Report

to

Harvard University Planning Group
1350 Massachusetts Avenue
912 Holyoke Center
Cambridge, Massachusetts 02138

on

Repairs to the Sears Tower at the Harvard Observatory Cambridge, Massachusetts

by

Boston Building Consultants
79 Milk Street, Suite 800
Boston, Massachusetts 02109

September 20, 1991

BOSTON
BUILDING
CONSULTANTS

79 Milk St., Boston MA 02109
617/542-3933

September 20, 1991

Mr. Richard Beckwith
Project Director
Harvard University Planning Group
1350 Massachusetts Avenue
Cambridge, MA 02138

Re: **Sears Tower**
Harvard Observatory, Cambridge, MA
BBC Job No. 91047

Dear Mr. Beckwith:

At your request, the Boston Building Consultants made an investigation of the present condition and future prospects of the roofing and flashing of the Sears Tower at the Harvard Observatory in August 1991. The enclosed report is a record of the results of this investigation and contains our conclusions, recommendations, and budgets for your consideration.

While the Sears Tower at the Observatory has not been actively used for a great number of years, it is an important building at Harvard University, is listed in the National Register of Historic Places, and houses the Great Refractor of the Harvard College Observatory. It is obviously a resource worth preserving.

There is evidence of substantial widespread leakage in the past into the building through the copper roofing. However, only minor leakage at the upper shutter was observed in the heavy rains after the recent hurricane. The metal roof cladding and shutters have been reworked a number of times in the 144 year history of the Sears Tower. At the present time, the copper cladding is covered with a silicone top coating apparently applied 20 years ago and nearing the end of its useful life. The upper copper cladding of the dome was replaced around 1955, but the lower cladding of the dome is considerably older. The shutters are caulked shut at the present time, the track mechanisms are in poor condition, and the shutter opening devices are inoperable.

There is evidence of decay of the wood framing of the apron surrounding the base of the Tower. A portion of the gutter and some of the copper soffit have pulled loose on the east side of the apron of the roof.

BOSTON
BUILDING
CONSULTANTS

I recommend that the existing copper cladding be completely removed and the dome sheathed in copper. The shutters should also be reclad in copper, the rails refurbished, and a collection system of interior gutters be devised to catch the water which will inevitably be driven through the overlapping shutters.

I suggest that you budget $150,000 for construction. Several options for a less ambitious repair are discussed at length in the enclosed report.

Sincerely yours,
Boston Building Consultants

Arthur L. Brown, Jr., President

Enc. Report, Sketches, Photos, and Budgets

BOSTON
BUILDING
CONSULTANTS

SEARS TOWER REPORT

Harvard Observatory,
Cambridge, Massachusetts

September 20, 1991

BACKGROUND

The original Sears Tower at the Harvard Observatory was constructed around 1847 and was originally part of a much larger observatory complex described in detail in the 1856 Annals of the Astronomical Observatory of Harvard College. These Annals contain photographs of the original building showing the porches and the north entry structure which were still in place in 1946.

The yearly Annals of the Astronomical Observatory of Harvard College indicate that the shutters were troublesome as early as 1858 when the outside steps were installed for maintenance. The early annals indicate that the shutters did not exclude snow and wind driven rain. They were apparently reworked and repaired a number of times over the years. The shutters were most recently repaired around 1960 when the upper shutters were rebuilt and sheathed with fiberglass.

The out buildings around the Sears Tower and some of the original balconies were removed over the years.

Nathan Hazen, in his study dated February 1970 on the History, Current Condition and Future Utilization of the 15 inch Great Refractor at the Harvard Observatory, reports that the upper half of the dome was resheathed in copper around 1955. He recommended that dome, apron and portico roofs be coated with a green colored silicone roofing membrane made by the General Electric Company to arrest the pitting and decay of the copper and to control the leakage into the building. This leakage had become widespread and was beginning to damage wood and plaster.

From the records and field observations, I estimate that the roofing system components have the following ages:

Item	Ages
Silicone Top Coating	15-20 yrs.
Fiber Glass Clad Upper Shutters	30 yrs.
Upper Copper Sheathing on Dome	36 yrs.
Lower Copper Sheathing	70-100 yrs.
Lead Base Flashing	144 yrs.
Gutters and their Attachments	60-70 yrs.

OBSERVATIONS

Leakage:

The Tower was examined on August 15, 1991 with the aid of an aerial lift. At that time, portions of wood boarding were removed from the interior to observe the condition of the framing. In each area observed, the wood framing was dry. Later, during the week of August 26, 1991 after a hurricane and heavy rains, the inside of the Tower was observed and at that time we found a small puddle of water which appeared to be coming from the end of the upper shutter. The balance of the roof appeared to be tight. There were no other signs of water intrusion into the building. Their is, however, ample evidence of past water staining on the surface of the interior wood cladding throughout the dome area.

Framing:

The Sears Tower (dome) is framed with 2x8.5 inch wood joists approximately 14 inches on center at the base cut to a 15 foot-4 inch radius and scabbed together. The dome is sheathed on the exterior with nominal 1 inch boards and on the inside with 5/8 inch matched boards varying in width from 3.5 inches to 4.5 inches. A 9x15 inch mechanically laminated wood ring beam at the base and individual blocking cut in between the ribs stabilize the dome (Photo 13). There are tie rods at the aperture to complete the circle. The structure of the dome appears to have held its shape and has withstood numerous storms over the years with no obvious distress.

In the main dome we did not see any significant amount of decay of the wood, though there is local decay at and around the shutters, at the apron surrounding the base of the dome, as well as at the supports to the copper sheathing at the guide rails for the lower shutters. If the copper dome cladding is removed, it is unlikely there will be extensive decay of the roof boarding, though some local repairs and reattachment may be necessary.

Soffits:

The copper soffits under the apron are tightly seamed together and supported by a wood sheathed soffit secured to cantilevered outriggers from the masonry wall. At the east elevation, the decay of some of the outriggers, the wood soffit boards and the wood fascia board at the end of the wood outriggers has allowed the gutter and copper soffit to pull loose from the apron above (Photo 14). It is temporarily supported from the roof of the adjacent building (Photo 1). The other elevations are similarly constructed. The south soffit is beginning to pull loose as is the northeast corner (Photos 11 & 12). The wood framing appears to be all original construction.

The copper soffit and fascia are covered with coating which is oxidized and alligatored (Photo 11).

Rain Leaders:

The copper rain leaders are a mixed lot. Some appear to be adequate, but others are completely rusted through (Photo 5).

Gutters:

The copper gutters are attached and supported by iron bars and with iron straps screwed through the copper roofing and then topped with a copper bib. These straps have begun to corrode and the gutter on the east side has broken loose. The gutters on the other sides are also in marginal condition (Photos 2, 4, & 12). The copper is covered with a heavily oxidized coating. The sagging gutter on the east side of the roof is not functioning at present to conduct the water to the rain leaders.

Shutters:

The shutters are arranged so that they extend to three degrees beyond the zenith to three degrees below the horizon. The two upper shutters are 9 feet long each and the three lower shutters are approximately 3 feet long. They are all about 5 feet wide. The lower three move in copper sheathed wood tracks similar to standard double hung window sash. The upper shutters travel along channel iron tracks secured to the dome (Photos 7 & 9).

The shutters are inoperable and are all caulked shut at the present time. The fiberglass cladding of the upper shutters has failed by splitting. Older cracks in the fiberglass cladding of these shutters have been temporarily sealed with roofing mastic but we observed fresh cracks near the peak of the dome (Photo 7). The top coating over the fiberglass base material has failed. The steel tracks for the upper shutters are heavily rusted (Photo 9).

The lower shutters are sheathed with copper which appears to be in satisfactory condition. However, the copper flashing of the tracks and the wood blocking supporting it are in poor condition.

Dome Cladding:

The copper cladding of the upper half of the dome was reportedly replaced in 1955. It appears to be watertight and in good condition. The copper cladding on the lower portion of the dome is pitted with local corrosion which can be seen as dimples through the silicone coating (Photos 1 & 3).

Apron:

There is no mention of the apron copper bracing replaced in 1955. However, the bulk of it looks entirely too good to be original material. It does not leak at the present time and the joints are all tight.

Counterflashing Where Apron Joins the Masonry of the Building Wall:

The junctions of the apron and the building are flashed with lead. This appears to be original material. It has torn in several locations and appears to be quite brittle (Photo 6).

Dome Coating:

The entire surface of the dome and the surrounding lower roofs is covered with an elastomeric material which still maintains its elasticity, though the original green color has begun to chalk. This indicates that the material is slowly breaking down. It has been very effective in sealing up the pin holes in the copper and appears to have been an inexpensive, expedient solution to maintaining the integrity of the copper roofing for the last 15 to 20 years. John Cazeault, a local roofer, remembers installing General Electric silicone material on the dome at the request of the Harvard Building Maintenance Department. However, because of numerous field problems with the material, it is no longer manufactured as a stands alone coating but only as a part of the total system over a urethane insulation.

There are other acrylic coatings on the market today for application over copper. However, the standard literature from a few that I have reviewed caution against applying the material over silicone. Nevertheless, we have made arrangements to test prime a small area to see if the silicone can be primed to accept a top coating.

CONCLUSIONS

Shutters:

While there was only minor leakage into the building through the upper shutter in the recent hurricane and rainstorm, it seems likely that once the shutters are made operable and the caulking is removed, there will be extensive leakage especially in the joints between the leaves of the shutters and possibly at the jambs where the wood supporting the sliding mechanism and the copper flashing has begun to decay. The shutters can of course be sealed shut and be kept reasonably watertight.

If the shutters are to operate, I believe that the shutters will all have to be reclad in copper and reflashed. The sliding mechanisms will have to be rebuilt, the upper shutters extended and redesigned to shed water better, and an internal gutter system installed to collect water which finds its way through the individual leaves of the shutter.

Apron:

The wood apron framing at the base of the dome is in poor condition in that the fascia, soffit boards and some of the wood outriggers are decayed and must be replaced. The original design of the copper soffit traps any moisture in an unventilated space that penetrates the upper roofing.

While the east soffit apron has obviously failed, the other elevations are suspect. The copper gutter and soffit must be removed to permit inspection of the framing and to permit the possible rebuilding of the wood framing of the fascia gutter support and soffit. The new soffit must be designed with appropriate ventilation arrangements to permit moisture and condensation that collects to escape to the outside. Any new wood would be pressure treated. The condition of the wood decking of the apron is unknown and any decayed wood should be replaced as part of any reroofing or repair program.

Gutters:

The gutters and rain leaders have reached the end of their useful life and should be replaced. It is technically possible and not unattractive to remove and replace the soffit and the gutter and to leave the bulk of the copper cladding of the apron in place.

Lead Counterflashing

The lead counterflashing at the base of the dome appears to be the original material. It is torn in several locations and appears to be brittle. In a complete reroofing project, the counterflashing should be completely backed up with a rubber membrane and the lead repaired or replaced as necessary.

Roof Top Coating:

The exposed surfaces of the copper of the dome, apron, and low roof are all coated with elastomeric top coating, approximately 20 mils thick. If this top coating were applied in 1970 as indicated, it has far outlived its useful life of 10 to 12 years. The coating is generally in good condition, though it has begun to chalk. I estimate that its useful life is two to three years. Field tests will be required to establish the compatibility of any new coating applied to this, should you opt to recoat the silicone areas. The top coats typically have a useful life of 10 years. Any new copper installed should not be coated to maintain flexibility in the future.

Dome:

It is obvious from inspection that the copper on the upper portion of the dome and skirt is in better condition than the copper at the lower portion of the dome. Since the silicone coating is near the end of its useful life, the apparently defective copper at the lower portion of the dome will be exposed and probably leak through pin holes in the copper and coating. While it is technically possible to replace this copper, the appearance of the new uncoated copper and the coated copper above would be very poor.

RECOMMENDATIONS

In my opinion, there are two clear paths to take in refurbishing the copper and roofing work at the Sears Tower. The first recognizes the historic importance of the building and maximizes the long-term protection of the 15 inch Great Refractor inside as well as further interior repairs. The other is a short-term budget driven solution to delay capital expenses for five to ten years.

Recommended Option 1:

The first option involves a complete removal of the existing copper cladding of the dome, soffit and apron; recladding, reflashing, and repainting the shutters and their tracks; repairing any decayed wood framing or sheathing; and installing new copper gutters and rain leaders. If left natural copper, the dome will in time (20-40 years) weather to a natural green patina, though it is unlikely that the color will be uniform, nor is it completely predictable when this will occur. Another option is to use lead coated copper.

Any decayed wood decking would be replaced and the soffits would be arranged to ensure that they were properly vented. I estimate that the useful life of a properly detailed repair of this type is 50 years with minimal maintenance.

The shutters should be reflashed and possibly equipped with an internal drainage system to collect rain driven through the perimeter of the shutters.

The proposed budget for this option is $150,000. The enclosed breakdown indicates the numerous components of the budget, some of which are independent of each other, while others are necessary or related and cannot be deleted.

Recommended Option 2:

It is possible to repair and/or replace those components which have already failed and postpone the inevitable recladding project for two to ten years depending on the success of finding a recoating material which will adhere to the silicone coating presently in place.

In this Option 2, the soffit of the apron, the gutter and rain leaders would be replaced with new copper and the shutters reclad and reflashed. The remaining existing copper dome would be recoated with a top coat after field testing to determine compatibility of the existing top coating.

I estimate that this repair is the minimal acceptable option and has a budget of $83,000. The details are included in the enclosed budget breakdown.

BOSTON
BUILDING
CONSULTANTS

SEARS TOWER BUDGET ESTIMATE
Option 1

Recommended Total Recladding Scheme
Refer to Sketches 1-3 for locations of work and terminology.

Item	Area	Budget
Staging		$ 8,000
Copper Dome: Removal of Existing & Recladding with 16 oz. Copper	1,500 s.f.	$ 56,000
Lead Counterflashing: Backup with Neoprene and Repair or Replace Lead	100 s.f.	$ 3,000
Gutters, Soffits, & Rainleaders: Remove Existing and Replace with Copper	L.S.	$ 30,000
Apron Cladding: Remove and Replace with Copper	500 s.f.	$ 16,000
Portico Roof Cladding: Remove and Replace with Copper	400 s.f.	$ 12,000
Shutters: Recladding and Flashing	L.S.	$ 12,000
Exterior Track: Repair, Cleaning and Painting	L.S.	$ 3,000
Carpentry	L.S.	$ 4,000
Internal Gutter Arrangement	L.S.	$ 3,000
	Subtotal	$147,000
Optional Lead Coating on Copper		$ 3,000
	Total	**$150,000**

Expected Bids for Uncoated Copper Cladding: $125-150,000

Time for Construction: 4-6 Weeks

BOSTON
BUILDING
CONSULTANTS

SEARS TOWER BUDGET ESTIMATE
Option 2

Partial Repair Scheme to Extend Existing Cladding for 10 Years and Replacing only Failed Elements.

Item		Budget
Staging		$ 6,000
Gutters, Soffits, & Rainleaders: Remove Existing and Replace with New Copper		$30,000
Lead Counterflashing: Repair Splits		$ 1,000
Shutters: Recladding and Flashing with New Copper		$12,000
Exterior Track: Repair, Clean & Paint		$ 3,000
Carpentry		$ 3,000
Internal Gutter Arrangement		$ 3,000
	Subtotal	$58,000
Optional Coating over Existing Silicone Surfaces*		$25,000
	Total	$83,000

*Technical feasibility will have to be demonstrated by test patches.

Actual bids may range from $60-85,000

Time for Construction: 3 weeks

Coating must be applied to dry surfaces with temperature greater than 50 degrees F.

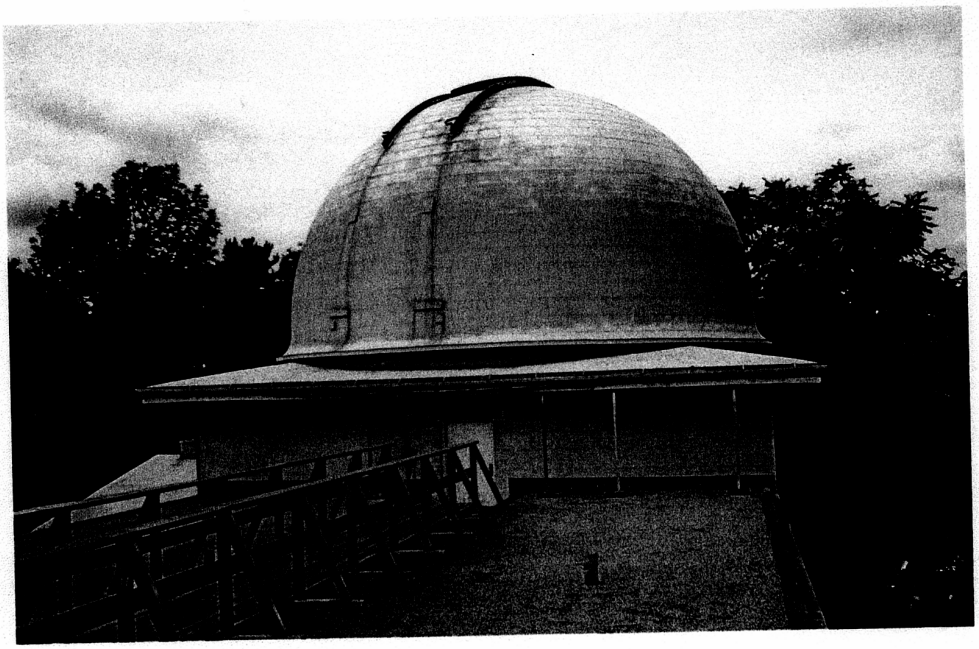


Photo 1

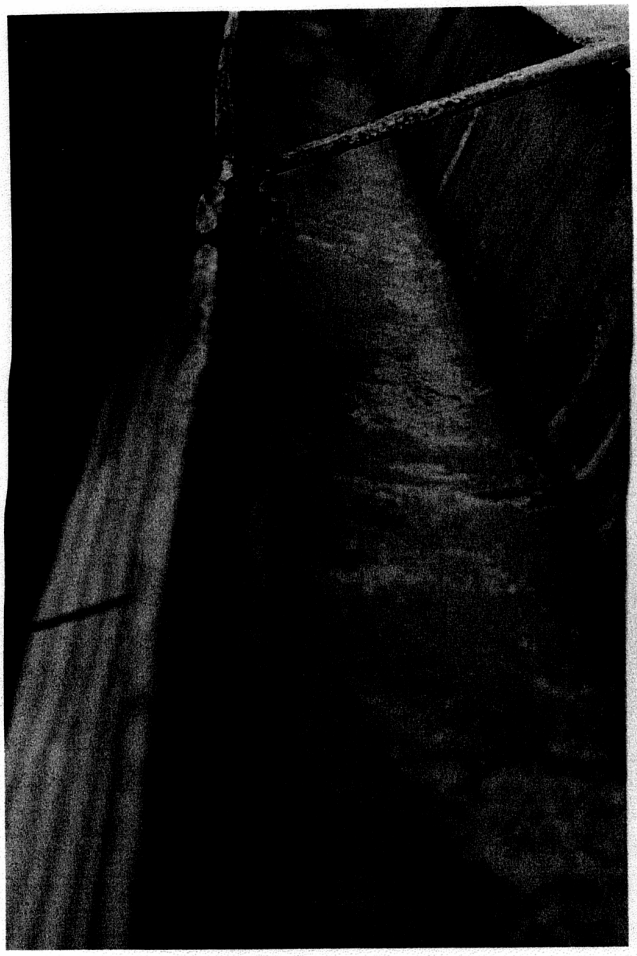


Photo 2

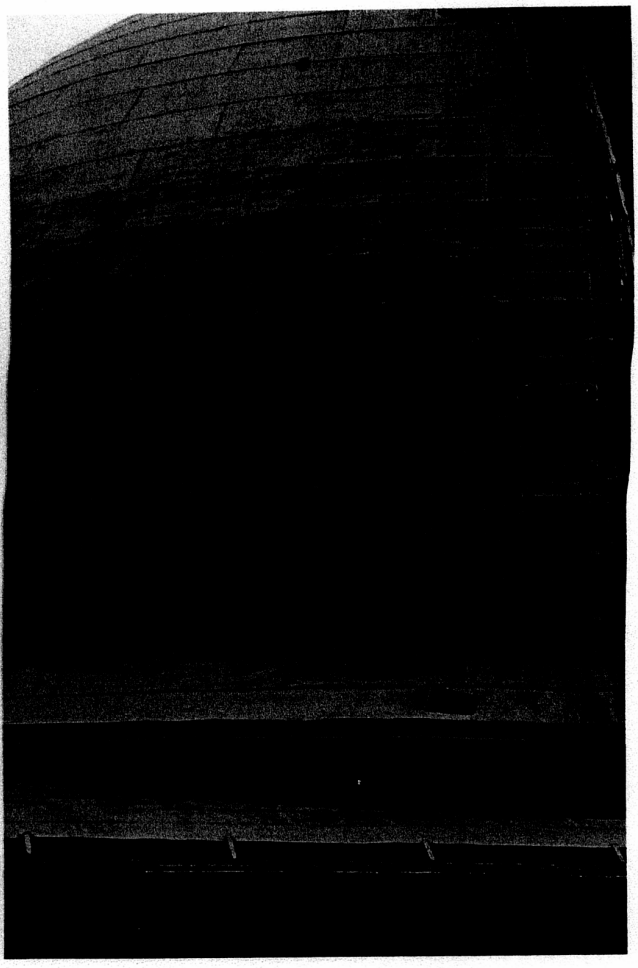


Photo 3

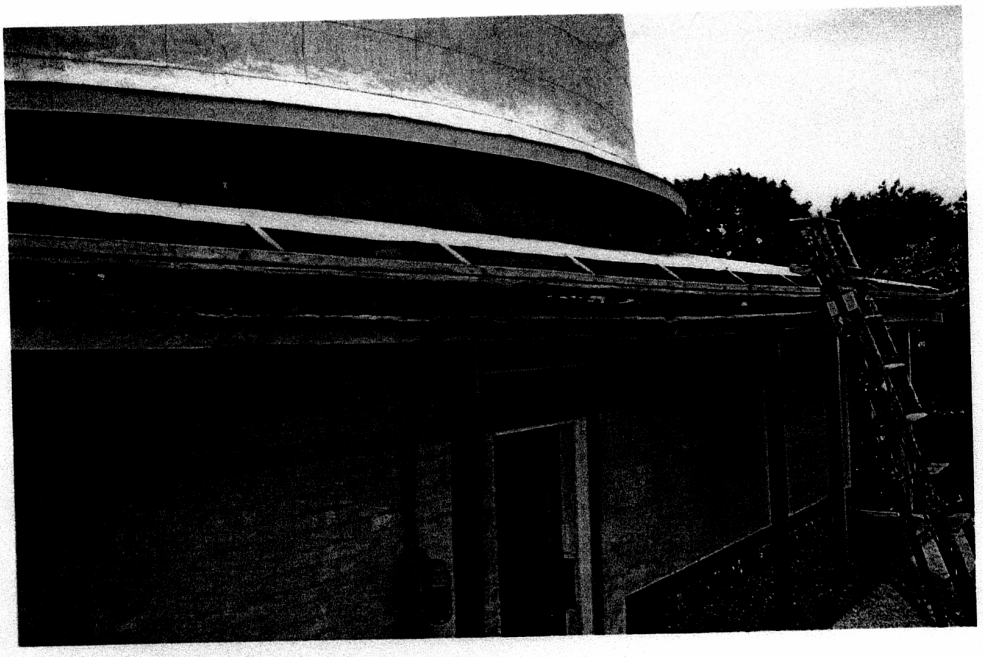


Photo 4

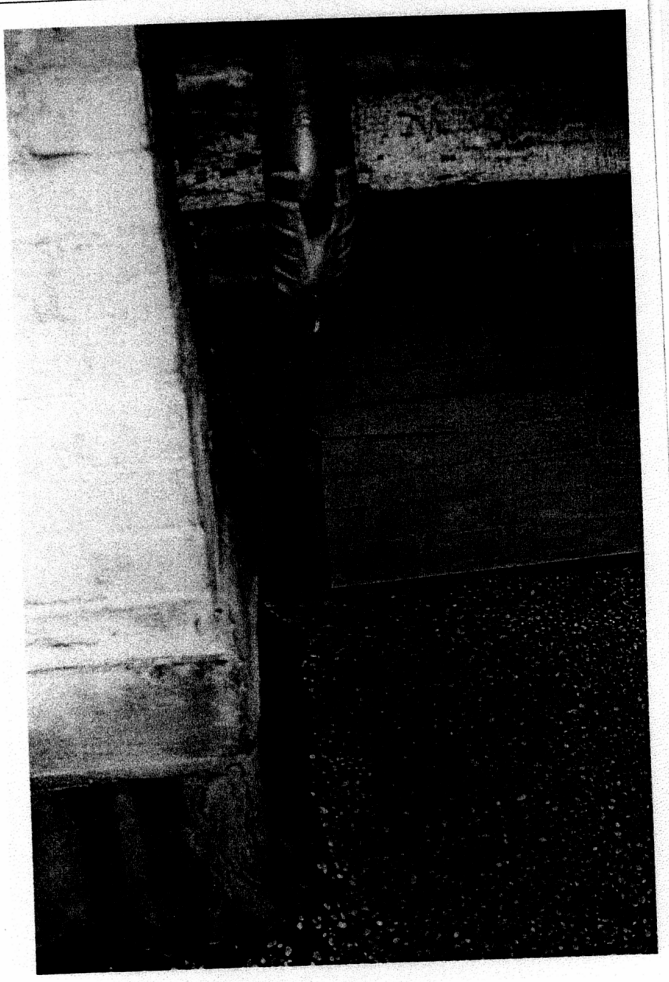


Photo 5

Photo 6

Photo 7

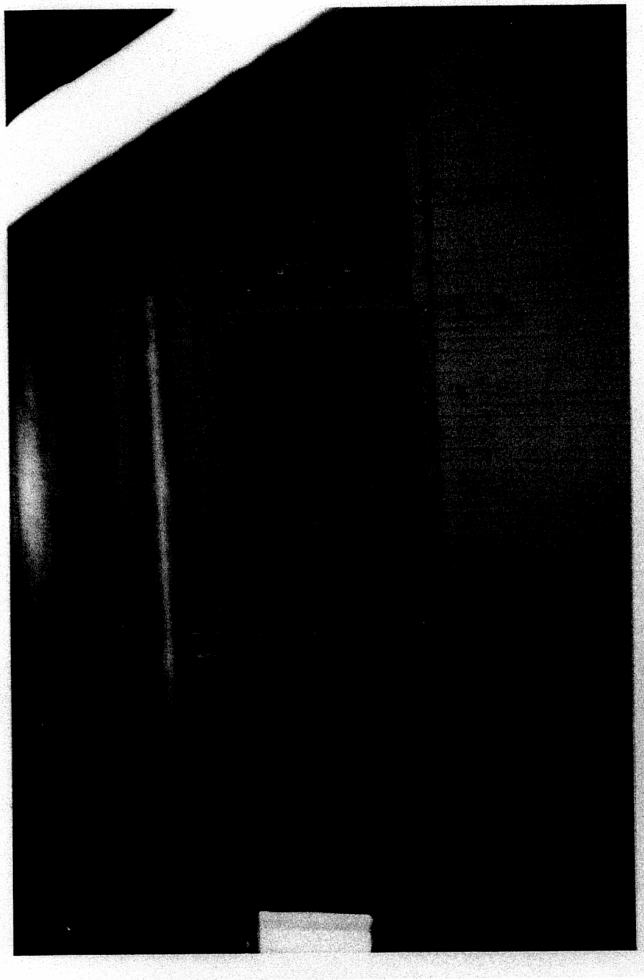


Photo 8

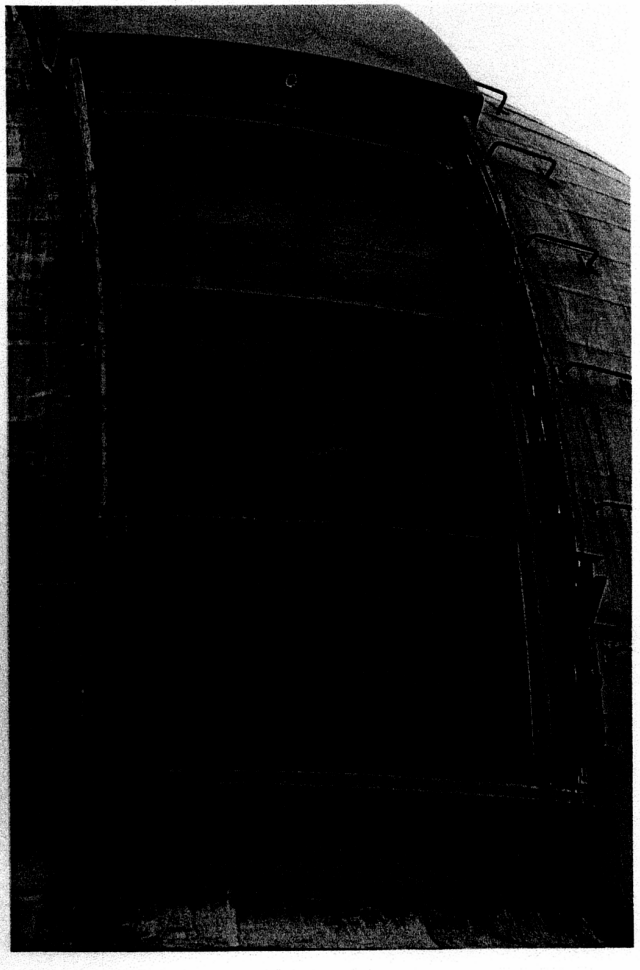


Photo 9

Photo 10

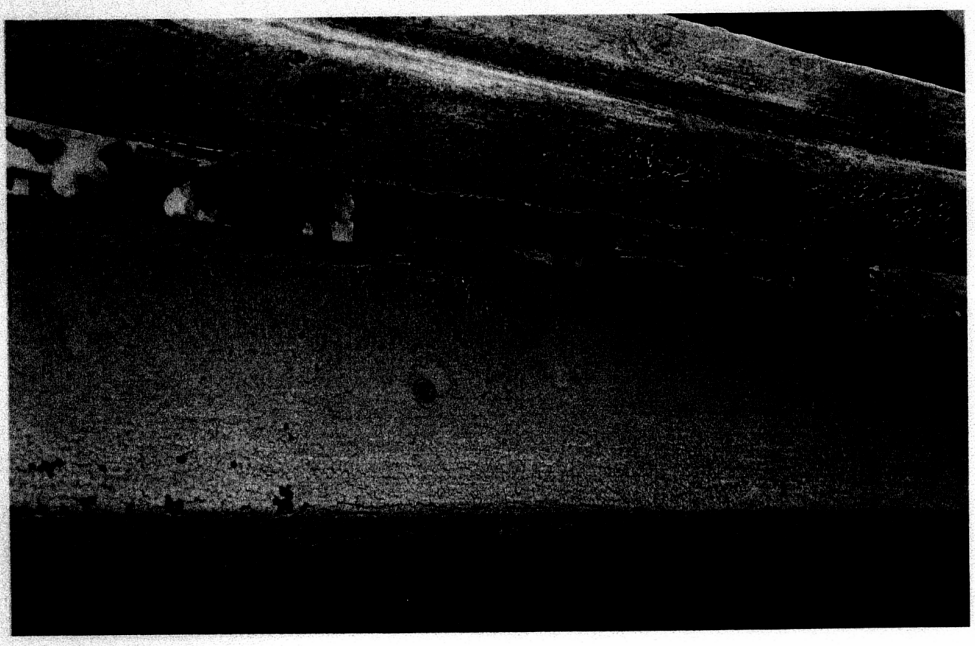


Photo 11

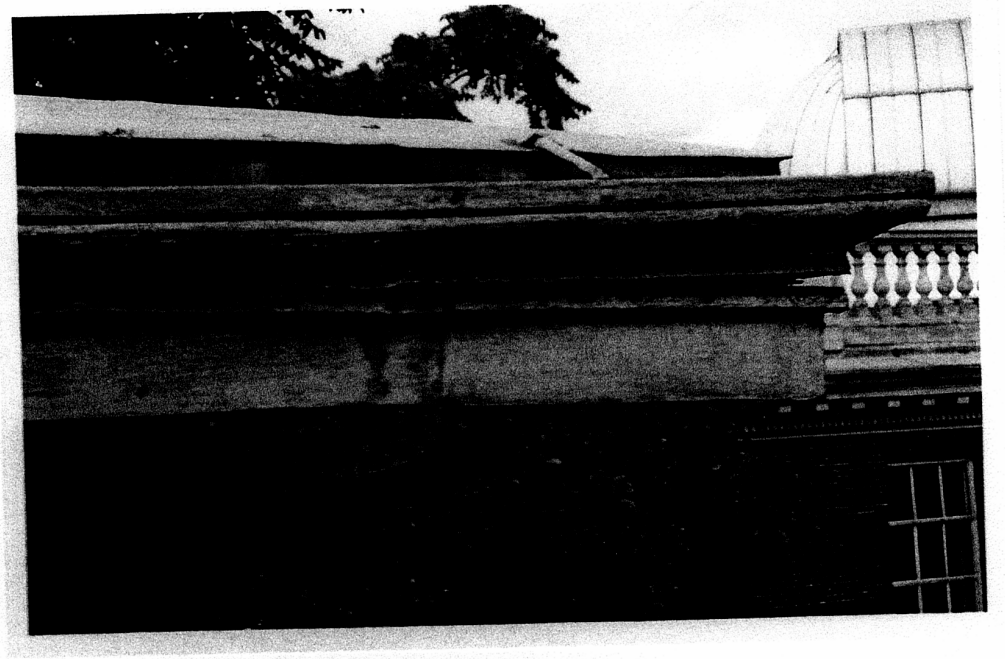


Photo 12

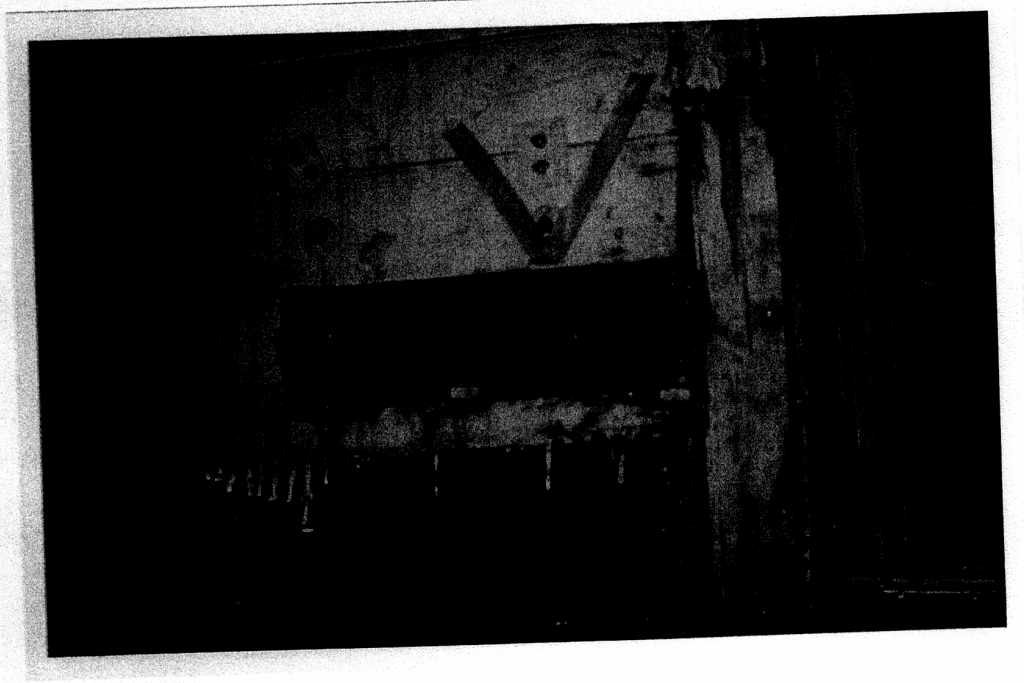


Photo 13

BOSTON
BUILDING
CONSULTANTS

Subject: SEARS TOWER

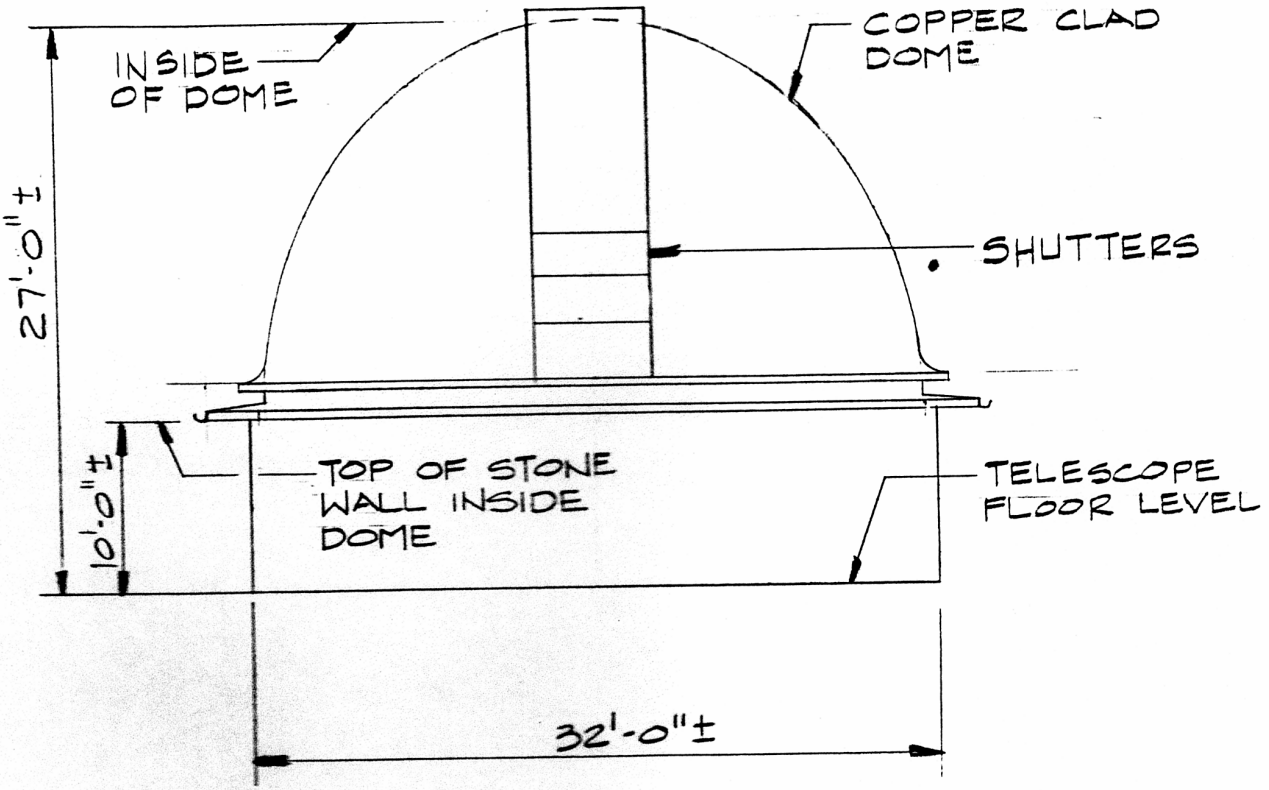
Job No: 91046

Sheet: 1

By: LL

Date: 9/20/91

Checked:



BOSTON
BUILDING
CONSULTANTS

Subject: SEARS TOWER

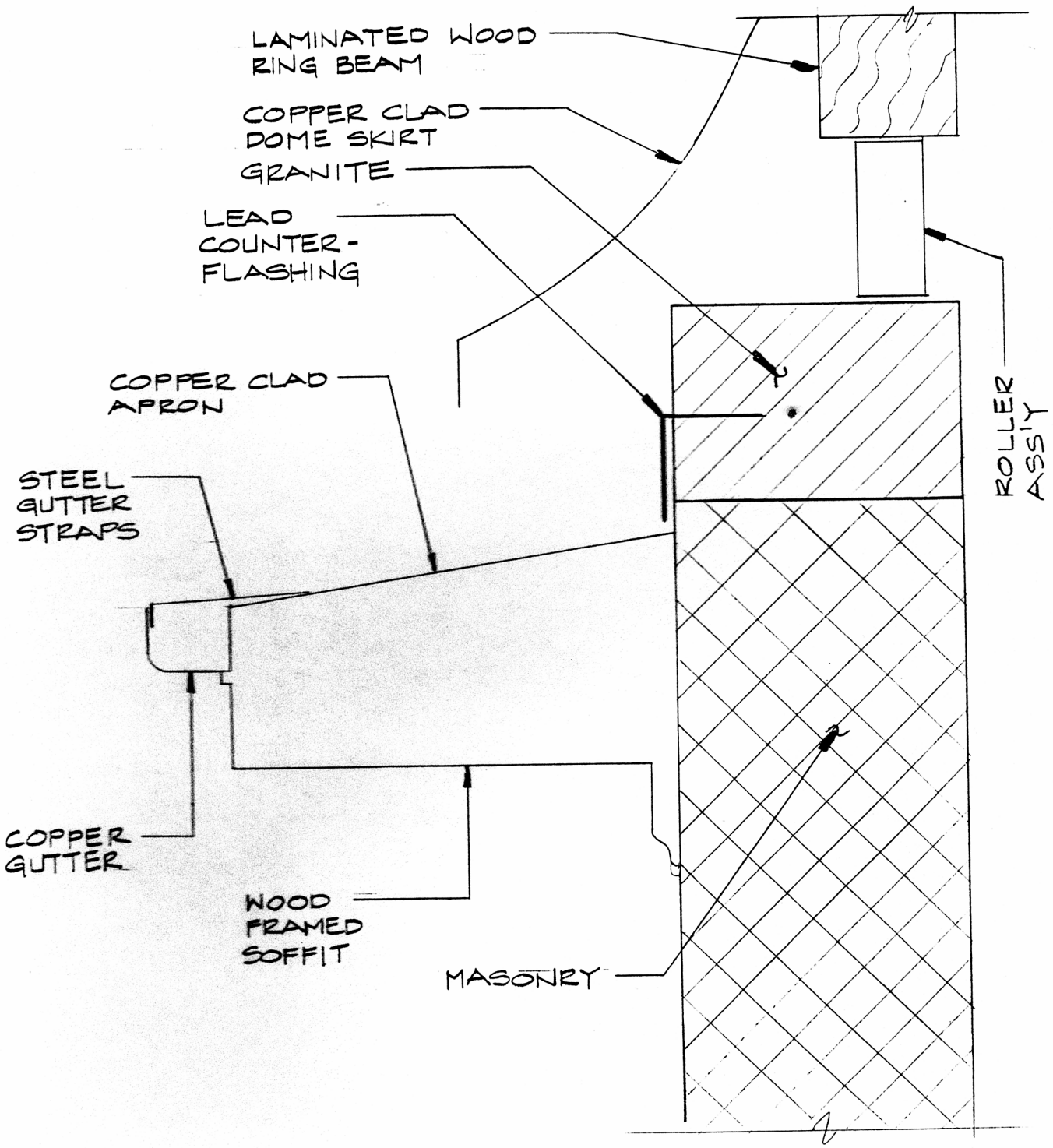
Job No: 91047

Sheet: 2

By: LL

Date: 9/20/91

Checked:



BOSTON
BUILDING
CONSULTANTS

Subject: SEARS TOWER

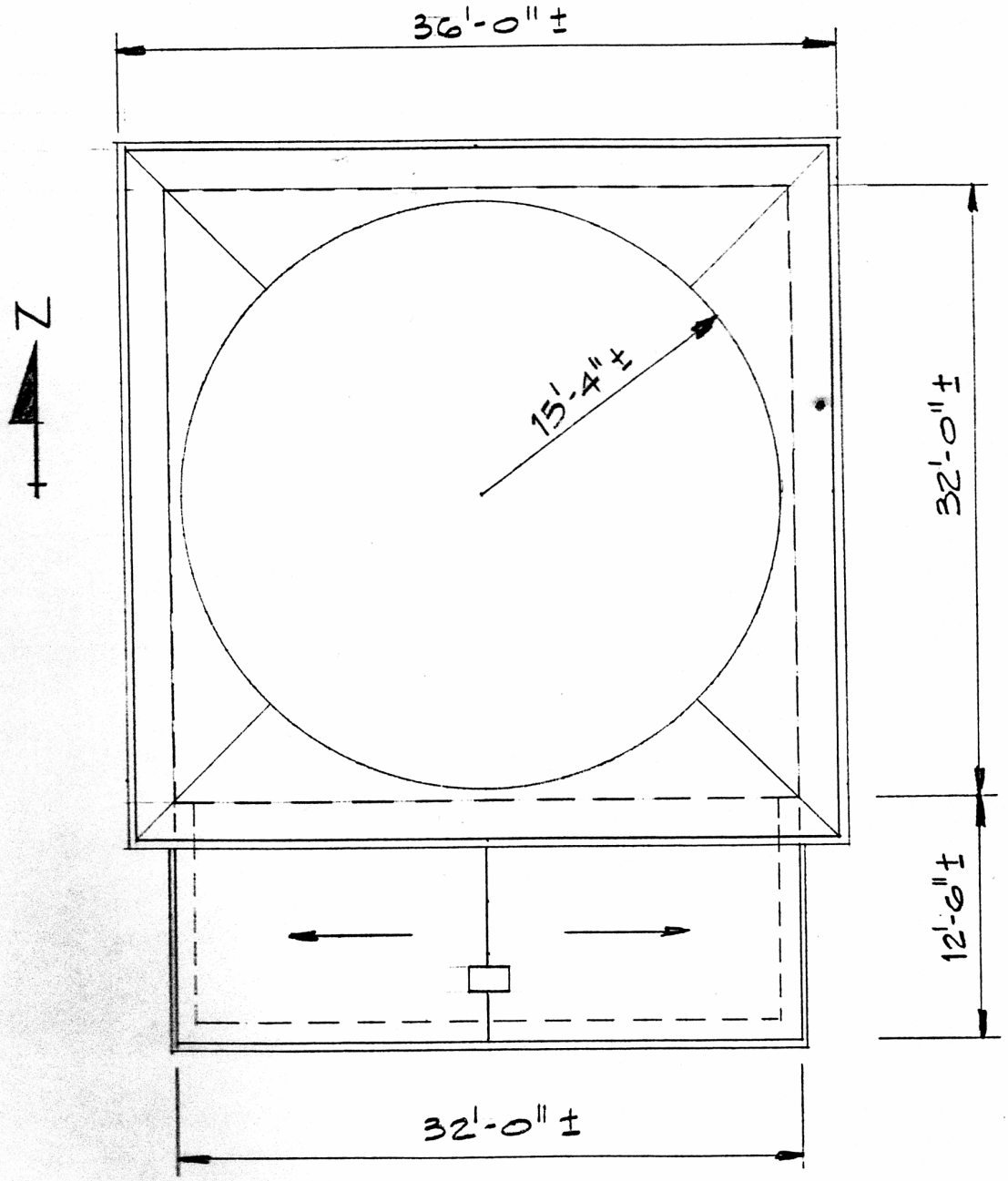
Job No: 91046

Sheet: 3

By: LL

Date: 9/20/91

Checked:



BOSTON
BUILDING
CONSULTANTS

Subject: SEARS TOWER

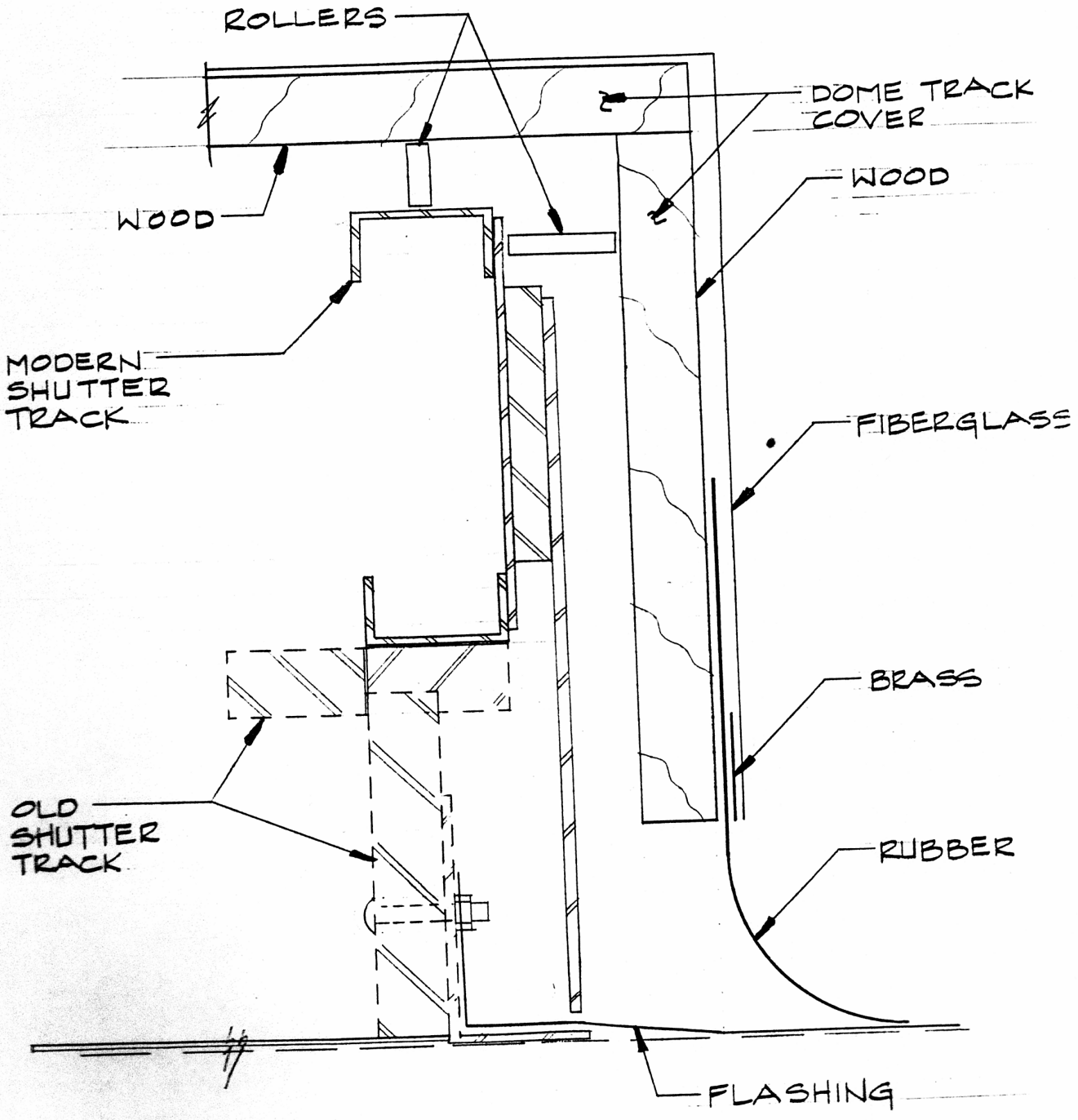
Job No: 91046

Sheet: 4

By: LL

Date: 9/20/91

Checked:



TRANSMITTAL

HARVARD UNIVERSITY PLANNING OFFICE
912 HOLYOKE CENTER 495-2234

To DR. OWEN J. GINGERICH
PROF. OF ASTRONOMY & HIST. OF SCI
A-208

From R.B.

Date 9/23/91

Re SEARS TOWER - STUDY BY BOSTON BLDG.

We are sending you the following

☒ Enclosed herewith ☐ By messenger

☐ Under separate cover ☐ Direct from Blueprinters

No of Copies	Date	Title or Description
1	9/20/91	REPAIRS TO SEARS TOWER

☒ For your approval or comment ☐ For your information ☐ Approved

Remarks

R.B.