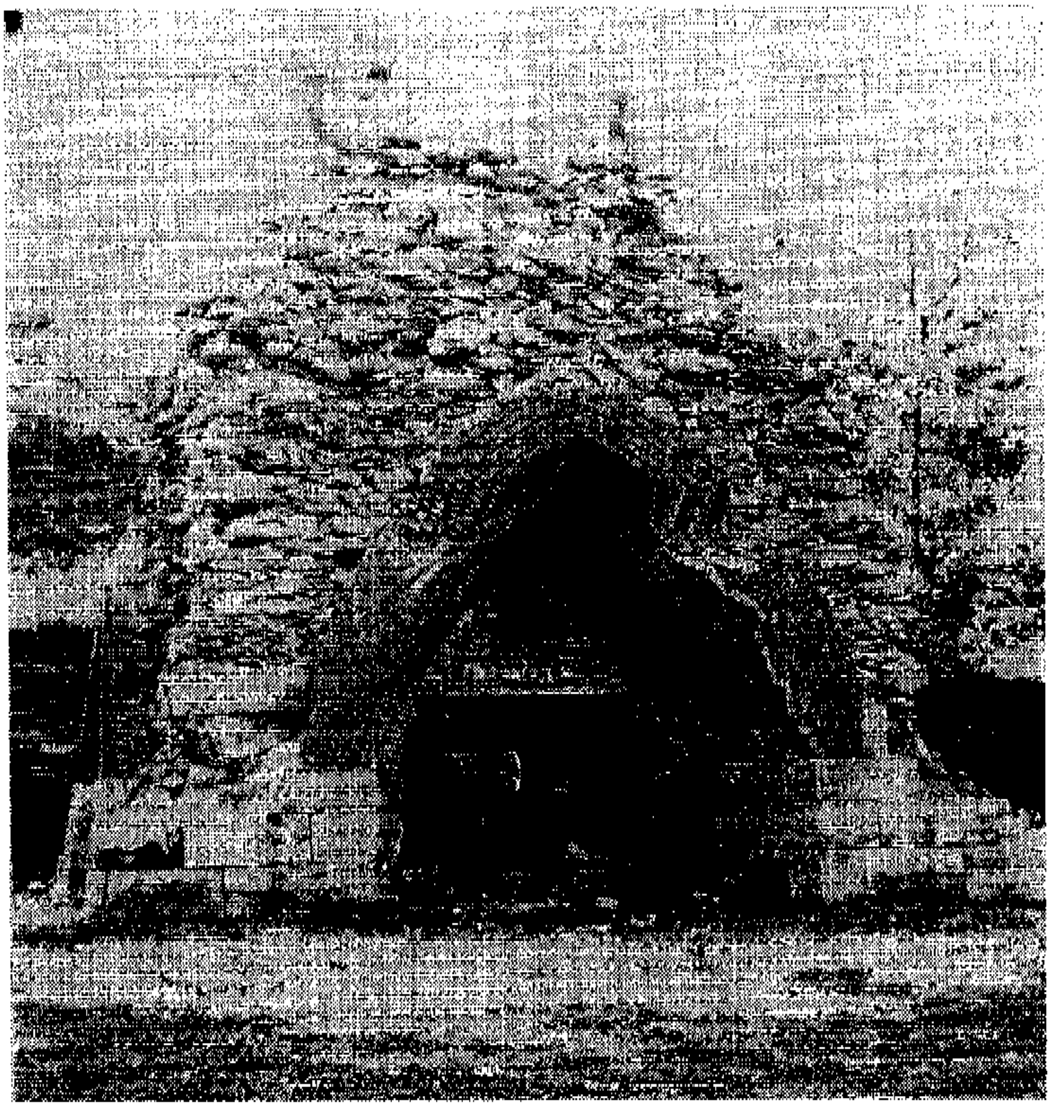


**Illustration 1: View of casting arch (north side) of furnace, circa 1935**
**(Photograph provided by Mr. Raymond Doherty, New York State Office of Parks, Recreation and Historic Preservation. The original source is unknown and the date is assumed.)**

**Illustration 2: East side of furnace, circa 1935.**
**The east tuyere arch is in perfect condition**
**(Photograph provided by Mr. Raymond Doherty, New York State Office of Parks, Recreation and Historic Preservation. The original source is unknown and the date is assumed.)**

**Illustration 3: Similar views from 1973 (above) and 2004 (below)**
**Casting arch side**

**(the 1973 Photograph is courtesy of Mr. Victor Rolando, Industrial Historian)**
**(the 2004 photograph is by Carla Cielo)**

**Illustration 4:**
**Casting arch side of furnace, c 1973 (above), 2004 (below)**

**(the 1973 Photograph is courtesy of Mr. Victor Rolando, Industrial Historian)**
**(the 2004 photograph is by Carla Cielo)**

**Illustration 5:**
**East tuyere arch,**
**c 1973 (above), 2004 (below)**

**(the 1973 Photograph is courtesy of Mr. Victor Rolando, Industrial Historian)**
**(the 2004 photograph is by Carla Cielo)**

**Illustration 6: Casting arch c. 1935 (above)**
**Casting arch 2004 (below)**

**(the circa 1935 photograph is featured in *The Early Iron Industry of Connecticut*, by Herbert C. Keith and Charles Rufus Harte on page 52)**
**(the 2004 photograph is by Carla Cielo)**

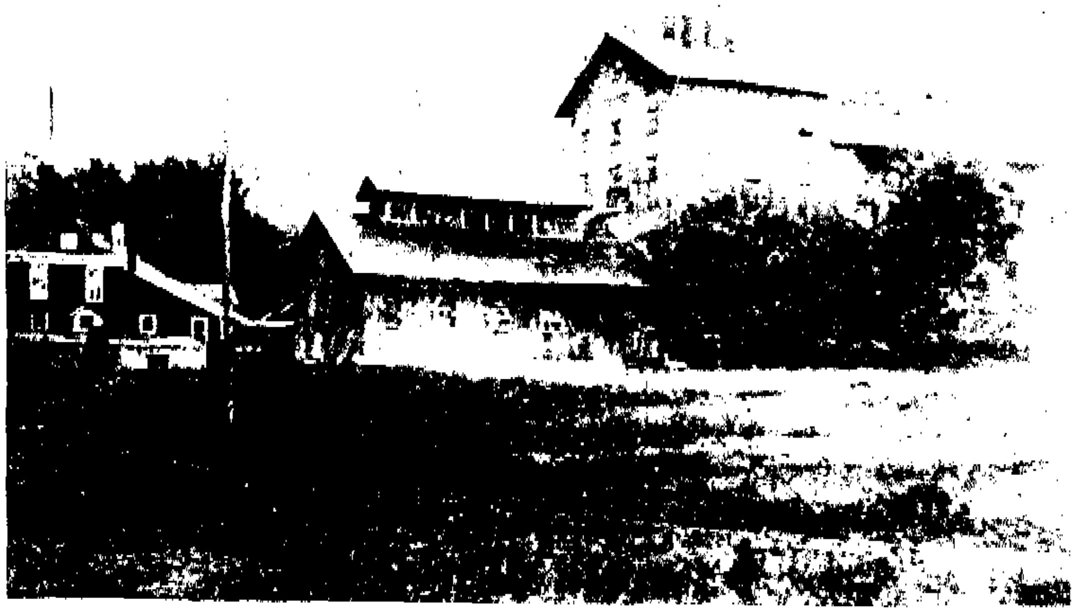
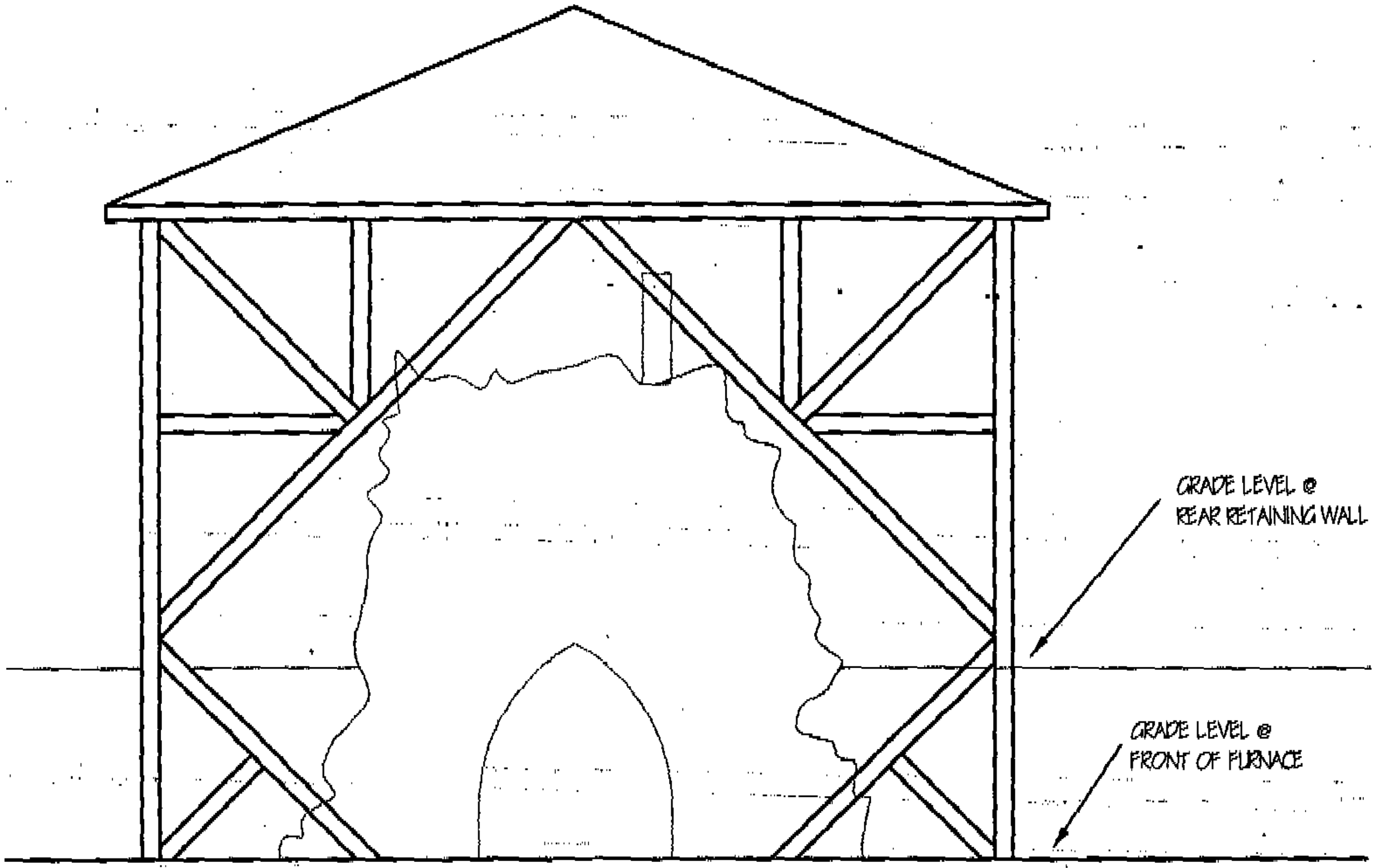


**Illustration 7: Last known operational period building**
**(Photograph provided by Mr. Raymond Doherty, New York State Office of Parks, Recreation and Historic Preservation.)**

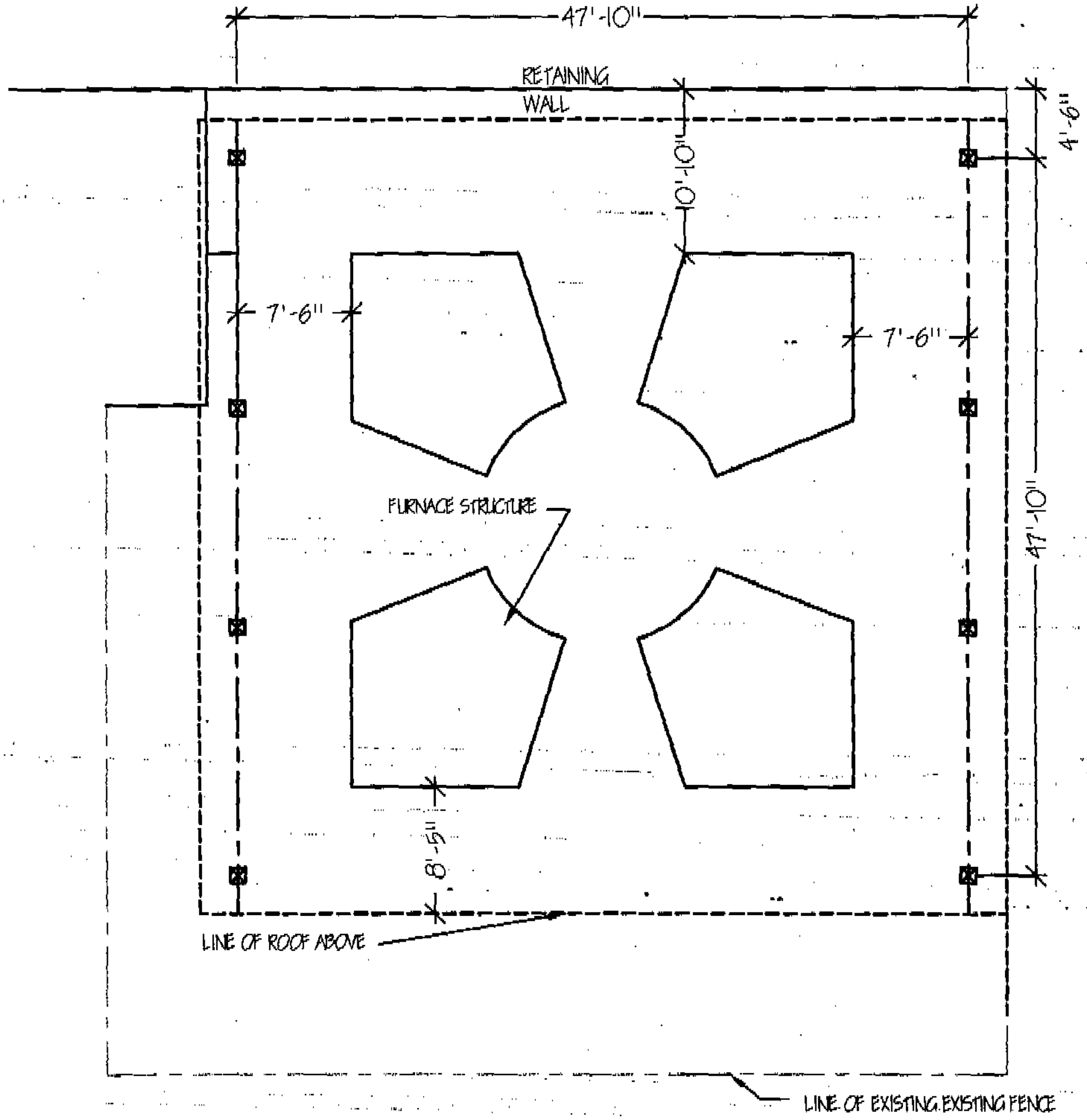

**Illustration 8: Example of a modern outdoor pavilion sheltering a ruin**

# PROPOSED DRAWINGS




FRONT ELEVATION
not to scale

OPTION # 1




# OPTION # 1

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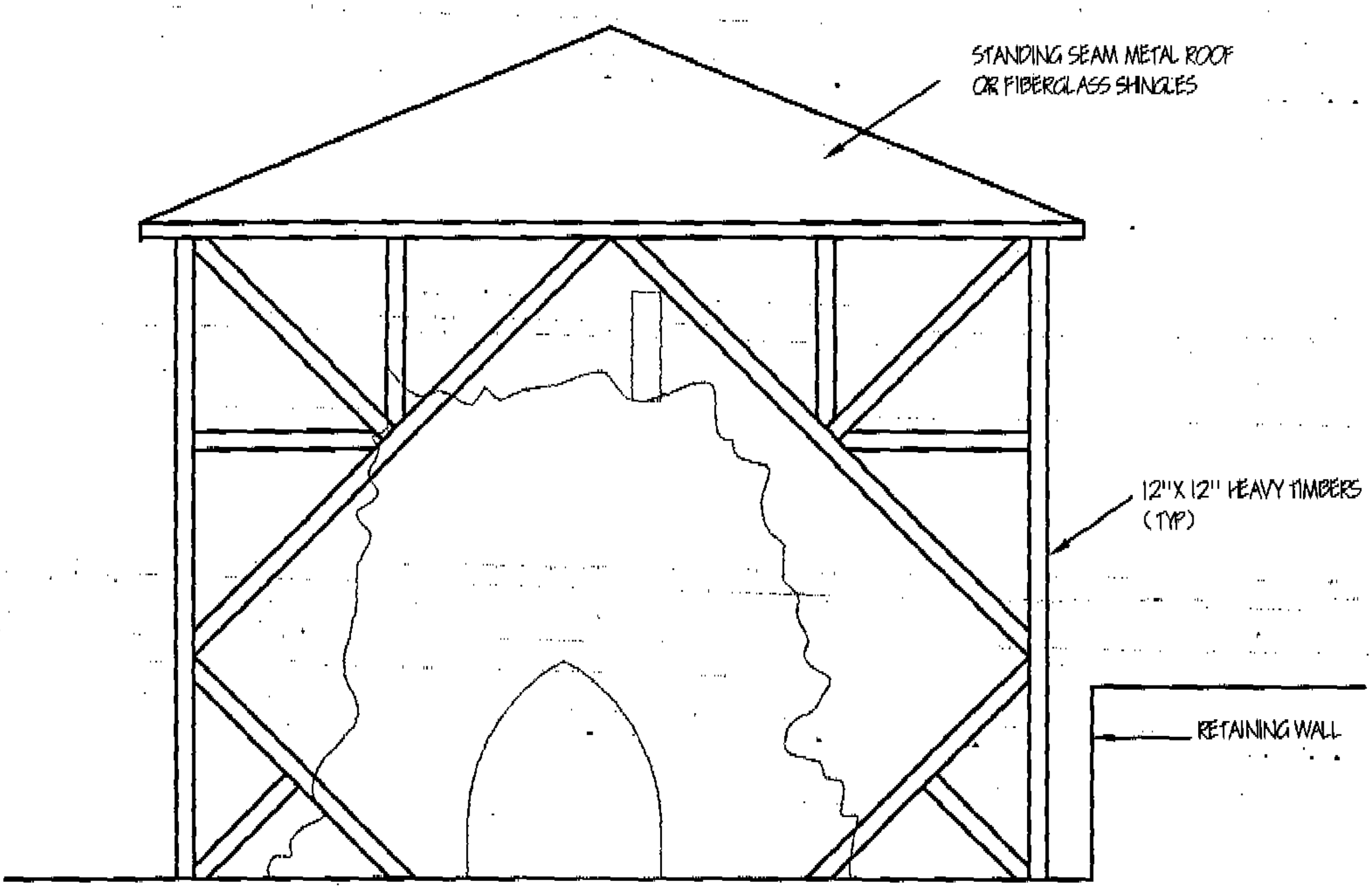
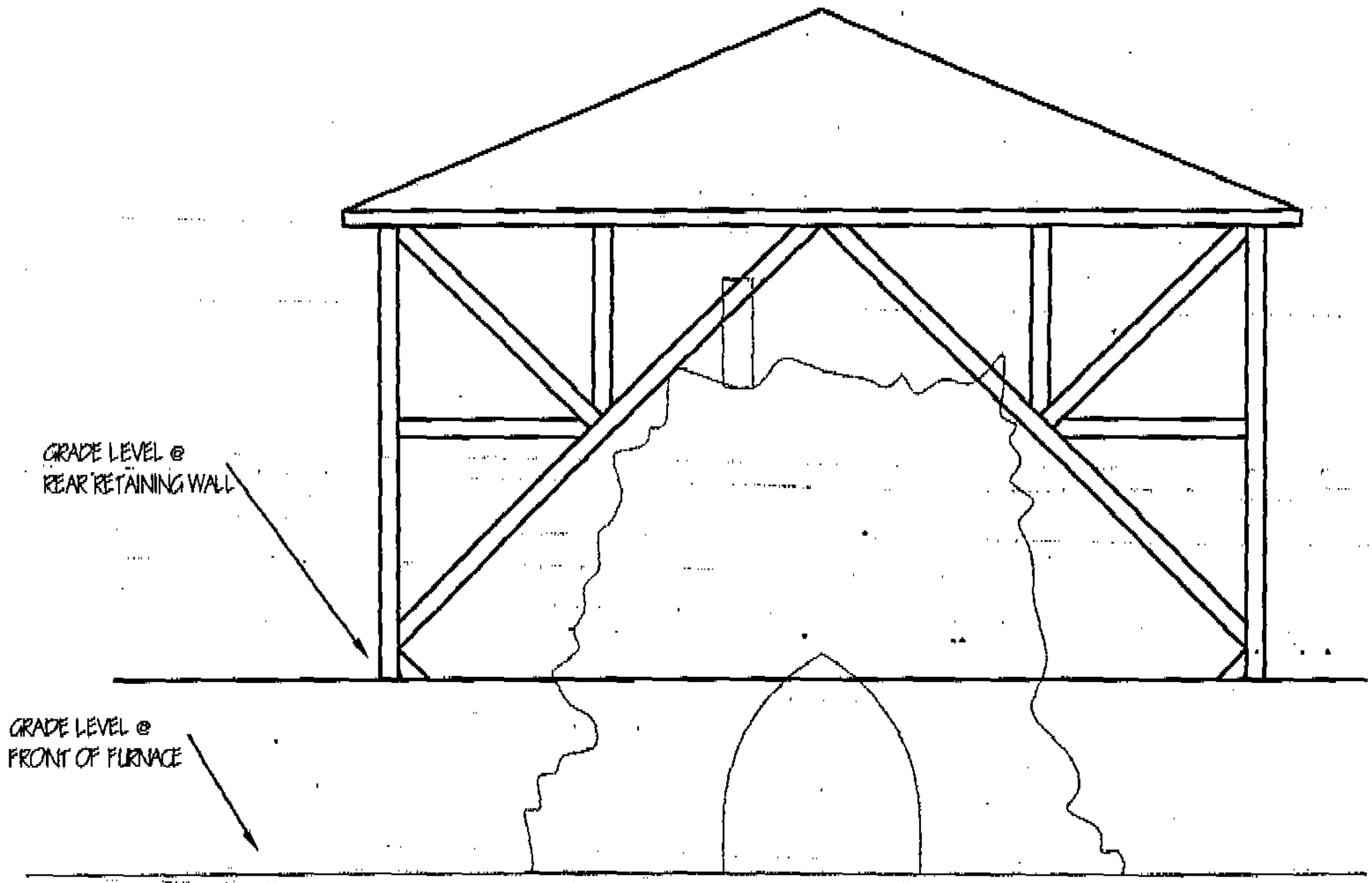
NOT TO SCALE




RIGHT SIDE ELEVATION

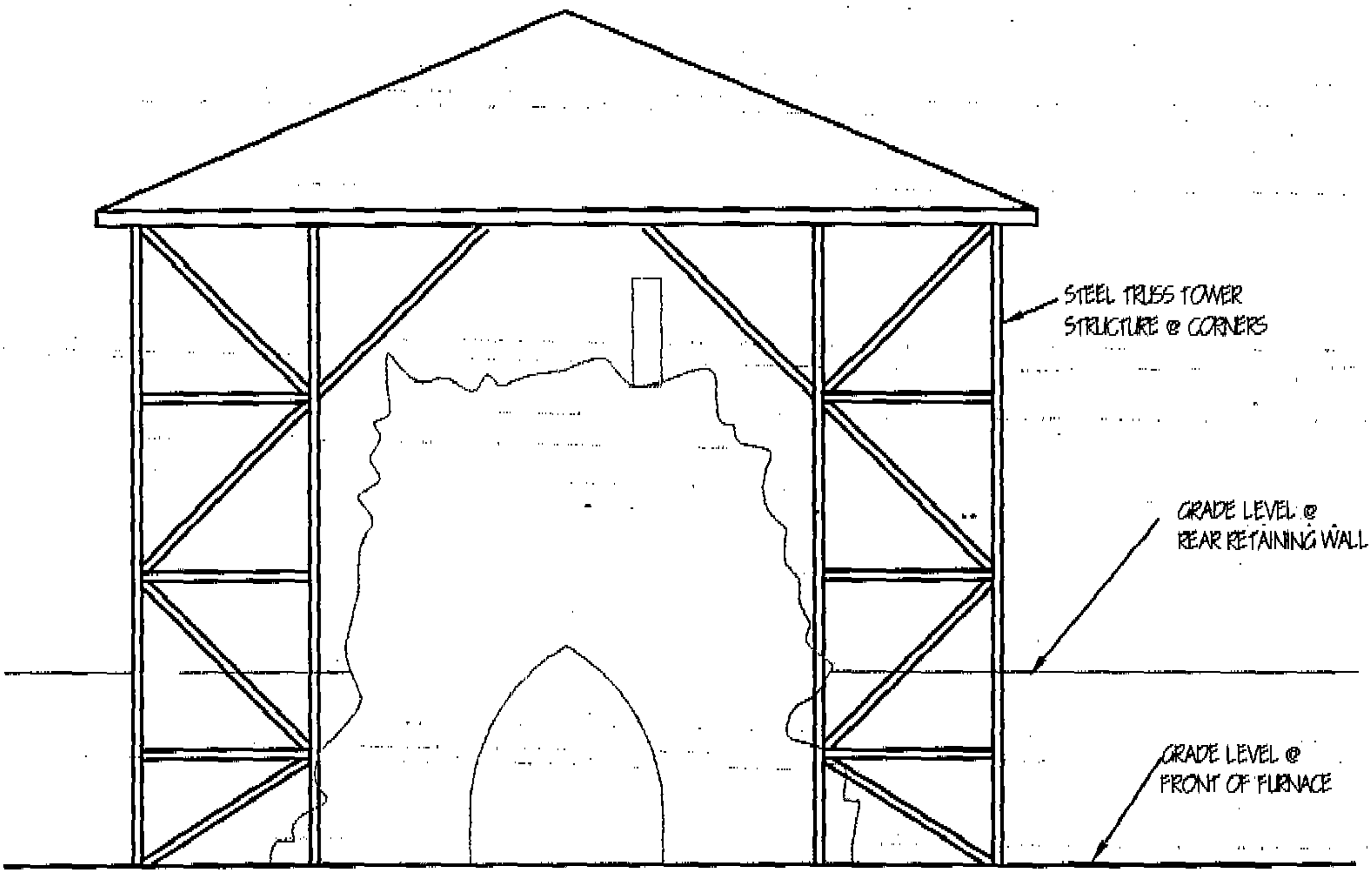
NOT TO SCALE

# OPTION # 1




REAR ELEVATION
NOT TO SCALE

OPTION # 1




FRONT ELEVATION
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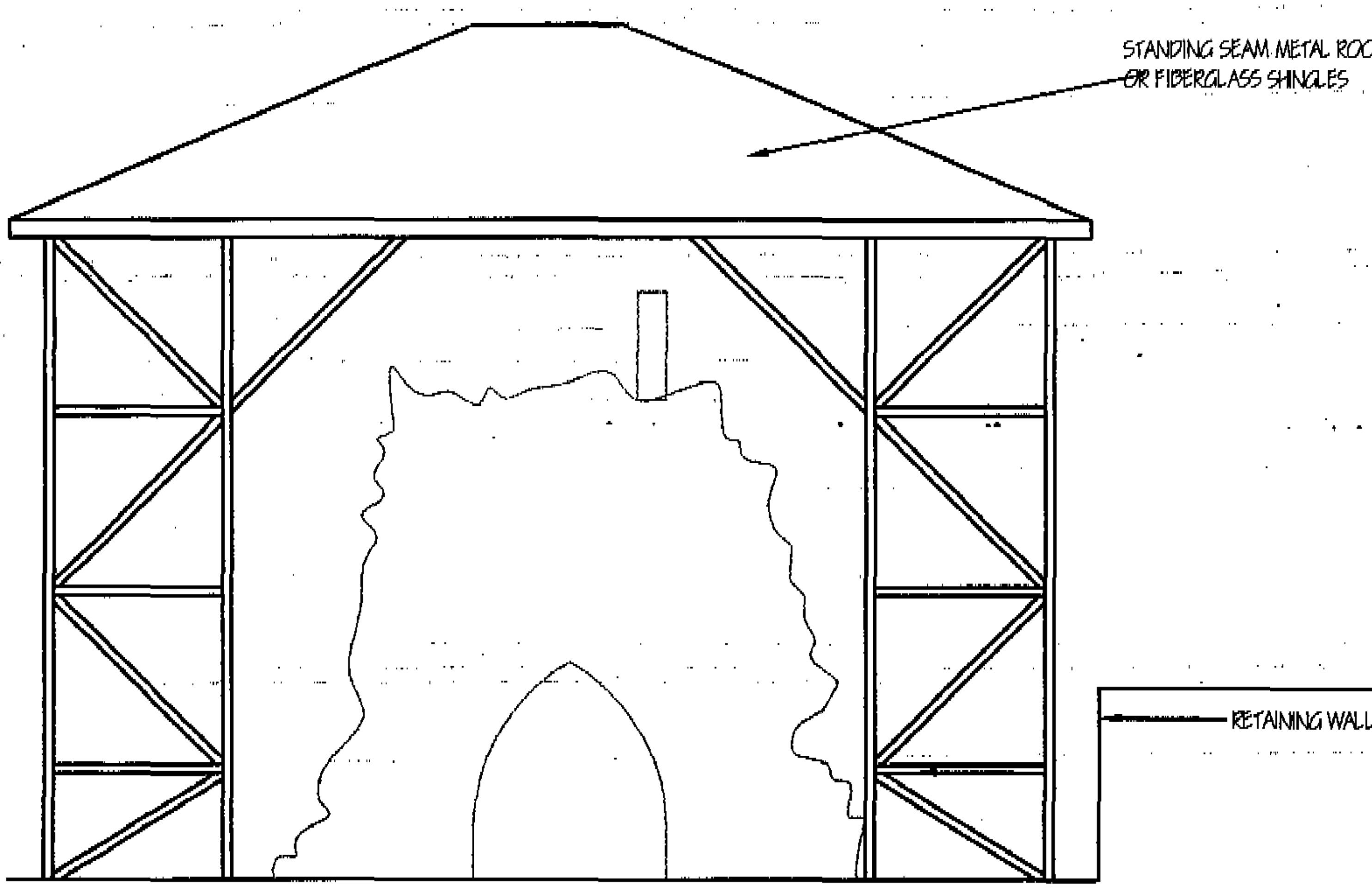
OPTION # 2




RIGHT SIDE ELEVATION
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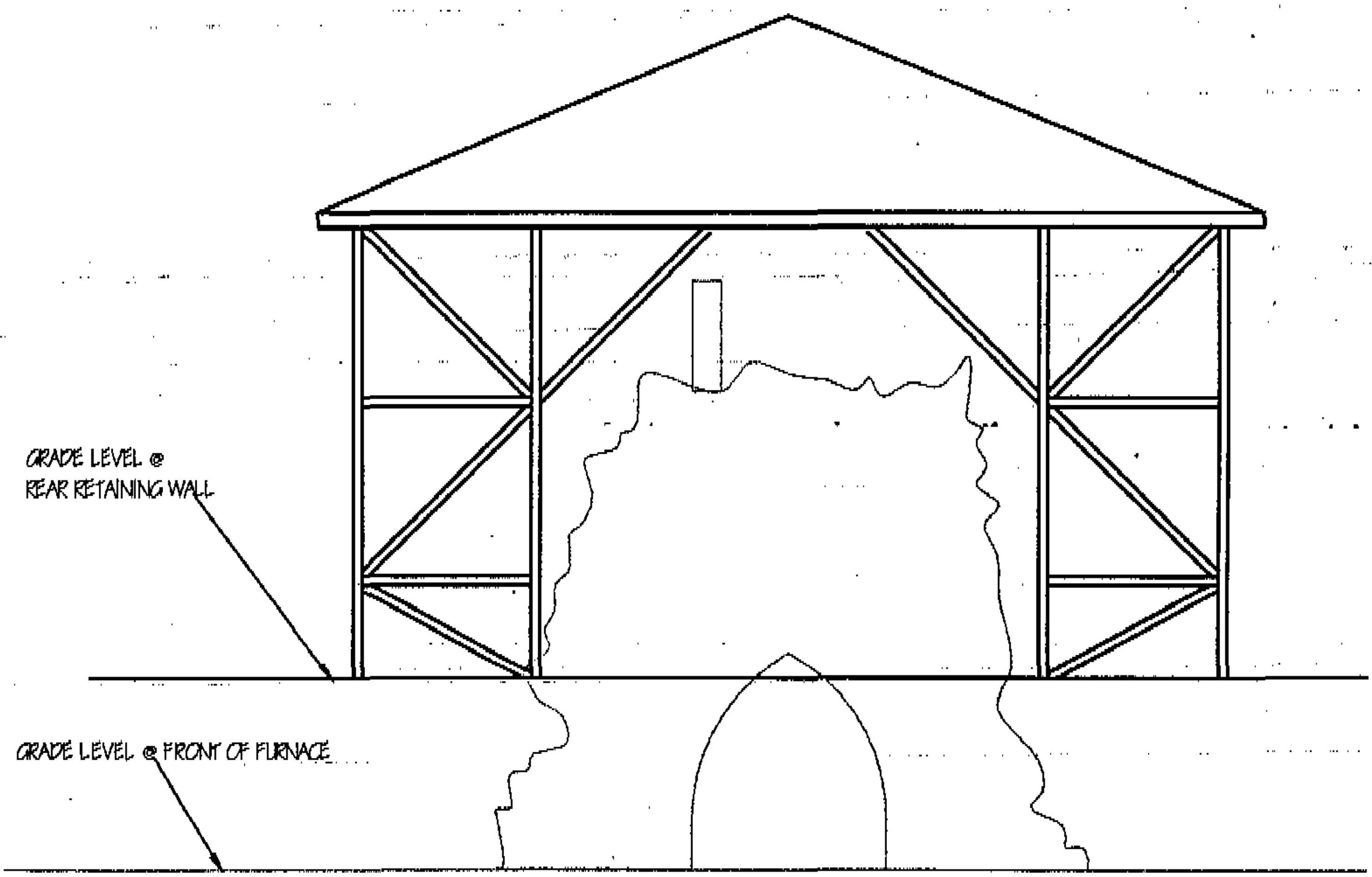
# OPTION # 2




## REAR ELEVATION
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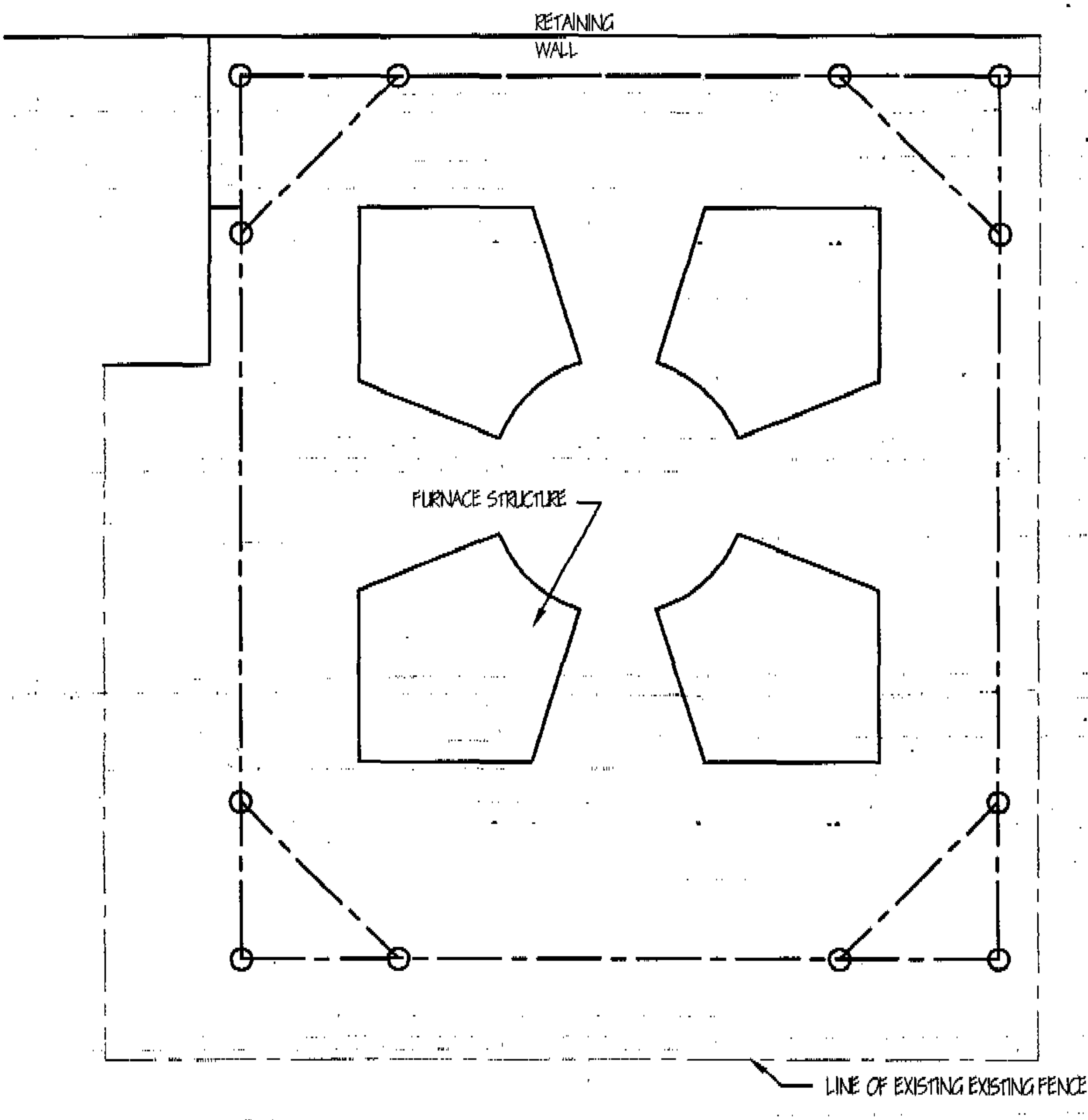
# OPTION # 2




PLAN
NOT TO SCALE

OPTION # 2