WIND-TUNNEL STUDY OF INTERNATIONAL PLACE, BOSTON

PART 3: MITIGATION OF PEDESTRIAN WINDS WITH CANOPIES

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J. A. Peterka* and J. E. Cermak*

FLUID MECHANICS AND
WIND ENGINEERING PROGRAM

COLLEGE OF ENGINEERING

COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

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J. A. Peterka* and J. E. Cermak*

for

The Chiofaro Company
One Post Office Square
Suite 3100
Boston, Massachusetts 02109

Fluid Mechanics and Wind Engineering Program
Fluid Dynamics and Diffusion Laboratory
Department of Civil Engineering
Colorado State University
Fort Collins, Colorado 80523

CSU Project 2-95820

April 1985

*Professor, Fluid Mechanics and Wind Engineering Program

CER83-84JAP-JEC35c

INTRODUCTION

On December 20, 1984, a meeting was held between representatives of the Chiofaro Company, representatives of the City of Boston Redevelopment Authority (BRA), and J. A. Peterka of Colorado State University to discuss results of wind-tunnel pedestrian and wind velocity measurements about the International Place project. Focus of the meeting was the predicted increase in wind speeds on many areas of the sidewalks immediately adjacent to the International Place project site. All but two locations (labeled 37 and 38, Figure 1) fell within city informal guidelines for pedestrian wind speeds. Several locations, however, showed significant increases in wind speed over those existing prior to project construction. It was recognized that the cause of the increased winds was the change in height of structures on the block--tall buildings are known to bring wind from higher elevations down to street level.

Amelioration studies which had been performed using trees on sidewalk areas had shown that reductions in wind speeds could be obtained at most locations, if needed, by the addition of trees or other equivalent surface roughness. Locations 37 and 38 were not improved by trees since a path had been left open for winds to converge on these locations without being blocked by trees.

Discussion of the December 20 meeting brought out the following reasons why canopies were not tested as an amelioration measure:

- For the geometry of the site, canopies would not likely be effective unless they were sufficiently extensive as to be architecturally unacceptable.
- There was no guarantee that canopies would be effective, and

- Canopies were likely to deflect winds across the street from the project site, making winds higher there.

A letter dated December 21, 1984, was written to clarify issues discussed in the meeting and to reiterate that, while the environment about the International Place would be windier than before construction, the resulting environment would be found to be generally acceptable.

At the request of BRA, a current series of wind-tunnel tests has been completed to show the effectiveness of canopies in reducing wind speed about the project site. This report describes these tests. Flow visualization studies were used to identify three canopy configurations for quantitative testing. Results of that testing, described in this report, showed that winds at some location on the sidewalks abutting the site can be reduced by the addition of canopies of sufficient size. However, this reduction is accompanied by significant deflection of winds to sidewalks across the street from the project site. On the basis of the flow visualization, quantitative measurements of wind speed were made for three sets of canopies. Quantitative data, summarized in Table 1, showed that canopies can provide reduced wind speeds at some locations about the site at the expense of increasing wind speeds on sidewalks across the street from the project site.

FLOW VISUALIZATION

Canopies considered in the flow visualization study are shown in Figure 2. Figure 1 shows the project configuration without canopies or landscaping. Each segment of canopy is identified by a letter for ease of discussion. Basic canopy width was 15 ft installed 18 ft above grade. Some canopies of 7.5 ft width were briefly considered, but did not appear to be wide enough to be effective based on flow visualization.

Canopy A over the main entrance at Oliver and High Streets was not visually effective in lowering wind speeds, based on smoke flow tests. (A 20 percent change in velocity is not readily detectable with smoke.) Winds for northerly and southerly approach winds, which cause the high wind velocities at locations 40 and 41, were essentially parallel to the ground approaching these locations. For this type of wind flow, parallel to the canopy, the canopy would not be expected to be effective in blocking winds; some reduction might occur from frictional effects. Flow visualization with and without the canopy showed no visible difference in wind velocity near locations 40 and 41. For the same reason, canopies B and C did not show any difference in smoke flow characteristics. Canopies A, B and C were observed with and without canopies D, E, and F in place.

Canopies D, E, and F together appeared to provide a velocity reduction at locations 37 and 38, with or without canopies B and C in place, for easterly winds which cause the largest velocities at 37 and 38. Winds flowing down the east and southeast faces of the building impinged on the canopy and were at least partially deflected out onto Oliver Street and onto the sidewalk on the opposite side of the street. Elimination of canopy F, leaving only D and E, caused high winds under the canopy to return. Canopy D by itself did not appear to be effective at all, since winds converging down toward location 37 had become almost horizontal by the time canopy D was encountered. Adding surface roughness, in the form of 20 ft trees, in the area of canopies E and F appeared to provide a similar deflection of winds as seen with canopies E and F in place.

Canopies G, H, I, and J together provided a reduction in wind speeds at location 44 and possibly at 45 for northerly and easterly winds which are responsible for the high winds at those locations. Winds at 45 for northerly winds rolled down over the canopy onto the ground and partially under the canopy. Thus, it was not clear that winds at 45 were reduced with the canopies. Removal of canopy G or G and H caused wind speeds at location 45 to appear similar to the no-canopy case for the northerly winds most responsible for high winds there, but did not affect wind speeds for easterly winds. At location 44, removal of canopies G and H caused some increase in wind speeds for northerly winds to levels similar to the no-canopy case but did not appear to cause an increase for southeasterly winds. Canopies G, H, I, J together, or I and J together, caused easterly winds to be deflected out away from the building onto the sidewalk on the opposite (north) side of High Street.

In summary, canopies of appropriate extent (D, E, F) appeared to provide wind speed reductions at locations 37 and 38 at the possible cost of deflecting winds to increase wind speeds in other areas. Canopies at the northeast corner provided some protection under the canopies at the cost of deflecting winds away from the building to the pedestrian areas. Canopies at the southwest corner near locations 40 and 41 did not appear to be effective.

QUANTITATIVE EVALUATION

Three configurations of canopies were selected for tests as shown in Figure 2, 3, and 4:

PH2C1 -- All canopies A-J were in place and were tested to confirm the conclusions of the flow visualization.

PH2C2 -- Canopies on the southeast corner were trimmed to the minimum which flow visualization showed to be effective (D, E, F). Canopies at the northeast corner were trimmed by about half to canopies I and J to observe the consequences of that action.

PH2C3+T -- Canopies at the southeast corner were trimmed to a size which might be more architecturally acceptable (D only) and trees were added in the area of the removed canopies E and F in an effort to replace the action of those canopies. Canopies at the northeast corner of the project site were trimmed to a size which might be more architecturally acceptable and trees were added in an attempt to simulate the effect of the adjacent canopies. Trees were added at the west entrance near locations 40 and 41 to demonstrate effectiveness of ground-based roughness at that location.

PH2 -- This configuration represents the project site with no amelioration devices in place.

Velocity measurements were made at the 14 locations shown in Figures 1-4. Location 51 is a new location not previously measured; it was added to quantify the flow deflection across the street noted in the flow visualization. The other locations were ones measured in previous tests. Velocity measurement procedures were identical to those used in earlier tests.

The results of the quantitative measurements are shown in Table 1 for both mean and effective gust winds exceeded 1 percent of the time. Data for configuration PRE in the table are for the pre-construction configuration measured and reported in earlier studies; they are listed here for convenience in making comparisons. Because the BRA guideline is stated in terms of gust velocity, conclusions herein are made primarily in terms of gust velocities in Table 1. Examination of Table 1 shows that:

1) Inclusion of canopies can improve the wind environment at locations 37, 38, 40, 41, and 44 so that those locations and 45, 47 fall within BRA guidelines.
2) Canopies which reduced winds at locations 37, 38, 44, and 47 caused wind speeds to increase at locations 8, 19, 20, and 36. Two of these locations, 20 and 36, were brought to a level exceeding BRA guidelines.
3) Locations 40 and 41 decreased somewhat in wind speed with the full-canopy case. This effect is apparently due to frictional loss rather than blocking since flow visualization showed no change in flow character (a 10-20 percent reduction in wind speed cannot be detected with smoke flow).
4) Location 38 showed a large velocity for the canopy with tree combination while location 37 was greatly reduced in velocity. A few trees along Oliver Street near location 38 might lower velocities there.
5) Location 51, not measured in previous studies, exceeded BRA guidelines without canopies and was not significantly affected by them.

CONCLUSIONS

On the whole, the presence of canopies can be summarized with the observation that canopies lower wind speeds in some areas under the canopies but increase winds in areas not intended for modification by the canopies. The canopies do not provide a net improvement in pedestrian wind environment.

The best strategy for management of winds about the International Place project may be to install no amelioration devices prior to completion of the project. If experience indicates that reduction of wind speeds is desirable, then roughness elements--trees, planters, sculpture, etc.--can be judiciously placed to decrease winds in selected areas. A quantitative measure of pedestrian wind acceptability can be obtained by properly designed interviews conducted on site by trained personnel. If amelioration is desired prior to project completion, roughness elements similar to those used in previous studies would suffice except that those on the southeast corner should be moved closer to the building.

Table 1. Measured Wind Velocities

Location	Velocity Exceeded 1% of the Time Configuration				
	PRE	PH2	PH2+C1	PH2+C2	PH2+C3+T
Gust (Mean + 1.5 RMS) Velocities in mph					
8	18	24	32	31	27
9	21	24	25	25	23
18	19	30	28	29	28
19	15	25	31	31	30
20	14	26	35	36	35
36	14	25	33	33	31
37	19	34	30	30	21
38	21	35	17	21	36
40	15	30	25	28	16
41	21	31	28	32	19
44	19	31	23	28	16
45	21	31	30	32	28
47	24	30	31	32	26
51	*	34	35	34	34
Mean Velocities in mph					
8	11	16	21	20	18
9	14	16	16	17	16
18	12	24	22	22	21
19	10	18	23	22	21
20	9	18	29	29	28
36	9	15	24	24	21
37	12	27	22	22	14
38	13	25	11	13	22
40	9	23	16	20	10
41	14	21	22	23	14
44	12	23	15	20	12
45	14	18	19	20	18
47	14	21	22	23	18
51	*	26	26	26	25

*Not measured

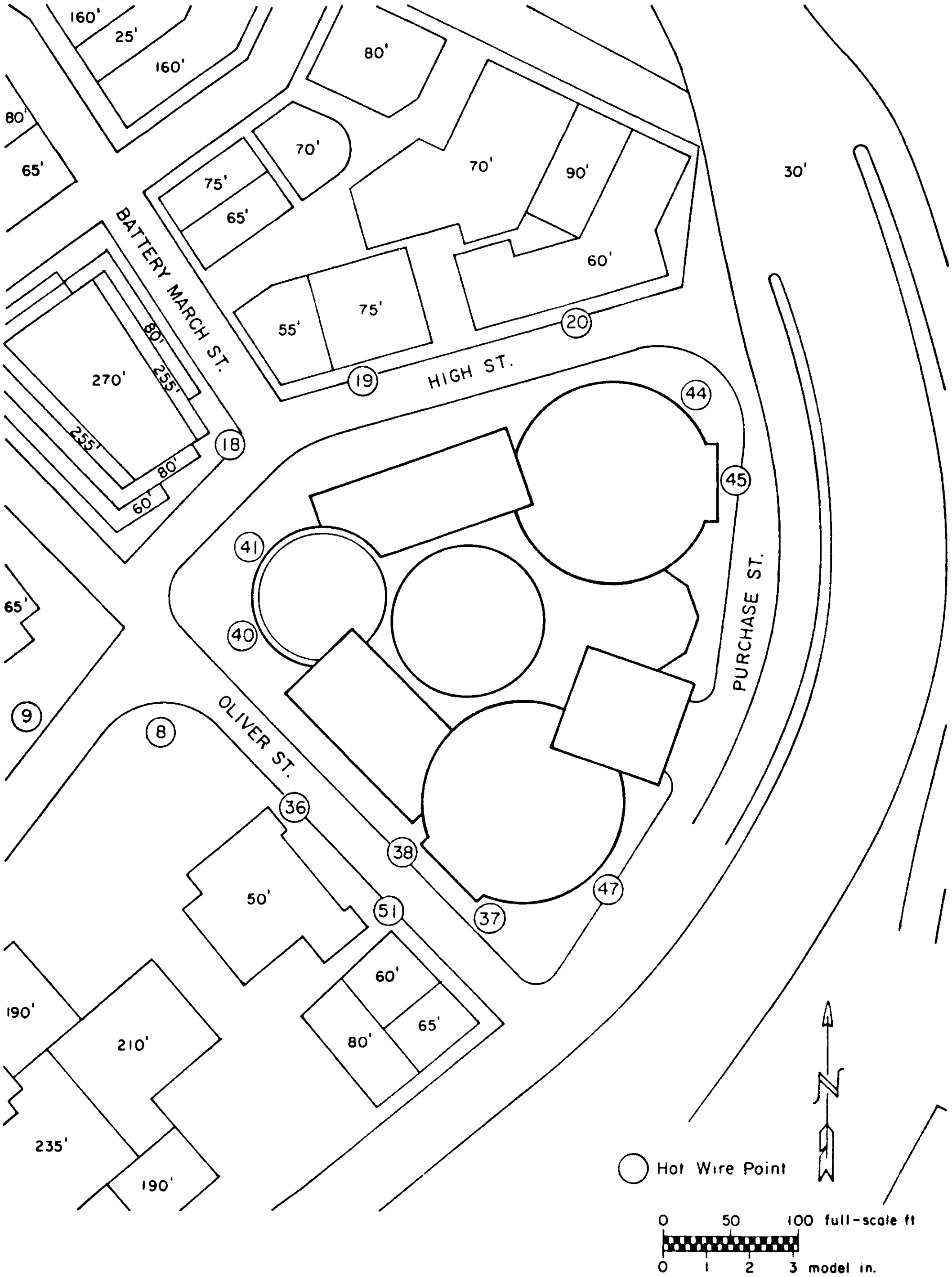

Figure 1. Model Geometry for Configuration PH2

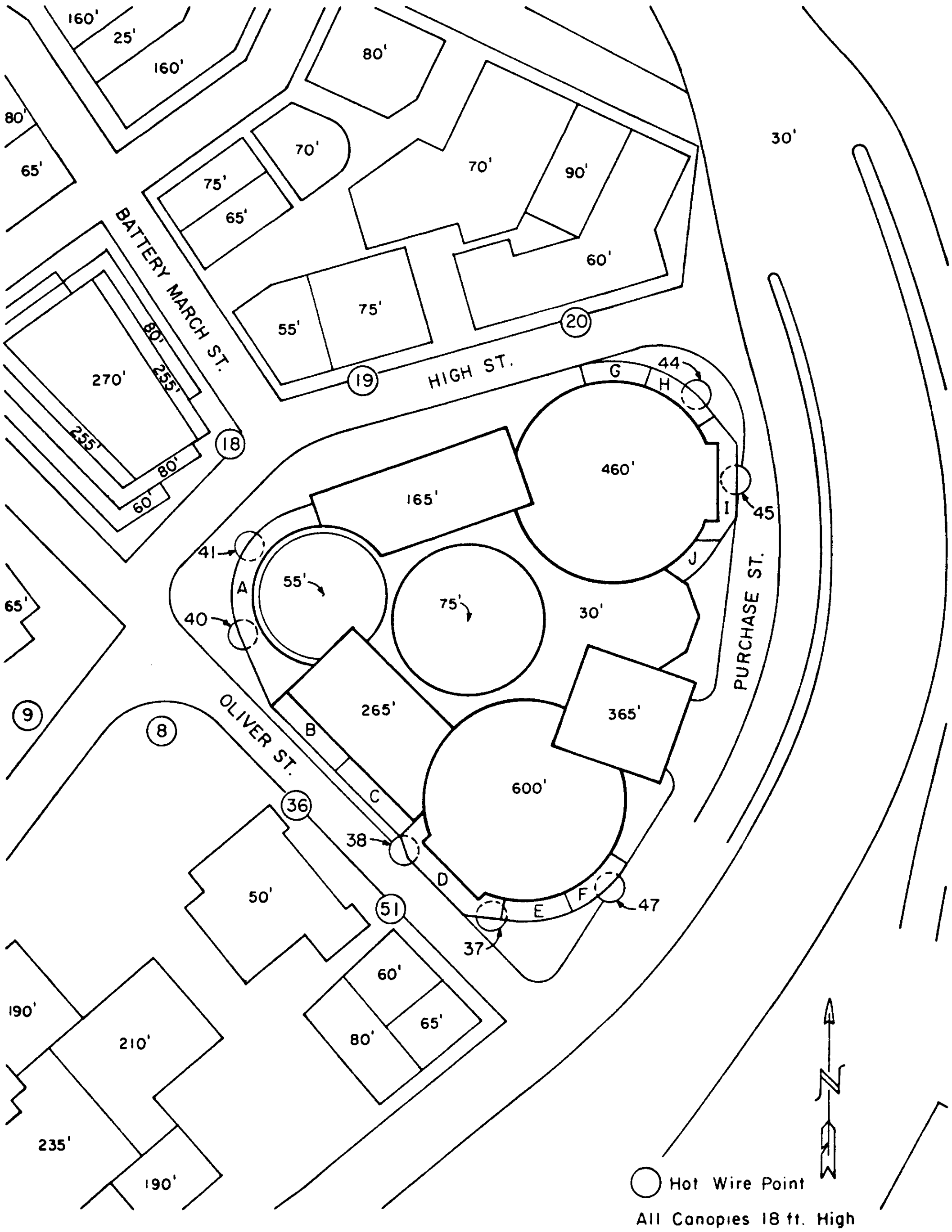

Figure 2. Model Geometry for Configuration PH2C1

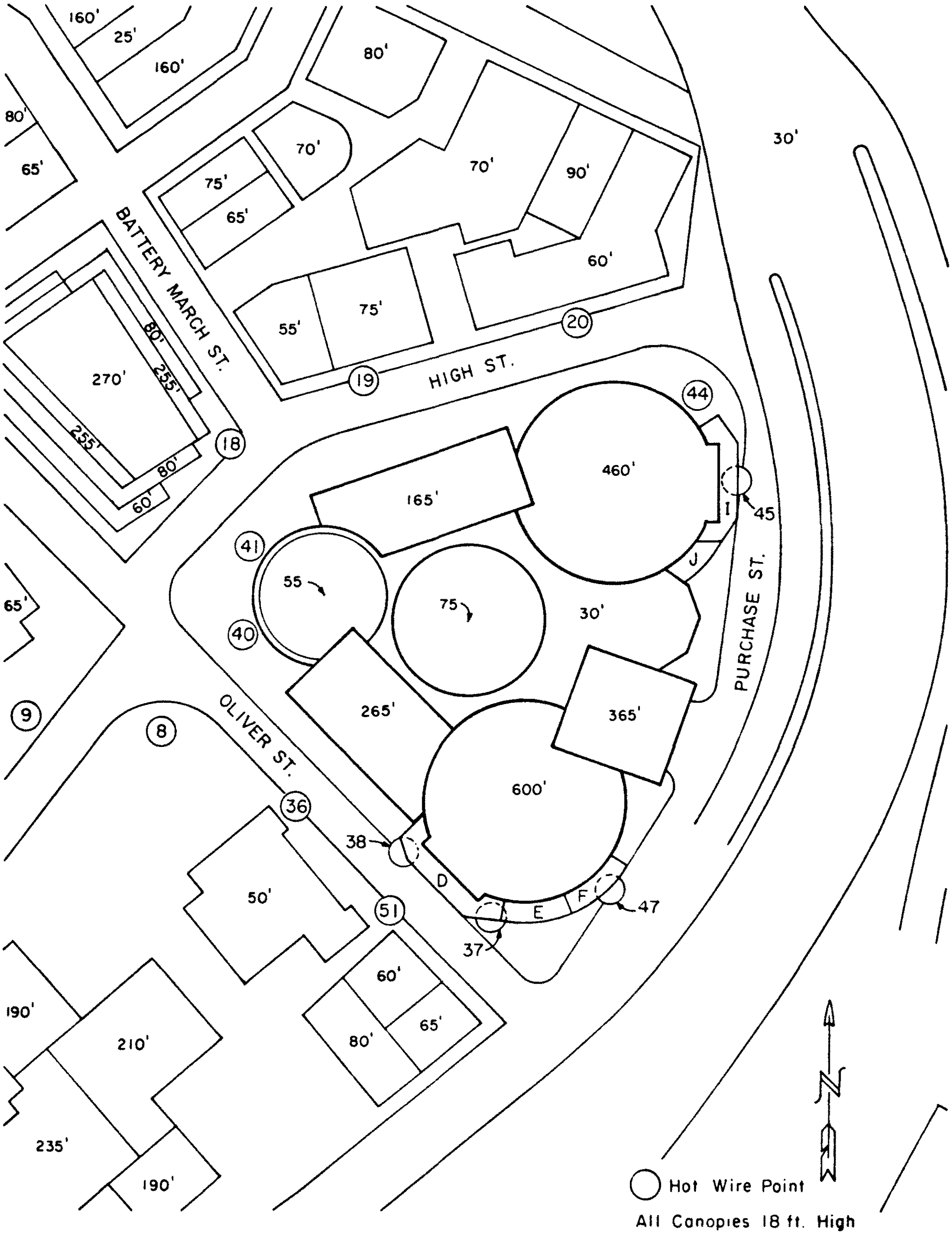

Figure 3. Model Geometry for Configuration PH2C2

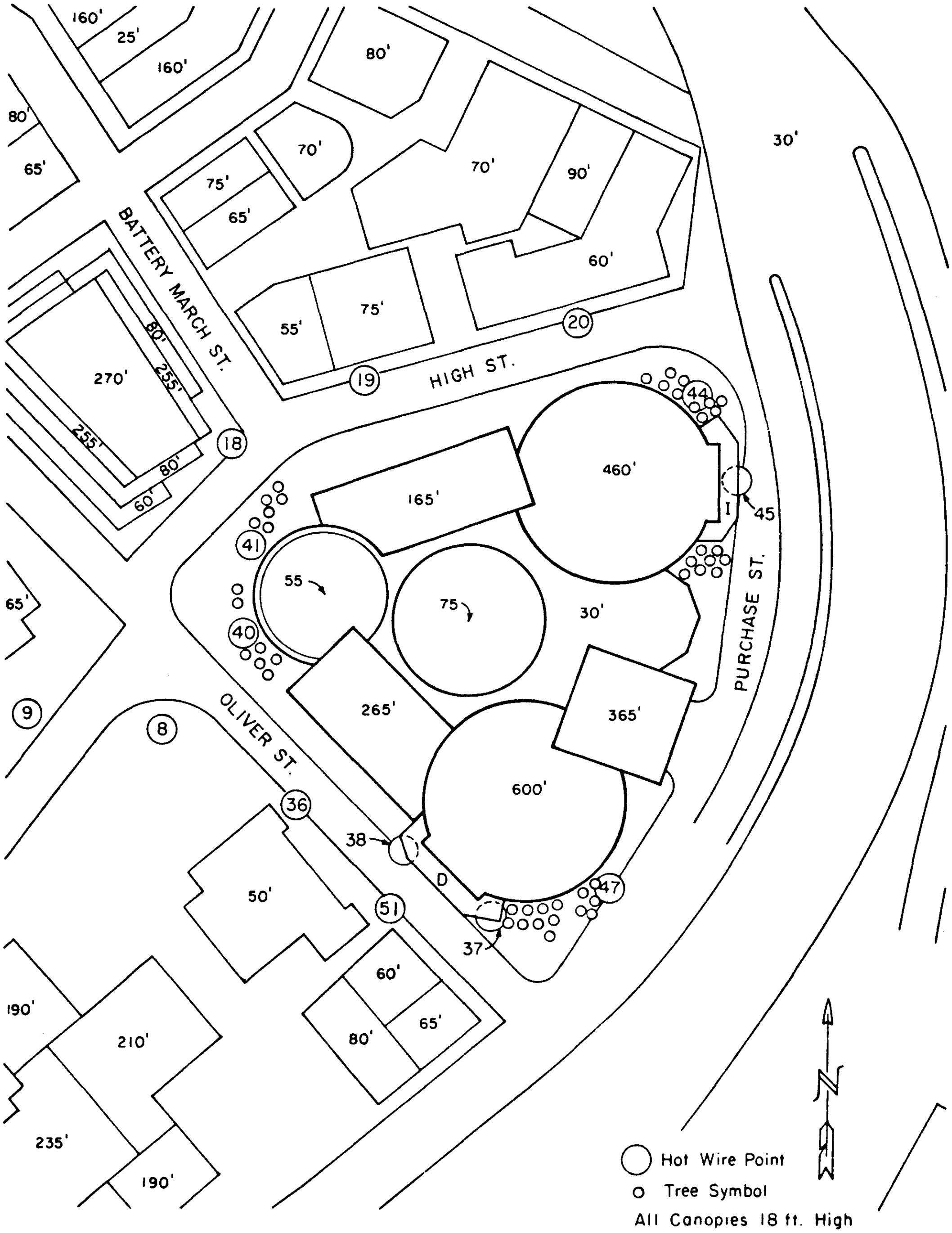

Figure 4. Model Geometry for Configuration PH2C3+T