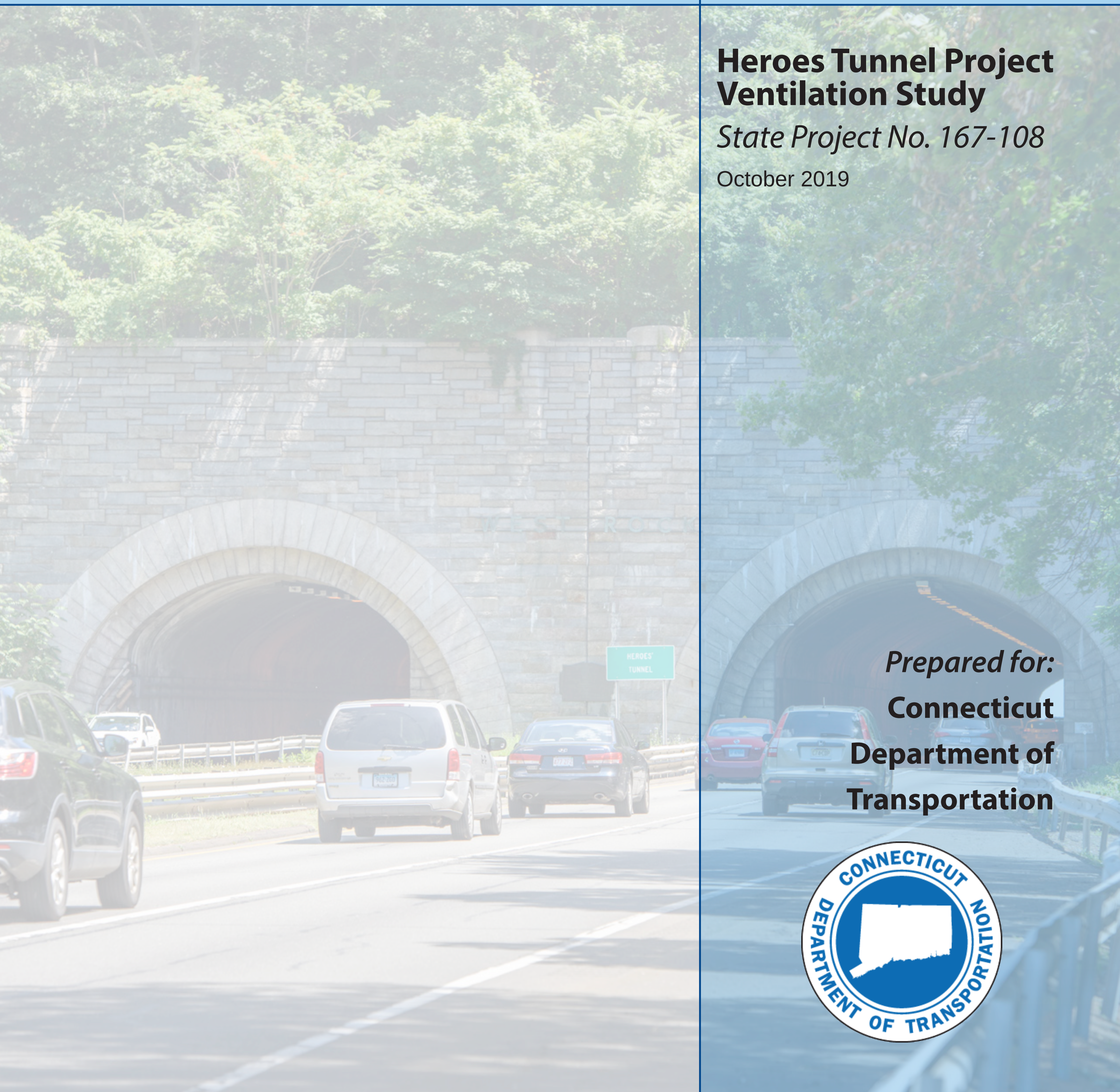
Technical Memorandum
Appendix

Heroes Tunnel Project



Heroes Tunnel Project Ventilation Study

State Project No. 167-108

October 2019

Prepared for:

Connecticut Department of Transportation

CONNECTICUT DEPARTMENT OF TRANSPORTATION

Appendix A

Existing Tunnel Plans

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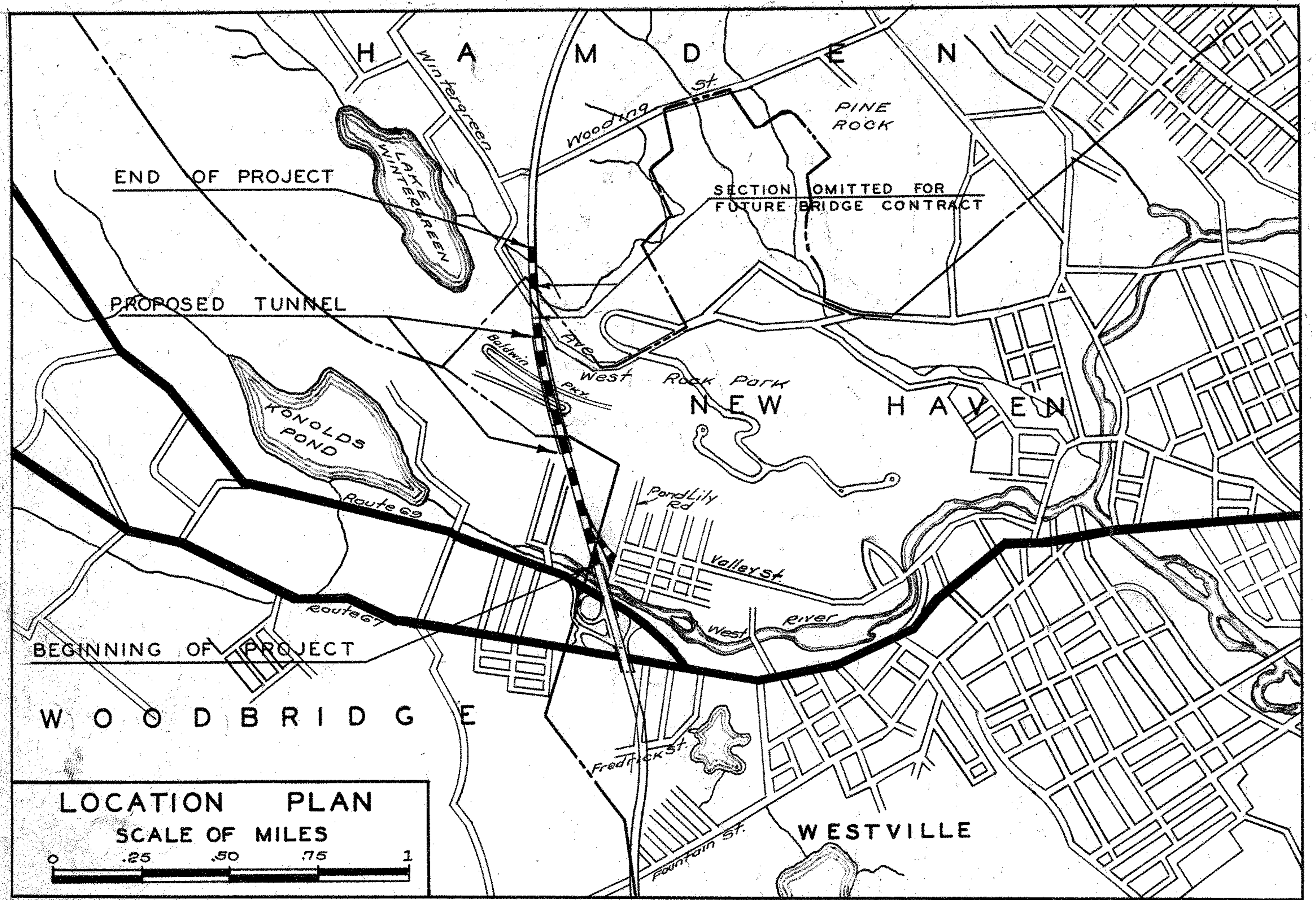


CONNECTICUT
STATE HIGHWAY DEPARTMENT
PLAN
FOR
CONSTRUCTION
OF

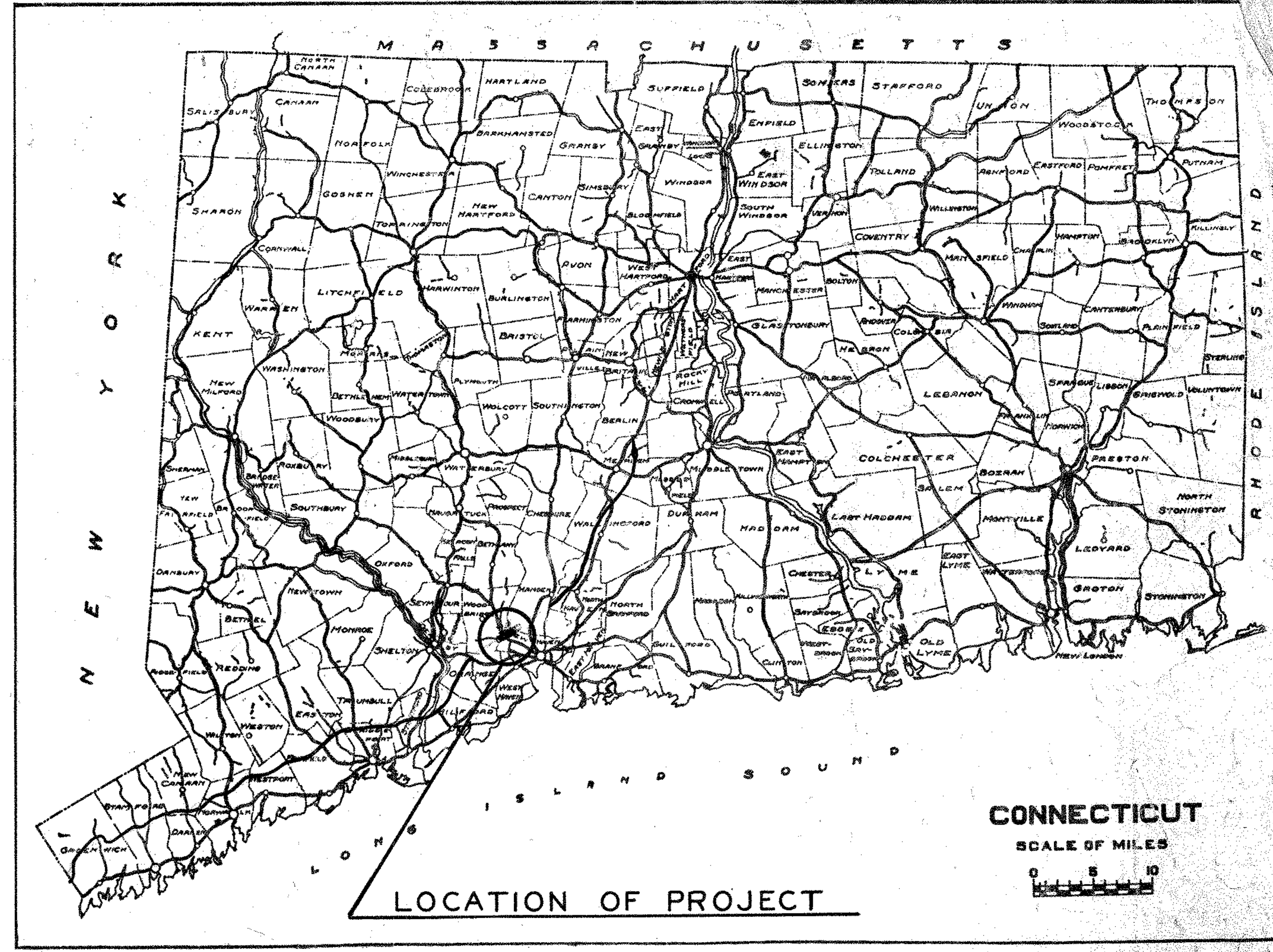
A TWIN BORE TUNNEL THRU WEST ROCK AND GRADING AND DRAINAGE OF A SECTION OF WILBUR CROSS PARKWAY IN THE TOWNS OF

NEW HAVEN - WOODBRIDGE - HAMDEN

FROM STA. SEE TO STA. BELOW

LENGTH SEE BELOW FT.

SCALES
- PLAN 1 IN.= 40 FT.
- PROFILE HOR. 1 IN.= 40 FT. VERT. 1 IN.= 4 FT.
- CROSS SECTIONS 1 IN.= 5 FT.
- 1 IN.= 10 FT.



1947 SPECIFICATIONS FORM 807 GOVERN

TOWN NO. 185
PROJECT NO. 90

ALL ELEVATIONS ON THIS PROJECT ARE BASED ON U.S.C.& G. SURVEY DATUM

TO BE MAINTAINED BY THE STATE

ROADWAY SECTION
- FROM STA. 689 + 00 TO STA. 708 + 65
- " " 720 + 65 " " 722 + 35
- " " 724 + 75 " " 729 + 00

LENGTH 2560 FT.

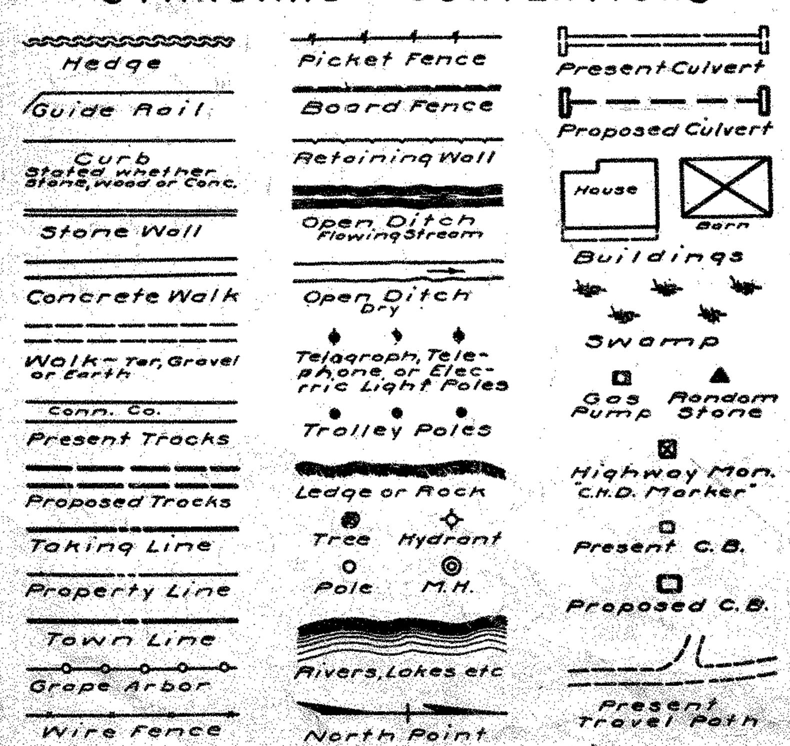
TUNNEL SECTION FROM STA. 708 + 65 TO STA. 720 + 65 LENGTH 1200 FT.

CONSTRUCTION STARTED: March 10, 1948
CONSTRUCTION COMPLETED: Oct. 22, 1949
PLANS REVISED BY: J.M. McCarthy DATE: Oct. 1950
PLANS CHECKED BY: A. Boczar DATE: Nov. 1950

LIST OF DRAWINGS

SHEET NO.	TITLE
1	Title Sheet
2	Small Scale Plan & Profile
3	Detail Estimate Sheet
4	Typical Cross Sections
5	Details of Type "P" Catch Basin
6 thru 13	Plans & Profiles Sta. 689+00 to Sta. 729+00
14 thru 57	Details of West Rock Tunnel Sta. 708+15 to 721+15
58 thru 69	Wilbur Cross Parkway cross sections
	Sta. 689+0 to 708+0 & Sta. 721+25 to 729+0
70 thru 73	Pond Lily Ave. Ramp Cross Sections
	~ STANDARD DRAWINGS ~
221E	Rein. Conc. Pipe, Perf. A.C.C.M. Pipe
	Foundation Underdrain
221F	Endwalls
222A	Curbs
223	Manhole
225	Curb Type Catch Basin
226	A.C.C.M. Pipe Elbows
228	Type "C" Catch Basin, Type E.S.
	Catch Basin, Type C.S. Drop Inlet
241D	Standard Paving Details
242	Load Transfer Units & Metal Plate
	Shield for Transfer Joints
248	Standard Expanded Metal Mesh
	Reinforcement for Conc. Pavement
249	Standard Fabric Reinforcement
	for Conc. Pavement
250	Standard Bar Mat Reinforcement
	for Concrete Pavement

STANDARD CONVENTIONS



THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

APPROVED Nov 20 1947
Ernest T. Perkins
ENGINEER OF HIGHWAY DESIGN

APPROVED Nov 20, 1947
D H B Starr
ENGINEER OF LOCATION & DESIGN

APPROVED Nov 20 1947
Marvin M Creamer
DIRECTOR OF ENGINEERING & CONSTRUCTION

185 90

147 90

1

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	New Haven & Woodbridge Hamden		1947		2	73

WILBUR CROSS PARKWAY
PROJECT 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

PLAN		BY	DATE	CHECKED BY	DATE
NOTE BOOK NO.	Surveyed / Plotted / Alignment / Traced / New Const. Noted / Designed				

PROFILE		BY	DATE	CHECKED BY	DATE
NOTE BOOK NO.	Surveyed / Plotted / Grades Plotted / Traced / New Const. Noted / Designed				

185 901

147 03

2

PUB. ROAD DIV. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
1	CONN.	Woodbridge-New Haven & Hamden		1947		3	73

DETAILED ESTIMATE SHEET

FOR THE CONSTRUCTION OF A TWIN BORE TUNNEL THRU WEST ROCK AND GRADING AND DRAINAGE OF A SECTION OF WILBUR CROSS PARKWAY IN THE TOWNS OF NEW HAVEN - WOODBRIDGE - HAMDEN

FROM STA. 689+00 / 724+75 TO STA. 722+35 / 729+00 LENGTH 3760 FEET; ROADWAY SECTION - GRADING AND DRAINAGE; TUNNEL SECTION - COMPLETE

PROJECT NO. 135-90

STA. 689+00 TO STA. 708+15 ROADWAY QUANTITIES STA. 721+15 TO STA. 729+00

THIS SHEET NOT CORRECTED

EXCAVATION AND BORROW

STA	TO STA.	Unclassified Excav. (C.Y.)		Fill (C.Y.)	Loam Excav. (C.Y.)	Borrow (C.Y.)
688+65	690+00			13196		
690+00	695+00			54555		
695+00	700+00	166		25502		
700+00	705+00			44719		
705+00	708+15	650		38348		
721+15	722+35	9969				
724+42	729+00	91		17991		
Pond Lily Ave Ramp		198		12678		
Totals from Cross Sections		11074		206989		
Miscellaneous		1107		20699		
Loam in Fill Areas				2350	2350	
				230038		
Total Excav.		12181			2350	
Portal Excav.		29150				
Tunnel Excav.		51300				
Shaft Excav.		1560				
		94191				
Rock Swell 40%		37676				
Available for Embankment		131867		- 131867		
Net Borrow				98171		
Plus 10% Shrinkage				9817		
Borrow						107988
Totals		12181			2350	107988

PIPE CULVERTS, END WALLS, ETC.

STA. TO STA.	Reinf. Concrete Pipe 15" (L.F.)	Reinf. Concrete Pipe 18" (L.F.)	Reinf. Concrete Pipe 24" (L.F.)	A.C.C.M. Pipe 15" (L.F.)	15" A.C.C.M. Pipe Elbows (L.F.)	Combination (L.F.)	Found. Udrain with 6" Perf. A.C.C.M. (L.F.)	Type "C" Catch Basin (No.)	Type "CS" Catch Basin (No.)	Type "P" Catch Basin (No.)	Curb Type C.B. (No.)	Type "CS" Drop Inlet (No.)	Manhole (No.)	Manhole over 10' Deep (No.)	Cement Rubble Masonry (C.Y.)	Outlets for Underdrain (L.F.)	Ditch Excavation (C.Y.)	Trench Excav. 0-6 (C.Y.)	Trench Excav. 6-10 (C.Y.)	Trench Excav. 10-15 (C.Y.)	Removal of Existing Masonry (C.Y.)
685+50Rt Intersection Rt 69 & Pond Lily Ave											1							16			
0+80 Pond Lily Ave Ramp							32								0.4	48	5	26			
1+68 " " "		64													3.7		56	27			
689+50 691+0Lt			148										1		2.7		35	114	37		
691+0Lt				96	12							1						62			
691+0 693+96Lt		12	296										1		1.8			200	10		
695+0				132	12	8		2		1								126			
693+96 695+80Lt			180										1					112			
695+80 699+40Lt			360										1					143	207		
696+68		224													1.8			84			
699+50				70	12	20		2		1								83			
698+40 701+45Rt																	255				
699+40 703+50Lt		408											1					236	81		
704+0				106	12	32		2		1								114			
703+50 705+30Lt		176											1					50	22		
704+35 705+50Rt																	100				
706+15							144									76		50			
705+30 706+50Lt		120											1					68	44		
706+50 707+65Lt		120											1					64	21		
707+65 708+54Lt		88																24			
708+54	84												4					53			
720+76	144							2	2									98			
720+80							116											40			
720+76 721+20Rt		44											1					43			
721+20 722+35Rt		128												1				11	85	81	
Removals																		97			7
Unassigned	24	60	40	40	12	12	16	1					1		4.6	12	49	159	53	9	3
Sub-Totals	252	1444	1024	444	60	72	308	9	2	3	1	1	14	1	15	136	500	2100	560	90	10
Totals	252	1444	1024	444	60	72	308	9	2	3	1	1	14	1	15	136	500	2100	560	90	10

Roadway items

STA. TO STA.	Clearing & Grubbing (L.S.)	Portland Cement (Bbl)	Joint Filler for Bridges (S.F.)	Deformed Steel Bars (Lb.)	Membrane Waterproofing (S.Y.)	Metal Flashing (Lb.)	Subbase (C.Y.)	Broken Stone for Base (Ton)	Transverse Expan. Joint (L.F.)	Mat Reinforcement for Conc. Pavement (S.Y.)	Steel Tie Bars (Lb.)	Concrete for Pavement (C.Y.)	Bituminous Concrete (Ton)	Bit. Conc. Sidewalk (S.Y.)	Concrete Gutter (S.Y.)	Single Posts (No.)
689+0 708+15							5108									
721+15 722+35							820									
722+75 729+0							1231									
Pond Lily Ave Ramp							702									
Intersection Rt 69 & Pond Lily Ave.		3						9					3	46		20
Roadway Drainage																
Endwalls		15														
Drainage Structures		127														
R.C. Pipe		12														
708+15 708+65							215									
720+65 721+15							215									
Unassigned		13					309	1					1	4		5
Sub-Totals	L.S.	170					8600	10					4	50		25
Tunnel Section 708+15 721+15		21750	700	673000	1500	1000		2860	260	6200	1600	1380			350	
Totals	LS	21920	700	673000	1500	1000	8600	2870	260	6200	1600	1380	4	50	350	25

TUNNEL QUANTITIES STATION 708+15 TO STATION 721+15

STA. TO STA.	Portal Excavation (C.Y.)	Bagged Screened Gravel (C.Y.)	Tunnel Excavation (C.Y.)	Shaft Excavation (C.Y.)	Rock Excav. for Enlargement of Tunnel & Ventilating Shaft (C.Y.)	Protective Coatings of Cement Mortar (C.Y.)	Steel Arch Ribs, Sills & Columns (Lb.)	Permanent Timber Lagging (MFBM)	Stone Packing (C.Y.)	Drilling Holes in Rock (L.F.)	Grout (C.Y.)	Sand for Grout (C.Y.)	Steel Pipes for Grouting and Panning (L.F.)	Sheet Steel for Panning (Lb.)	Dowel Rods (L.F.)	Conc. Lining of Tunnel (C.Y.)	Conc. in Portals (C.Y.)	Conc. Lining of Ventilating Shaft (C.Y.)	Wire Mesh (Lb.)	Tunnel Drainage System (L.S.)	Portal Drainage System, 6" V.C. Pipe (L.F.)	Portal Drainage System, 6" C.I. Pipe (L.F.)	Glazed Tile Facing (S.Y.)	Intercepting Ditch, Stone Masonry Paved (on Hillside) (S.Y.)	Baldwin Pkwy Drainage System (L.S.)	Random Ashlar Stone Masonry (C.Y.)	Dimension Stone Masonry (C.Y.)	Concrete Safety Curb (C.Y.)	Ventilating House (L.S.)	Miscellaneous Tunnel Work (L.S.)	Ventilating System (L.S.)	Tunnel Electrical System (L.S.)	Conc. Curbing (L.F.)
Intersection Rt 69 & Pond Lily Ave.																																	45
Sub-Totals																																	50
Tunnel Section 708+15 721+15	29150	530	51300	1560	150	50	365000	20	300	1500	100	100	1000	1000	500	8820	2950	820	7500	L.S.	430	120	4500	510	L.S.	280	250	1600	L.S.	L.S.	L.S.	L.S.	
Totals	29150	530	51300	1560	150	50	365000	20	300	1500	100	100	1000	1000	500	8820	2950	820	7500	L.S.	430	120	4500	510	LS	280	250	1600	L.S.	L.S.	L.S.	L.S.	50

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TYPICAL CROSS SECTIONS

NOT TO SCALE

PUB. ROAD DIV. NO.	STATE	TOWN	FED. AID PROJ. NO.	PROJ. NO.	YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
1	CONN.	WOODBRIDGE, NEW HAVEN AND HAMDEN		185-90	1947		4	73

WILBUR CROSS PARKWAY

PROJECT NO. 185-90

Revised Sept. 9th 1948 To show raised median strip.

THIS SHEET NOT CORRECTED

STAGE CONSTRUCTION

Note A:
For Rock Cut ~ 0' to 12'-0"; Normal Width of 5'-0"
For Rock Cut over 12'-0", Minimum Width of 10'-0" or as directed

Note: For details of Rock Slope adjacent to East & West Portals - See Special Cross Section Sheets.

Where Rock is removed to a Flat Slope, it shall be excavated 12" below the normal slope or as directed.
Top of Slope to be rounded as shown or as directed.

ALL LOAM TO BE PLACED BY STATE FORCES

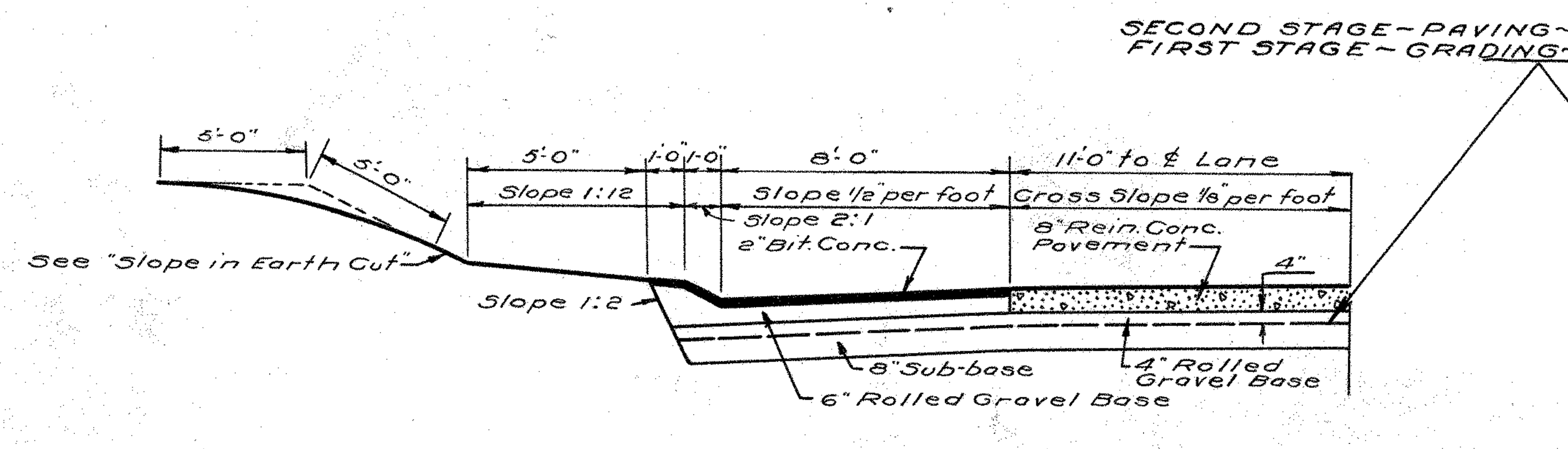
Width of Median Strip, Back to Back of Curbs, varies as shown in detailed instructions on Construction Plans.

~ SLOPE IN ROCK CUT ~
A 1:2 Slope where Rock is more than 12 ft. above gutter grade.
A 2:1 Slope where Rock Cut depth is between 7½ ft. and 12 ft.
A 3:1 Slope or as directed where Rock Cut depth is between 0 ft. and 7½ ft.

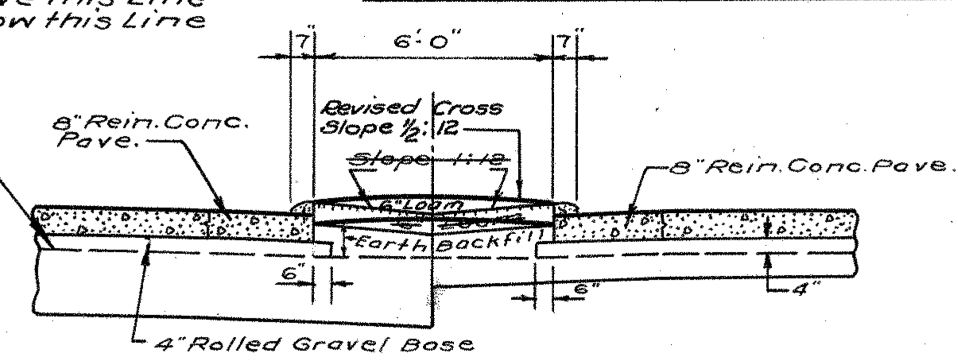
~ SLOPE IN EARTH CUT ~
A 4:1 Slope for depth 0 ft. to 7½ ft.
A 3:1 Slope for depth 7½ ft. to 12 ft.
A 2:1 Slope for depth over 12 ft. where limits of Right of Way permit or as directed.

~ SLOPE ON FILL ~
A 6:1 Slope for Fills 0 ft. to 6 ft.
A 4:1 Slope for Fills 6 ft. to 9 ft.
A 2:1 Slope for Fills over 9 ft. or as directed

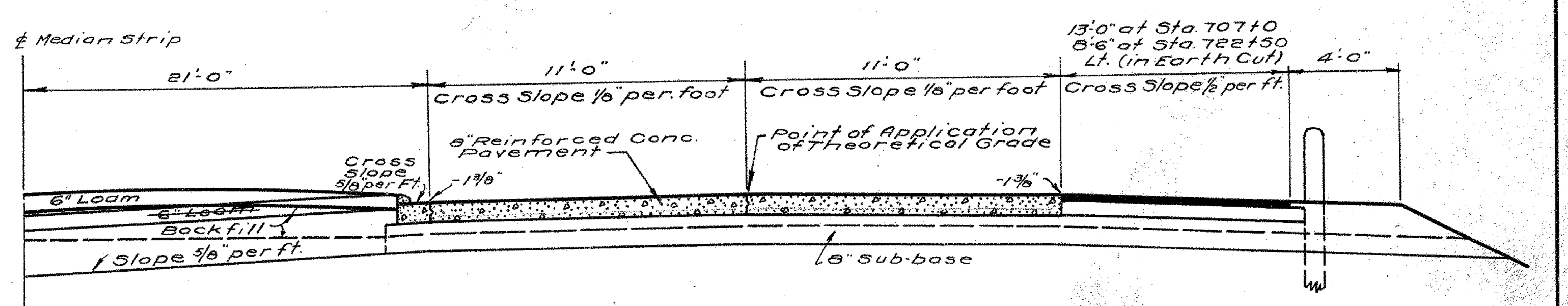
TYPICAL NORMAL SECTION



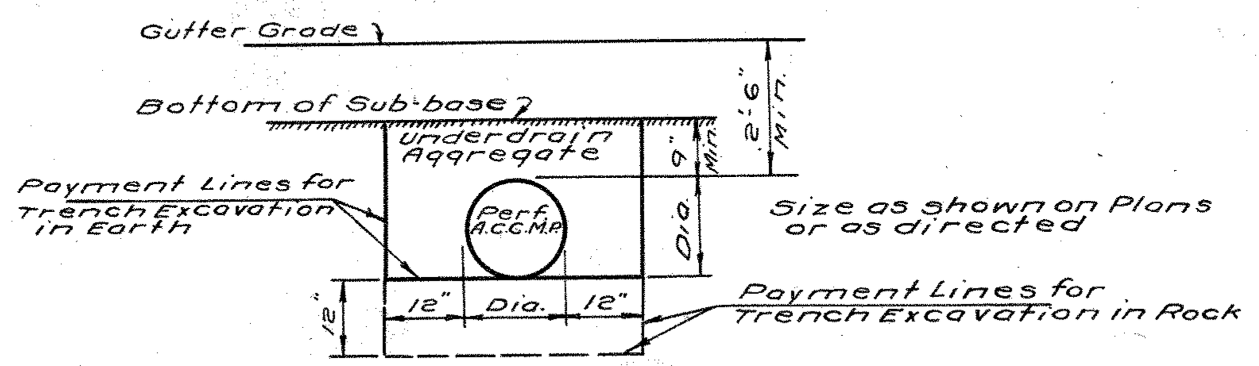
SKETCH SHOWING TYPICAL SHOULDER TREATMENT IN EARTH CUT



SKETCH SHOWING TREATMENT OF 6'-0" MEDIAN STRIP-NORMAL SECTION

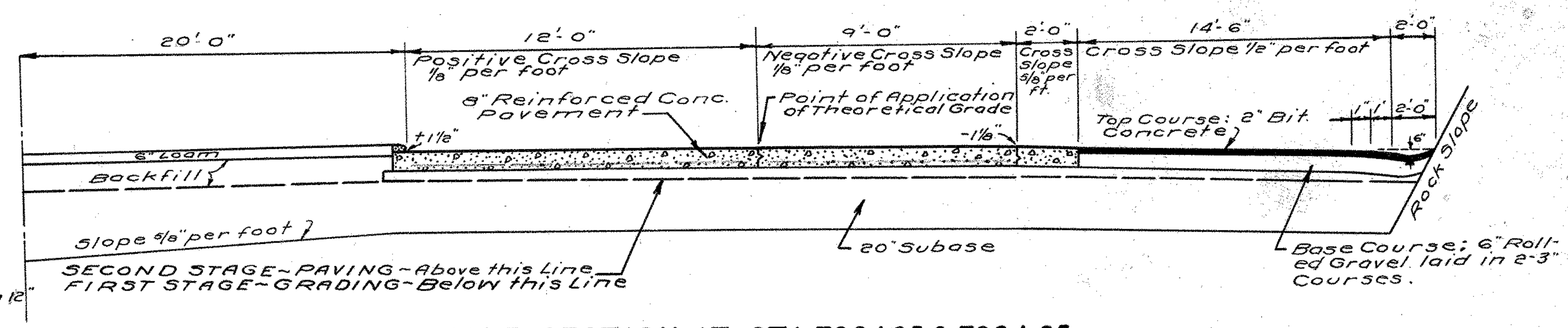


HALF SECTION AT STA. 707+0 & 722+50

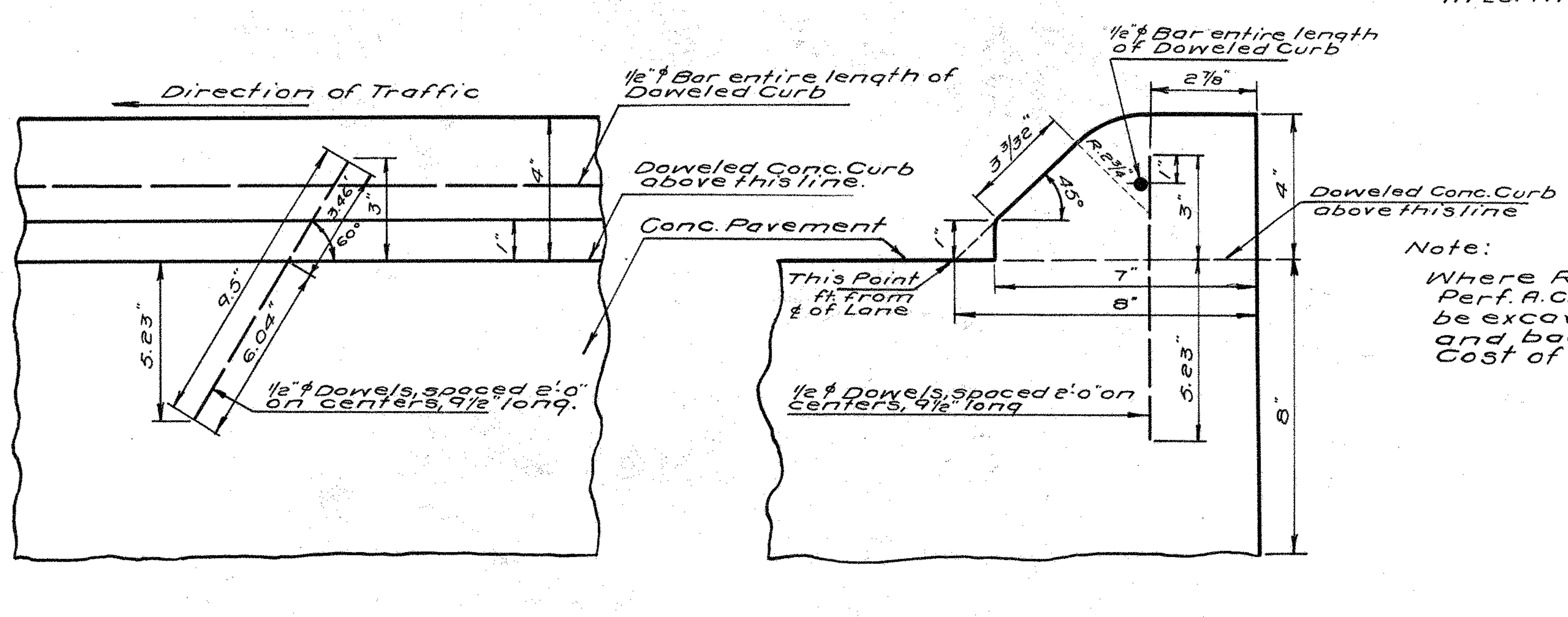


COMBINATION 12" PERF. A.C.C.M.P. & FOUNDATION UNDERDRAIN

Note:
Where Rock is encountered in constructing "Combination 12" Perf. A.C.C.M.P. & Foundation Underdrain", the Trench shall be excavated to a depth of one foot below the Flow Line and backfilled with impervious material.
Cost of material to be included in Underdrain item.



HALF SECTION AT STA. 708+65 & 720+65 SHOWING SPECIAL MANNER OF BANKING



DETAIL OF DOWELED CONCRETE PARK CURBING

PLAN	NOTE BOOK	NO.

	BY	DATE	CHECKED BY	DATE
Surveyed				
Plotted				
Traced				
Designed				
New Const. noted				

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THIS SHEET NOT CORRECTED

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	Woodbridge & Hamden		1947		5	73

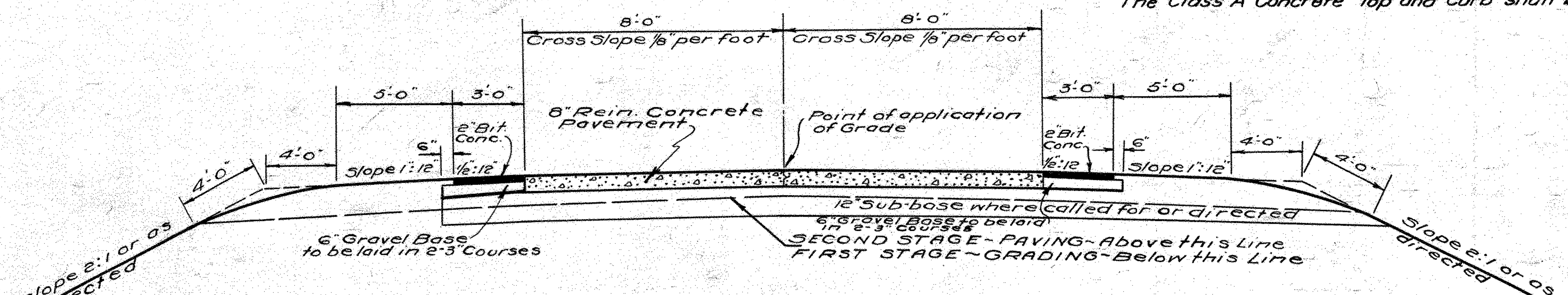
WILBUR CROSS PARKWAY
Project No. 185-90

- NOTES -

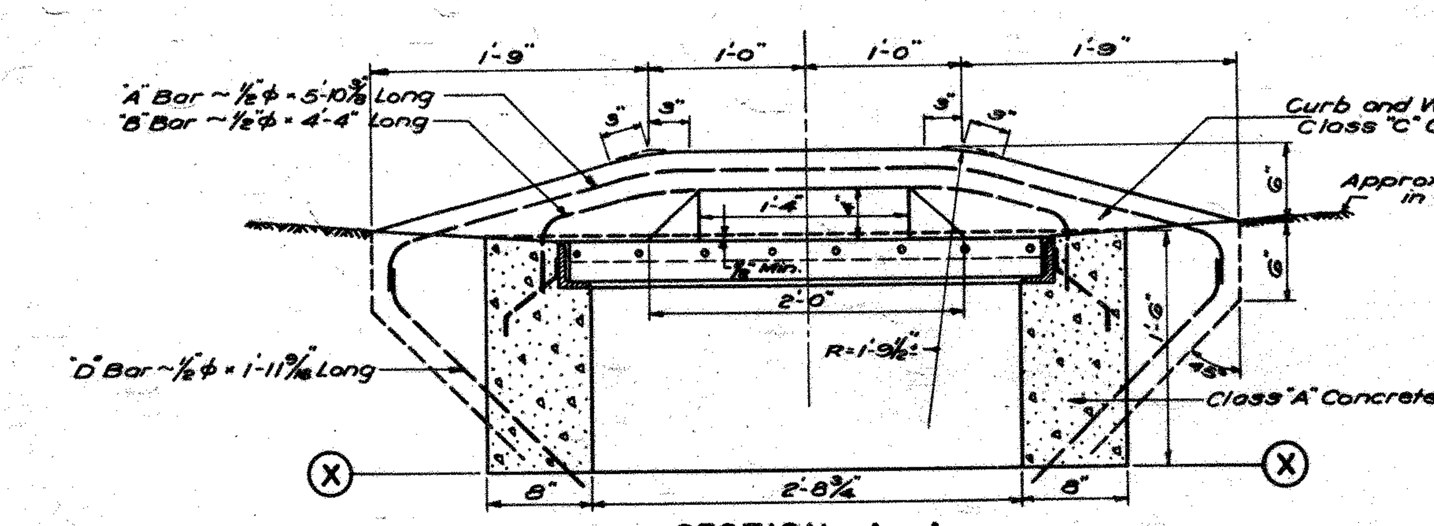
For Frame and Grate, see Standard Sheet No. 228.

In such cases and at such locations as the Engineer may direct, on projects where grading only is called for, Type "P" Catch Basin shall be constructed to Line X-X. The Frame and Grate shall be furnished and set securely in mortar, in a manner satisfactory to the Engineer, at this elevation so as to permit the proper drainage of the area intended. The Class "A" Concrete Top and Curb shall be omitted.

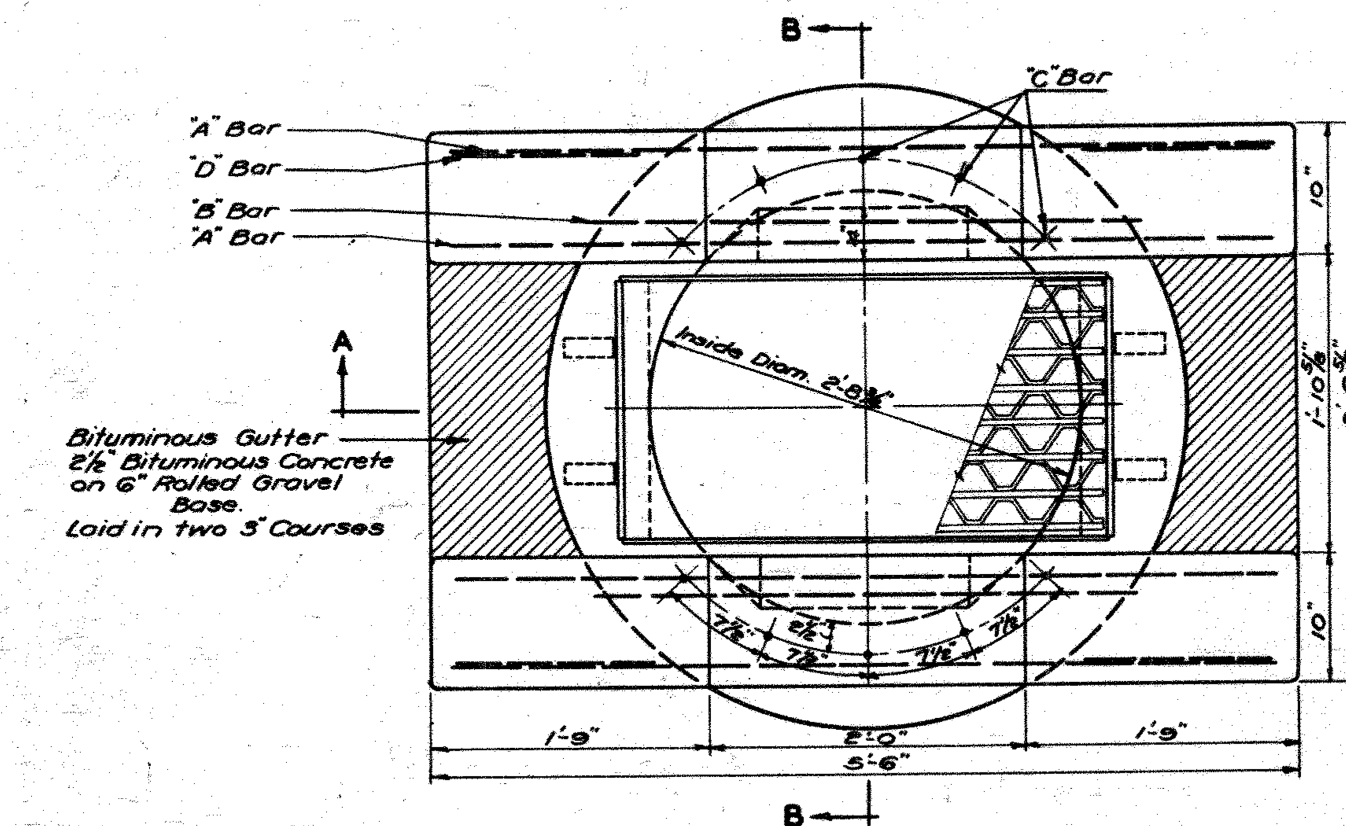
Not to Scale



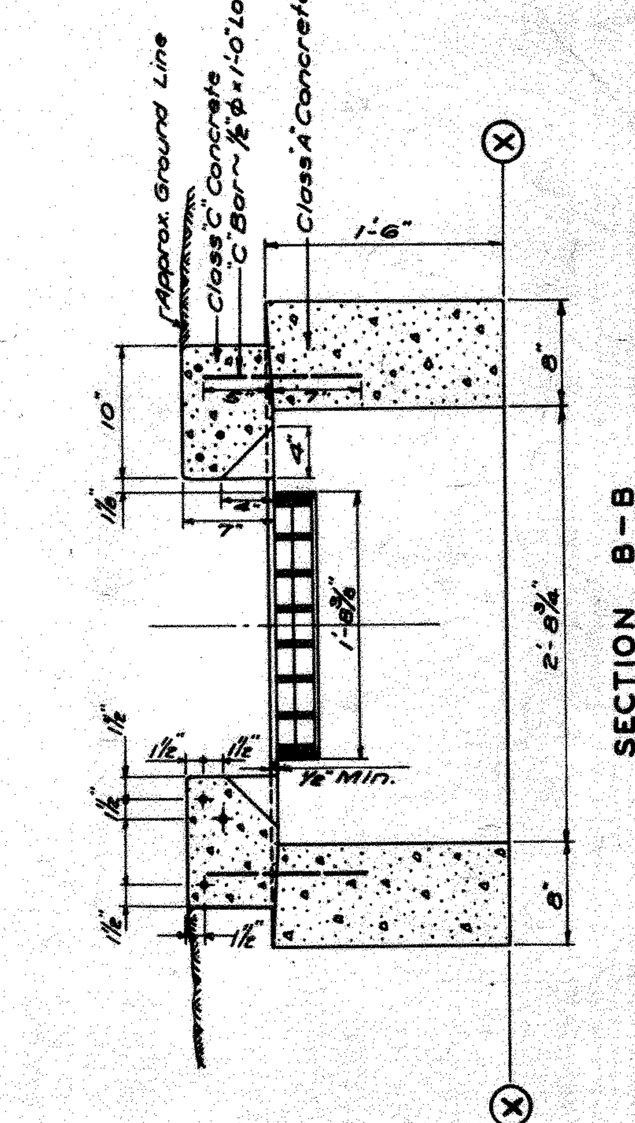
TYPICAL SECTION
POND LILY AVE. RAMP



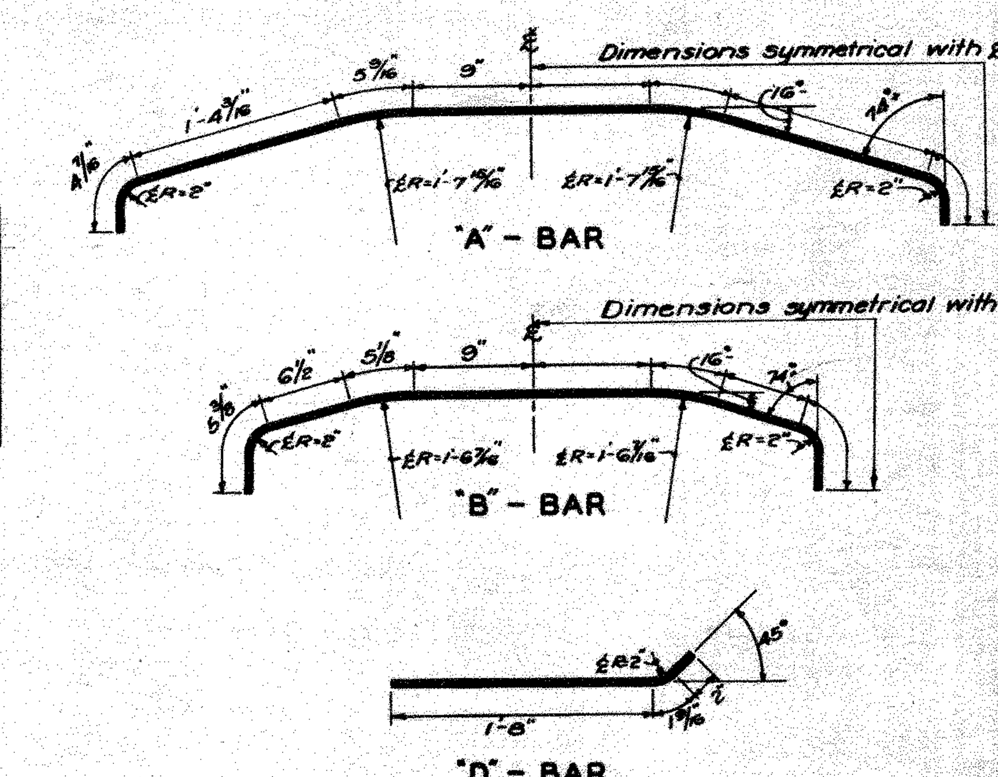
SECTION A-A



CURB & TOP
PLAN
Scale 1" = 1'-0"

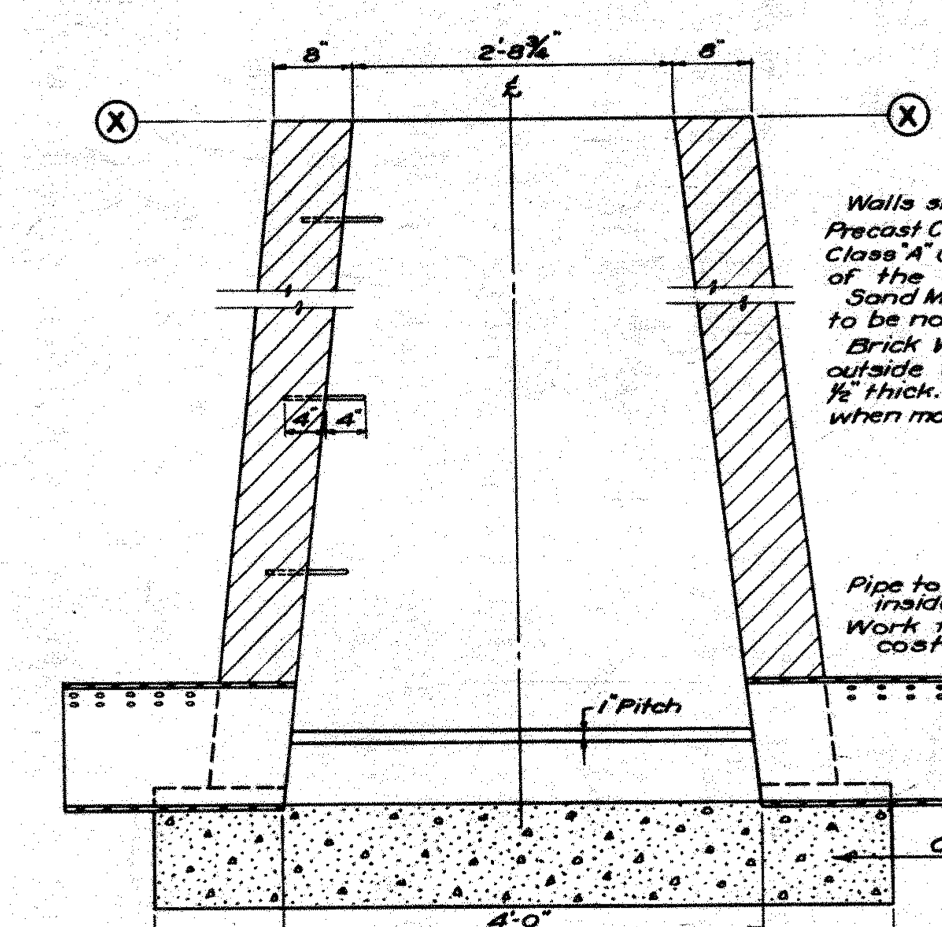


SECTION B-B



BAR DETAILS

BAR BILL				
Bar	Size	Length	No.	Total Wt.
A	1/2" φ	5'-10 3/8"	4	15.7 lbs.
B	1/2" φ	4'-4"	2	5.8 lbs.
C	1/2" φ	1'-0"	10	6.7 lbs.
D	1/2" φ	1'-11 9/16"	4	5.3 lbs.
		TOTAL		33.5 lbs.

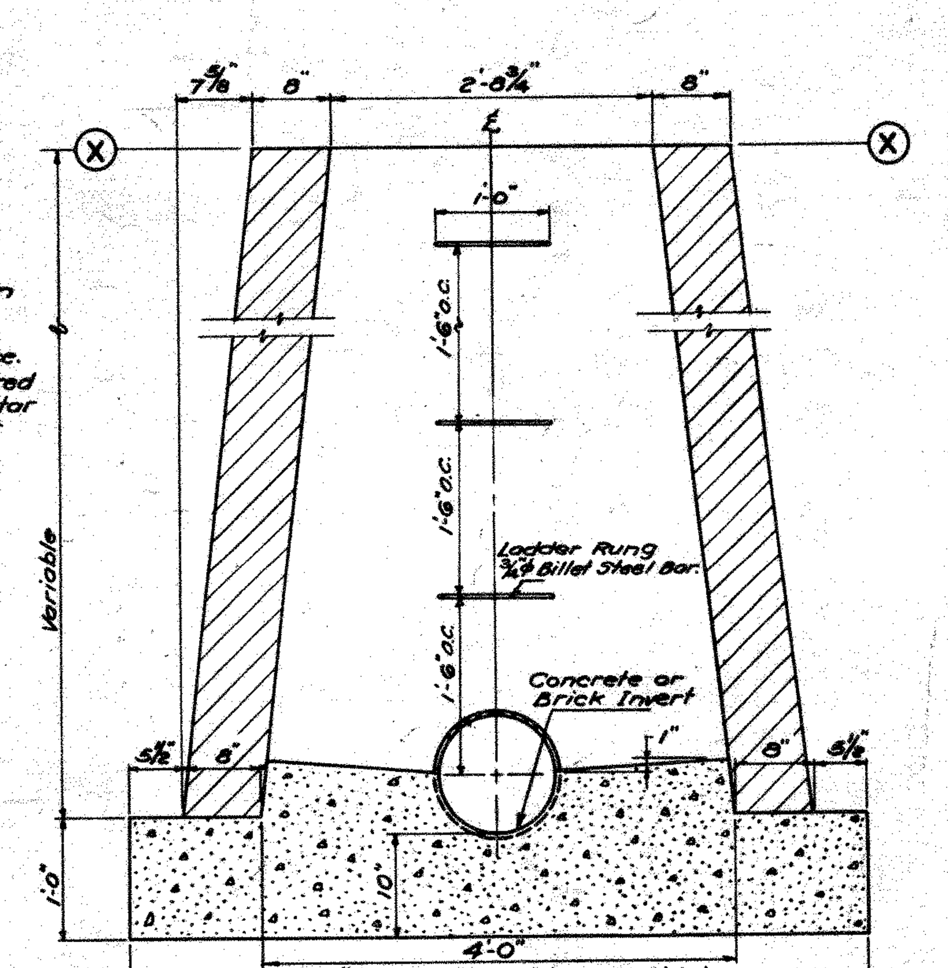


LONGITUDINAL SECTION

Walls shall be built of Brick, Precast Concrete Units or Class "A" Concrete at the option of the Contractor.
Sand Mortar 1:2 mix. Joints to be not over 1/2" on inside face.
Brick Walls are to be plastered outside with 1:2 cement mortar 1/2" thick. Bricks must be wet when mortar is applied.

Pipe to be cut flush with inside of Catch Basin. Work to be included in cost of Catch Basin.

BASE
Scale 3/4" = 1'-0"



CROSS SECTION

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REVISIONS		
NO.	DATE	DESCRIPTION

CONNECTICUT
STATE HIGHWAY DEPARTMENT

TYPE "P" CATCH BASIN

DESIGNED BY W. S. Bissell
SCALES As Noted
MADE BY W. S. Bissell DATE 8/20/47
CHECKED BY ______ DATE ______
APPROVED ______ DATE ______
PROJECT NO.
BRIDGE SHEET NO. ____ OF ____

185 90

147 03

STANDARD NO. 5

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN & WOODBRIDGE		1947		6	73

WILBUR CROSS PARKWAY
PROJECT 185-90

CENTER PARK TRANSITION -					
STA.	℄ to Curb Face	STA.	℄ to Curb Face	STA.	℄ to Curb Face
689	3.58	692	4.39	695	6.82
+50	3.60	+50	4.68	+50	7.39
690	3.67	693	5.02	696	8.00
+50	3.78	+50	5.40		
691	3.94	694	5.83		
+50	4.14	+50	6.31		

CURVE DATA
ALONG FACE OF CURBS
$\Delta = 0°-48'-01.95''$
$D = 0°-06'-11.88''$
$R = 55468.2$
$T = 387.50$
$L = 774.99$

GENERAL CONSTRUCTION NOTES

Remove all existing drainage culverts where and as directed.
All proposed drainage may be varied by the Engineer to fit conditions found in the field.
All buildings within the limits of the right of way are to be removed under separate contract.
If so directed, all underdrains, gravel fill, and subbase may be varied as to depth, length and location, according to conditions found in the field, or they may be entirely eliminated.
Where buildings have been removed to clear the way for construction, or where old foundations and cellar or other holes exist, the removal as directed of the cellar walls and other concrete and masonry to 2 feet below the directed finished grading and the filling of the cellar or other holes will be paid for as per section 2.02.
Type "C-5" Catch Basins shall conform to Std. Drawing #228 except that the open throats adjacent to the inlet grate shall be omitted.

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Revised for Drainage 1/30/48.

PLAN	BY	DATE	CHECKED BY	DATE
Surveyed				
Plotted				
Traced				
Designed	Redding	2-47		
New Const. noted				

NOTE BOOK
NO.

BOSTON BLUE PRINT ARKWRIGHT TRACING CLOTH

185 90

147 03

6

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE & NEW HAVEN		1947		7	73

WILBUR CROSS PARKWAY
PROJ. 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

PROFILE			
NOTE BOOK			
NO.			
SURVEYED			
PLOTTED			
GRADES PLOTTED			
GRADES CHECKED			
B. Ms. NOTED			
	BY	DATE	

185-90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE AND NEW HAVEN		1947		8	73

WILBUR CROSS PARKWAY
PROJ. 185-90

CENTER PARK TRANSITION					
STA.	℄ to Curb Face	STA.	℄ to Curb Face	STA.	℄ to Curb Face
696	8.00	+50	14.23	705	16.90
+50	8.66	+74.99	14.58	+50	19.19
+74.99	8.99	701	14.92	706	19.44
697	9.34	+50	15.57	+50	19.64
+50	10.04	702	16.20	707	19.80
698	10.74	+50	16.76	+50	19.91
+50	11.44	703	17.27	708	19.98
699	12.14	+50	17.75	+49.98	20.00
+50	12.84	704	18.18		
700	13.54	+50	18.56		

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PLAN	Surveyed	BY	DATE
NOTE BOOK	Plotted		
NO.	Line plotted		
	Traced		
	Structures noted		

185-90

147 03

3 8

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE		1947		9	73

WILBUR CROSS PARKWAY
TUNNEL 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

PROFILE
SURVEYED
PLOTTED
GRADES PLOTTED
GRADES CHECKED
B. Ms. NOTED
NOTE BOOK NO.

PLAN
Surveyed / Plotted / Line plotted / Traced / Structures noted.
NOTE BOOK NO.
BY | DATE | CHECKED BY | DATE

185-90
147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE & NEW HAVEN		1947		11	73

WILBUR CROSS PARKWAY
TUNNELL 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

PROFILE	BY	DATE
NOTE BOOK NO.		
Surveyed		
Plotted		
Grades Plotted		
Grades Checked		
B. Ms. Noted		

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN AND HAMDEN		1947		12	73

WILBUR CROSS PARKWAY
PROJ. 185-90

CENTER PARK TRANSITION					
STA.	℄ to Curb Face	STA.	℄ to Curb Face	STA.	℄ to Curb Face
720+75	20.00	726	17.51	+50	12.84
721	19.99	+50	17.01	731	12.41
+50	19.95	+6247	16.88	+50	12.02
722	19.86	727	16.48	732	11.69
+50	19.72	+50	15.95	+50	11.39
723	19.54	728	15.42	733	11.14
+50	19.32	+50	14.89	+50	10.94
724	19.05	729	14.36	734	10.78
+50	18.73	+50	13.83	+50	10.67
725	18.37	+6247	13.70	735	10.60
+50	17.96	730	13.31	+49.95	10.58

CURVE DATA
ALONG FACE OF CURBS
Δ = 0°-36'-28.58"
D = 0°-06'-12.54"
R = 55367.33'
T = 293.75'
L = 587.475'

CURVE DATA
ALONG FACE OF CURBS
Δ = 0°-36'-28.58"
D = 0°-06'-12.54"
R = 55367.33'
T = 293.75'
L = 587.475'

P.T. Face of Curbs
Sta. 735+49.95

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN & HAMDEN		1947		13	73

WILBUR CROSS PARKWAY
PROJ. 185-90

PROFILE		BY	DATE
NOTE BOOK	SURVEYED		
NO.	PLOTTED		
	GRADES PLOTTED		
	GRADES CHECKED		
	B. Ms. NOTED		

Retraced W.S. Bissell July 1948

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

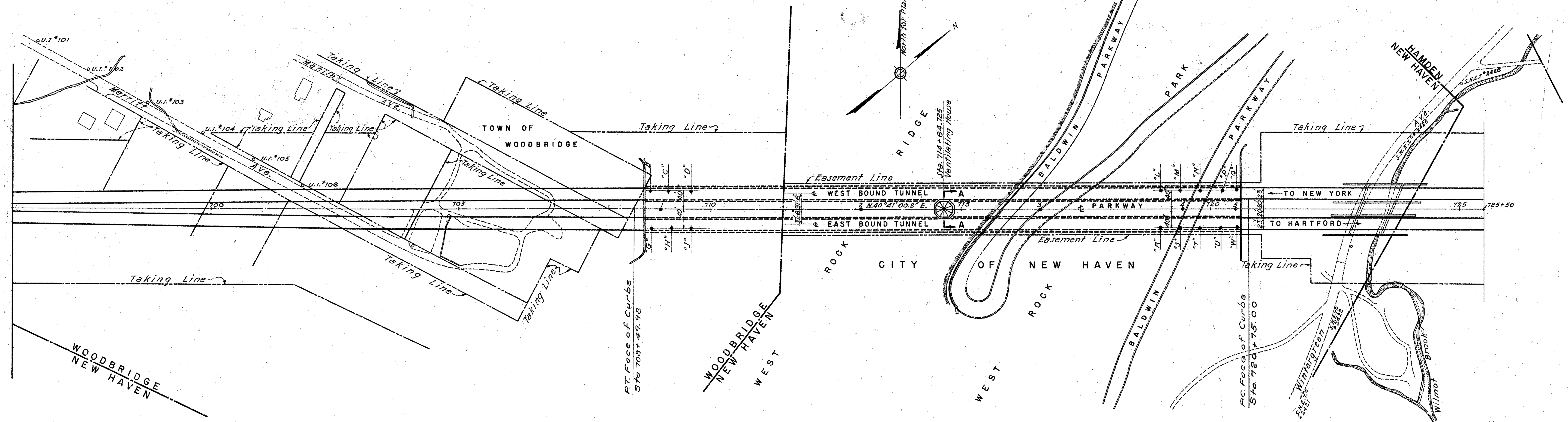
185-90

147 03

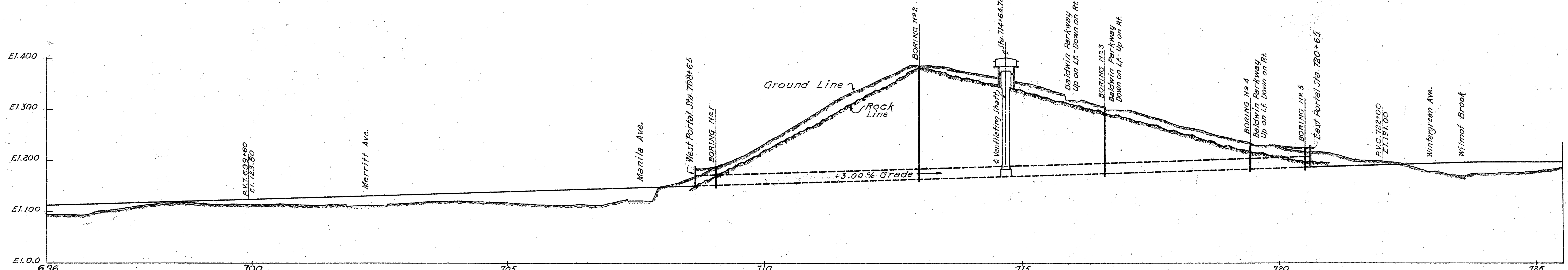
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		14	73

PROJECT NO. 185-90

NO REVISIONS SUBMITTED FOR THIS SHEET



PLAN
~Scale 1"=100'~



ELEVATION ALONG ℄ PARKWAY

Scale { HOR. 1"=100' / VERT. 1"=100' }

NOTE:
For stationing and details of Borings "B", "C", "D" etc. and 1, 2, 3, 4 & 5, see Sheet No. 3
For Section "A-A" see Sheet No. 31

~GENERAL NOTES~

This Project to be constructed under the Standard Specifications of the State of Connecticut, Form #807 dated March 1947, and special provisions.

Dimensions of reinforcement are to center line of reinforcement bars unless otherwise noted.

All bars are deformed bars, with splices lapped 45 diameters and placed in contact and wired together, unless otherwise noted.

Where Bagged Sceened Gravel is specified the contractor has the option of furnishing Screened Gravel or Crushed Stone. The gradation shall be nominal 3/8" in either case

Adequate keys shall be provided at all construction joints.

Construction joints other than those shown will not be permitted without written approval of the Engineer.

For definition of "A" Line and "B" Line see Supplementary Specifications, "Special Provisions."

Item of Joint Filler For Bridges shall include that required for outside edges of pavement. All Joint Filler shall be premoulded bituminous type of the sizes specified

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
GENERAL PLAN

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE As Noted
MADE BY A.H.R.
CHECKED BY G.V.
APPROVED ______ DATE ______

PROJECT NO. ______
TUNNEL SHEET NO. 1 OF 44

185-901

147 03

14

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		15	73

PROJECT NO. 185 – 90

LIST OF DRAWINGS

SHEET NO.	TITLE
	GENERAL
1	GENERAL PLAN
2	LIST OF DRAWINGS AND SUMMARY OF QUANTITIES
3	BORINGS
	ARCHITECTURAL
4	WEST PORTAL - PLAN AND ELEVATIONS
5	EAST PORTAL - PLAN AND ELEVATIONS
6	ARCHITECTURAL DETAILS - WEST PORTAL ARCH
7	ARCHITECTURAL DETAILS - EAST PORTAL ARCH
8	ARCHITECTURAL DETAILS - TURRETS
9	ARCHITECTURAL DETAILS - TURRETS
10	MISCELLANEOUS STONE DETAILS
11	TILE AND GRILLE DETAILS - TUNNEL WALLS
12	CONTROL ROOM DETAILS
13	VENTILATING HOUSE
	GRADING
14	WEST PORTAL GRADING PLAN I
15	WEST PORTAL GRADING PLAN II
16	EAST PORTAL GRADING PLAN I
17	EAST PORTAL GRADING PLAN II
18	GRADING CROSS SECTIONS
	STRUCTURAL
19	WEST AND EAST PORTALS - PROFILES
20	WEST PORTAL
21	WEST PORTAL - SECTIONS

SHEET NO.	TITLE
	STRUCTURAL - CONTINUED
22	WEST PORTAL - SECTIONS
23	WEST PORTAL - SECTIONS AND PORTAL DRAINAGE
24	EAST PORTAL
25	EAST PORTAL - SECTIONS
26	EAST PORTAL - SECTIONS
27	EAST PORTAL - SECTIONS, DETAILS AND PORTAL DRAINAGE
28	CONCRETE DETAILS AT TURRETS
29	TYPICAL TUNNEL SECTION TYPE I
30	SPECIAL TUNNEL SECTIONS TYPE II & TYPE III
31	VENTILATING SHAFT AND CONTROL ROOM
32	VENTILATING HOUSE - FRAMING PLAN
	MECHANICAL
33	CONTROL ROOM
34	DRAINAGE
35	VENTILATION
36	DETAILS OF FAN
	ELECTRICAL
37	WIRING DIAGRAM
38	PULL BOX DETAILS
39	CONDUIT PLAN - TUNNEL
40	CONDUIT DETAILS
41	LIGHTING
42	FEEDER CABLE PLAN
43	CONTROL ROOM CONDUIT PLAN
44	GENERAL ARRANGEMENT PLAN - CONTROL ROOM

SUMMARY OF QUANTITIES

ITEM No.	DESCRIPTION	UNIT	QUANTITY
130	PORTLAND CEMENT	bbl.	21,750
141	JOINT FILLER FOR BRIDGES	s.f.	700
153	DEFORMED STEEL BARS	lb.	673,000
163	MEMBRANE WATERPROOFING	s.y.	1,500
164	METAL FLASHING	lb.	1,000
179	BROKEN STONE FOR BASE	ton	2,860
188	TRANSVERSE EXPANSION JOINT	l.f.	260
191	MAT REINFORCEMENT FOR CONCRETE PAVEMENT	s.y.	6,200
192	STEEL TIE BARS	lb.	1,600
195	CONCRETE FOR PAVEMENT	c.y.	1,380
245	CONCRETE GUTTER	s.y.	350
300 A	PORTAL EXCAVATION	c.y.	29,150
300 B	BAGGED SCREENED GRAVEL	c.y.	530
301	TUNNEL EXCAVATION	c.y.	51,300
302	SHAFT EXCAVATION	c.y.	1,560
303	ROCK EXCAVATION FOR ENLARGEMENTS OF TUNNEL AND VENTILATING SHAFT	c.y.	150
304	PROTECTIVE COATINGS OF CEMENT MORTAR	c.y.	50
305	STEEL ARCH RIBS, SILLS AND COLUMNS	lbs.	365,000
306	PERMANENT TIMBER LAGGING	m.f.b.m.	20
307	STONE PACKING	c.y.	300
308	DRILLING HOLES IN ROCK	l.f.	1,500

ITEM No.	DESCRIPTION	UNIT	QUANTITY
309	GROUT	c.y.	100
310	SAND FOR GROUT	c.y.	100
311	STEEL PIPES FOR GROUTING AND PANNING	l.f.	1,000
312	SHEET STEEL FOR PANNING	lbs.	1,000
313	DOWEL RODS	l.f.	500
314	CONCRETE LINING OF TUNNEL	c.y.	8,820
315	CONCRETE IN PORTALS	c.y.	2,950
316	CONCRETE LINING OF VENTILATING SHAFT	c.y.	820
317	WIRE MESH	lbs.	7,500
318	TUNNEL DRAINAGE SYSTEM	l.s.	
319 A	PORTAL DRAINAGE SYSTEM, 6" V.C. PIPE	l.f.	430
319 B	PORTAL DRAINAGE SYSTEM, 6" C.I. PIPE	l.f.	120
320	GLAZED TILE FACING	s.y.	4,500
321	INTERCEPTING DITCH, STONE MASONRY PAVED (ON HILLSIDE)	s.y.	510
322	BALDWIN PARKWAY DRAINAGE SYSTEM	l.s.	
323	RANDOM ASHLAR STONE MASONRY	c.y.	280
324	DIMENSION STONE MASONRY	c.y.	250
325	CONCRETE SAFETY CURB	c.y.	1,600
326	VENTILATING HOUSE	l.s.	
327	MISCELLANEOUS TUNNEL WORK	l.s.	
328	VENTILATING SYSTEM	l.s.	
329	TUNNEL ELECTRICAL SYSTEM	l.s.	

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
LIST OF DRAWINGS AND SUMMARY OF QUANTITIES

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE ______
MADE BY A.H.R.
CHECKED BY G.V.
APPROVED ______ DATE ______

PROJECT NO. ______
TUNNEL SHEET NO. 2 OF 44

185 - 90

147 03

15

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CON N.	NEW HAVEN		1947		16	73

PROJECT NO. 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
BORINGS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1" = 10' Vert.
MADE BY R.C.
CHECKED BY A.T.W.
APPROVED ______ DATE ______

PROJECT NO.
TUNNEL SHEET NO. 3 OF 44

185 90

147 03

16

FED. ROAD	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		17	73

PROJECT NO. 185-90

PLAN.

DEVELOPED REAR ELEVATION AT TOP OF WALL

ELEVATION.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL

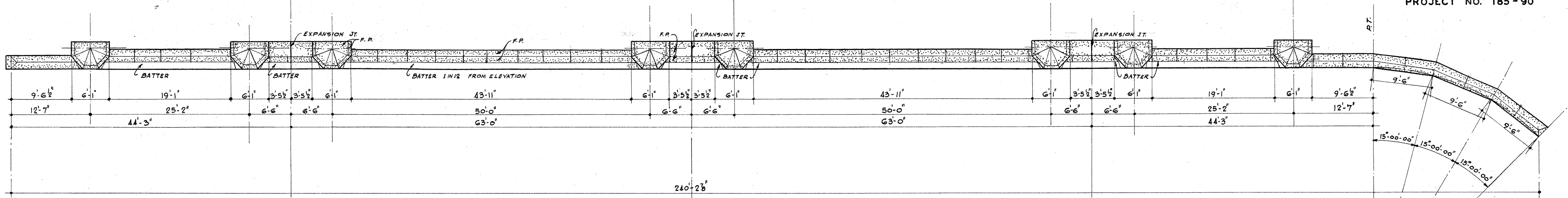
PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS — NEW YORK, N.Y.

SCALE 1/8" = 1'-0"
MADE BY CARVEN
CHECKED BY C.C.C.-L.J.H.
APPROVED
DATE 11/7/47
PROJECT NO.
TUNNEL SHEET NO. 4 OF 44

185 90
147 03
17

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN	NEW HAVEN		1947		18	73

PROJECT NO. 185-90



PLAN.

REAR ELEVATION AT TOP OF WALL.

ELEVATION.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
EAST PORTAL

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/8" = 1'-0"
MADE BY CARVEN
CHECKED BY G.C.G. - L.J.H.
APPROVED
DATE 11/7/47

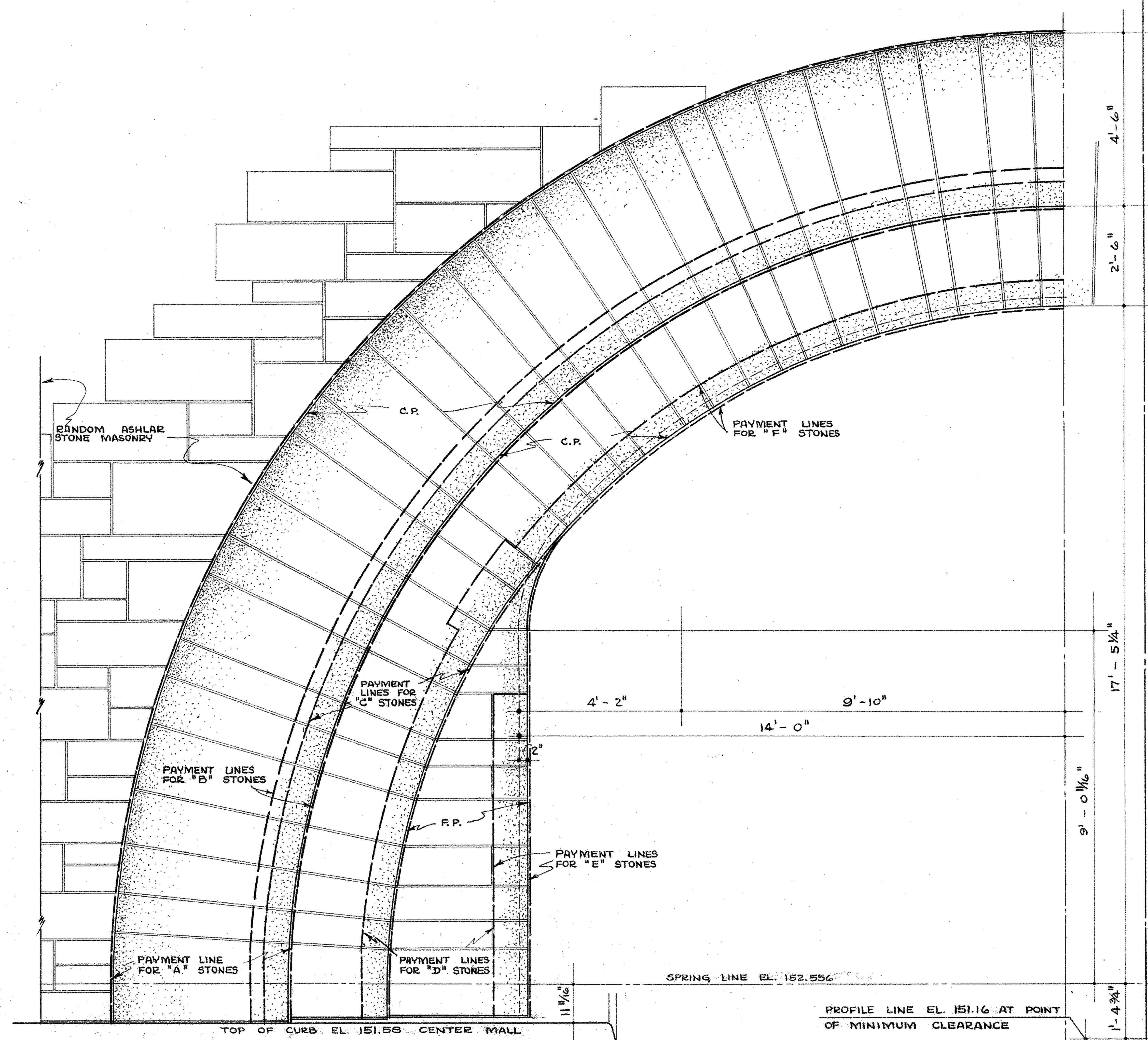
PROJECT NO.
TUNNEL SHEET NO. 5 OF 44

185 90

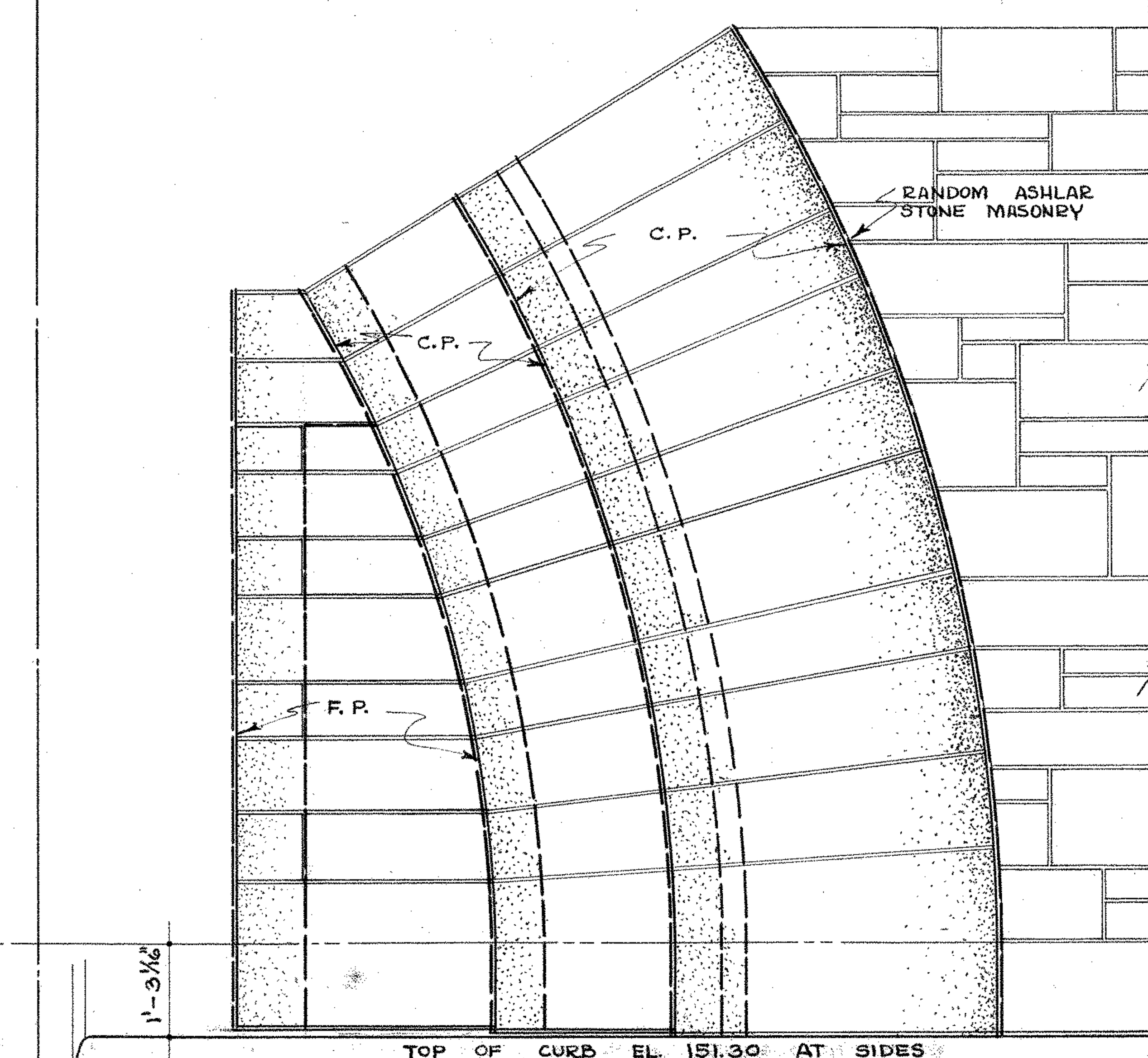
147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		19	73

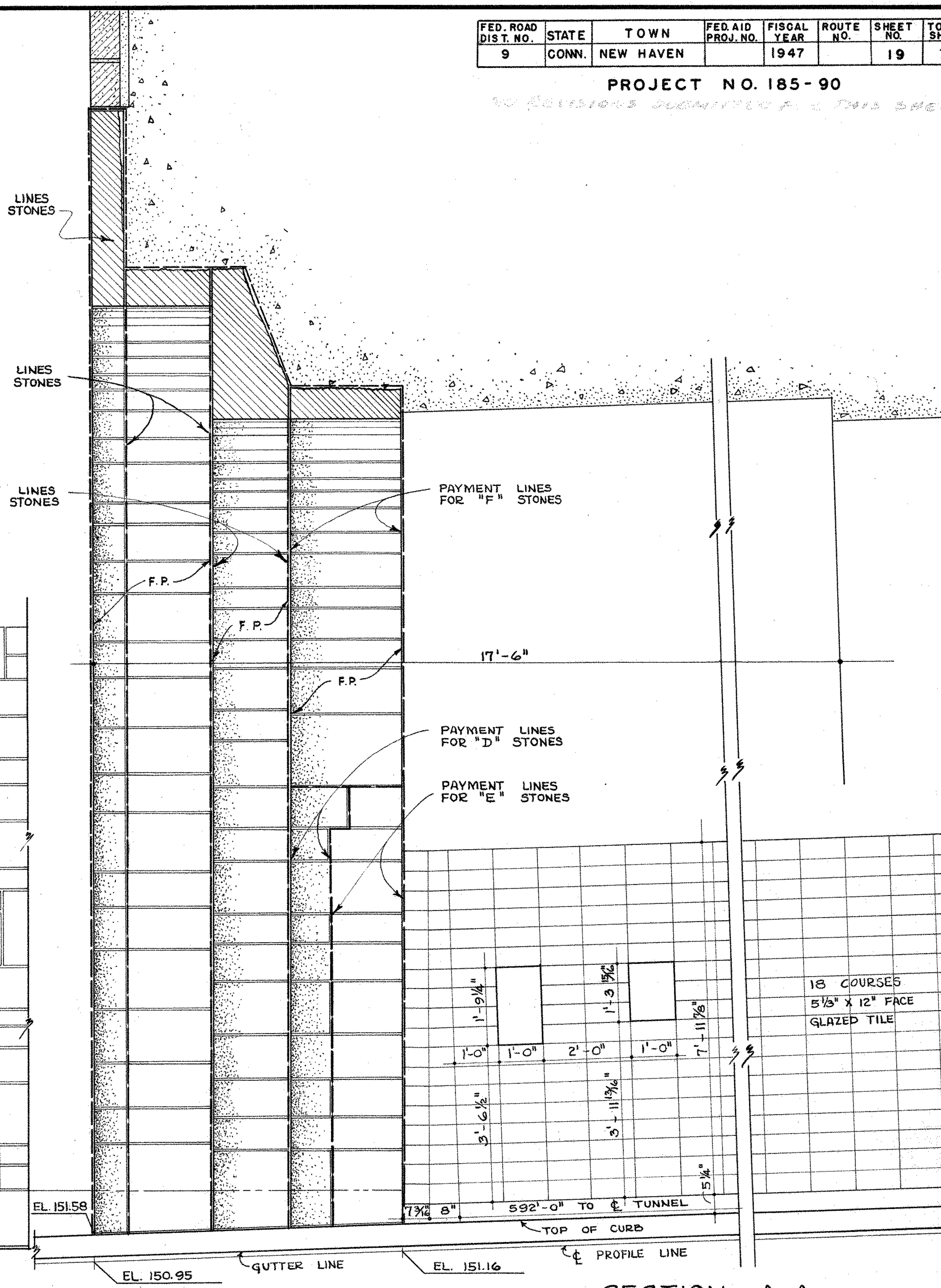
PROJECT NO. 185-90



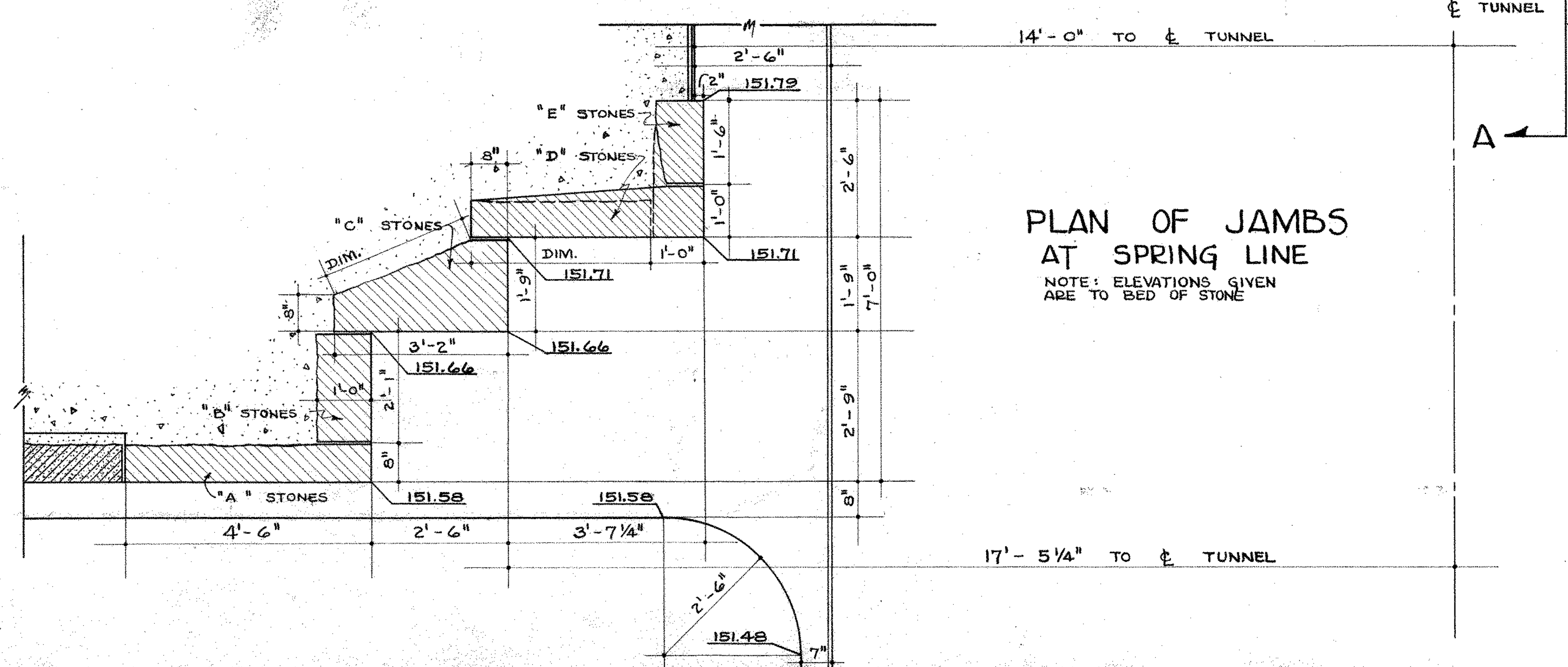
½ ELEVATION AT CENTER MALL



PART ELEVATION AT SIDES

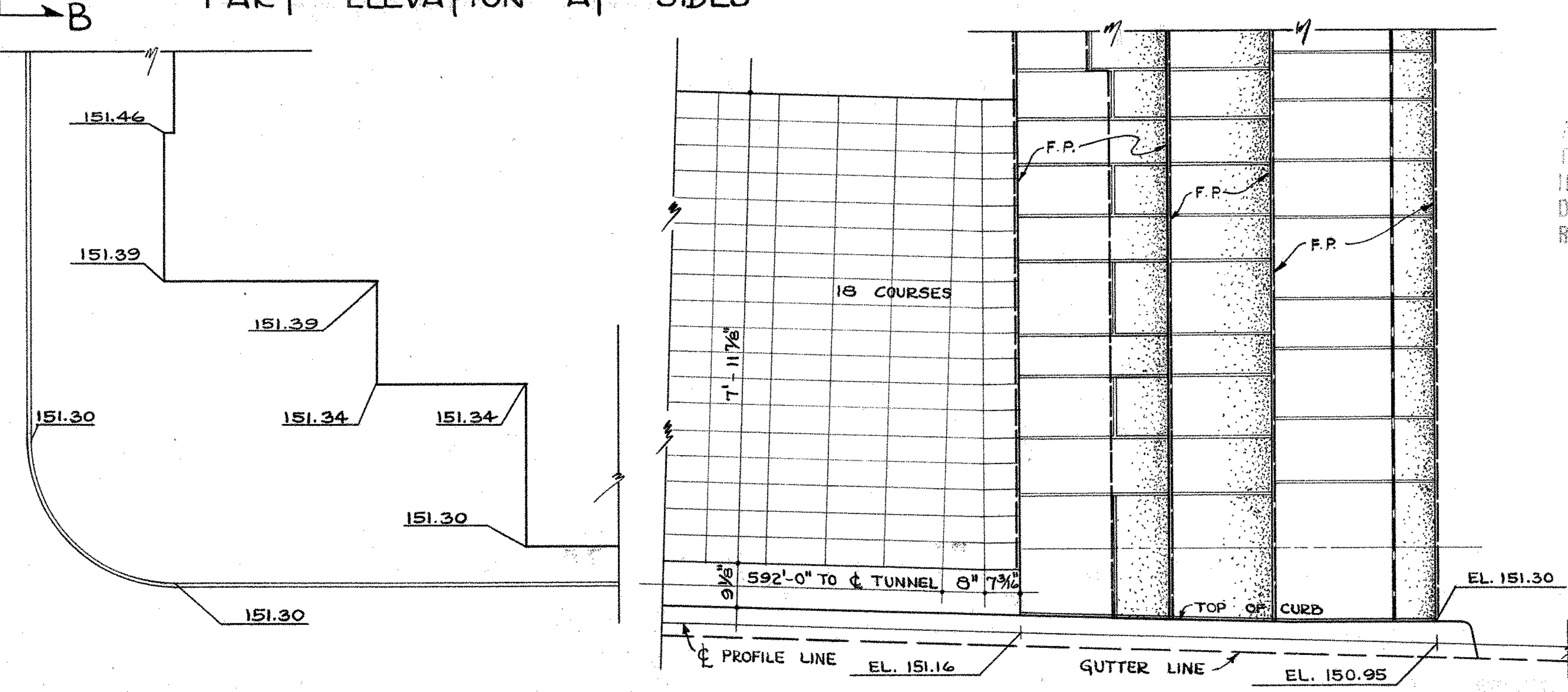


SECTION A-A



PLAN OF JAMBS AT SPRING LINE

NOTE: ELEVATIONS GIVEN ARE TO BED OF STONE



SECTION B B

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
ARCHITECTURAL DETAILS
WEST PORTAL ARCH

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE ½" = 1'-0"
MADE BY C.C.C. - H.O.
CHECKED BY L.J.H. - C.C.C.
APPROVED
DATE 11/7/47

PROJECT NO.

TUNNEL SHEET NO. 6 OF 44

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		20	73

PROJECT NO. 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
ARCHITECTURAL DETAILS
EAST PORTAL ARCH

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE ½" = 1'-0"
MADE BY C.C.C. - H.O.
CHECKED BY L.J.H. - C.C.C.
APPROVED
DATE 11/7/47

PROJECT NO.
TUNNEL SHEET NO. 7 OF 44

185 90

147 03

23

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		21	73

PROJECT NO. 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

NOTE: FOR DETAILS OF TYPE A AND TYPE B QUOINS SEE DWG Nº 10

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

ARCHITECTURAL DETAILS
TURRETS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE ½" = 1'-0"
MADE BY C.C.C. - S.J.I.
CHECKED BY C.C.C. - L.J.H.
APPROVED
DATE 11/7/47

PROJECT NO.

TUNNEL SHEET NO. 8 OF 44

185-90

147-03

21

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		22	73

PROJECT NO. 185-90

PAYMENT LINES FOR DIMENSION MASONRY COPING STONES & TURRETS.

NOTE -
1- VOLUME OF STONE FOR COPING SHALL BE DETERMINED BY CROSS SECTION AREA TIMES LINEAL LENGTH MEASURED ALONG CENTER LINE.

2- FOR DETAILS OF TYPE A & TYPE B QUOINS SEE SHEET Nº 10.

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

ARCHITECTURAL DETAILS
TURRETS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

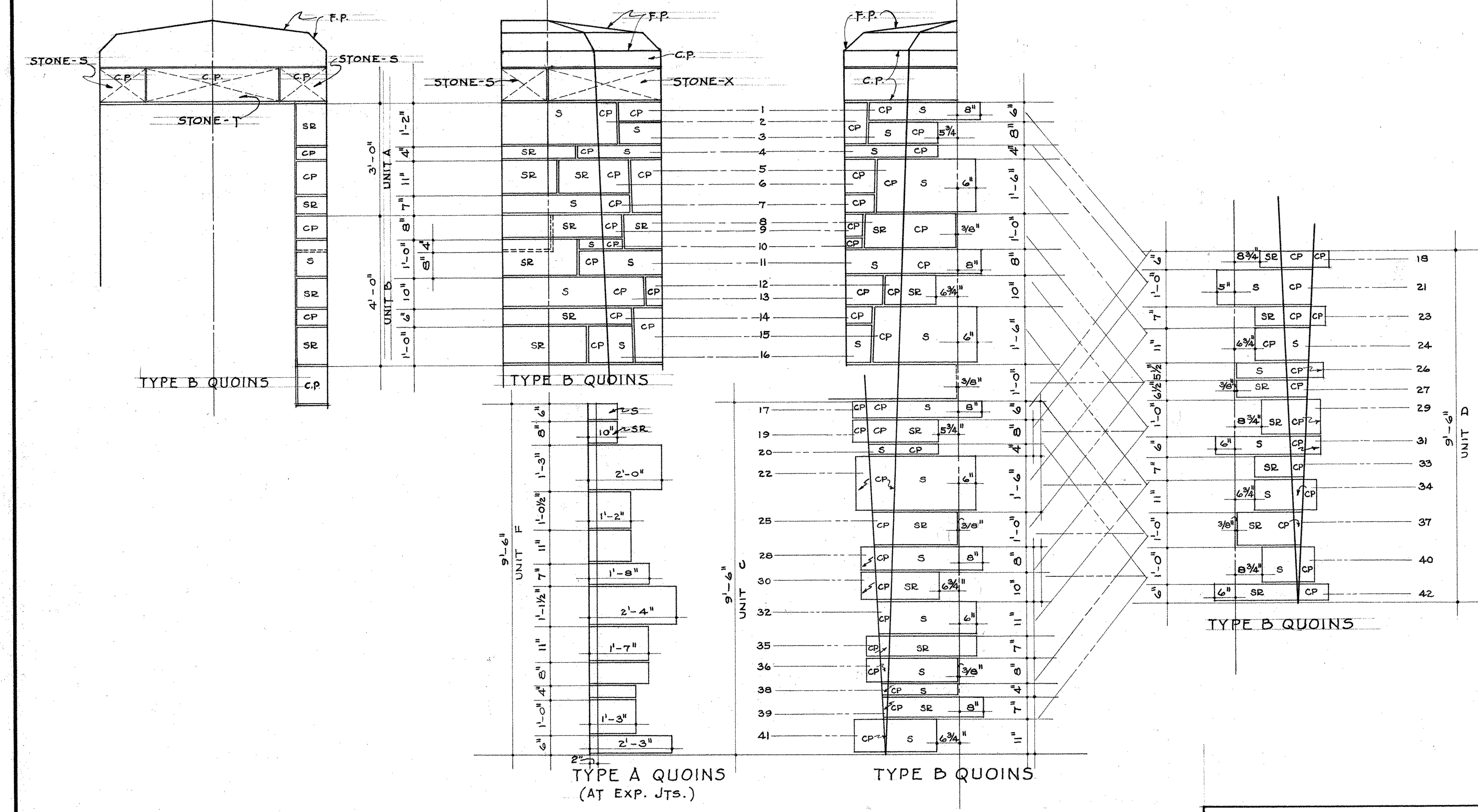
SCALE 1/2" = 1'-0"
MADE BY C.C.C.-L.J.H.
CHECKED BY C.C.C.-L.J.H.
APPROVED
DATE 11/7/47
PROJECT NO.
TUNNEL SHEET NO. 9 OF 44

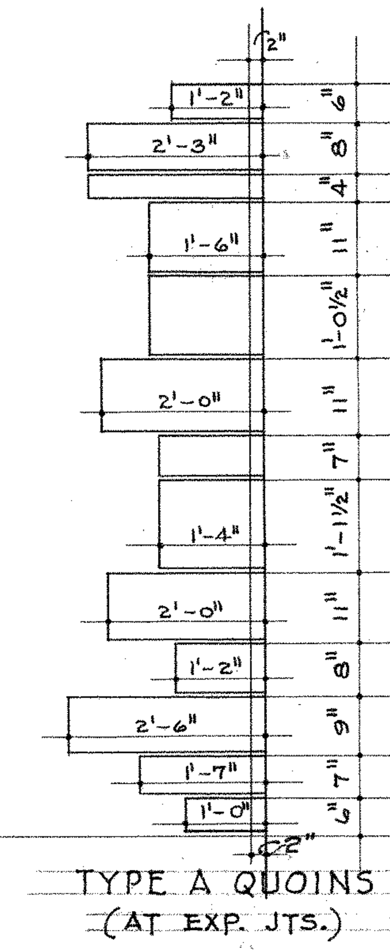
185 90

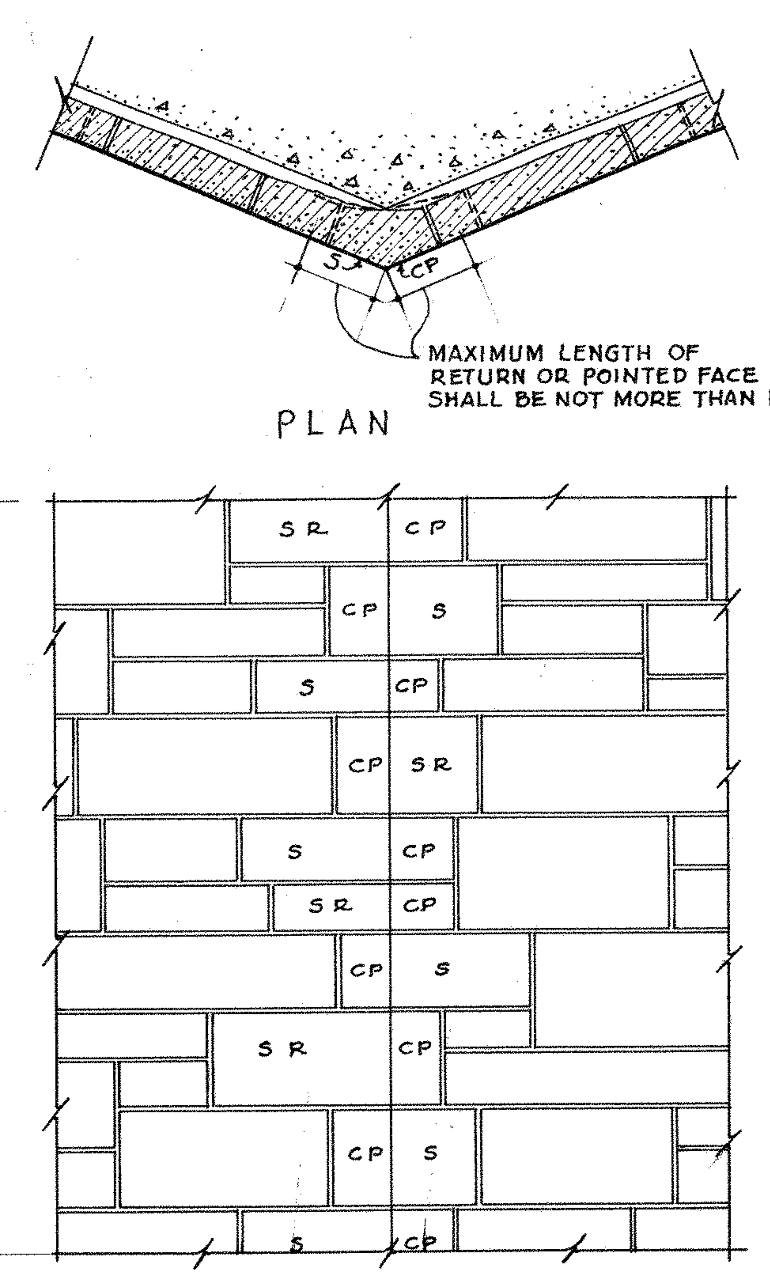
147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		23	73

PROJECT NO. 185-90



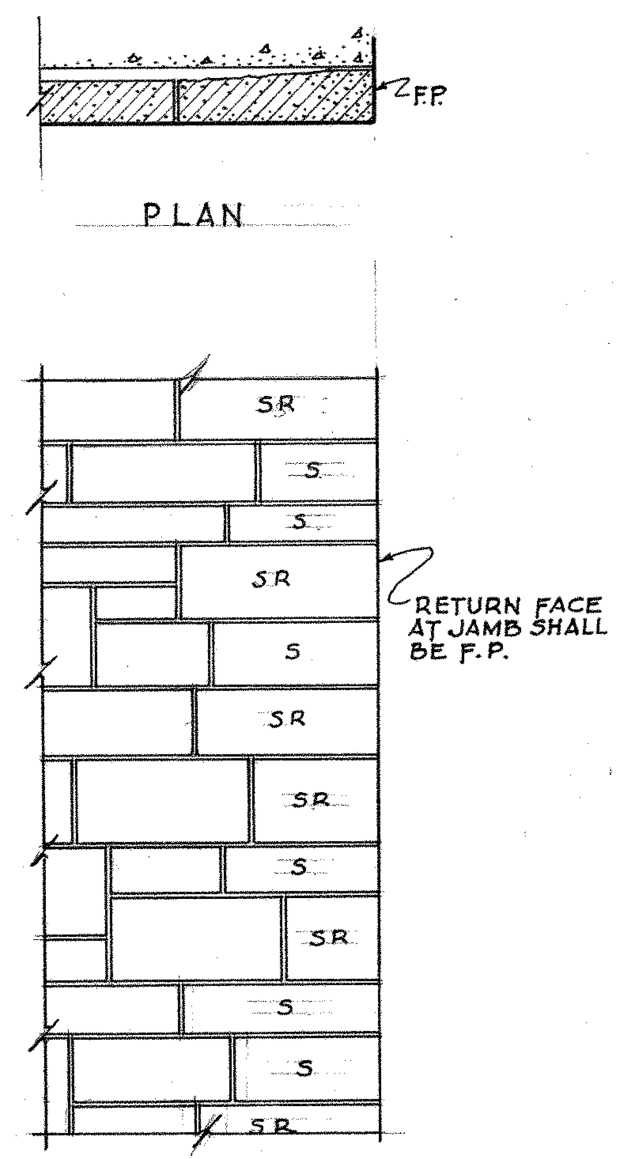




TYPICAL ELEVATION

TYPE A QUOINS

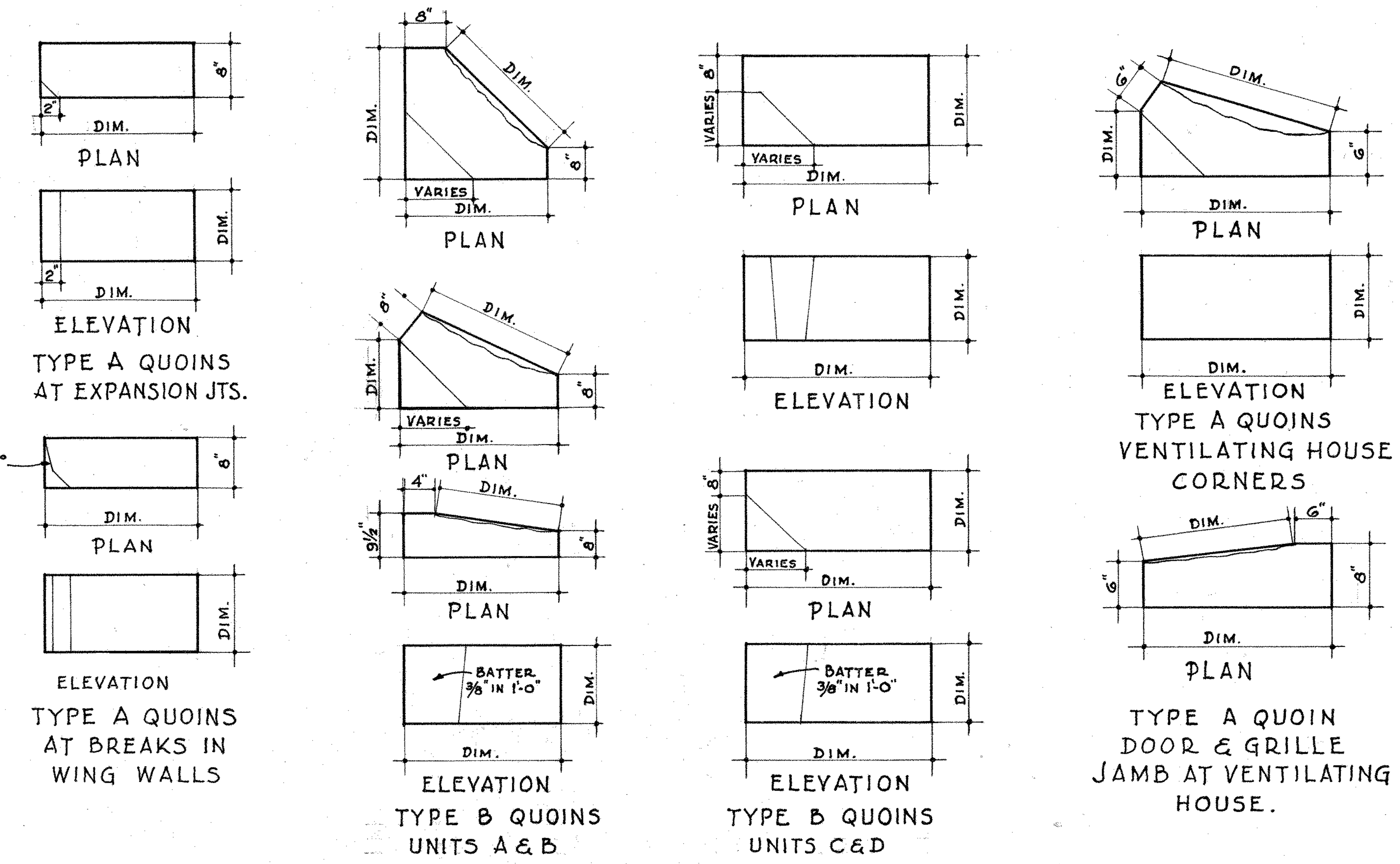
VENTILATING HOUSE CORNERS.



TYPICAL ELEVATION

TYPE A QUOINS

DOOR AND GRILLE JAMBS AT VENTILATING HOUSE.



PAYMENT LINES FOR TYPE A&B QUOINS.

(NO SCALE)

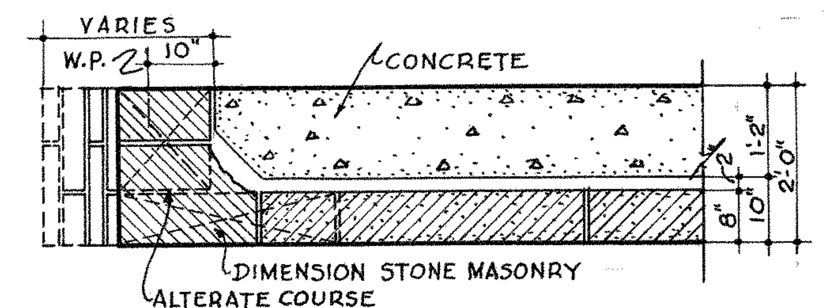
LEGEND

INDICATES CONCRETE IN SECTION	
INDICATES DIMENSION STONE MASONRY IN PLAN & SECTION	
INDICATES DIMENSION STONE MASONRY IN ELEVATION.	
INDICATES RANDOM ASHLAR STONE MASONRY IN PLAN & SECTION	
INDICATES RANDOM ASHLAR STONE MASONRY IN ELEVATION	
INDICATES METAL IN SECTION	
F.P INDICATES FINE POINT FINISH	C.P INDICATES COARSE POINT FINISH.
S INDICATES SEAM FACE	S.R. INDICATES SPLIT OR ROCK FACE

GENERAL NOTES

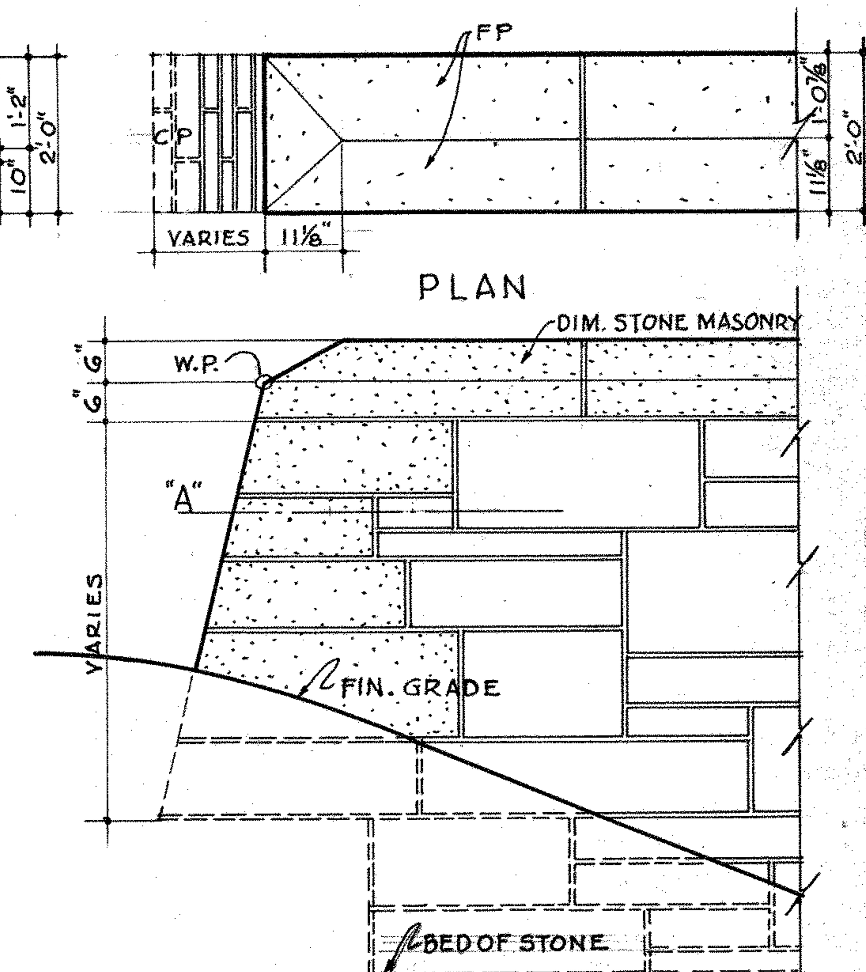
1. FOR METHODS OF ANCHORING MASONRY SEE STRUCTURAL DRAWINGS.
2. ALL DIMENSION STONE MASONRY & RANDOM ASHLAR STONE MASONRY SHALL BE CARRIED DOWN TO TOP OF CONCRETE ELEVATIONS SHOWN OR NOTED (SEE STRUCTURAL DWG'S)
3. ALL COPING AND CAPSTONES SHALL BE DOWELLED TO WALLS AND TURRETS WITH 1/2"×4" LONG BRONZE DOWELS - NOT LESS THAN TWO TO EACH STONE
4. DIMENSION MASONRY JOINTS SHALL BE 1/2" RANDOM ASHLAR STONE MASONRY JOINTS SHALL BE 3/4"
5. RANDOM ASHLAR STONE MASONRY JOINTS SHALL BE RAKED TO A DEPTH OF 1/2" TO 3/4"
6. ALL STONE SURFACES IN CONTACT WITH SLIDING OR EXPANSION JOINTS SHALL BE FINE POINTED
7. POINTING OF DIMENSION STONE MASONRY SHALL BE AS SHOWN ON DETAILS AND UNLESS OTHERWISE NOTED ALL WASHES ON COPINGS AND CAPSTONES AND THE SOFFITS OF ALL ARCH RING STONES SHALL BE FINE POINT. ALL OTHER EXPOSED SURFACES SHALL BE COARSE POINT.
8. TYPE 'A' AND TYPE 'B' QUOINS WILL BE PAID FOR AS DIMENSION STONE MASONRY BUT SHALL BE OF THE SAME SOURCES AND IN THE SAME PROPORTION AS THE RANDOM ASHLAR STONE MASONRY RETURN FACES SHALL BE POINTED AS DETAILED OR CALLED FOR.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

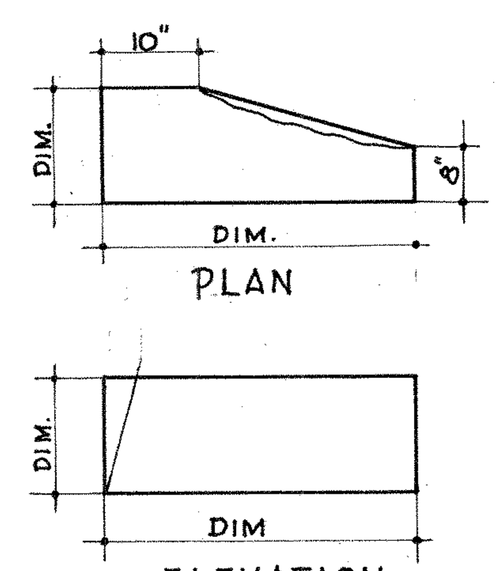


PLAN AT "A"

DETAILS OF END PIERS AT WING WALLS.



ELEVATION



PAYMENT LINES

DIMENSION MASONRY

QUOINS AT END PIERS.

(NO SCALE.)

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

MISCELLANEOUS STONE DETAILS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/4" = 1'-0"	PROJECT NO.
MADE BY C.G.G. - L.J.H.	
CHECKED BY L.J.H. - C.G.G.	TUNNEL SHEET NO.
APPROVED	DATE 11/7/47 10 OF 44

185 - 90 1

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		24	73

PROJECT NO. 185 - 90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
TILE & GRILLE DETAILS
TUNNEL WALLS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE AS NOTED
MADE BY C.C.C. - P.S.H.
CHECKED BY C.C.C. - L.J.H.
APPROVED
DATE 11/7/47

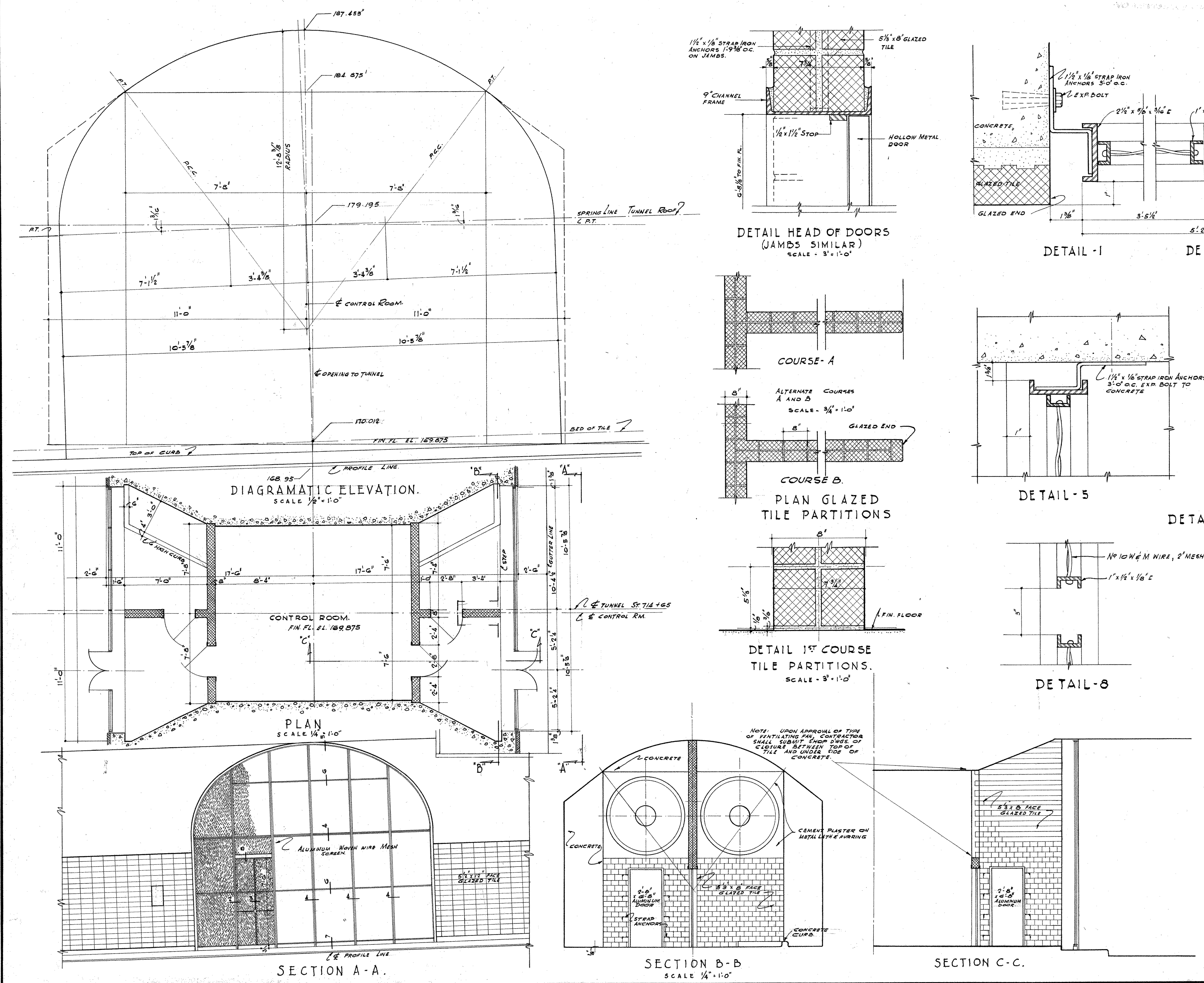
PROJECT NO.
TUNNEL SHEET NO. 11 OF 44

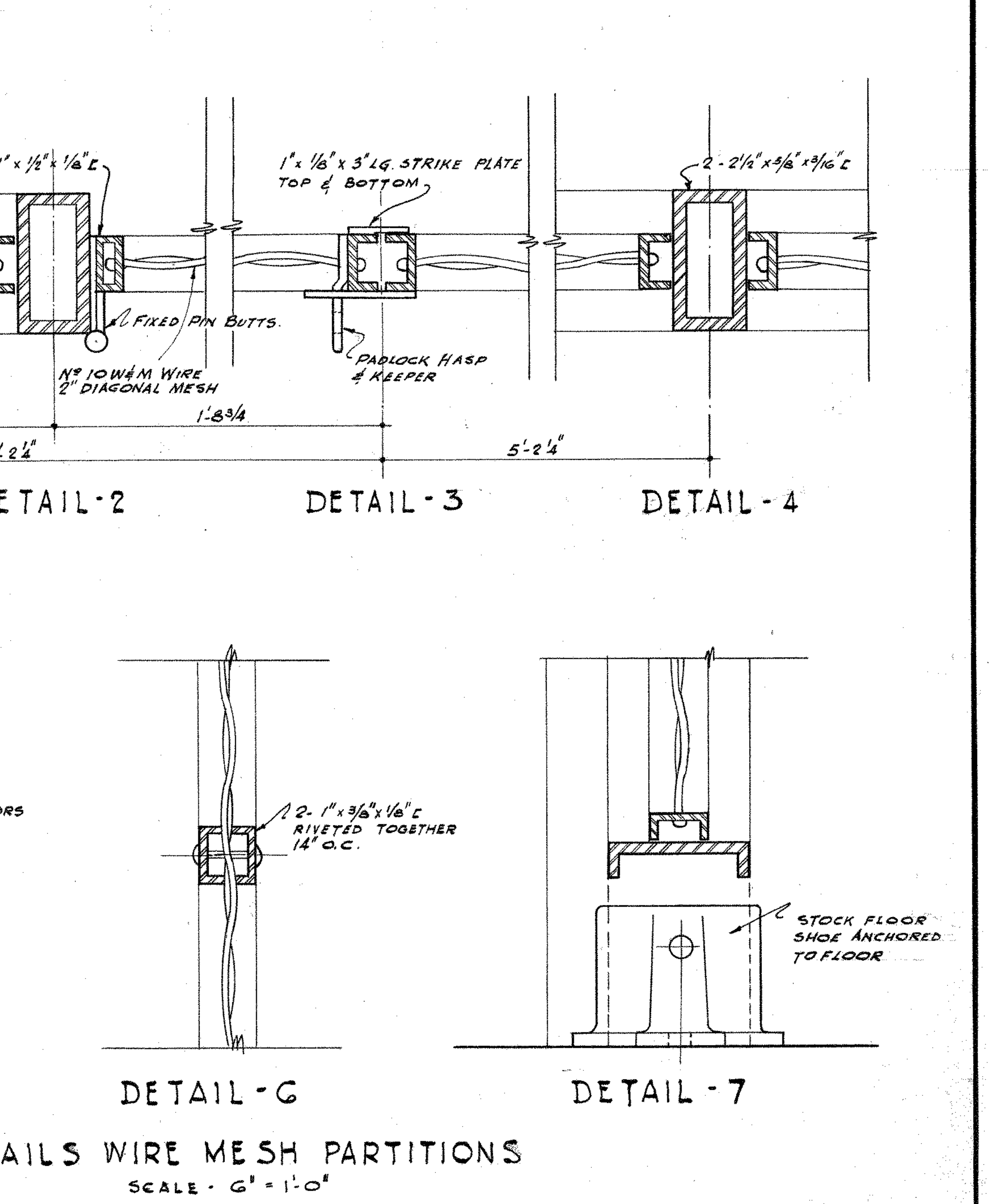
185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		25	73

PROJECT NO. 185 - 90





THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

CONTROL ROOM DETAILS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE AS NOTED
MADE BY C.G.C. - P.S.H.
CHECKED BY C.G.C. - L.J.H.
APPROVED
DATE 11/7/47

PROJECT NO.
TUNNEL SHEET NO. 12 OF 44

185 90

147 03

25

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		26	73

PROJECT NO. 185 - 90

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

VENTILATING HOUSE

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS — NEW YORK, N.Y.

SCALE: AS NOTED
MADE BY: C.C.C. - S.J.I.
CHECKED BY: C.C.C. - L.J.H.
APPROVED
DATE: 11/7/47
PROJECT NO.
TUNNEL SHEET NO. 13 OF 44

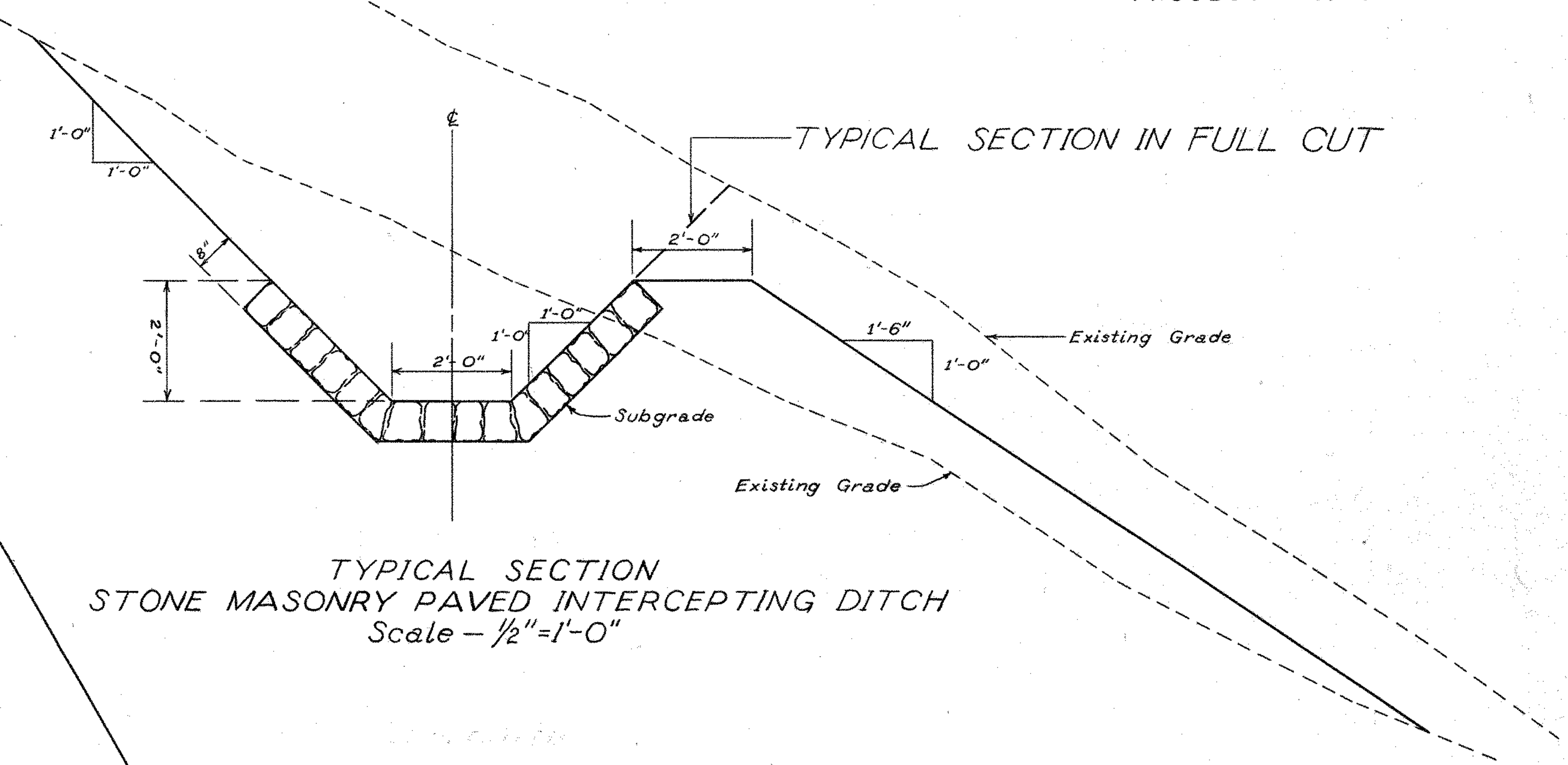
THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

185 90

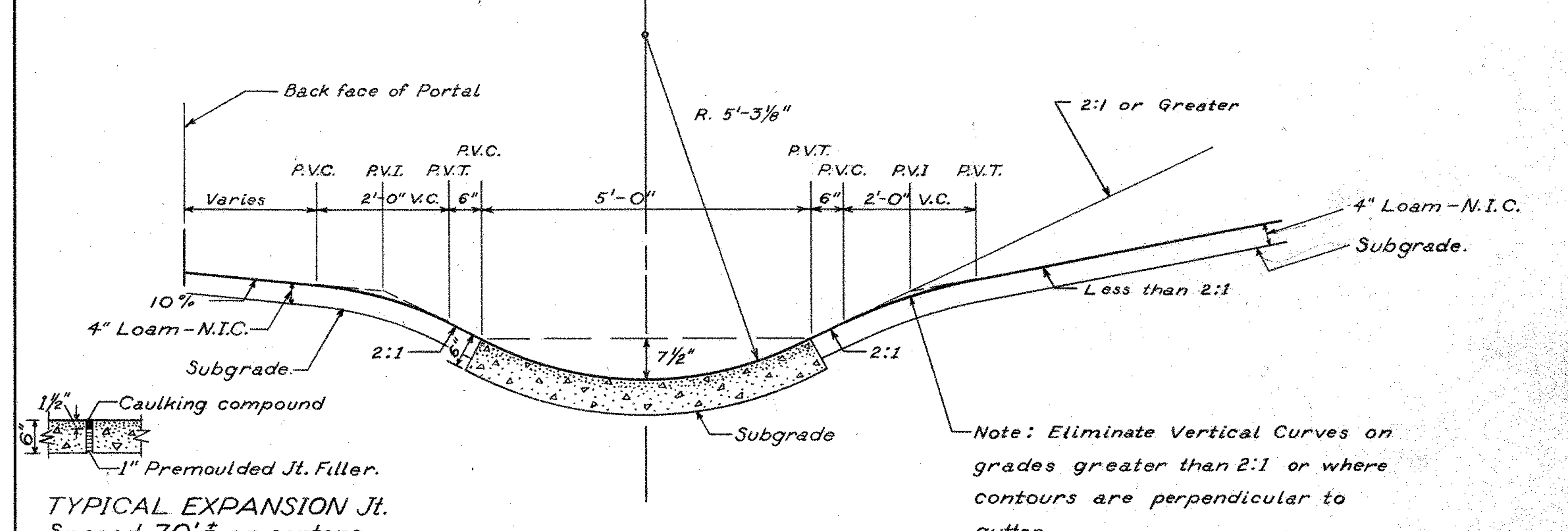
147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		27	73

PROJECT NO. 185 - 90



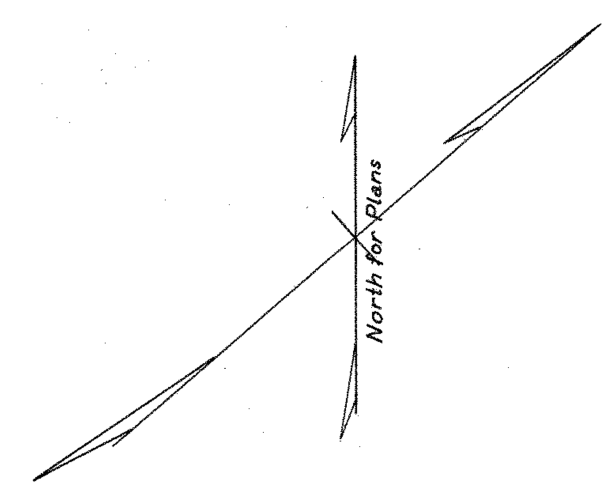
TYPICAL SECTION
STONE MASONRY PAVED INTERCEPTING DITCH
Scale - ½" = 1'-0"



TYPICAL EXPANSION Jt.
Spaced 70' ± on centers.

TYPICAL SECTION
CONCRETE PAVED GUTTER
TOP OF EAST & WEST PORTALS
Scale - ½" = 1'-0"

Note:
Parkway gutters approaching Portal see Gutter Detail Sheet No. 15
Rock Gutters are shown in section, Sheet No. 18
For construction of Parkway approach paving see Sheet No. 18
See General Notes Sheet No. 16



THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL
GRADING PLAN I

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/8" = 1'-0"
MADE BY R.T.
CHECKED BY J.W.T.
APPROVED DATE

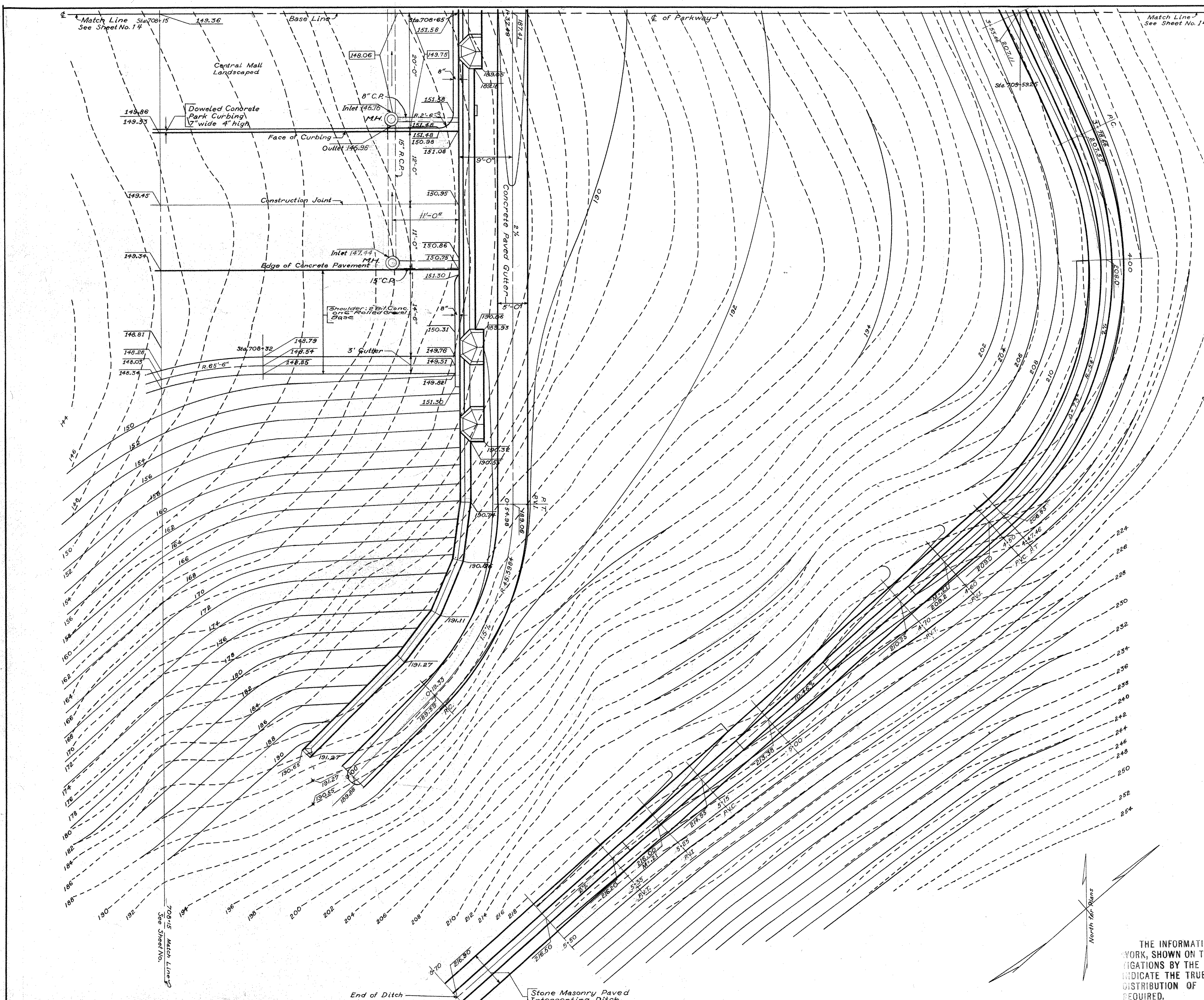
PROJECT NO.
TUNNEL SHEET NO. 14 of 44

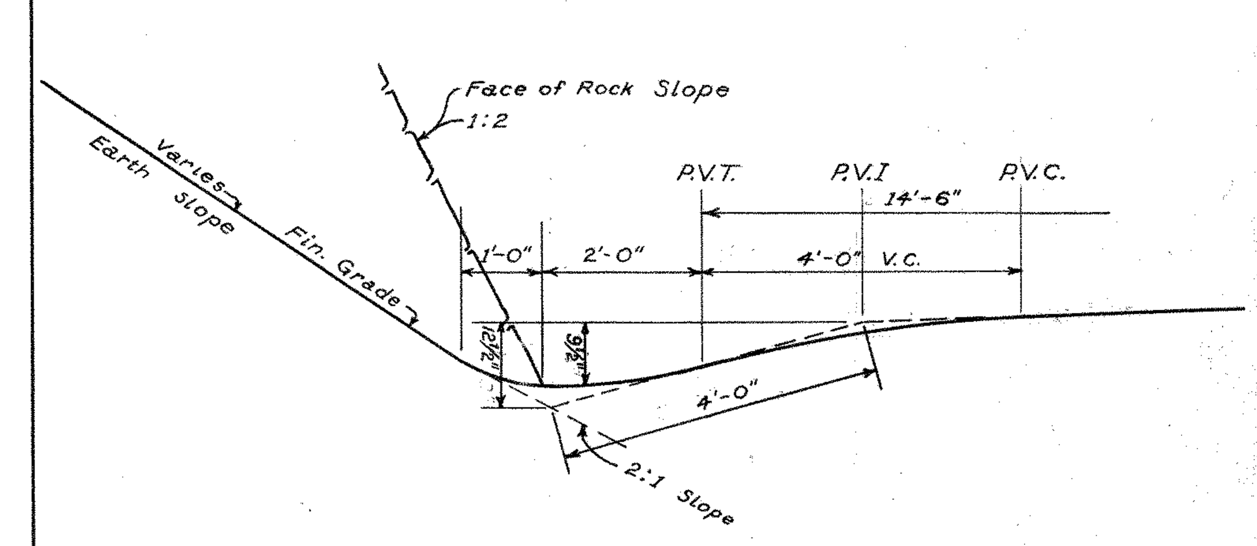
185 901

147 03

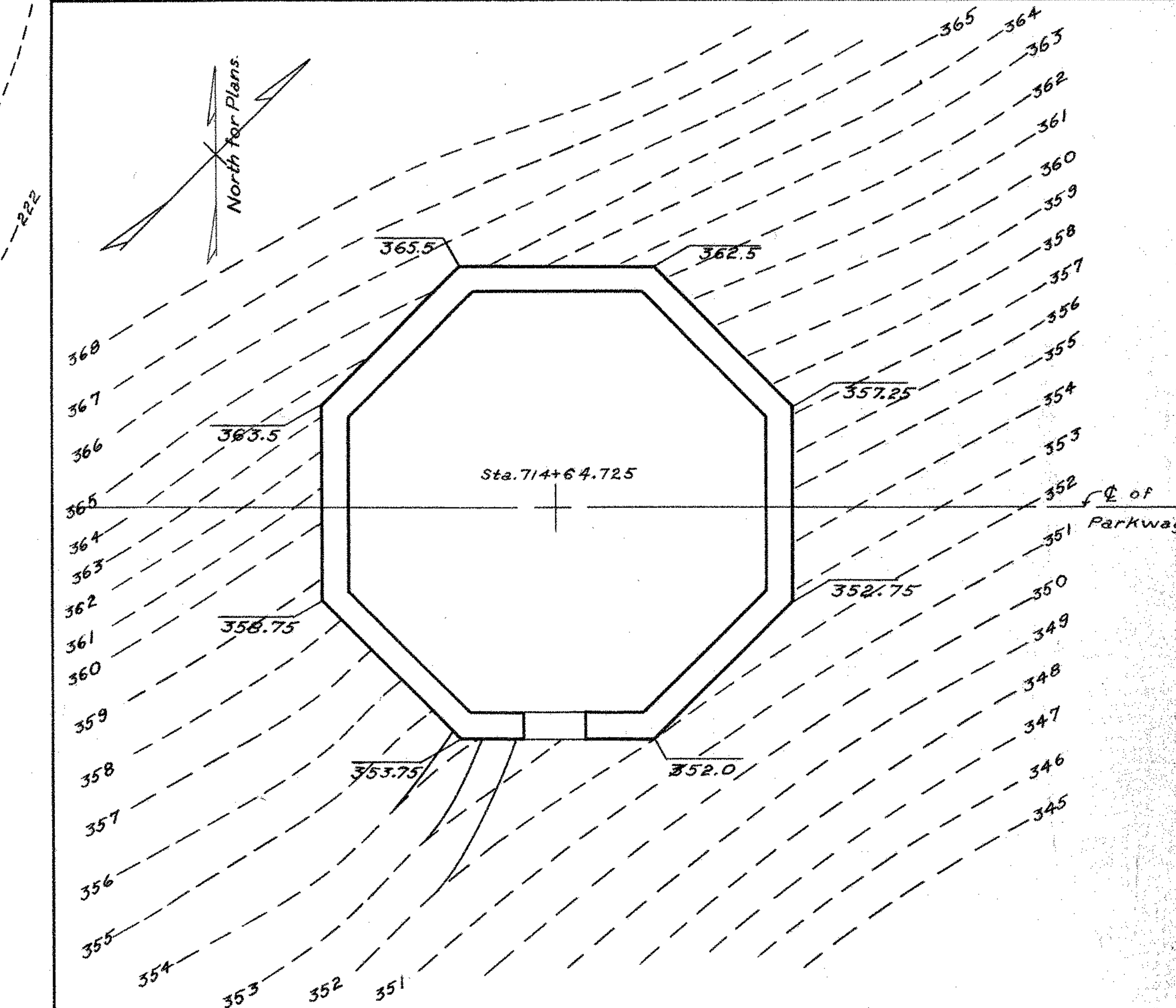
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		28	73

PROJECT NO. 185-90





GUTTER DETAIL
Scale ½"=1'-0"



VENTILATING HOUSE
Scale ⅛"=1'-0"

See Sheet Nos. 14, 16 for all notes.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL
GRADING PLAN II

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/8"=1'-0"
MADE BY R.T.
CHECKED BY J.W.T.
APPROVED ______ DATE ______

PROJECT NO.

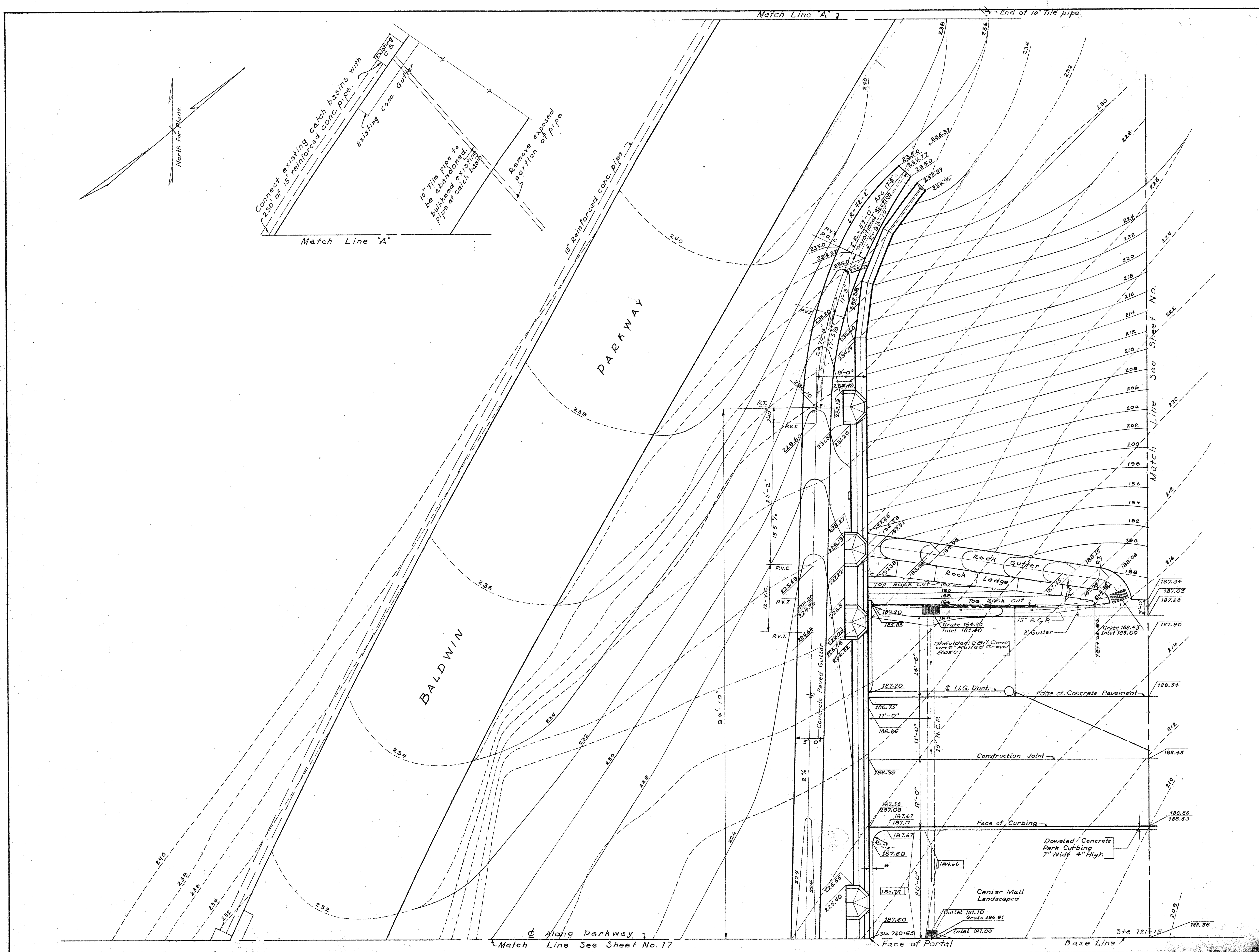
TUNNEL SHEET NO. 15 OF 44

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		29	73

PROJECT NO. 185-90



NOTE

For Typical Section of Concrete Paved Gutter see Sheet No. 14

Parkway Gutter approaching Portal see Gutter Detail Sheet No. 15

Rock Gutters are shown in section, Sheet No. 18

For construction of Parkway appoach paving see Sheet No. 18

GENERAL NOTES FOR GRADING

Existing Contours

Finished Contours

Reinforced Concrete Pipe

Excavation Spot Grades – Mall 184.66

Finished Spot Grades 186.95

The subgrade in all unpaved areas shall be 4" below finished contours and spot grades except for rock gutters, rock ledges, exposed rock slopes as shown, cut and fill areas for intercepting ditch, and center mall.

In center mall the subgrade shall be 6" below finished grade.

For rock gutters and ledges, and rock slopes, excavation shall be to finished grade.

Cut and fill areas for intercepting ditch, the work shall be carried to finished grade.

Subgrade for paved intercepting ditch and gutters as shown on Sheet No. 14

See Sheet No. 18 for Excavation, Pay Line under approach paving

In unpaved areas the top 3' of fill up to subgrade to be selected and approved material.

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
EAST PORTAL
GRADING PLAN I

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/8" = 1'-0"
MADE BY J.W.T.
CHECKED BY J.W.T.
APPROVED
DATE
PROJECT NO.
TUNNEL SHEET NO. 16 OF 44

185 90

147 03

23

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		30	73

PROJECT NO. 185 - 90

The information, including estimated quantities of work, shown on these sheets is based on limited investigations by the State and is in no way warranted to indicate the true conditions or actual quantities or distribution of quantities of work which will be required.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
EAST PORTAL
GRADING PLAN II

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/8" = 1'-0"
MADE BY J.W.T.
CHECKED BY J.W.T.
APPROVED
DATE

PROJECT NO.
TUNNEL SHEET NO. 17 OF 44

185 90

147 03

30

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		31	73

PROJECT NO. 185-90

NO REVISIONS SUBMITTED FOR THIS SHEET

~ NOTE ~

For additional spot grades and finished contours in front and behind Portals, and General Notes See Sheet No's 14, 15, 16, 17
Excavation Pay Line — — — —

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

GRADING
CROSS SECTIONS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE VER. & HOR. 1" = 10'-0"
MADE BY J.W.T.
CHECKED BY J.W.T.
APPROVED ________ DATE ________

PROJECT NO.
TUNNEL SHEET NO. 18 OF 44

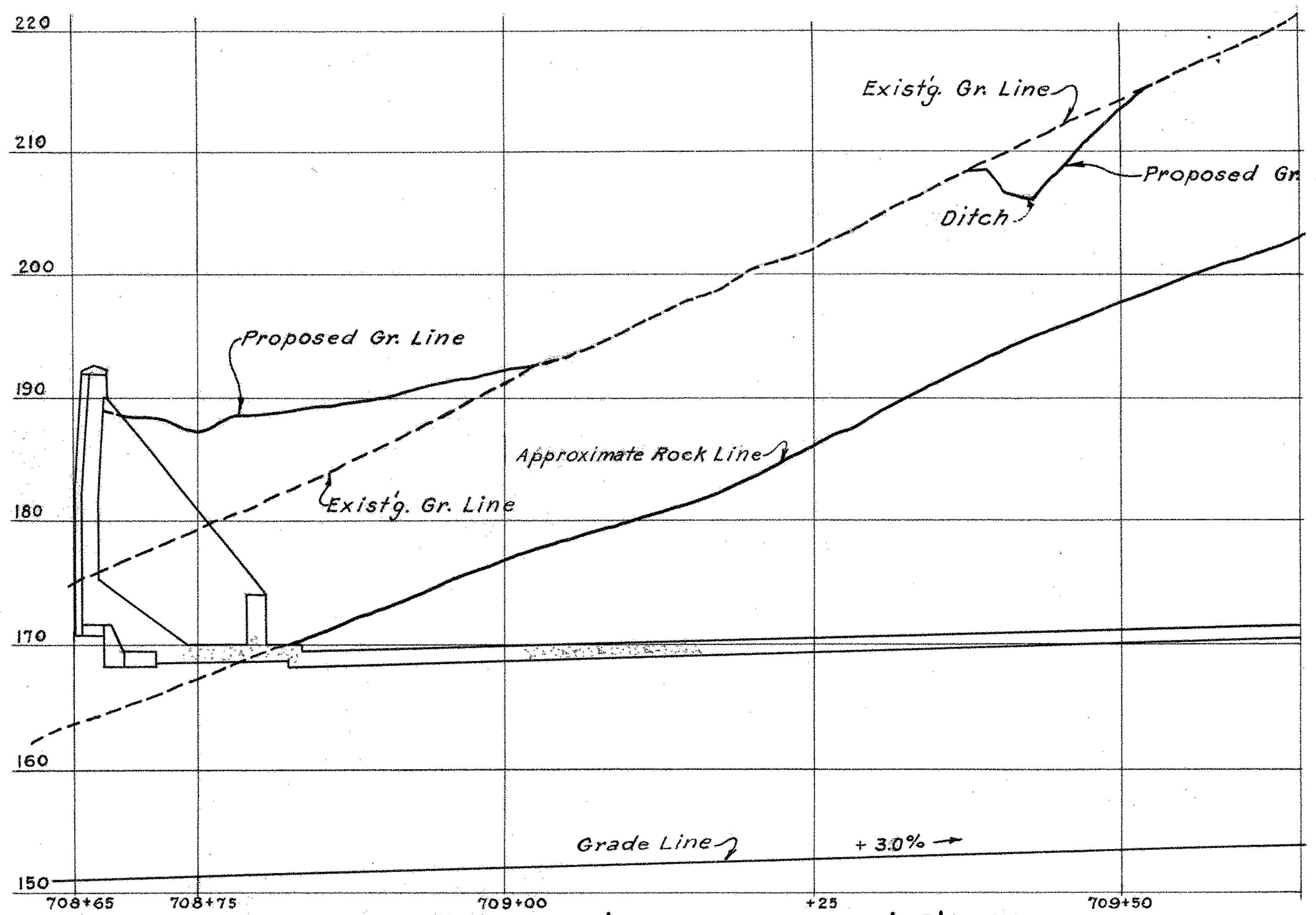
185 90

147 03

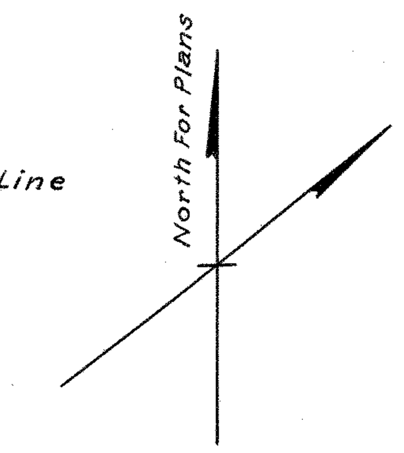
NO REVISIONS SUBMITTED FOR THIS SHEET

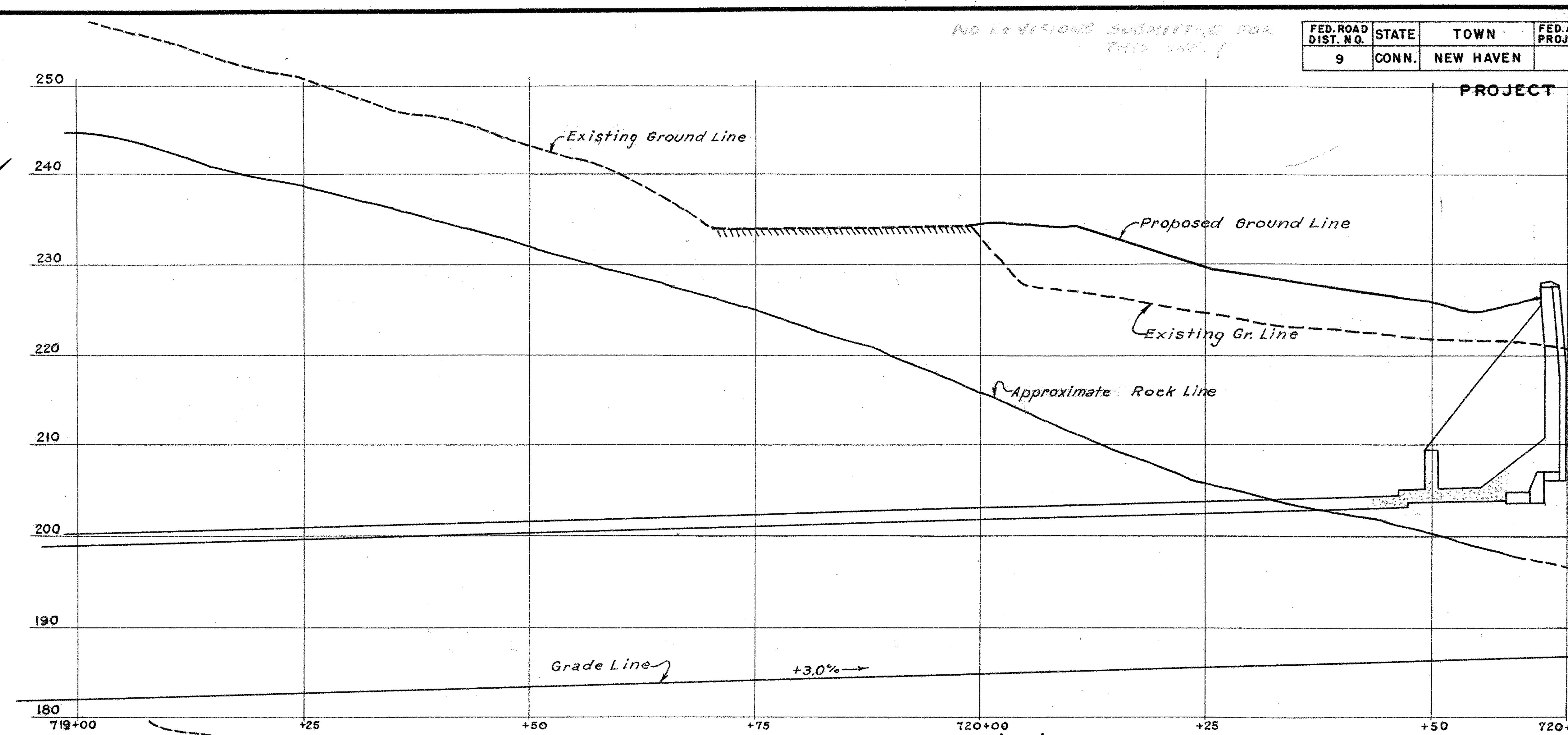
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		32	73

PROJECT NO. 185 - 90

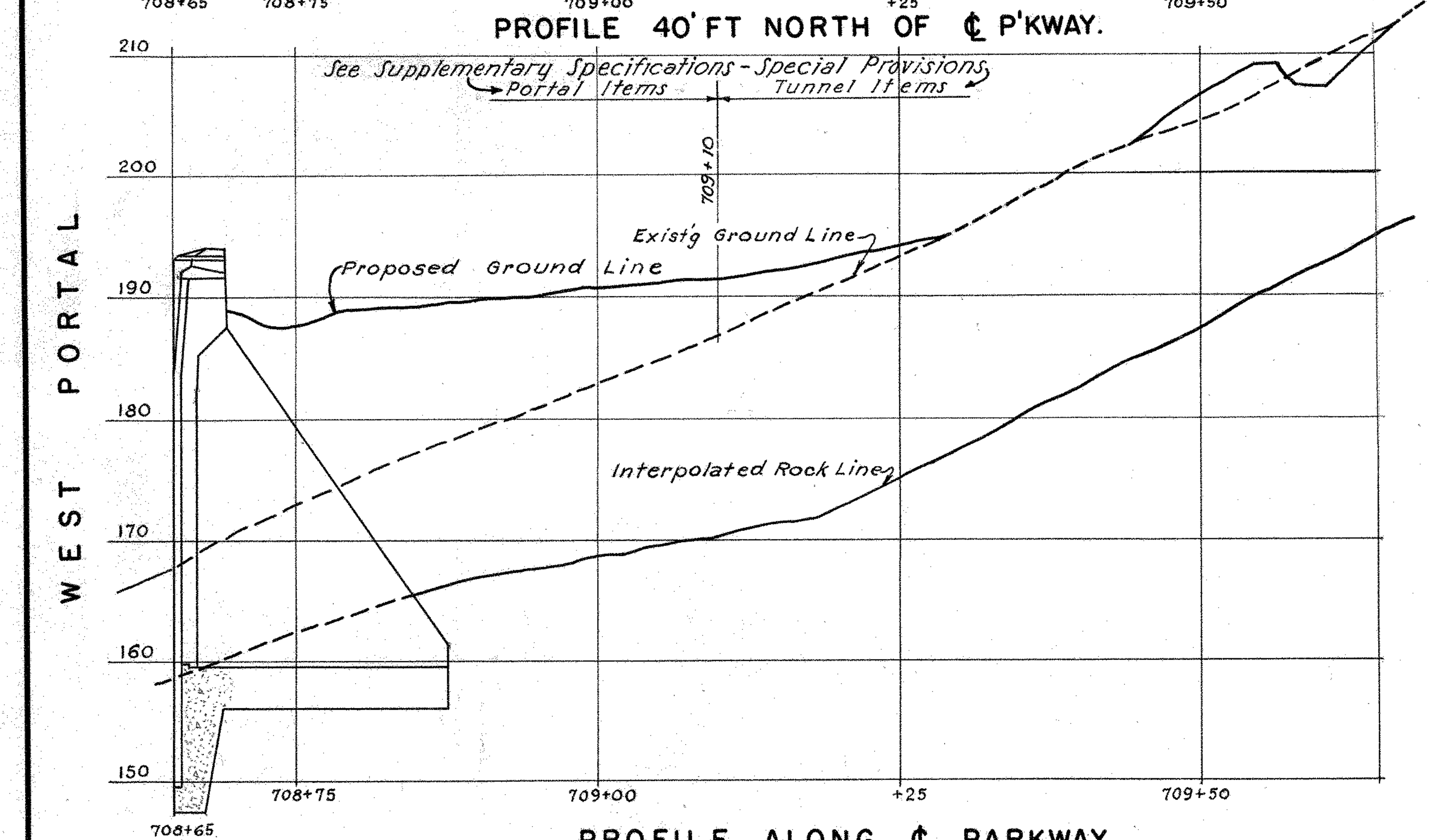


PROFILE 40' FT NORTH OF ℄ P'KWAY.

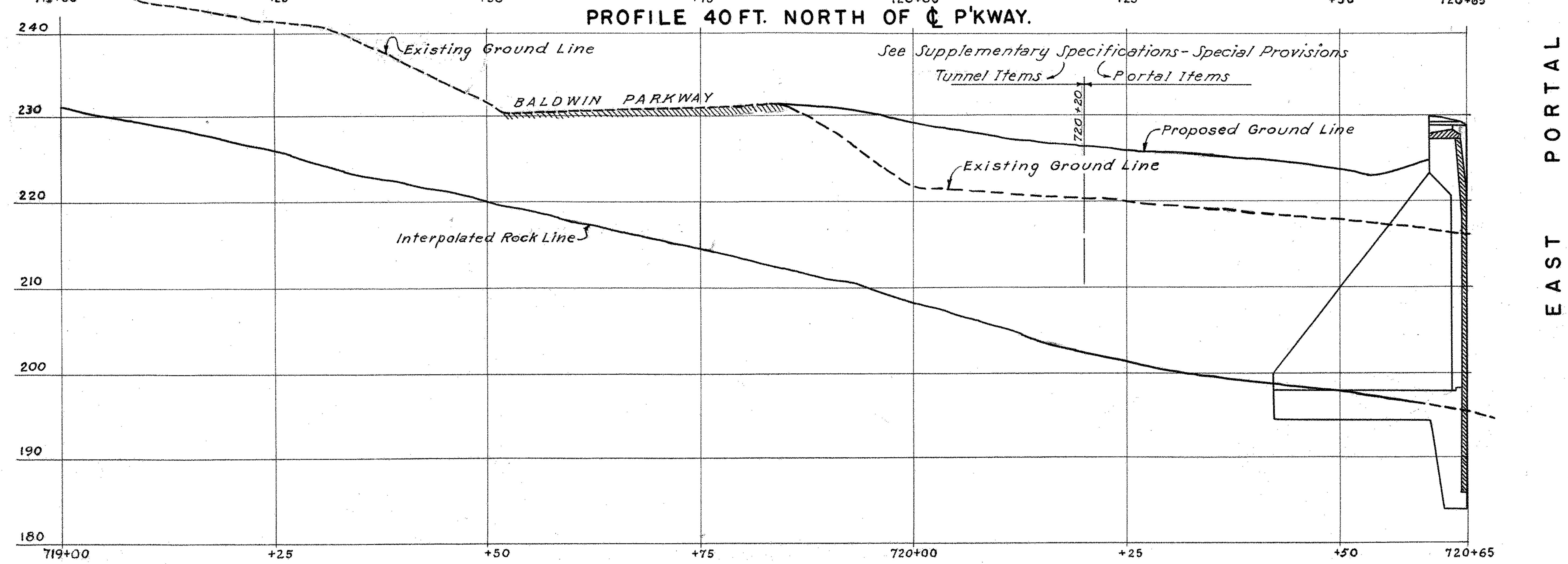




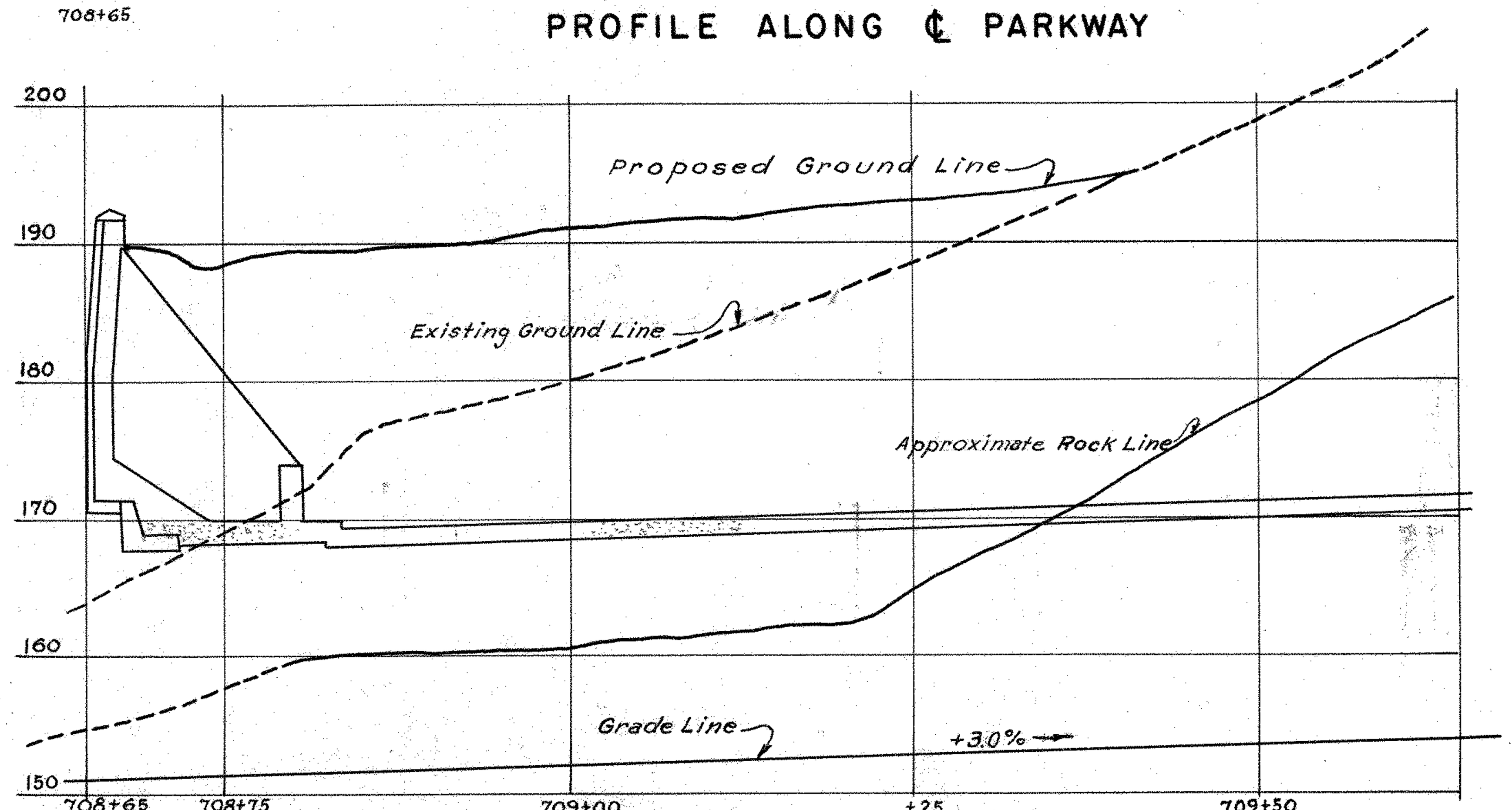
PROFILE 40 FT. NORTH OF ℄ P'KWAY.



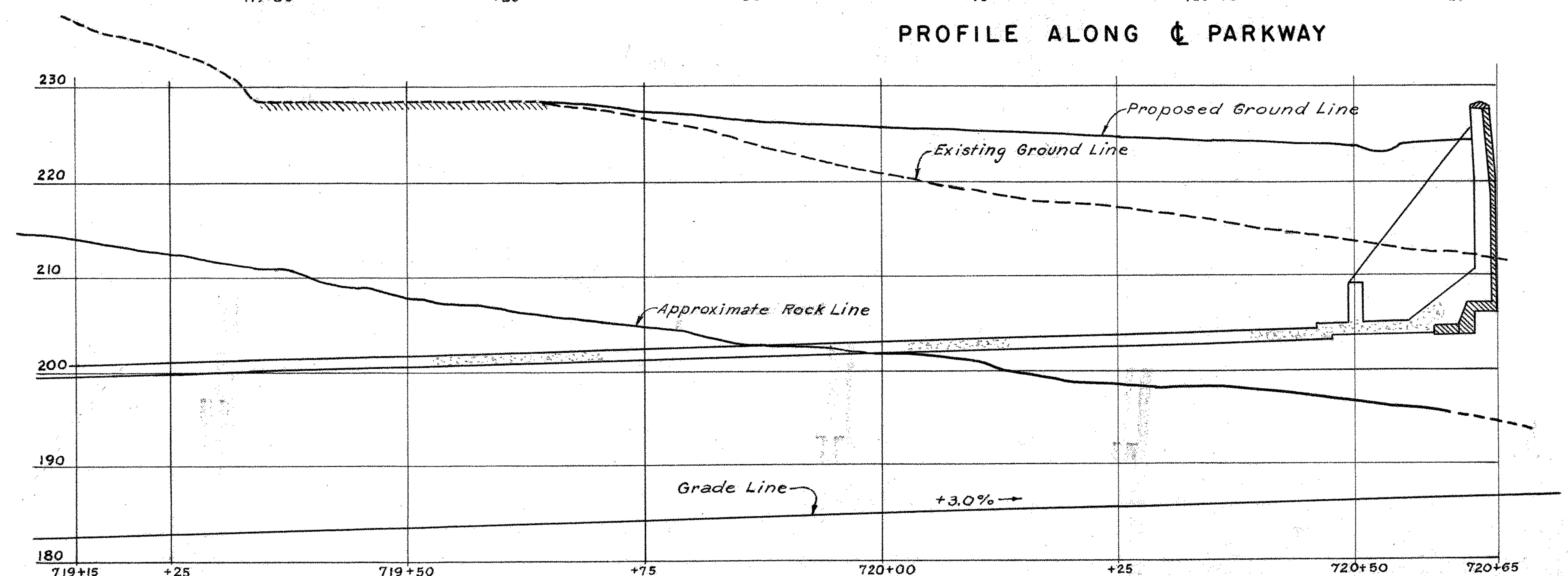
PROFILE ALONG ℄ PARKWAY



PROFILE ALONG ℄ PARKWAY



PROFILE 40 FT. SOUTH OF ℄ P'KWAY



PROFILE 40 FT. SOUTH OF ℄ P'KWAY.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST AND EAST PORTALS
PROFILES

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS — NEW YORK, N.Y.

SCALE 1"=10' Hor. & Vert.
MADE BY P.C.
CHECKED BY A.T.W.
APPROVED ______ DATE ______
PROJECT NO. ______
TUNNEL SHEET NO. 19 OF 44

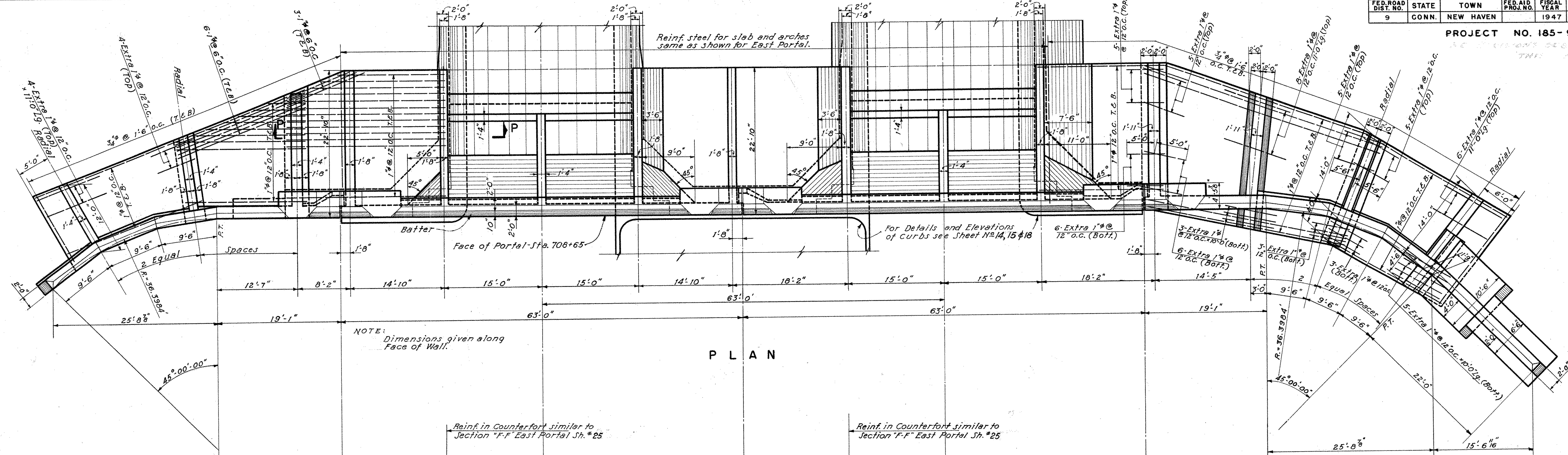
185 90

147 03

32

FED.ROAD DIST. NO.	STATE	TOWN	FED.AID PROJ.NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		33	73

PROJECT NO. 185-90



PLAN

ELEVATION

NOTES

1. For General Notes see Sheet Nº 1
2. For Sections A-A, B-B, C-C, D-D, H-H, X-X, & Y-Y see Sheet Nº 21
3. For Sections E-E, P-P, R-R, S-S, T-T & Z-Z see Sheet Nº 23
4. For Sections J-J, K-K, L-L, M-M, N-N, Q-Q, U-U, V-V, & W-W see Sheet Nº 22
5. Section F-F similar to Section F-F East Portal shown on Sheet Nº 25
6. Section G-G similar to Section G-G East Portal shown on Sheet Nº 25
7. Sections A'-A', B'-B' & C'-C' similar to Section X-X East Portal shown on Sheet Nº 25
8. For Portal Drainage see Sheet Nº 23
9. For Tunnel Drainage see Sheet Nº 34
10. For Details and location of Electrical Conduits see Sheets Nº 39 & 40
11. For Elevations and dimensions of stone steps see Sheet Nº 4

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/8" = 1'-0"
MADE BY G.V.
CHECKED BY A.B.J.
APPROVED DATE

PROJECT NO.

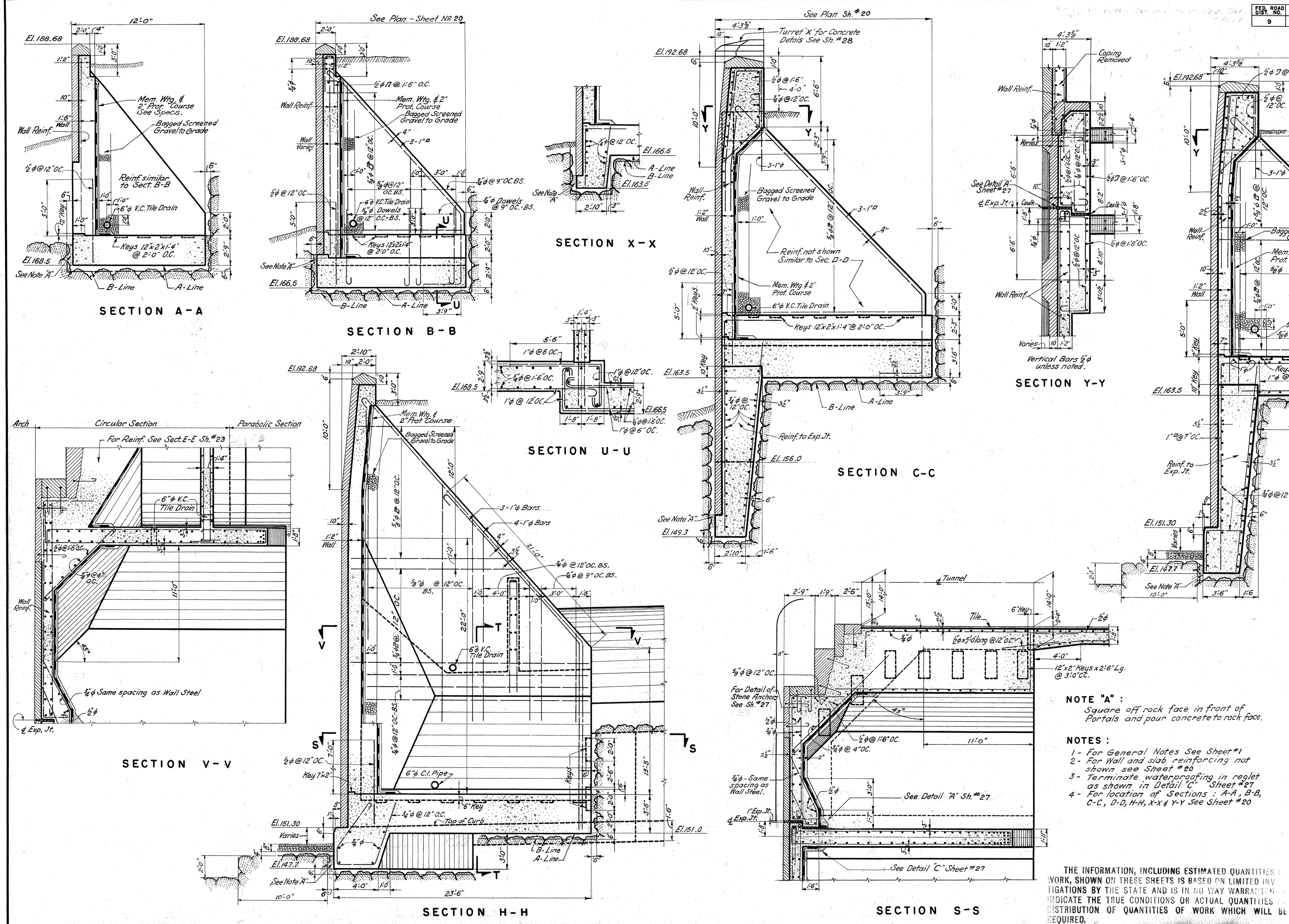
TUNNEL SHEET NO. 20 OF 44

185-901

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		34	73

PROJECT NO. 185-90



NOTE "A" :
Square off rock face in front of Portals and pour concrete to rock face.

NOTES :
1- For General Notes See Sheet #1
2- For Wall and slab reinforcing not shown see Sheet #20
3- Terminate waterproofing in reglet as shown in Detail "C" Sheet #27
4- For location of Sections : A-A, B-B, C-C, D-D, H-H, X-X & Y-Y See Sheet #20

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL
SECTIONS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE : 1/4"=1'-0"
MADE BY: G.V.
CHECKED BY A.B.J.
APPROVED
DATE

PROJECT NO.
TUNNEL SHEET NO. 21 OF 44

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		35	73

PROJECT NO. 185-90

NOTE "A"
Square off rock in front of Portals and pour concrete to rock face.

NOTES
1. For Wall and Slab reinforcing not shown see Sheet No 20
2. Terminate waterproofing in reglet as shown in DETAIL "C" Sheet No 27
3. For location of Sections J-J, K-K, L-L, M-M, N-N, Q-Q, U-U, V-V, & W-W see Sheet No 20
4. Section S-S similar to Section S-S East Portal see Sheet No 27
5. For General Notes see Sheet No 1

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL
SECTIONS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS — NEW YORK, N.Y.

SCALE 1/4" = 1'-0" Unless noted
MADE BY G.V.
CHECKED BY A.B.J.
APPROVED
DATE
PROJECT NO.
TUNNEL SHEET NO. 22 OF 44

185 90

147 03

NO REVISIONS SUBMITTED FOR THIS SHEET

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		35	73

PROJECT NO 185-90

NOTES:

1. These revisions supersede Sections C-C, D-D, M-M, N-N, and Q-Q shown on Sheet No 22.
2. For Section L-L see Sheet No 22.
3. For General Notes see Sheet No 1.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL
REVISIONS AT SOUTH END OF PORTAL

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/4"=1'-0 UNLESS NOTED.
MADE BY – G.V.
CHECKED BY – ABJ
APPROVED –
DATE
PROJECT NO.
TUNNEL SHEET No. 22A

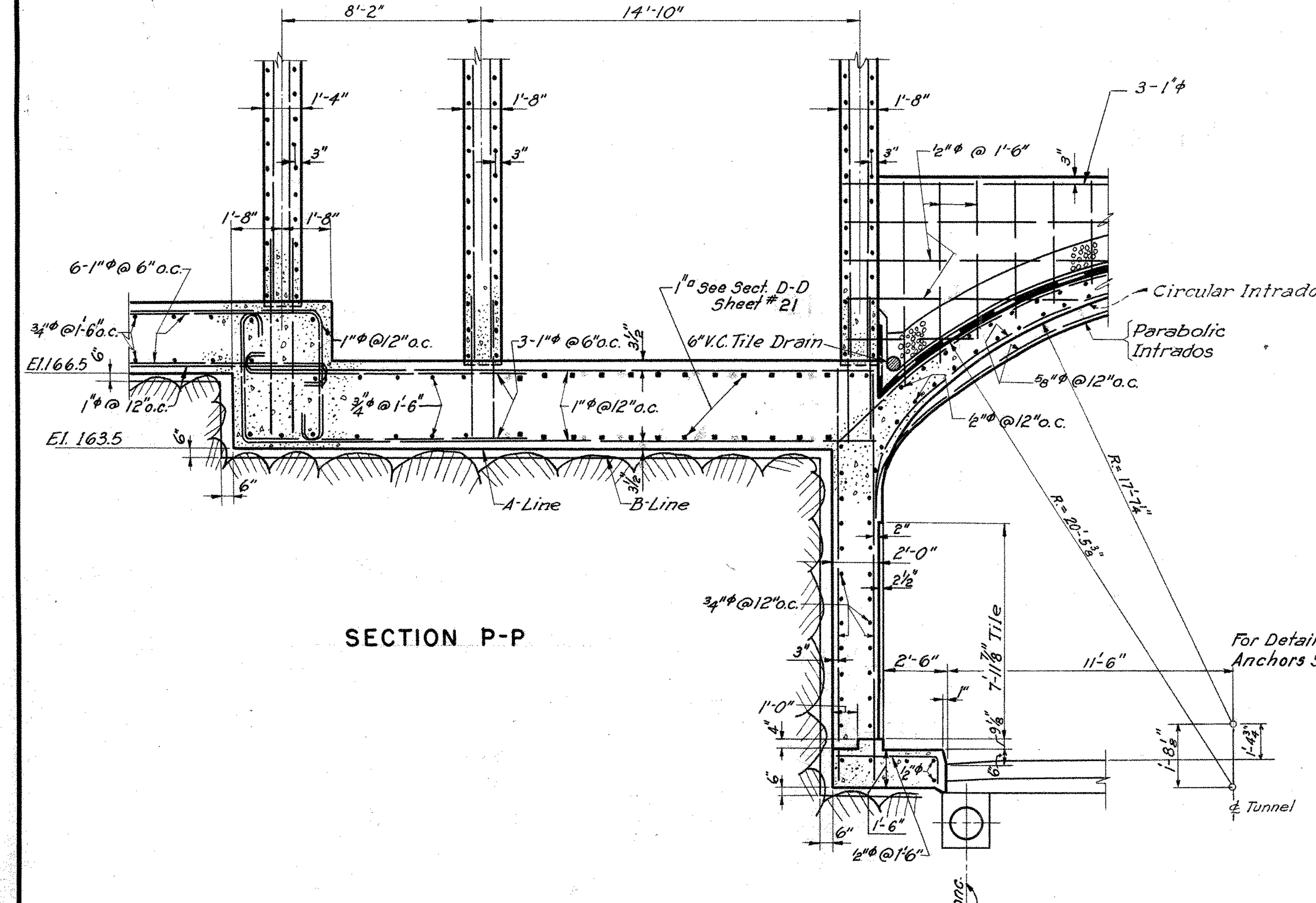
185 90 147 03

NEW HAVEN PROJ. 185-90

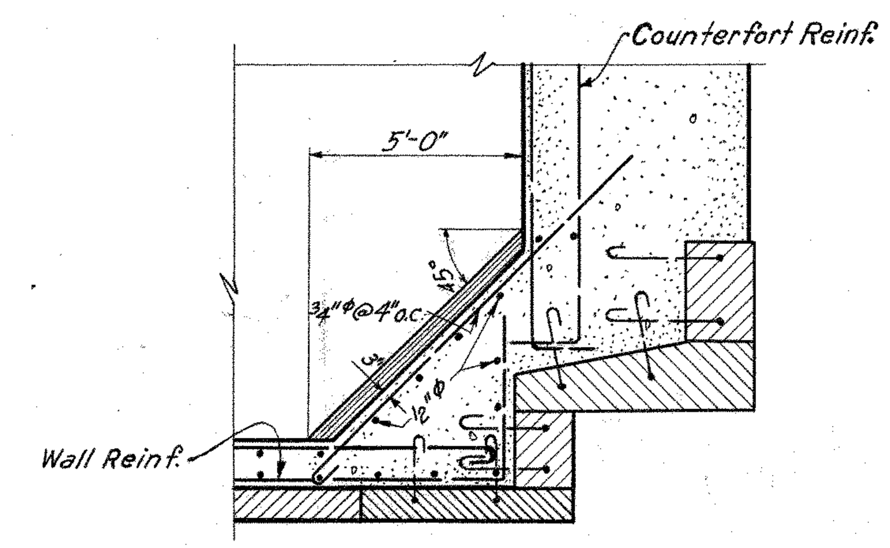
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		36	73

PROJECT NO. 185-90

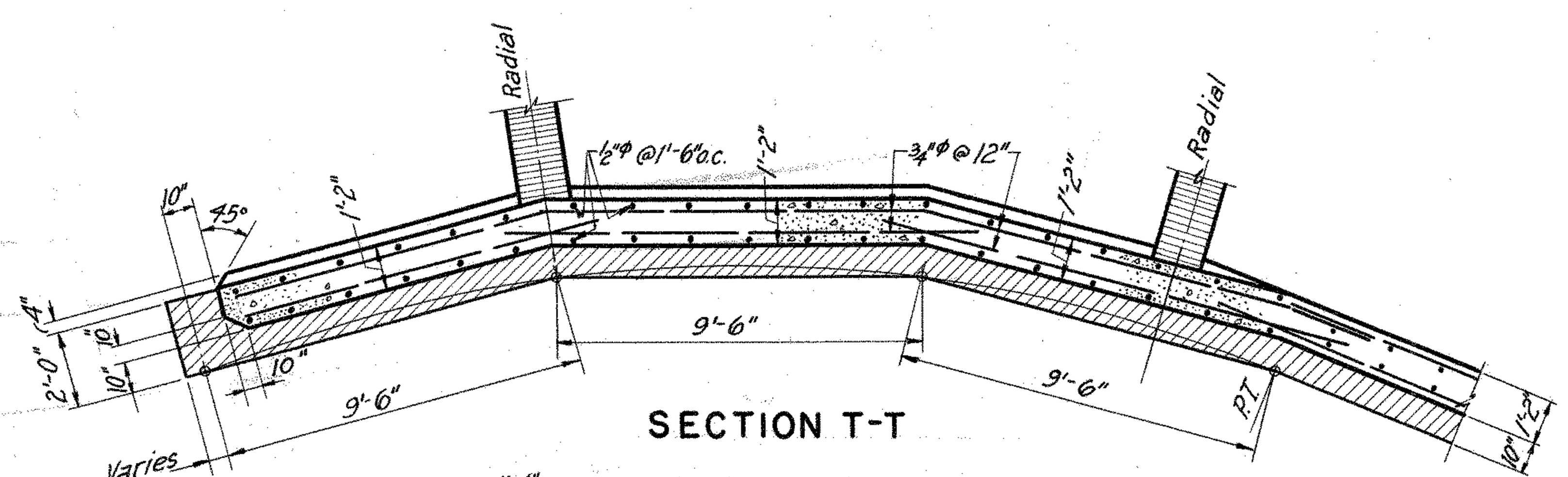
NO REVISIONS SUBMITTED FOR THIS SHEET



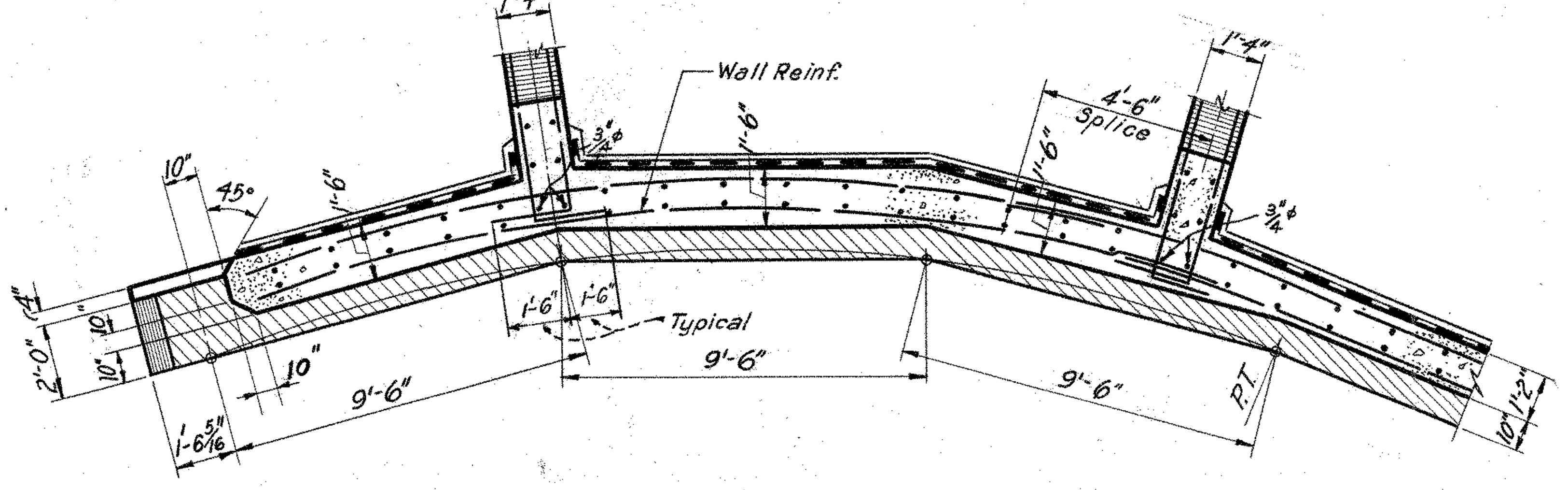
SECTION P-P



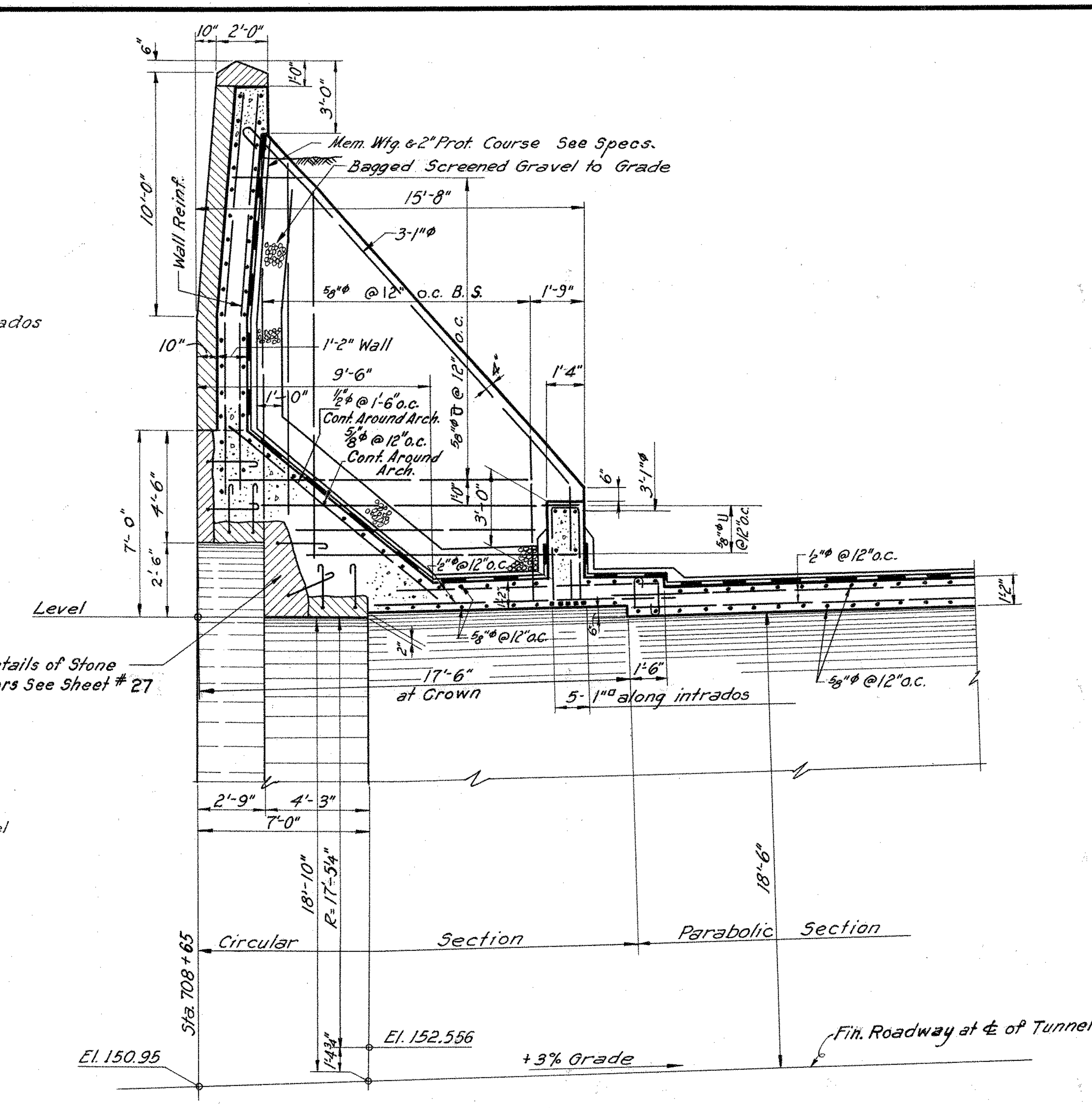
SECTION R-R



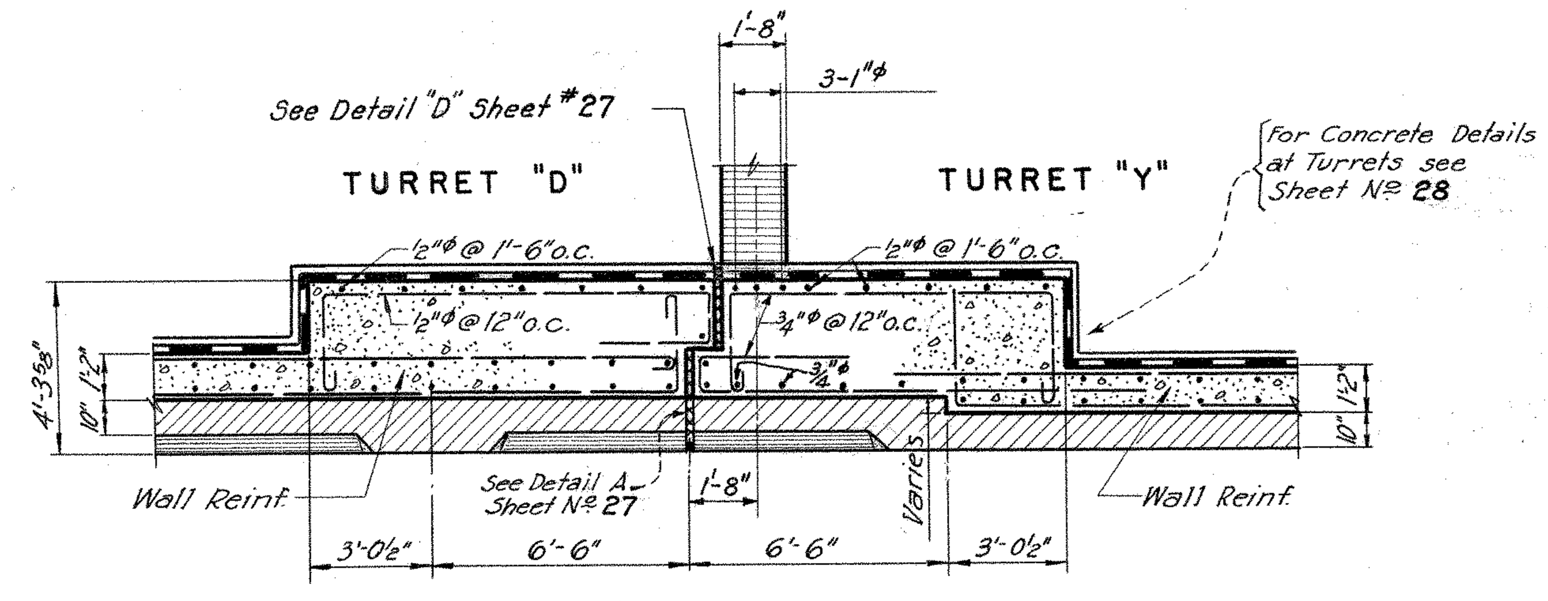
SECTION T-T



SECTION S-S

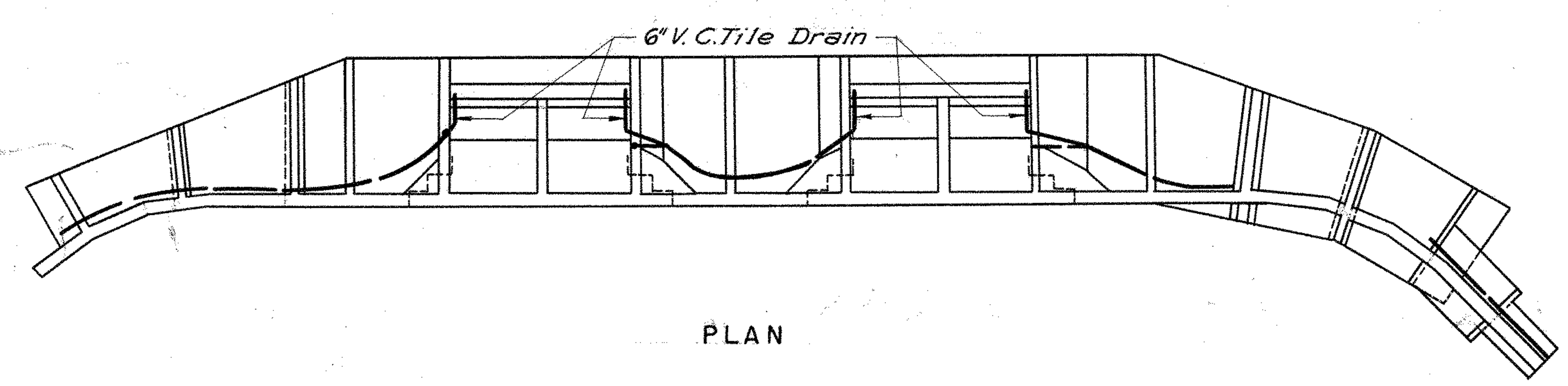


SECTION E-E

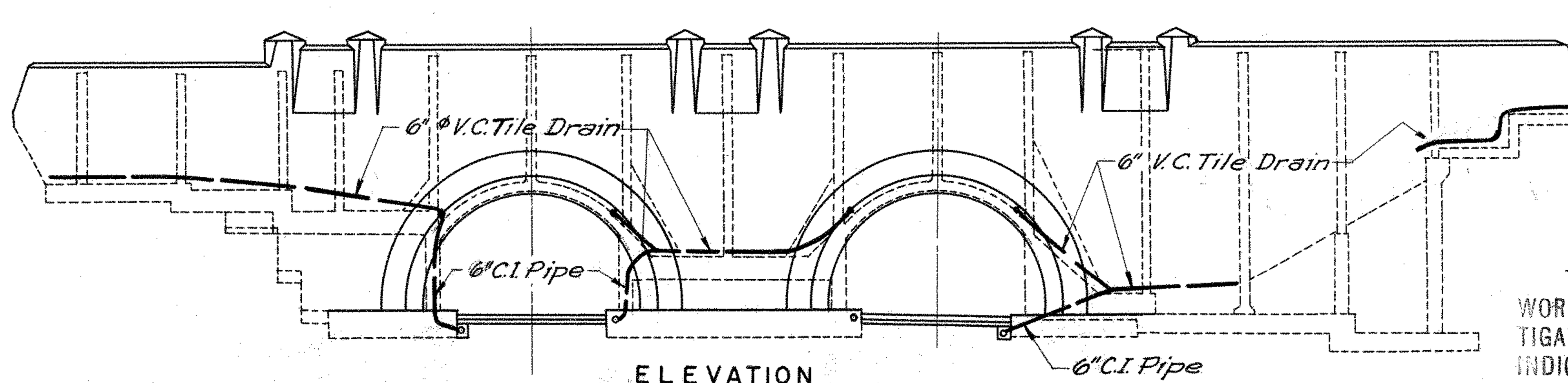


SECTION Z-Z

NOTES:
1 - For General Notes See Sheet No. 1
2 - Terminate Waterproofing in Reglet as Shown in Detail "C" Sheet No. 27
3 - For Locations of Sections See Sheet No. 20



PLAN



ELEVATION

DRAINAGE
SCALE: 1" = 20'-0"

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WEST PORTAL
SECTIONS & PORTAL DRAINAGE

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE ¼" = 1'-0" Unless noted
MADE BY G.V.
CHECKED BY A.B.J.
APPROVED
DATE

PROJECT NO.
TUNNEL SHEET NO. 23 OF 44

185 90

147 03

36

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		37	73

PROJECT NO. 185 - 90

NOTES

1. For General Notes see Sheet Nº 1
2. For Sections A-A, B-B, C-C, L-L, M-M, N-N, O-O, P-P, Q-Q, R-R, T-T, & U-U see Sheet Nº 26
3. For Sections E-E, F-F, G-G, & X-X see Sheet Nº 25
4. For Sections D-D, J-J, K-K, S-S, V-V & W-W see Sheet Nº 27
5. Section H-H similar to Section G-G Sheet Nº 25
6. Sections A'-A', B'-B' & C'-C' similar to Section X-X shown on Sheet Nº 25
7. For Portal Drainage see Sheet Nº 27
8. For Tunnel Drainage see Sheet Nº 34
9. For Details and location of Electrical Conduits see Sheets Nº 39 & 40
10. For Elevations and dimensions of stone steps see Sheet Nº 5

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

EAST PORTAL

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/8"=1'-0"
MADE BY G.V.
CHECKED BY A.B.J.
APPROVED
DATE

PROJECT NO.
TUNNEL SHEET NO. 24 OF 44

185 - 90 147 03 37

NOTES

These revisions supersede Sections J-J, K-K, L-L, M-M, Q-Q & R-R shown on Sh.#24.
For Sections H-H, V-V & W-W see Sh.#25 & #27.
For General Notes see Sh.#1.
Terminate Waterproofing in reglet as shown in Detail "C" Sheet #27.
Install 6" V.C. Tile Drain similar to North Wingwall of West Portal as shown on Sh.#23.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

EAST PORTAL

REVISED NORTH WINGWALL

Scale 1/8" & 1/4" = 1'-0"
Made by V.H.M. Dec. 9, 1948
Checked by
Approved by

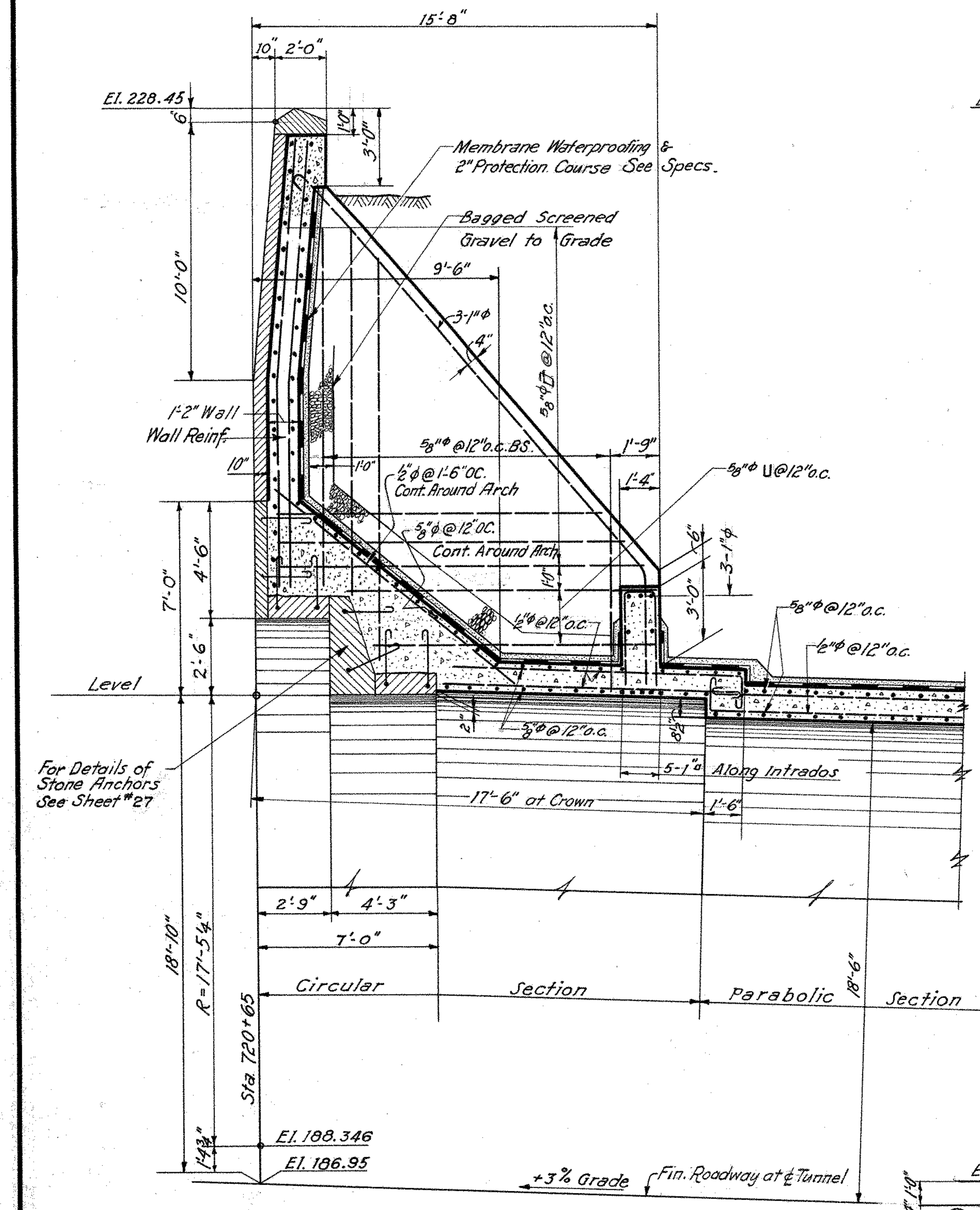
Project No. 185-90
Tunnel Sh. No. 24A

185 90

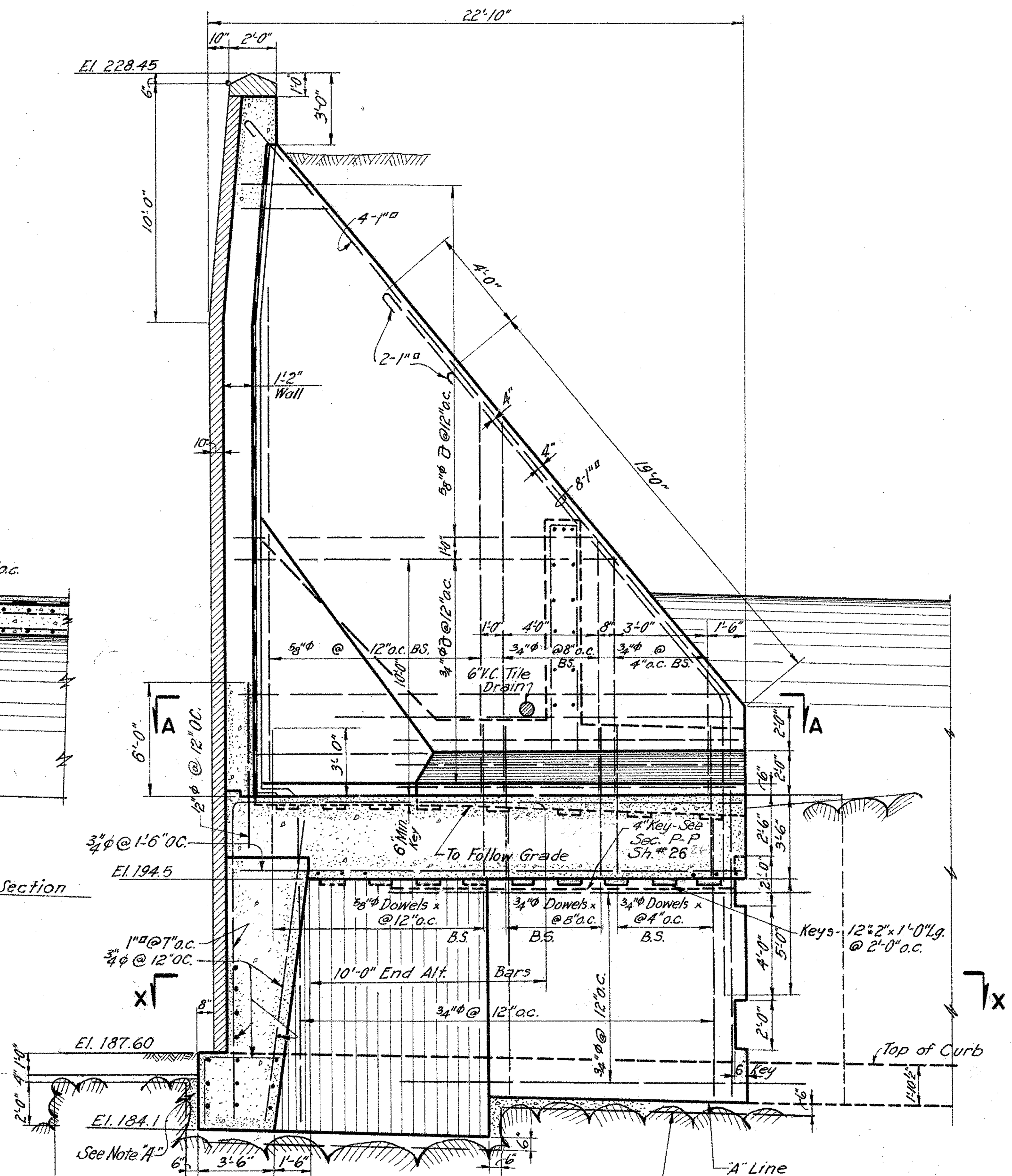
147-03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		38	73

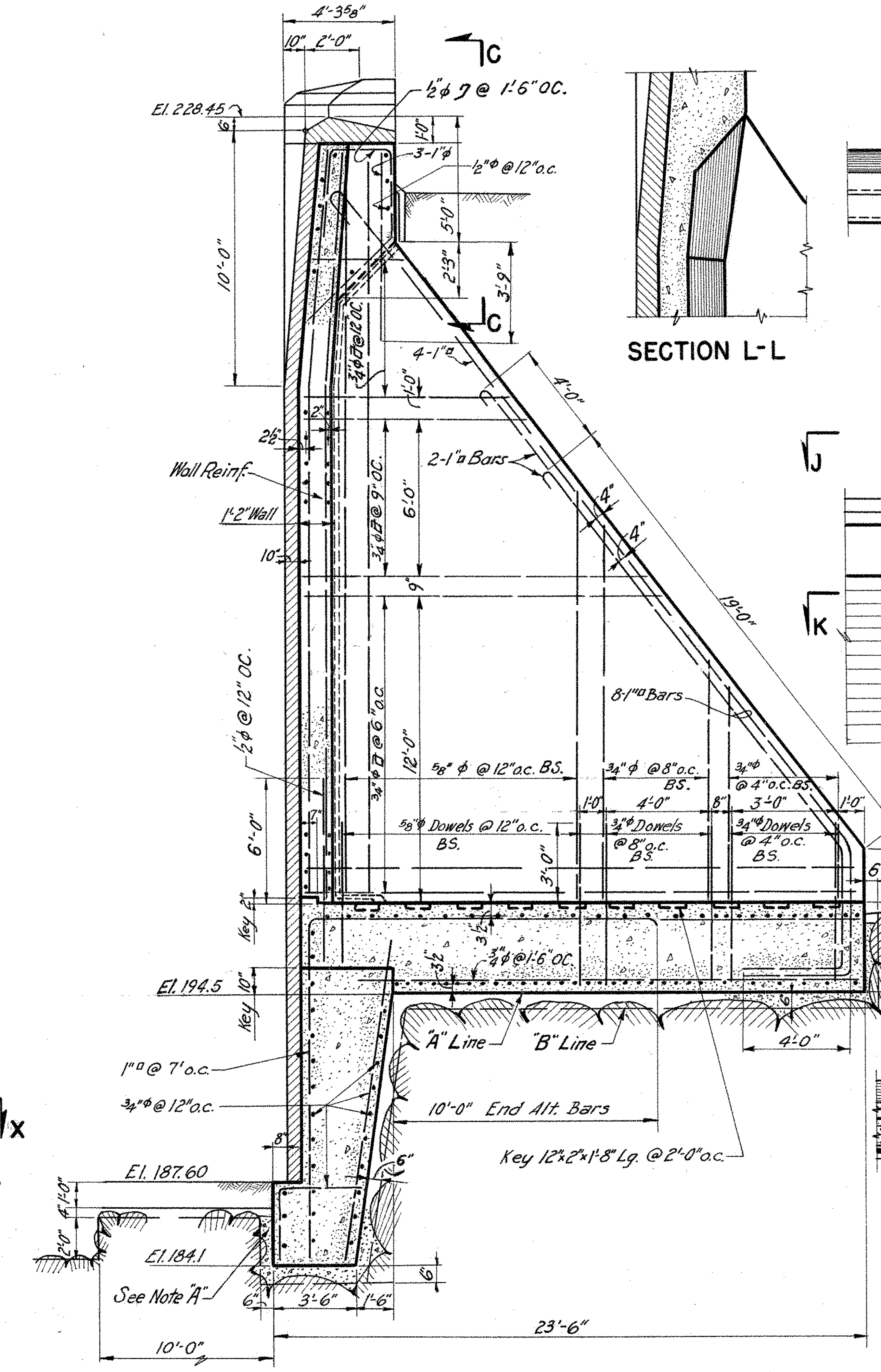
PROJECT NO. 185-90



SECTION E-E

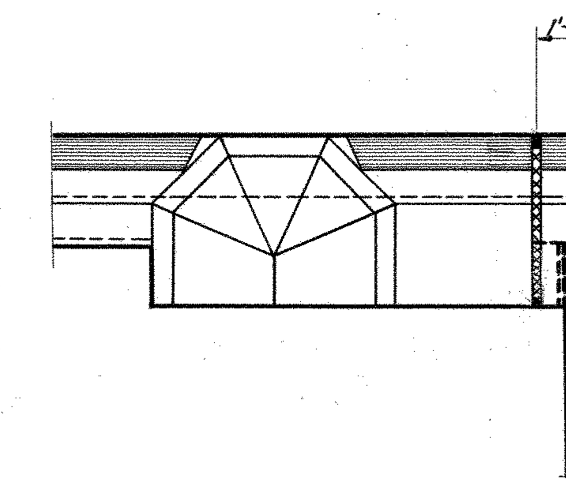


SECTION F-F

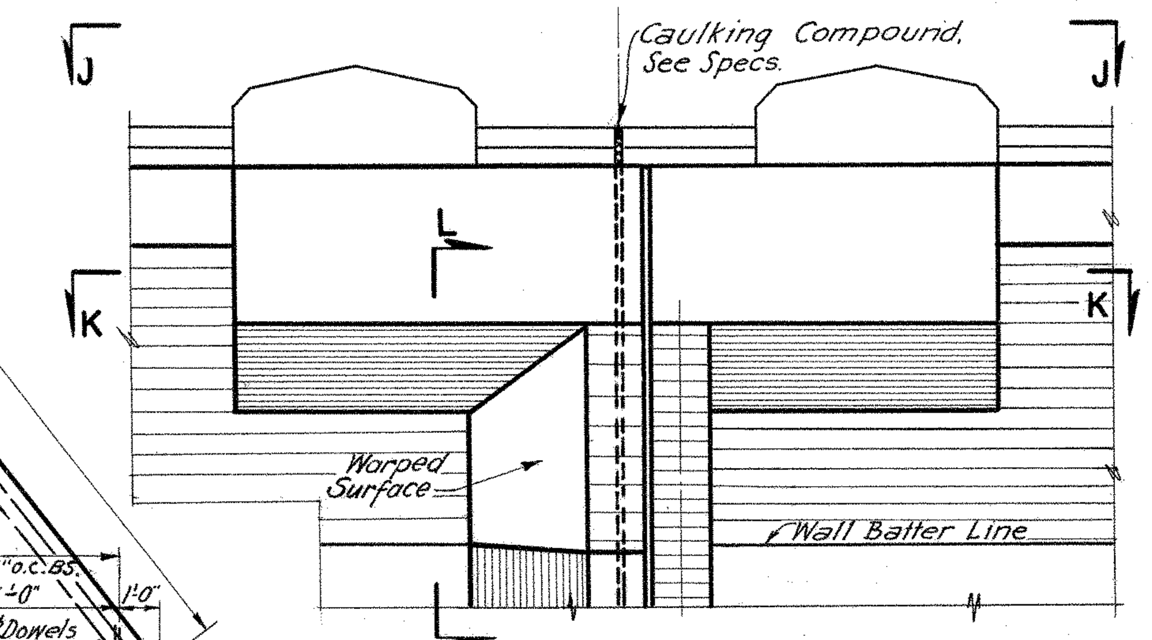


SECTION G-G

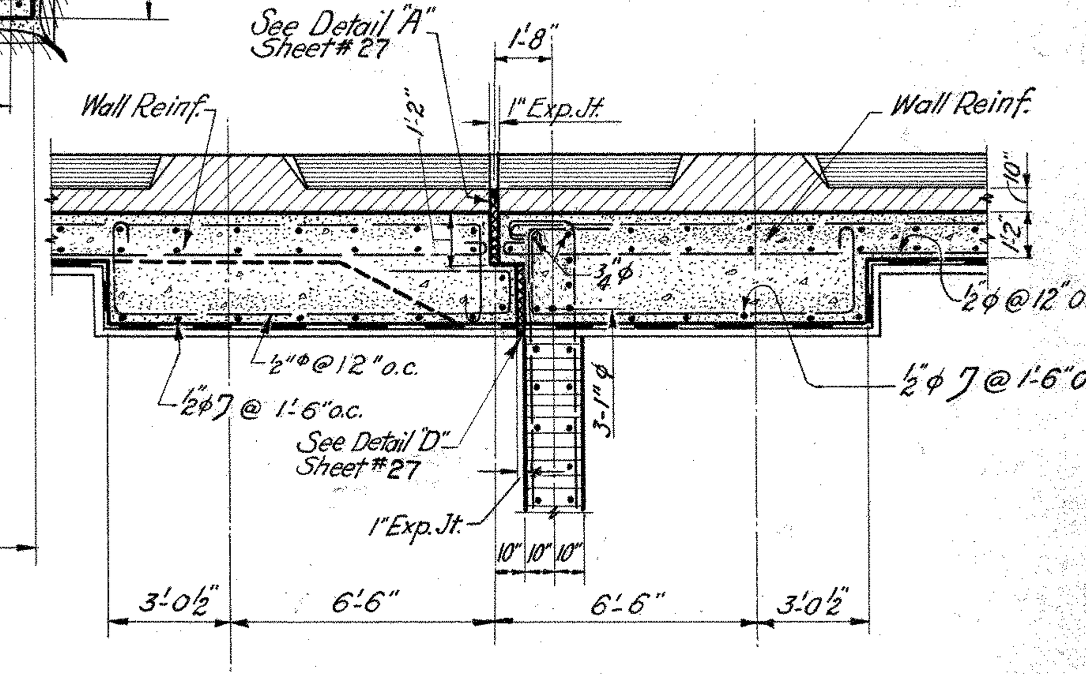
SECTION L-L



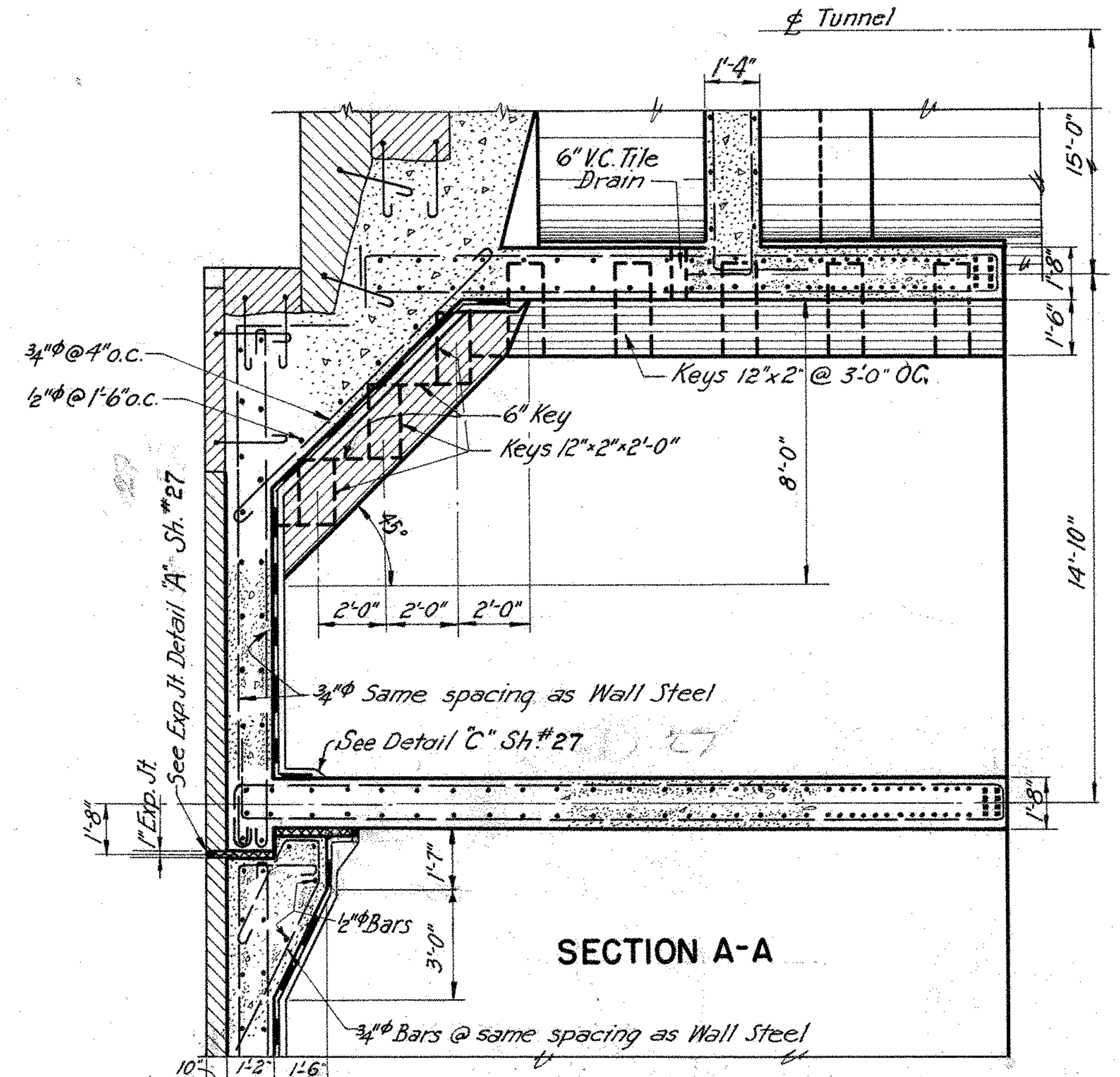
VIEW J-J



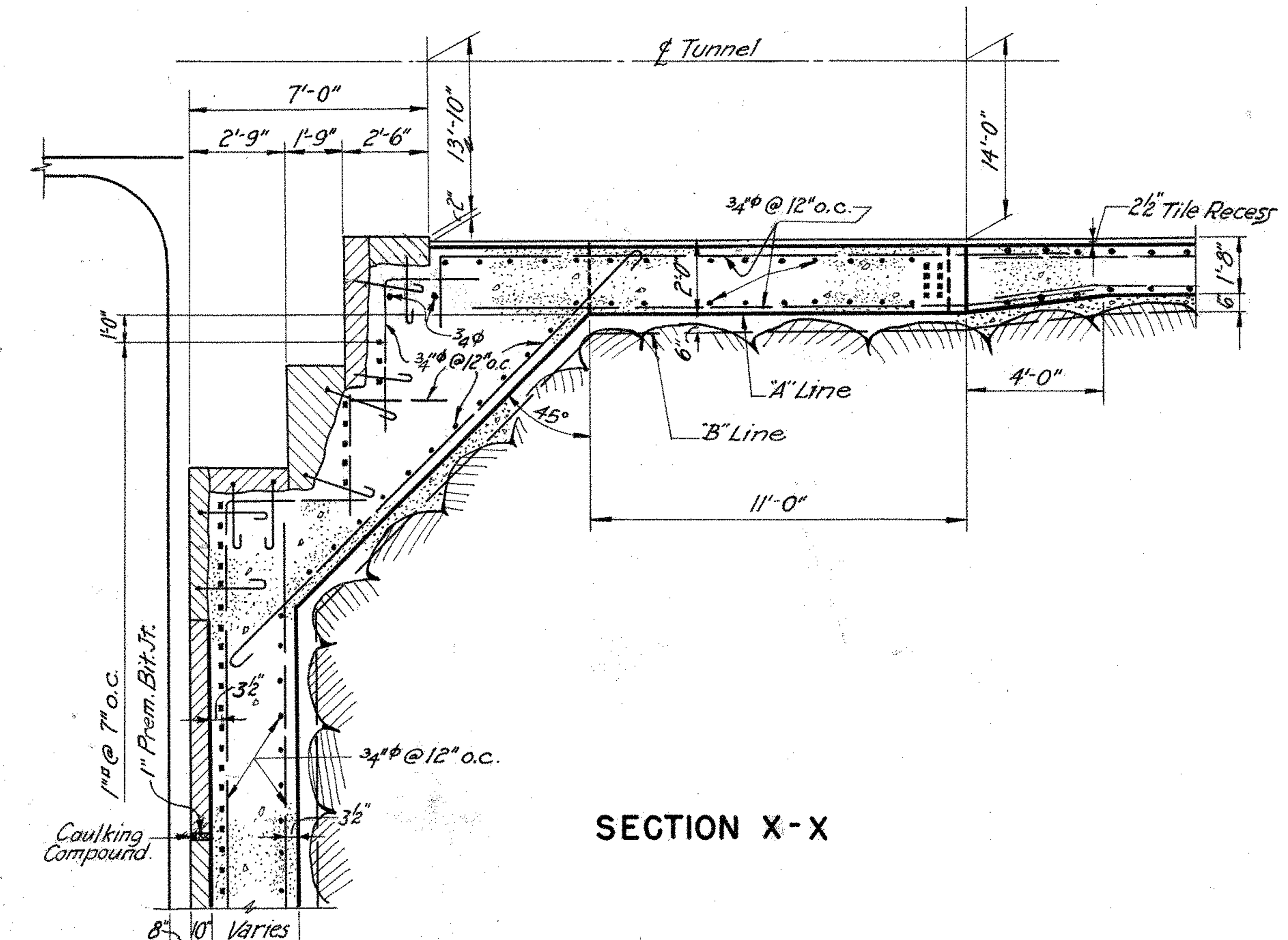
VIEW C-C



SECTION K-K



SECTION A-A



SECTION X-X

NOTE "A":

Square off rock in front of Portals and pour concrete to rock face.

NOTES:

1 - For General Notes see Sheet No. 1
2 - For Wall and slab steel not shown see Sheet No. 24.
3 - Terminate waterproofing in reglet as shown in Detail "C" Sheet No. 27
4 - For location of Sections: E-E, F-F, G-G. & X-X. see Sheet No. 24

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
EAST PORTAL
SECTIONS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS — NEW YORK, N.Y.

SCALE: 1/4" = 1'-0"
MADE BY G.V.
CHECKED BY A.B.J.
APPROVED
DATE

PROJECT NO.

TUNNEL SHEET NO. 25 OF 44

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		39	73

PROJECT NO. 185-90

NOTES

1. For General Notes see Sheet Nº 1
2. For wall and slab reinforcing see Sheet Nº 24
3. Terminate waterproofing in reglet as shown in DETAIL "C" Sheet Nº 27
4. For location of Sections A-A, B-B, C-C, L-L, M-M, N-N, O-O, P-P, Q-Q, R-R, T-T & U-U, see Sheet Nº 24

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
EAST PORTAL
SECTIONS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS — NEW YORK, N.Y.

SCALE 1/4" = 1'-0" Unless Noted
MADE BY G.V.
CHECKED BY A.B.J.
APPROVED ______ DATE ______

PROJECT NO.

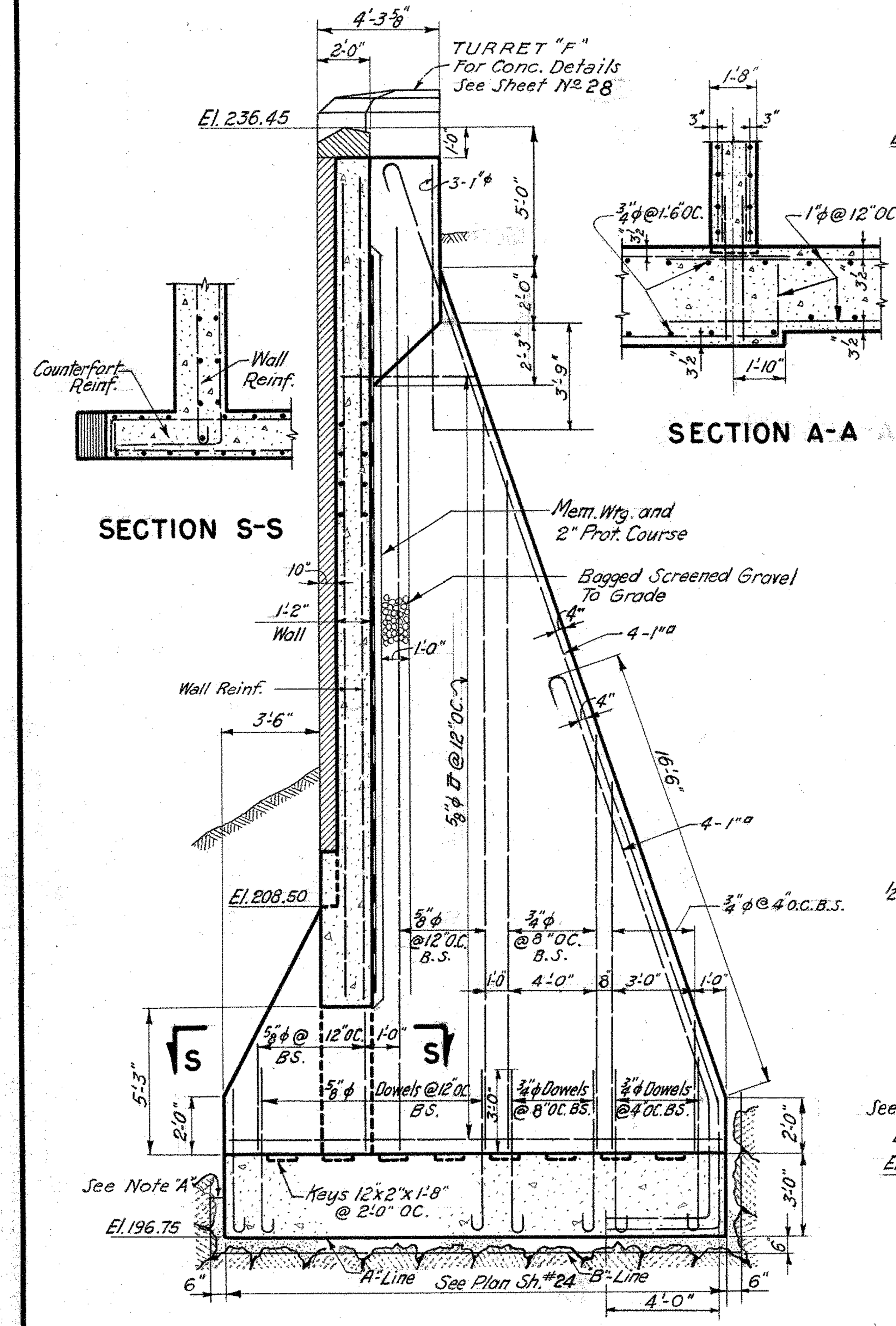
TUNNEL SHEET NO. 26 OF 44

185-90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PRO. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		40	73

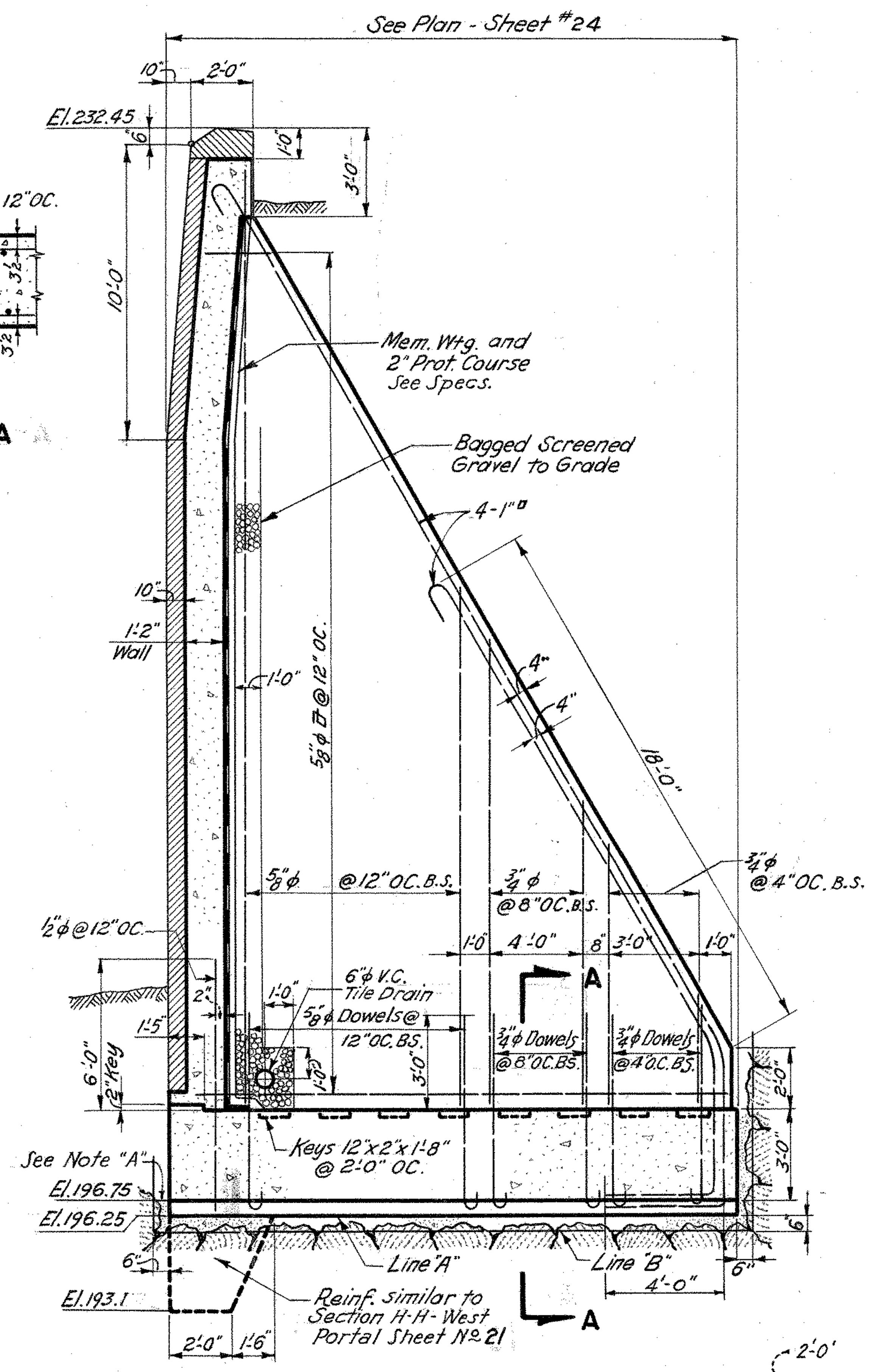
PROJECT NO. 185-90



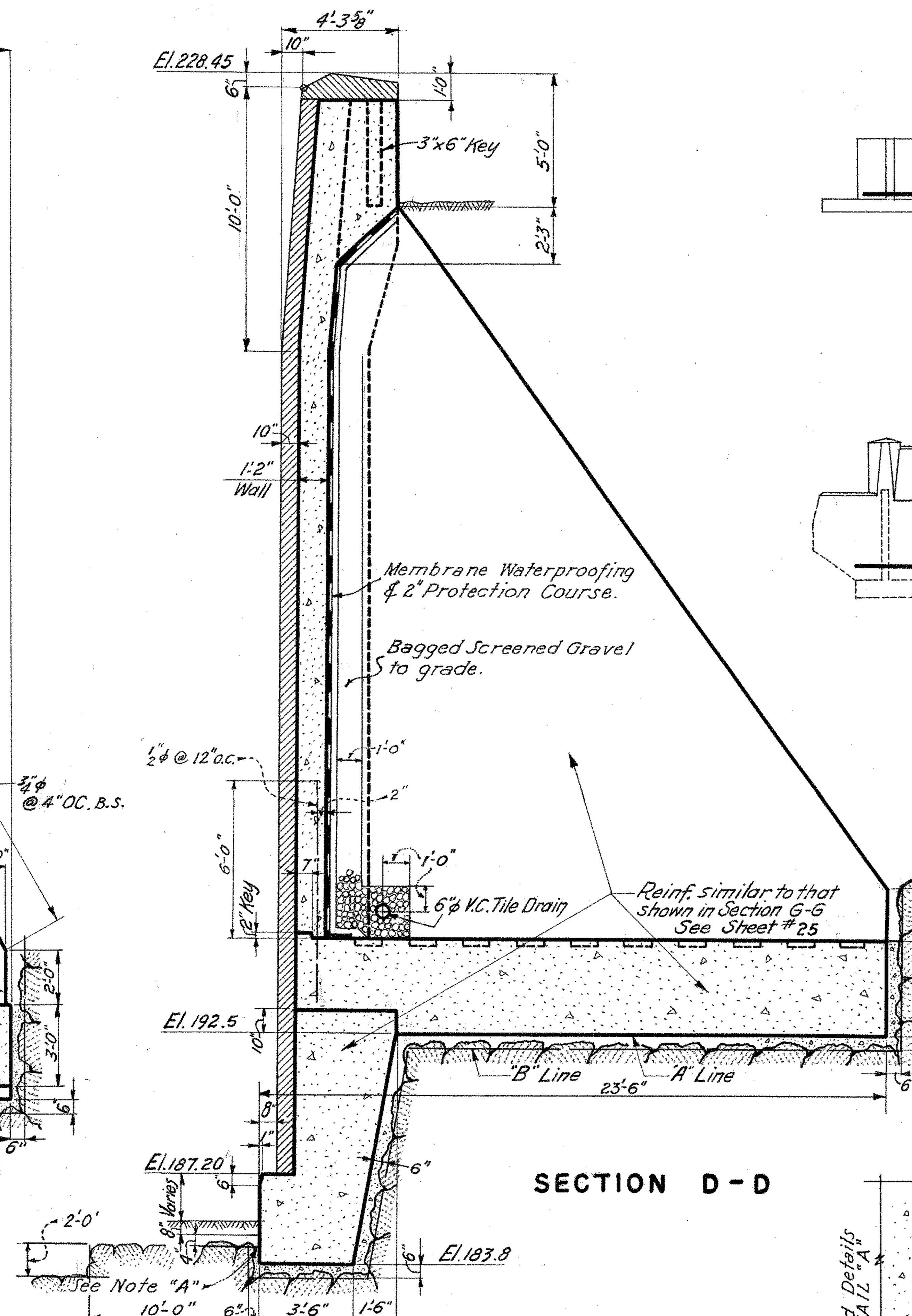
SECTION S-S

SECTION A-A

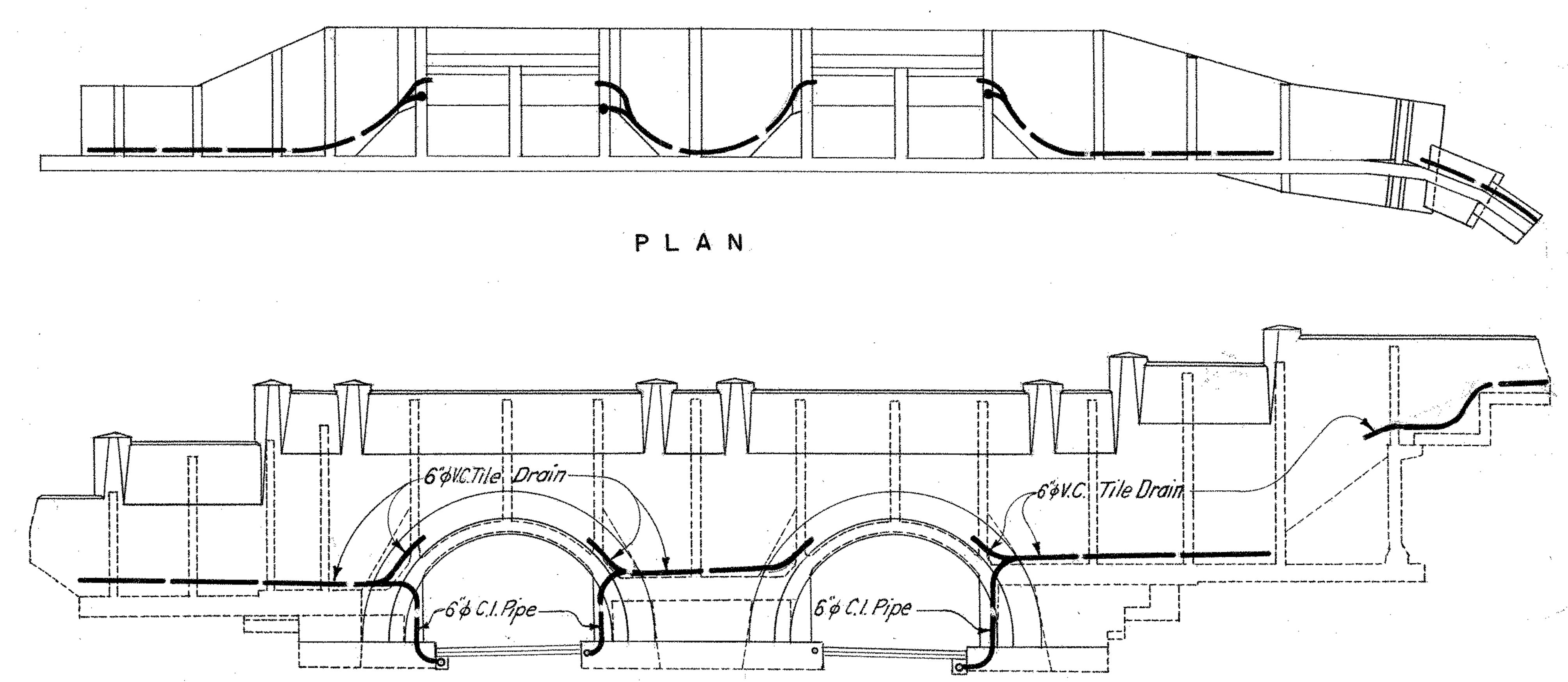
SECTION K-K



SECTION J-J

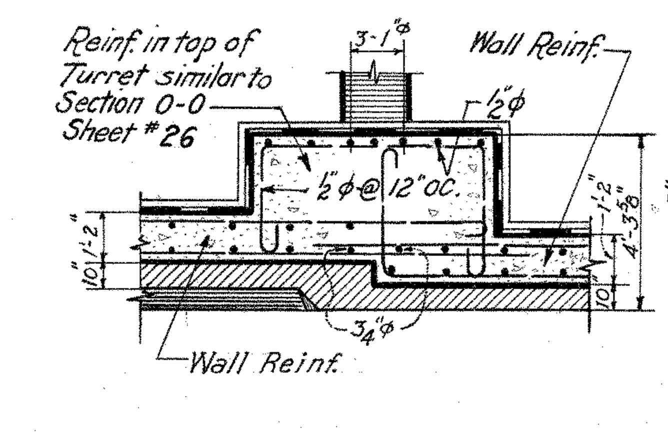


SECTION D-D

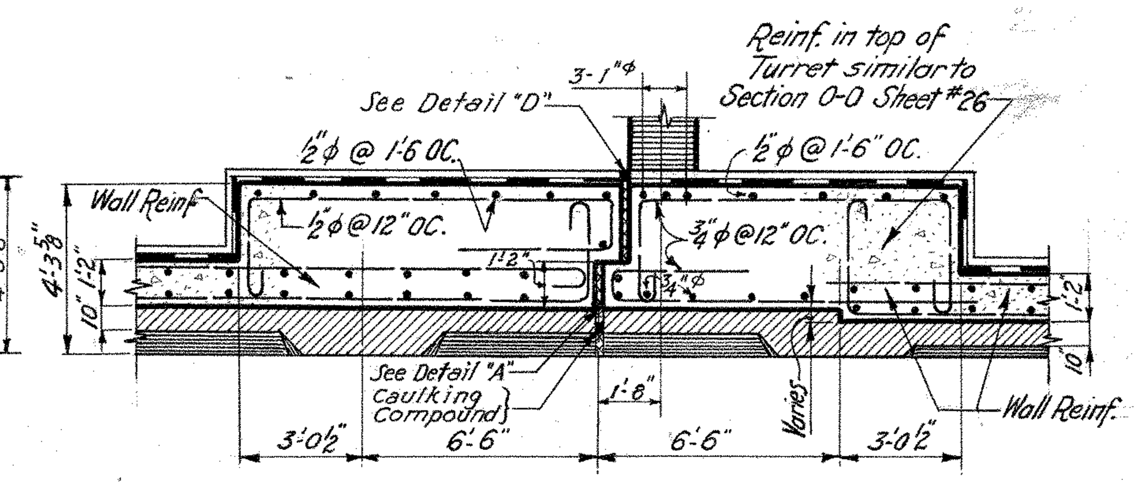


DRAINAGE

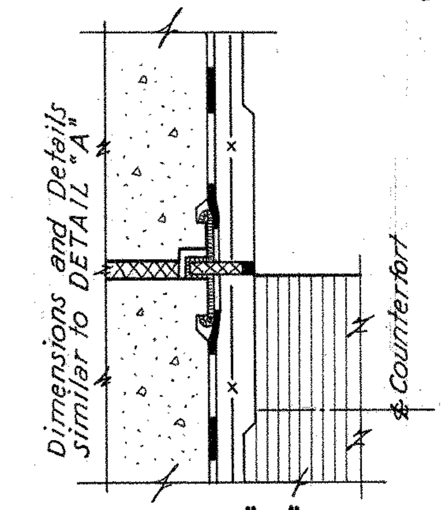
Scale: 1" = 20'



SECTION W-W

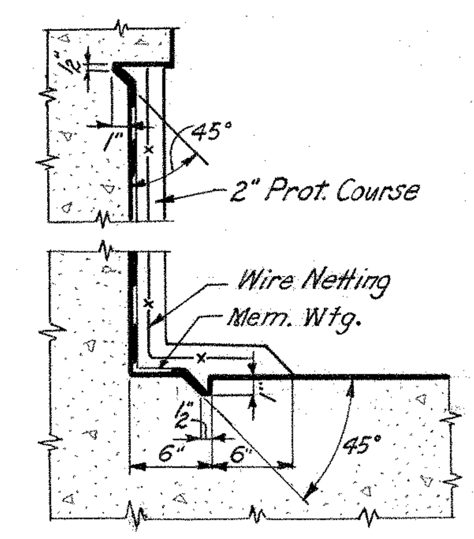


SECTION V-V



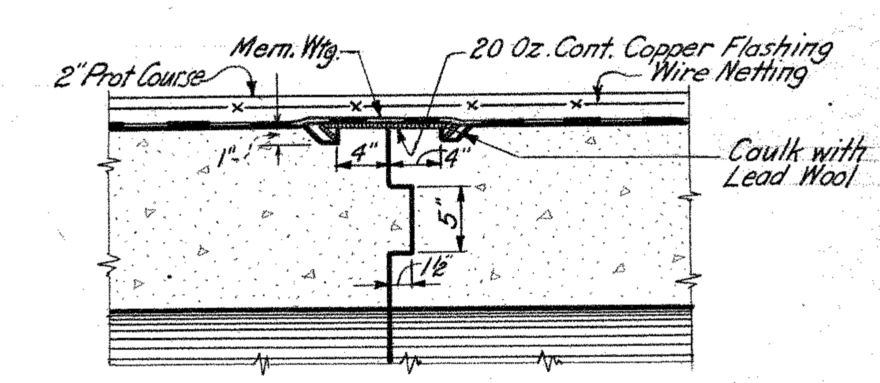
DETAIL "D"

~Scale 1"=1'-0"~



DETAIL "C"

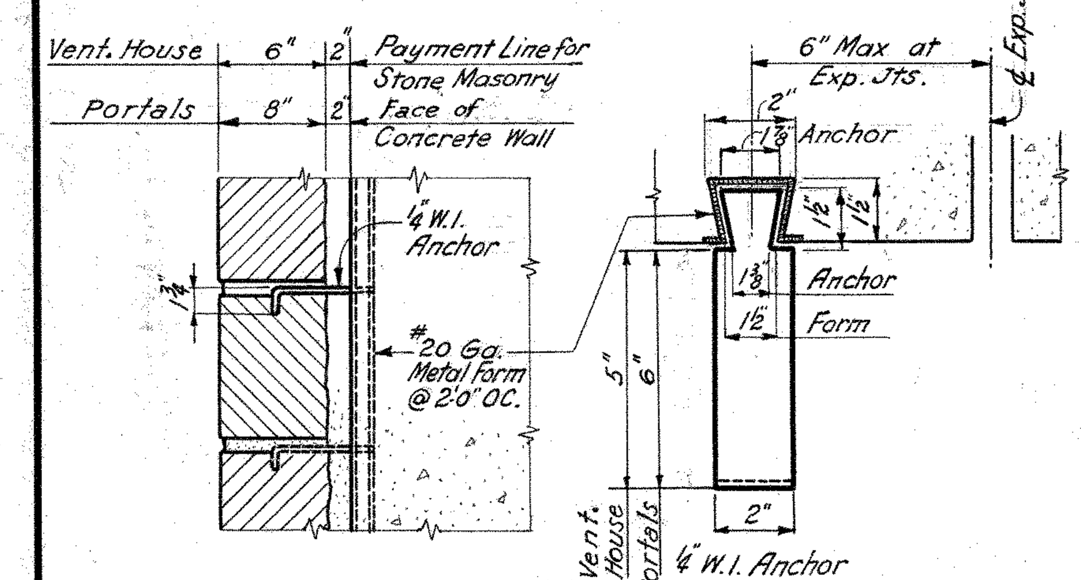
Scale: 1" = 1'-0"



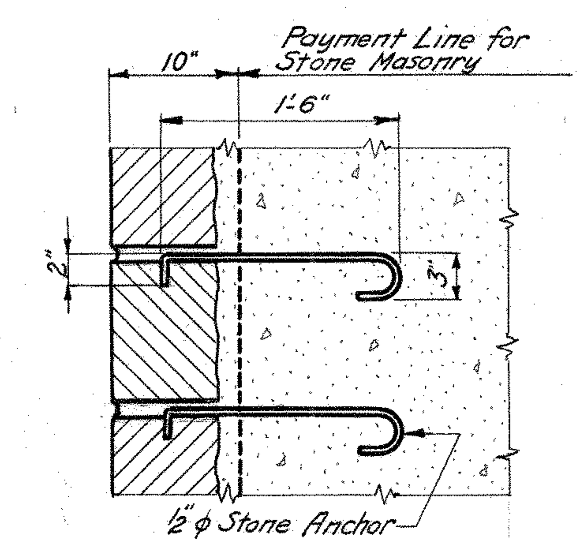
DETAIL "B"

TYPICAL TRANSVERSE CONSTRUCTION JOINT IN ARCH AT CUT & COVER SECTION

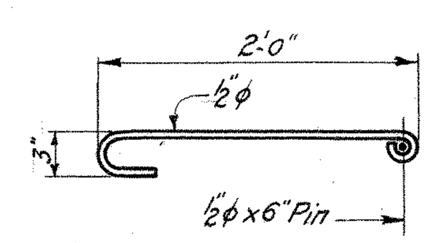
Scale: 1" = 1'-0"



STONE SET AFTER CONCRETE IS POURED



STONE SET BEFORE CONCRETE IS POURED

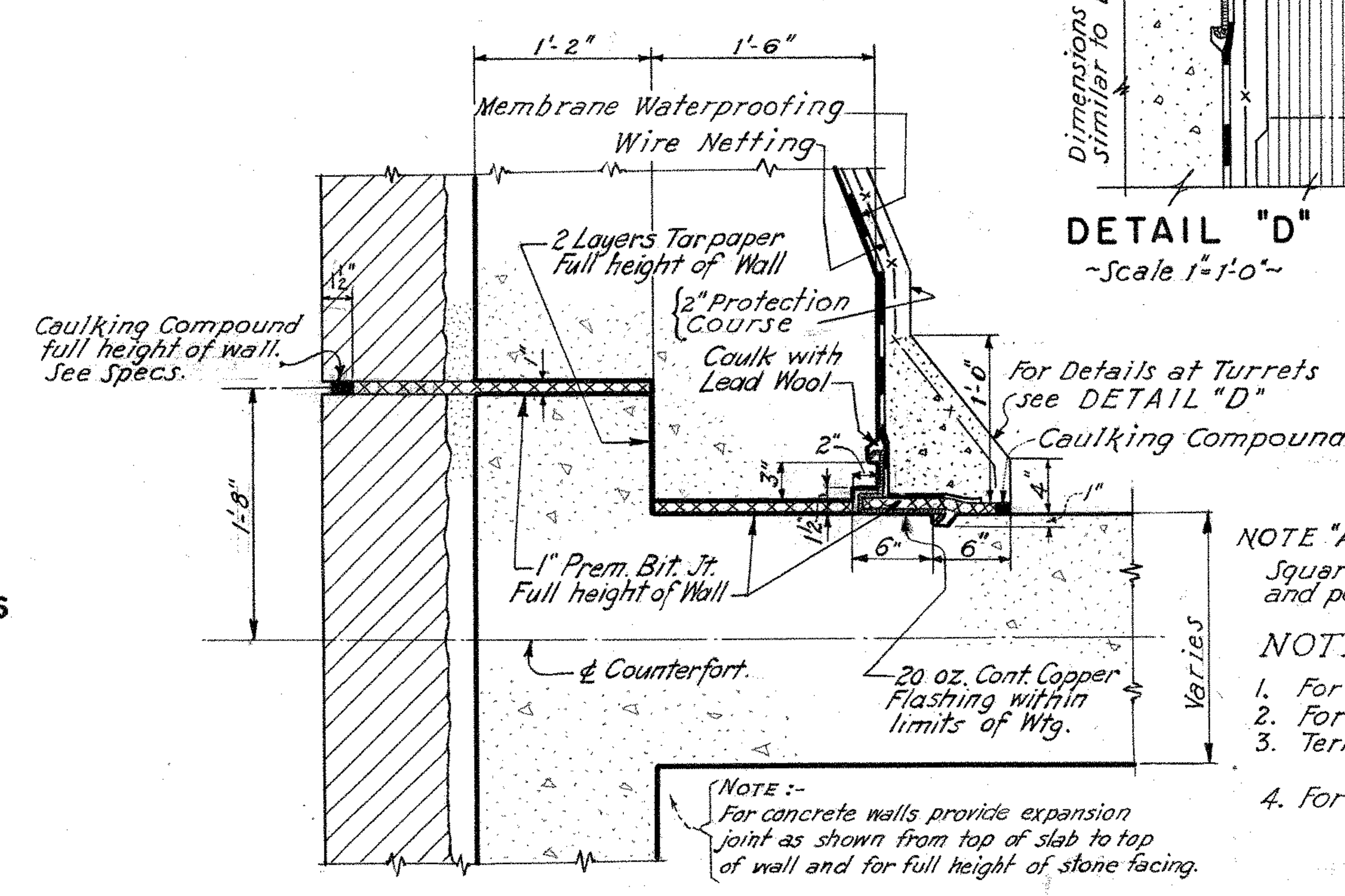


DETAIL OF ANCHORS FOR RING STONES

DETAIL OF ANCHORS FOR STONE MASONRY

Scale: 1" = 1'-0"

NOTE: One Anchor per 6 Sq. Ft. of Stone Masonry. At least one Anchor to each dimension stone. Two Anchors to each dimension stone 3'-0" long or more and all ring stones.



DETAIL "A"

EXPANSION JOINT DETAIL

~Scale 1"=1'-0"~

NOTE "A"
Square off rock in front of Portals and pour concrete to rock face.

NOTES:
1. For General Notes see Sheet № 1
2. For Wall and Slab Reinforcing not shown see Sheet № 24
3. Terminate Waterproofing in reglet as shown in Detail "C"
4. For location of Sections D-D, J-J, K-K, S-S, V-V, & W-W see Sheet № 24

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

EAST PORTAL
SECTIONS, DETAILS & PORTAL DRAINAGE

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/4"=1'-0" unless noted
MADE BY G.V.
CHECKED BY A.B.J.
APPROVED ______ DATE ______

PROJECT NO.

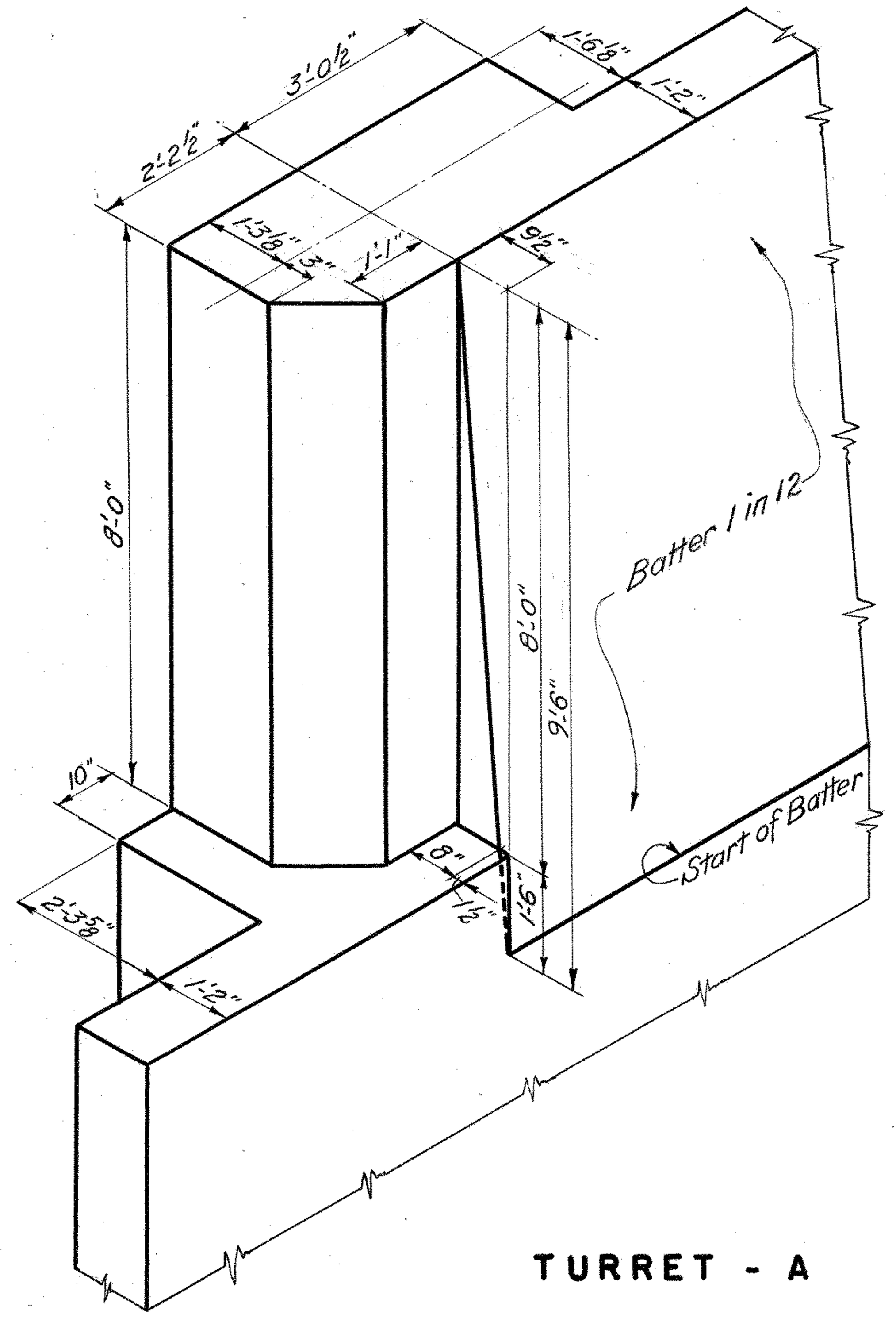
TUNNEL SHEET NO. 27 OF 44

185 90

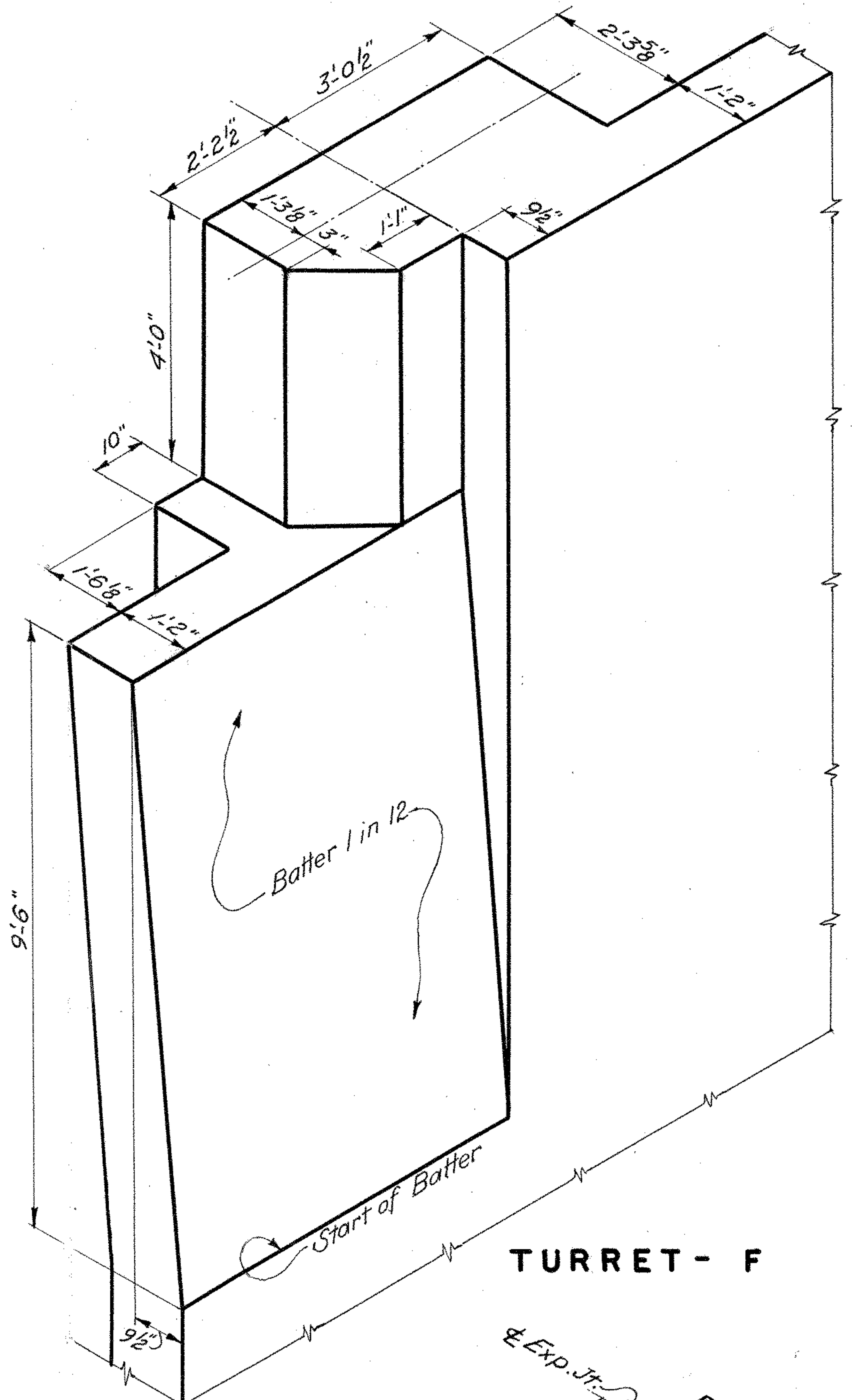
147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		41	73

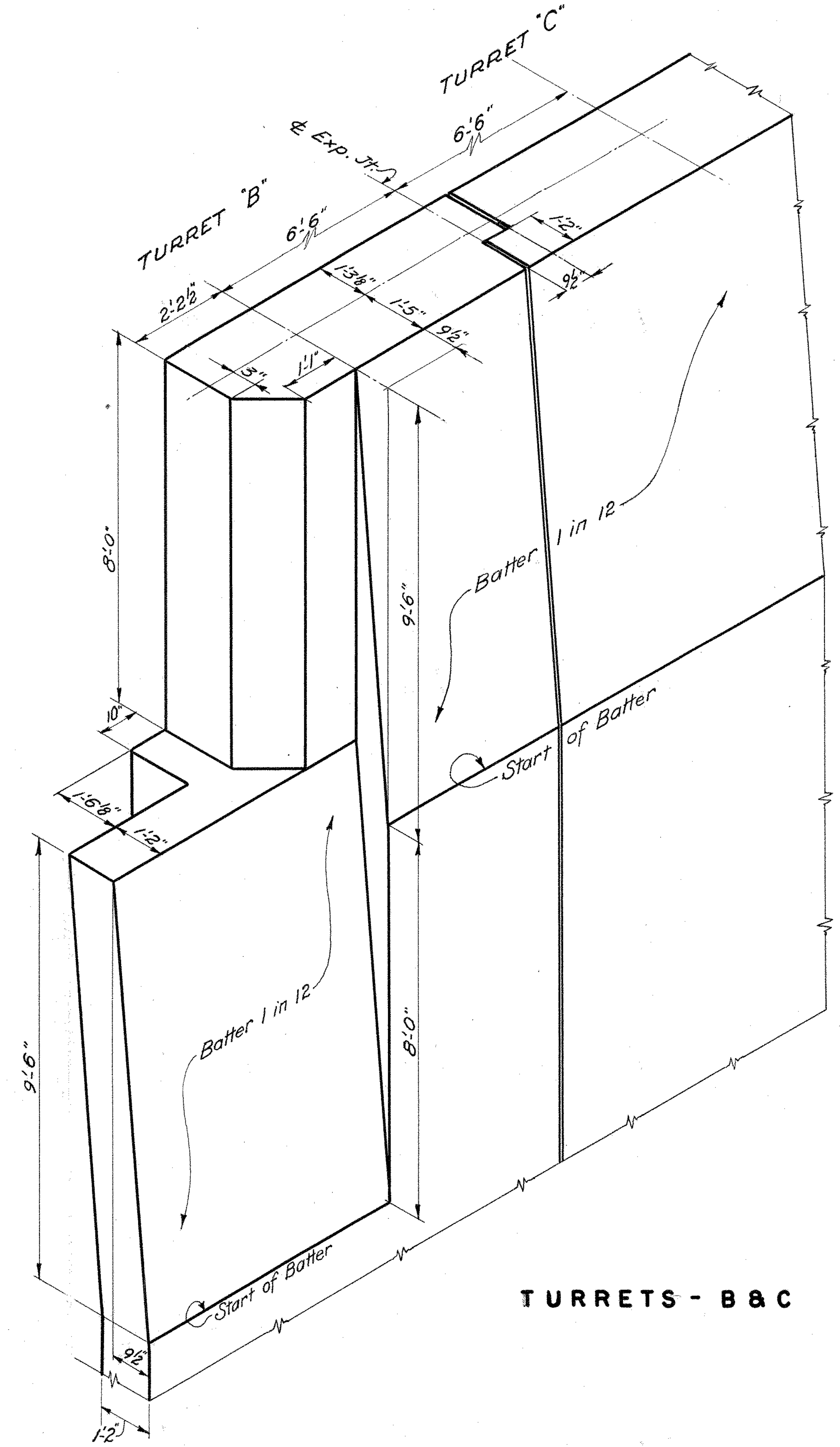
PROJECT NO. 185-90



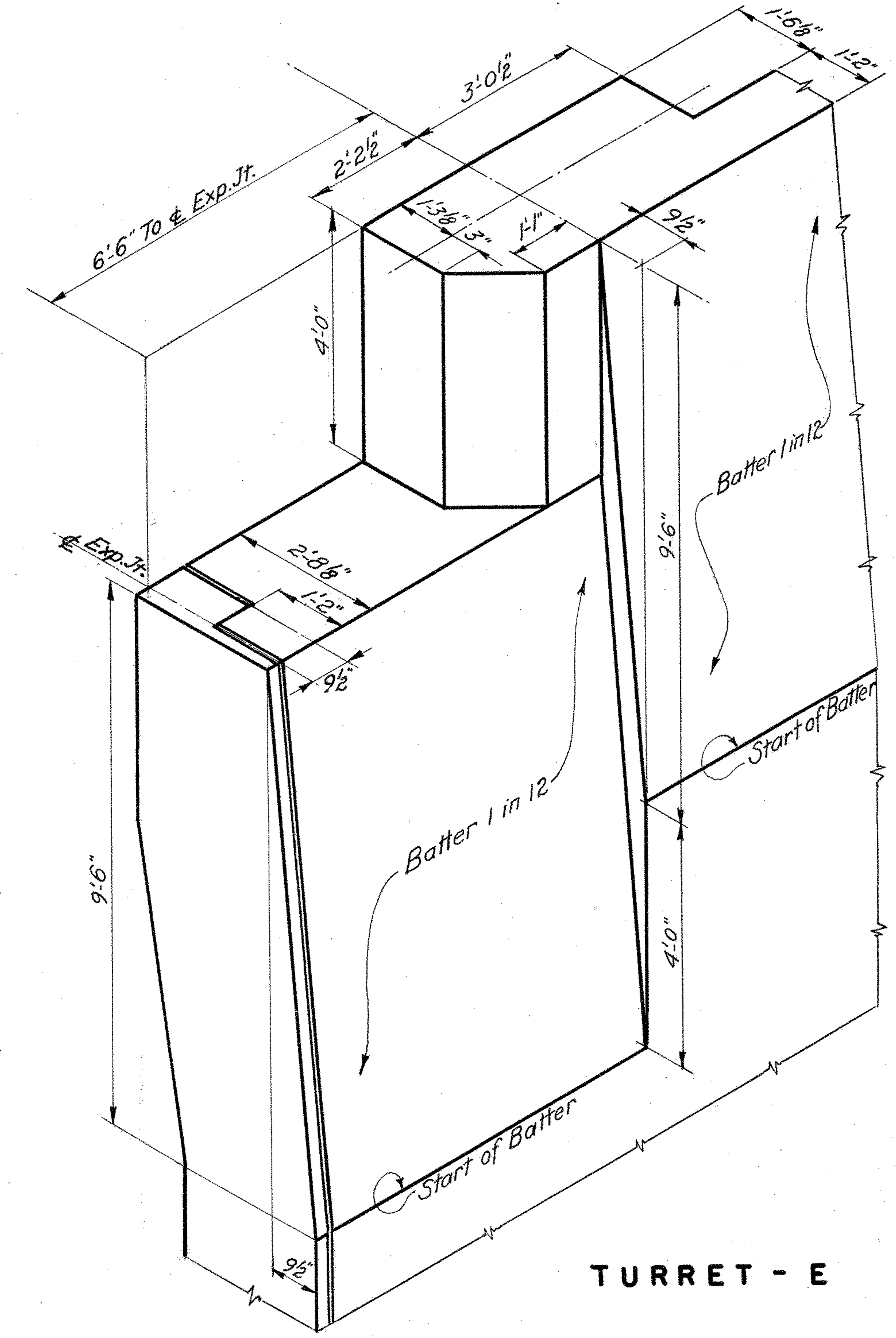
TURRET - A



TURRET - F

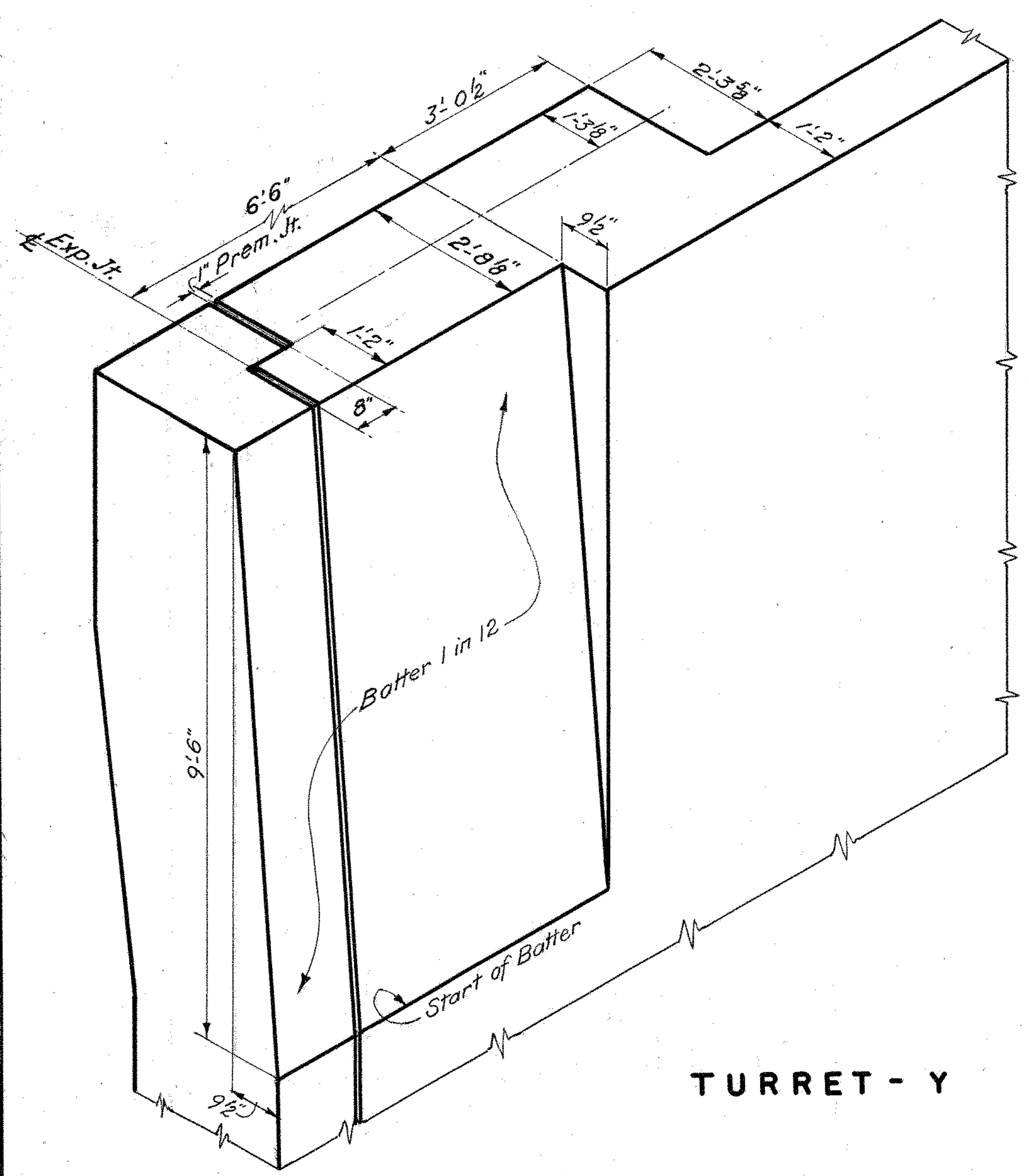


TURRETS - B & C

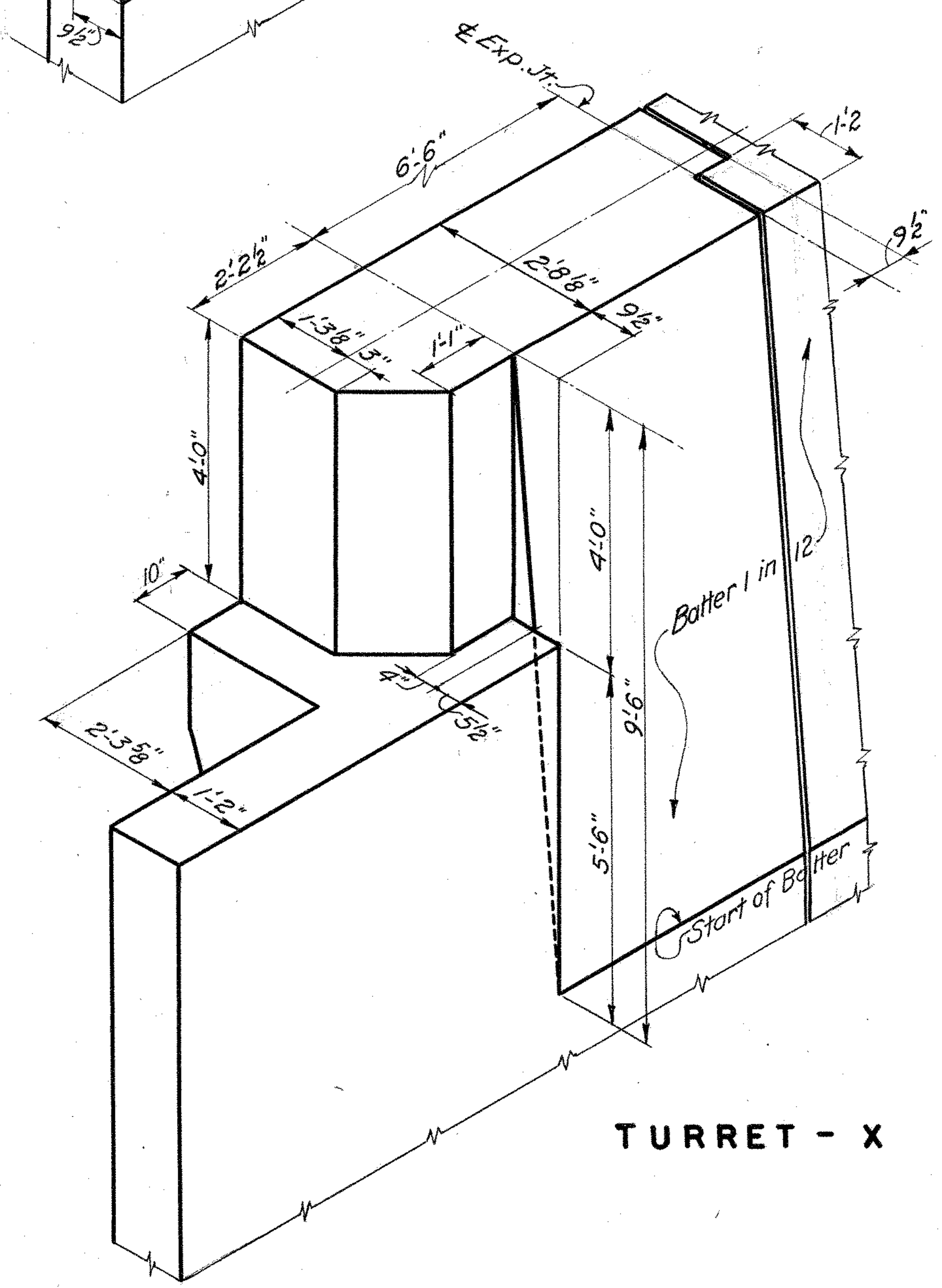


TURRET - E

NOTE:-
For location see East & West Portals Sheets Nº20 & Nº24



TURRET - Y



TURRET - X

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

CONCRETE DETAILS AT TURRETS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE: ½" = 1'-0"
MADE BY C.C.C.
CHECKED BY A.B.J.
APPROVED ____ DATE ____

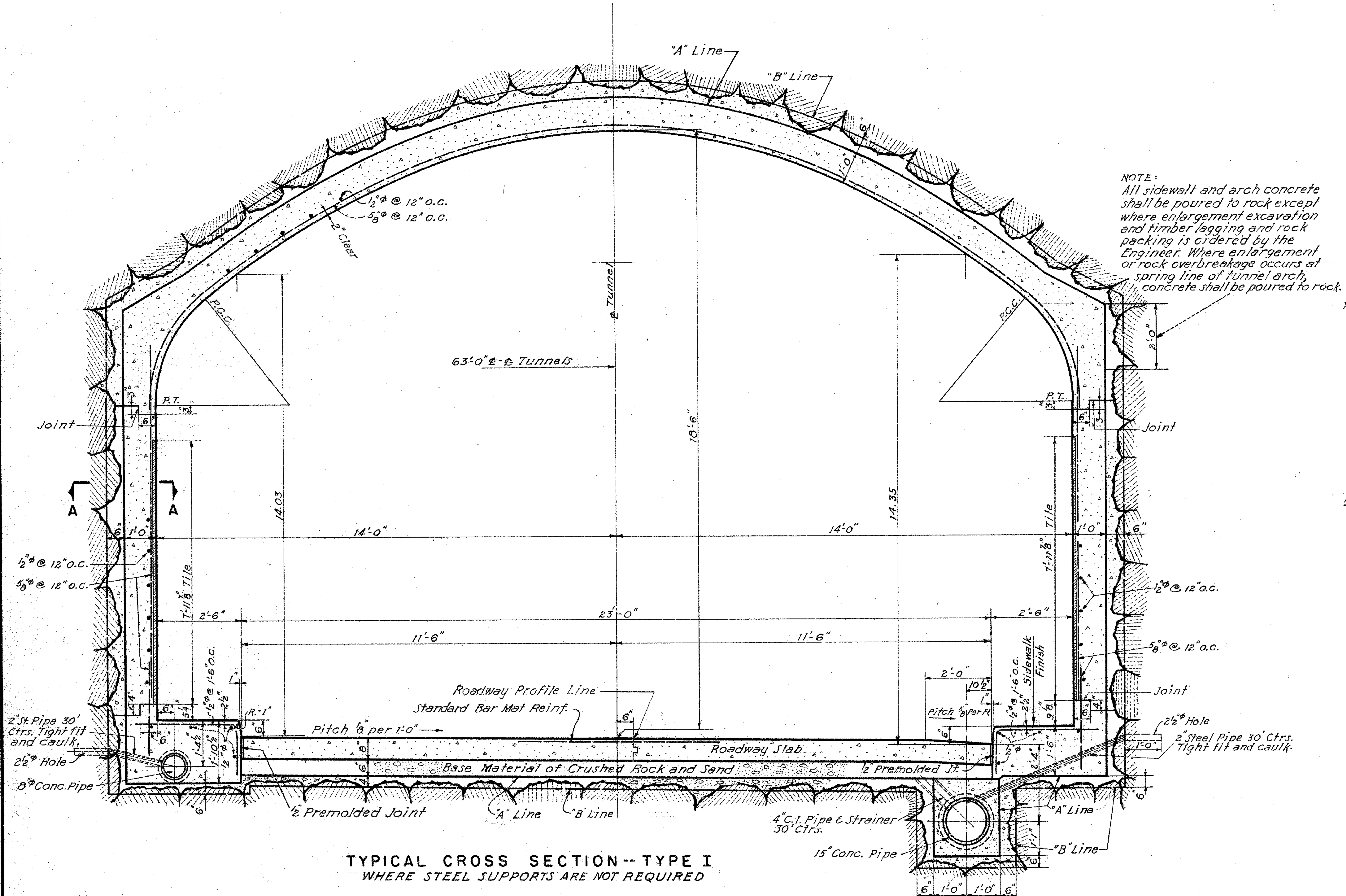
PROJECT NO.

TUNNEL SHEET NO. 28 OF 44

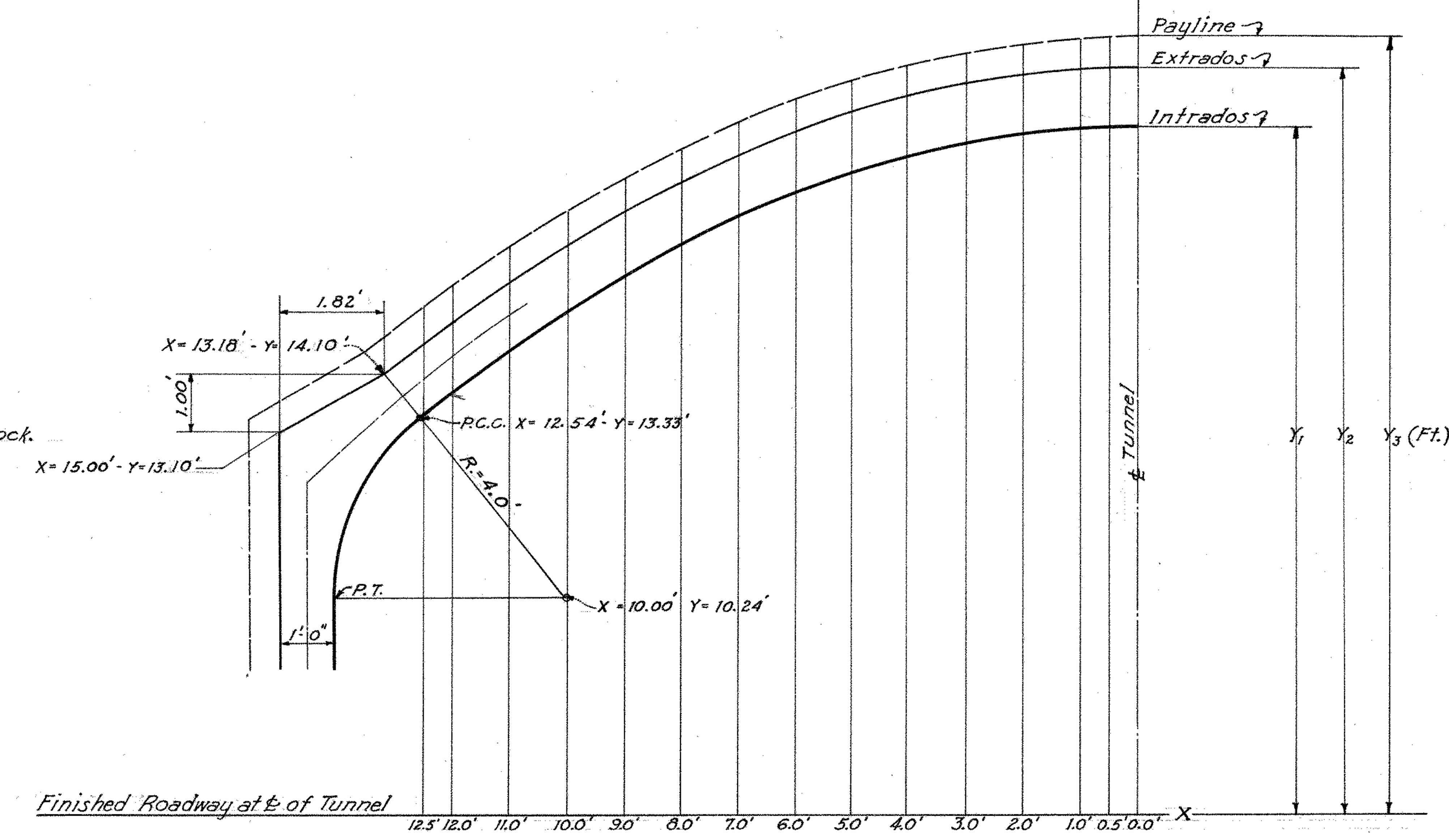
185 90 147 03 41

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		42	73

PROJECT NO. 185 - 90



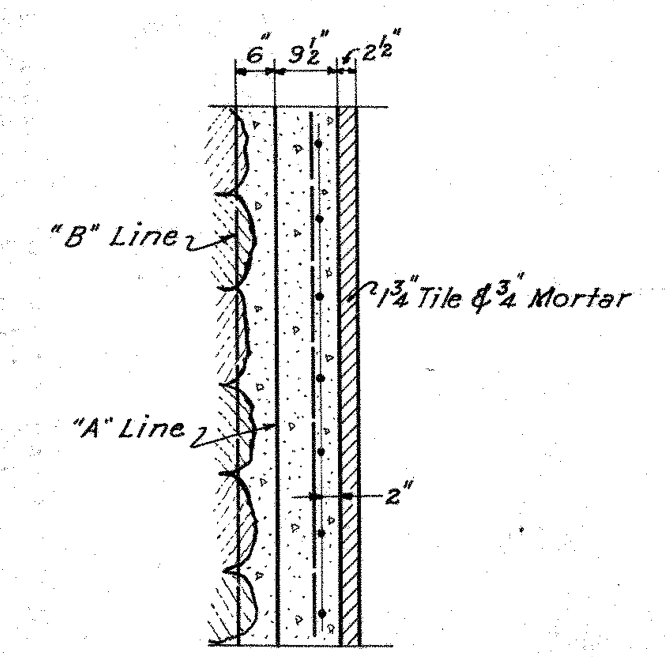
TYPICAL CROSS SECTION -- TYPE I
WHERE STEEL SUPPORTS ARE NOT REQUIRED



COORDINATES OF TUNNEL ARCH

Y \ X	0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	12.5
INTRADOS --- Y_1	18.50	18.49	18.47	18.37	18.20	17.97	17.68	17.31	16.88	16.39	15.83	15.21	14.52	13.76	13.36
EXTRADOS --- Y_2	19.50	19.49	19.47	19.38	19.22	19.00	18.73	18.38	17.98	17.51	16.99	16.39	15.74	15.02	14.64
PAYLINE --- Y_3	20.00	19.99	19.97	19.88	19.73	19.52	19.25	18.92	18.53	18.08	17.56	16.99	16.35	15.65	15.28

~~TYPE I TUNNEL SECTION NOT USED~~



SECTION A-A

NOTES:
1. For General Notes see Sheet № 1
2. For location of electrical conduits see Sheet № 38, 39 & 41
3. For location of tunnel drainage see Sheet № 34
4. For definition of "A" Line and "B" Line see Supplementary Specifications, "Special Provisions."
5. For Details and locations of Niches in Walls See Sheet No. 11
6. For Details and locations of Niches for Lights See Sheet No. 41
7. For Details of Control Room See Sheet No. 31
8. For Details of Expansion and Construction Joints in Pavement See: "Standard Paving Details"

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
TYPICAL TUNNEL SECTION
TYPE I

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/2" = 1'-0"
MADE BY P.C.
CHECKED BY G.V.
APPROVED
DATE

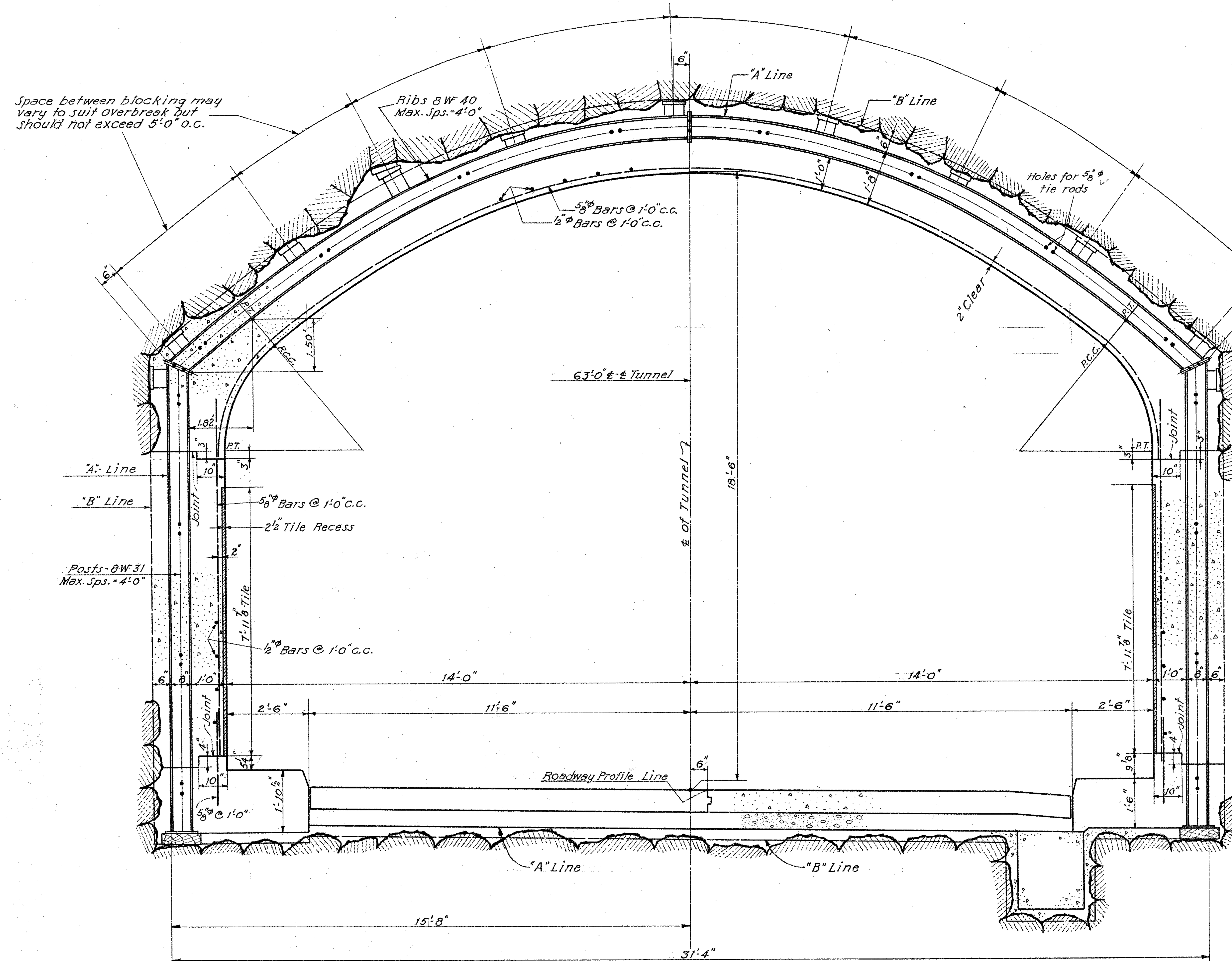
PROJECT NO.
TUNNEL SHEET NO. 29 OF 44

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		43	73

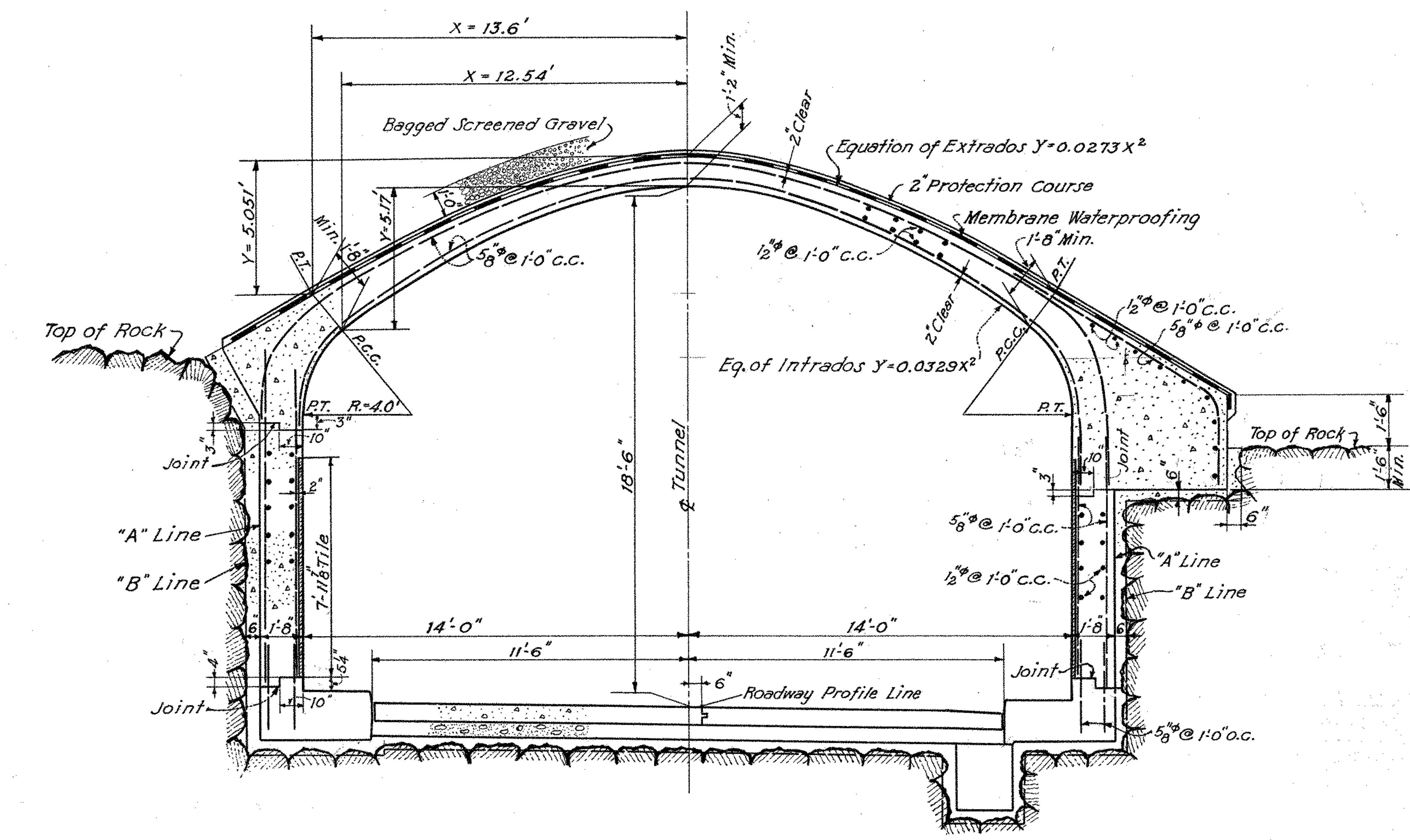
PROJECT NO. 185-90



TYPICAL CROSS SECTION TYPE II

WHERE STEEL SUPPORTS ARE REQUIRED

~Scale 1/2"=1'-0"~



TYPICAL CROSS SECTION TYPE III

WHERE TOP OF ROCK IS BELOW SPRING LINE OF ARCH AND FOR CUT AND COVER SECTION.

~Scale 1/4"=1'-0"~

NOTES:

1. For General Notes see Sheet Nº 1
2. For location of electrical conduits see Sheet Nº 38, 39 & 41
3. For location of tunnel drainage see Sheet Nº 34
4. For definition of "A" Line and "B" Line see Supplementary Specifications "Special Provisions."
5. For Details of Curbs and Roadway see Sheet Nº 29
6. For Coordinates of Intrados see Sheet Nº 29
7. For Details of Expansion and Construction Joints in pavement see "Standard Paving Details"
8. For Details and locations of Niches in Walls see Sheet Nº 11
9. For Details and locations of Niches for Lights see Sheet Nº 41

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
SPECIAL TUNNEL SECTIONS
TYPE II & TYPE III

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, NY.

SCALE *As Noted*
MADE BY *P.C.*
CHECKED BY *G.V.*
APPROVED ______ DATE ______

PROJECT NO.
TUNNEL SHEET NO. 30 OF 44

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		44	73

PROJECT NO. 185-90

NOTES:-
For Location of Section A-A See Sheet #1
For Sections C-C & D-D See Sheet #32
For Section B-B See Section B-B Sheet #33
For General Notes See Sheet #1
For Details Not Shown See Architectural Dwgs.
For Drainage see Sheet #34
For Electrical Conduits see Sheet #43

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
VENTILATING SHAFT
AND CONTROL ROOM

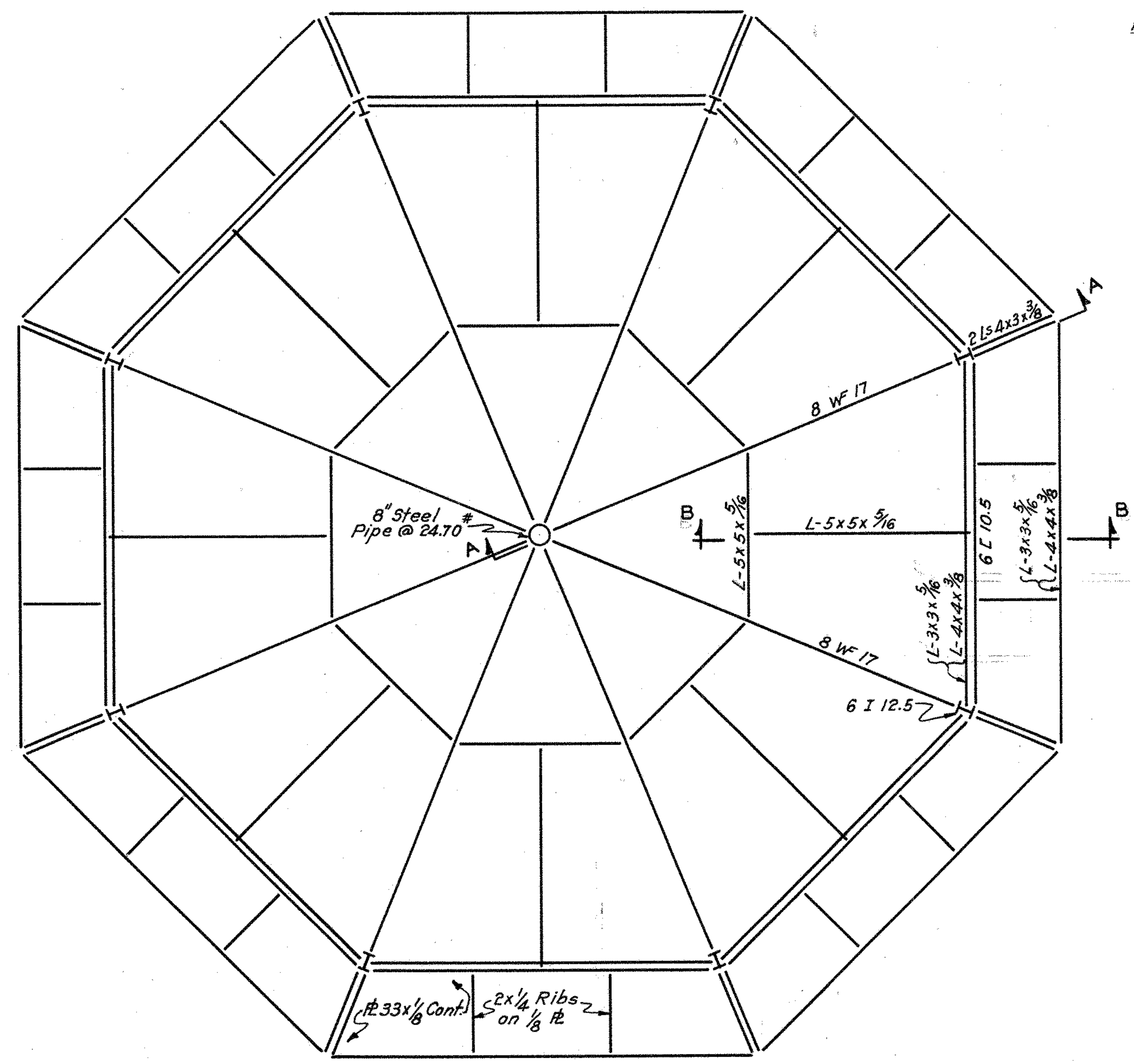
PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/4"=1'-0" Unless noted.
MADE BY P.C.
CHECKED BY G.V.
APPROVED DATE
PROJECT NO.
TUNNEL SHEET NO. 31 OF 44

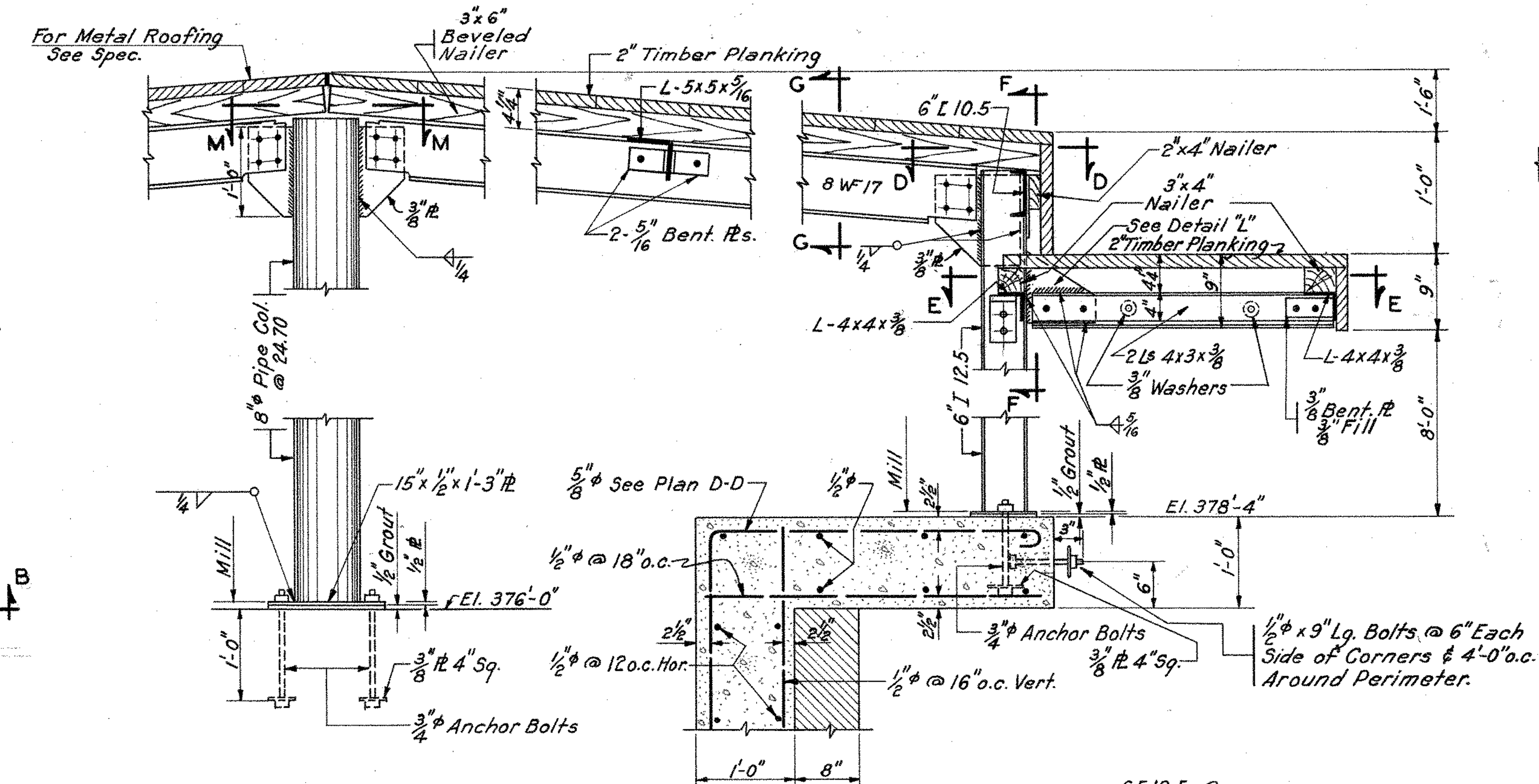
185 90
147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		45	73

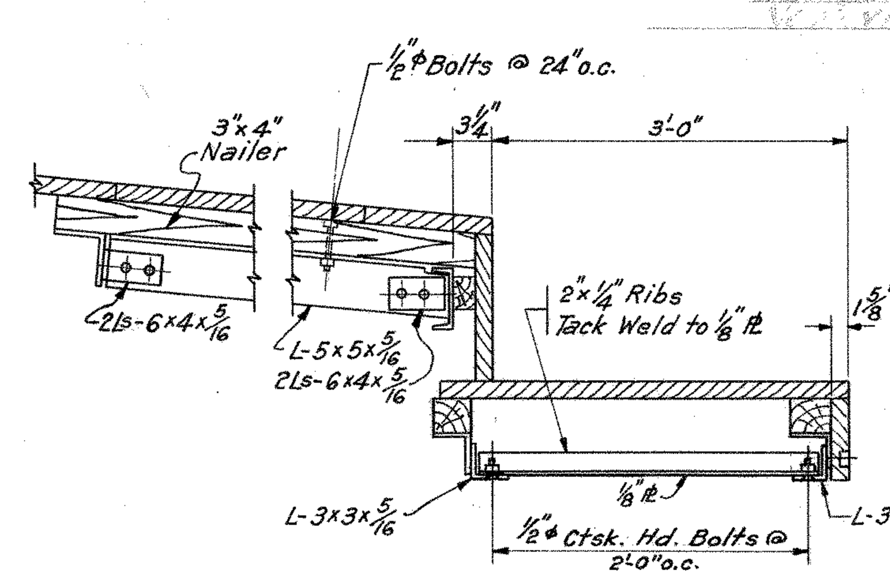
PROJECT NO. 185-90



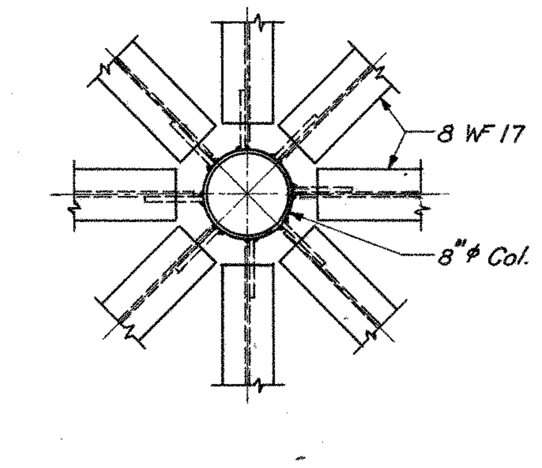
ROOF FRAMING PLAN
SCALE: 1/4" = 1'-0"



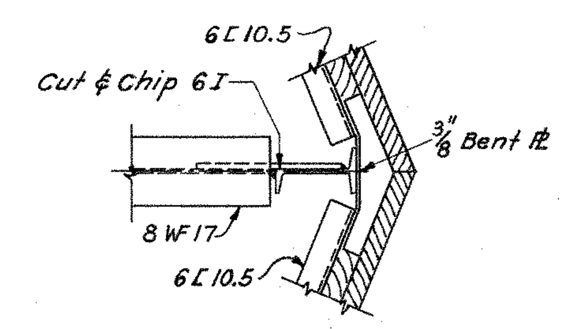
SECTION A-A
SCALE: 3/4" = 1'-0"



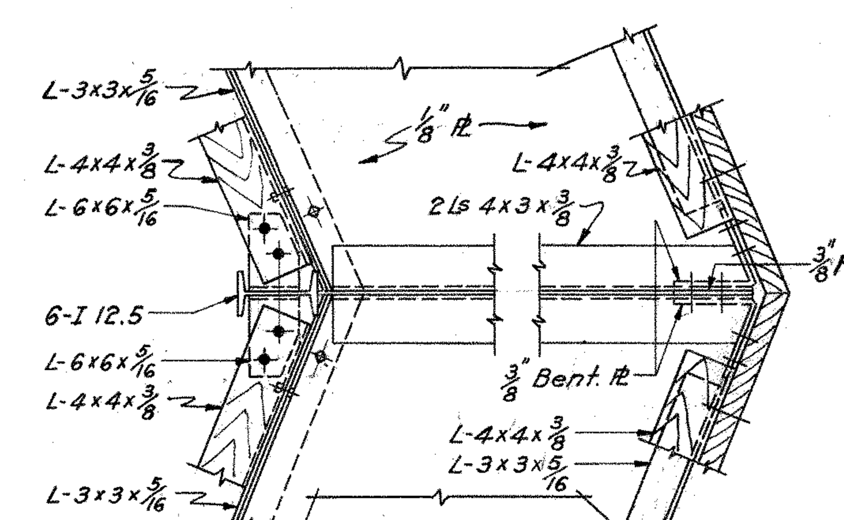
SECTION B-B
SCALE: 3/4" = 1'-0"



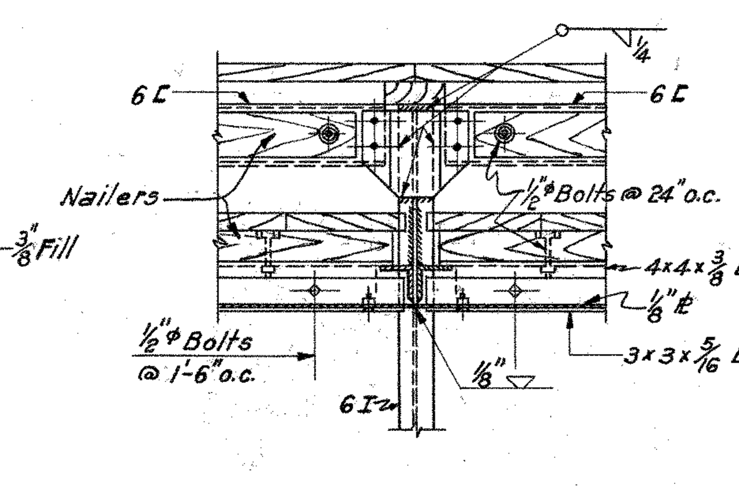
SECTION M-M
SCALE: 3/4" = 1'-0"



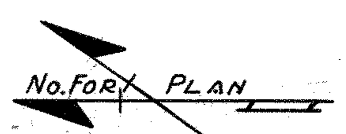
SECTION D-D
SCALE: 1" = 1'-0"

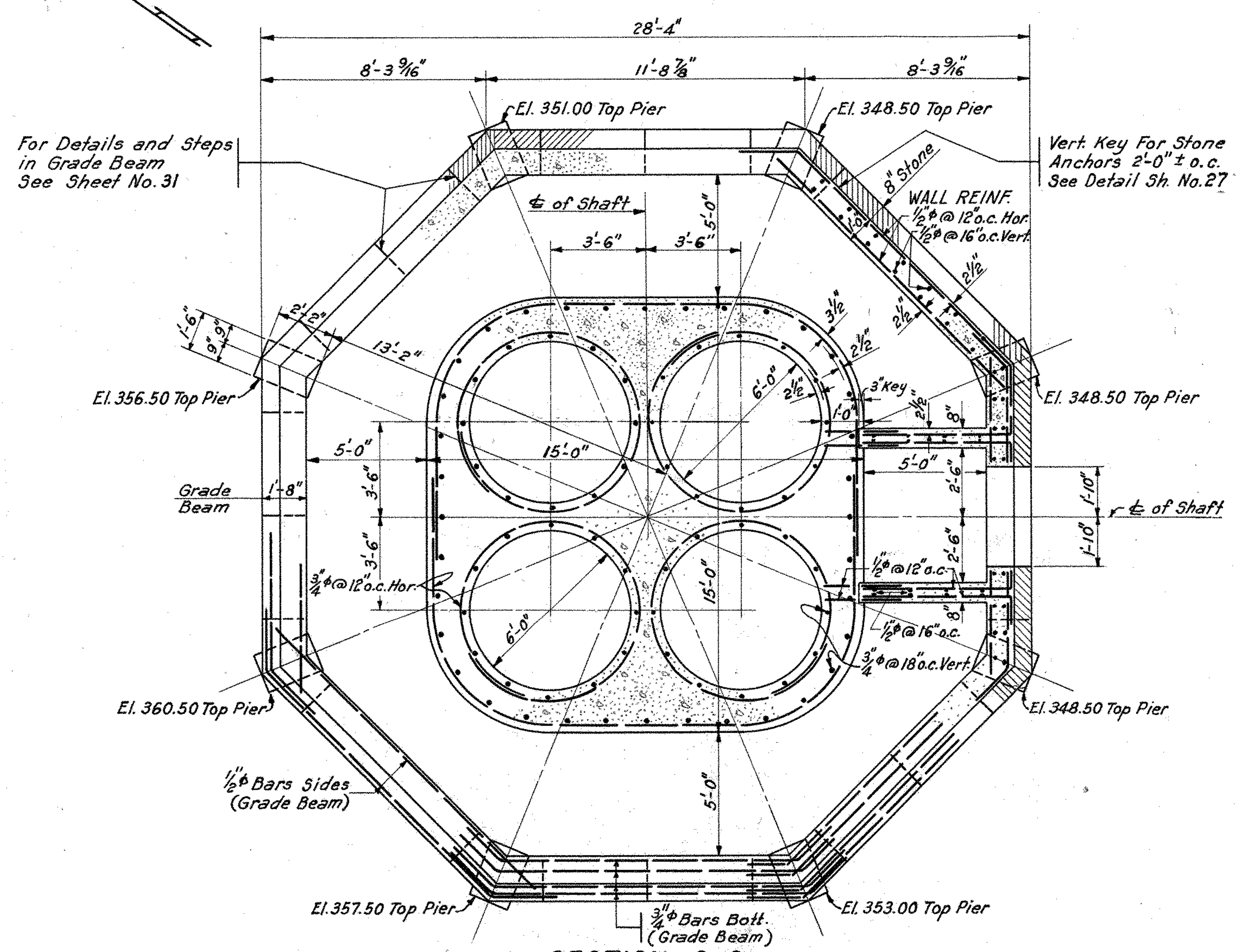


SECTION E-E
SCALE: 1" = 1'-0"

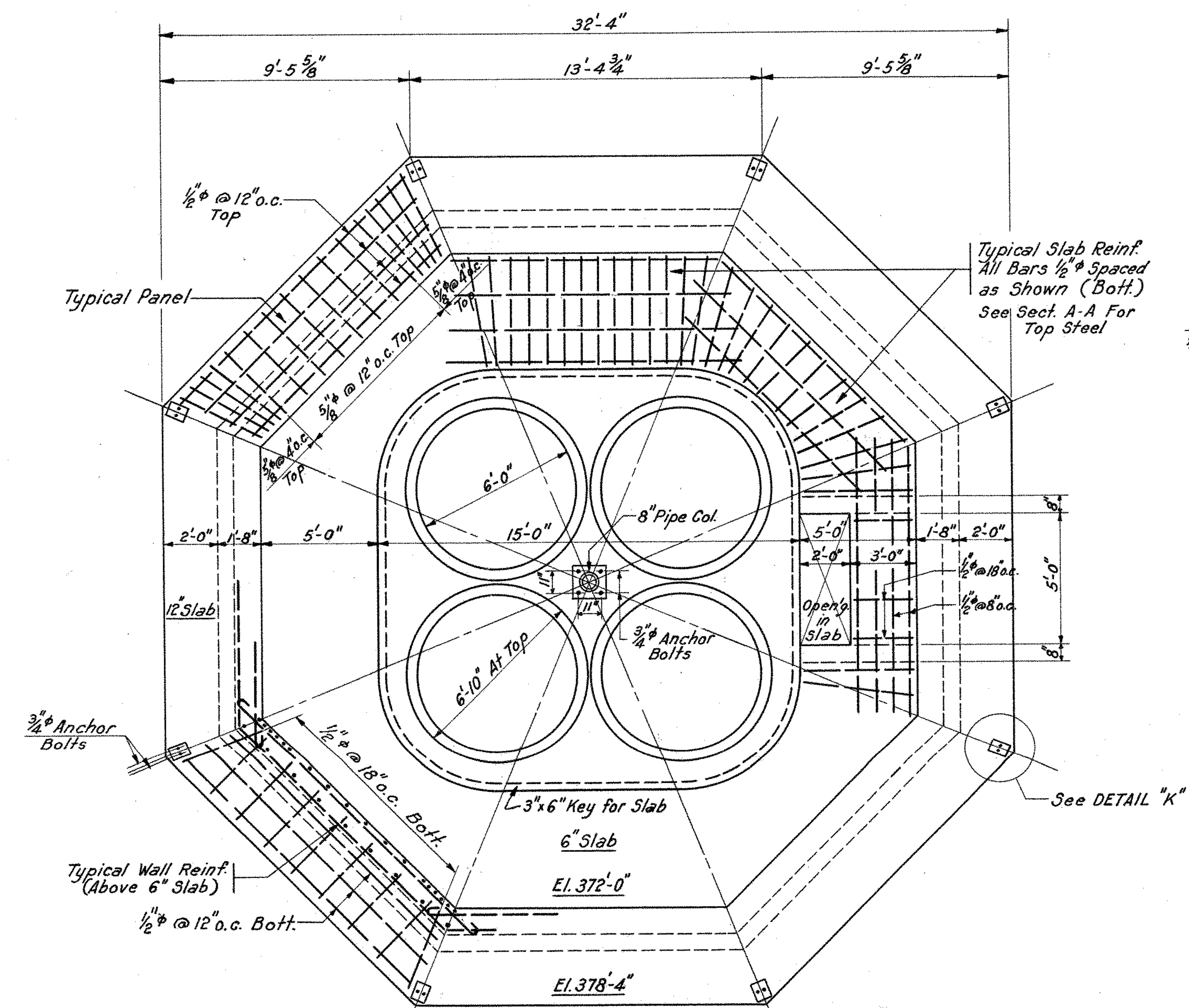


SECTION F-F
SCALE: 3/4" = 1'-0"

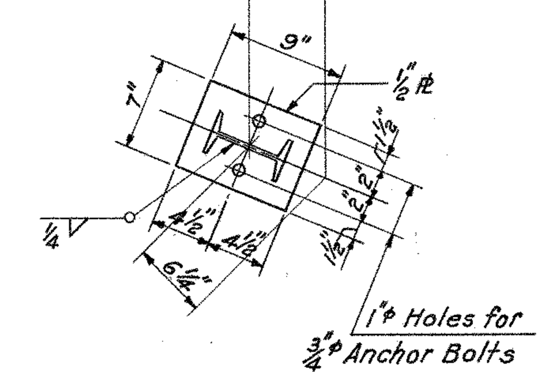




SECTION C-C
SCALE: 1/4" = 1'-0"

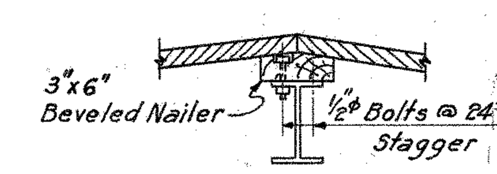


PLAN D-D
SCALE: 1/4" = 1'-0"



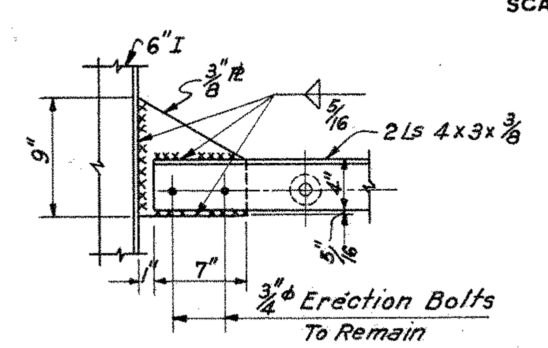
DETAIL "K"
SCALE: 1" = 1'-0"

NOTES:
Rivets 3/4"
Open Holes 13/16" Unless Noted
For Location of Section C-C and Plan D-D See Sheet # 31
For Details Not Shown See Architectural Dwgs.



SECTION G-G
SCALE: 3/4" = 1'-0"

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.



DETAIL "L"
SCALE: 1" = 1'-0"

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
VENTILATING HOUSE
FRAMING PLAN

PARSONS, BRINCKERHOFF HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

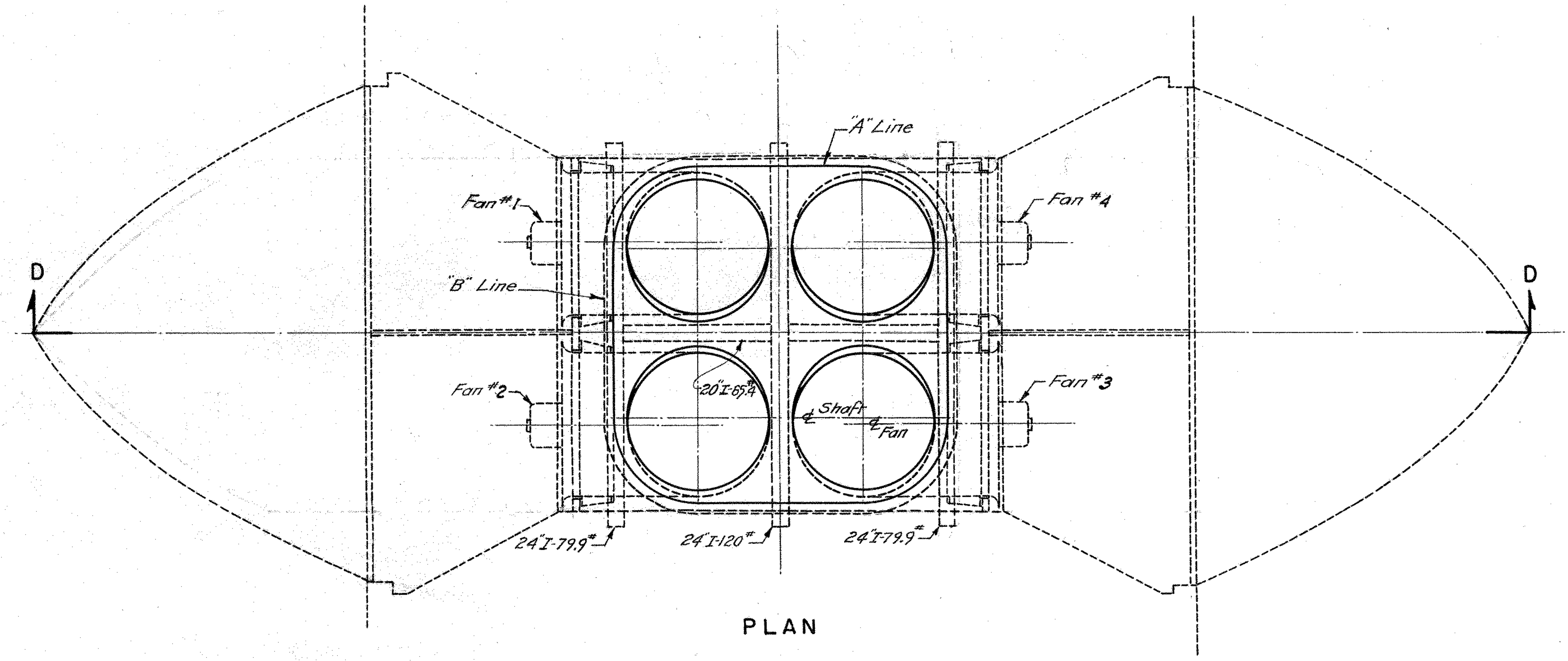
SCALE As Shown
MADE BY P. C.
CHECKED BY G. V.
APPROVED DATE

PROJECT NO.
TUNNEL SHEET NO. 32 OF 44

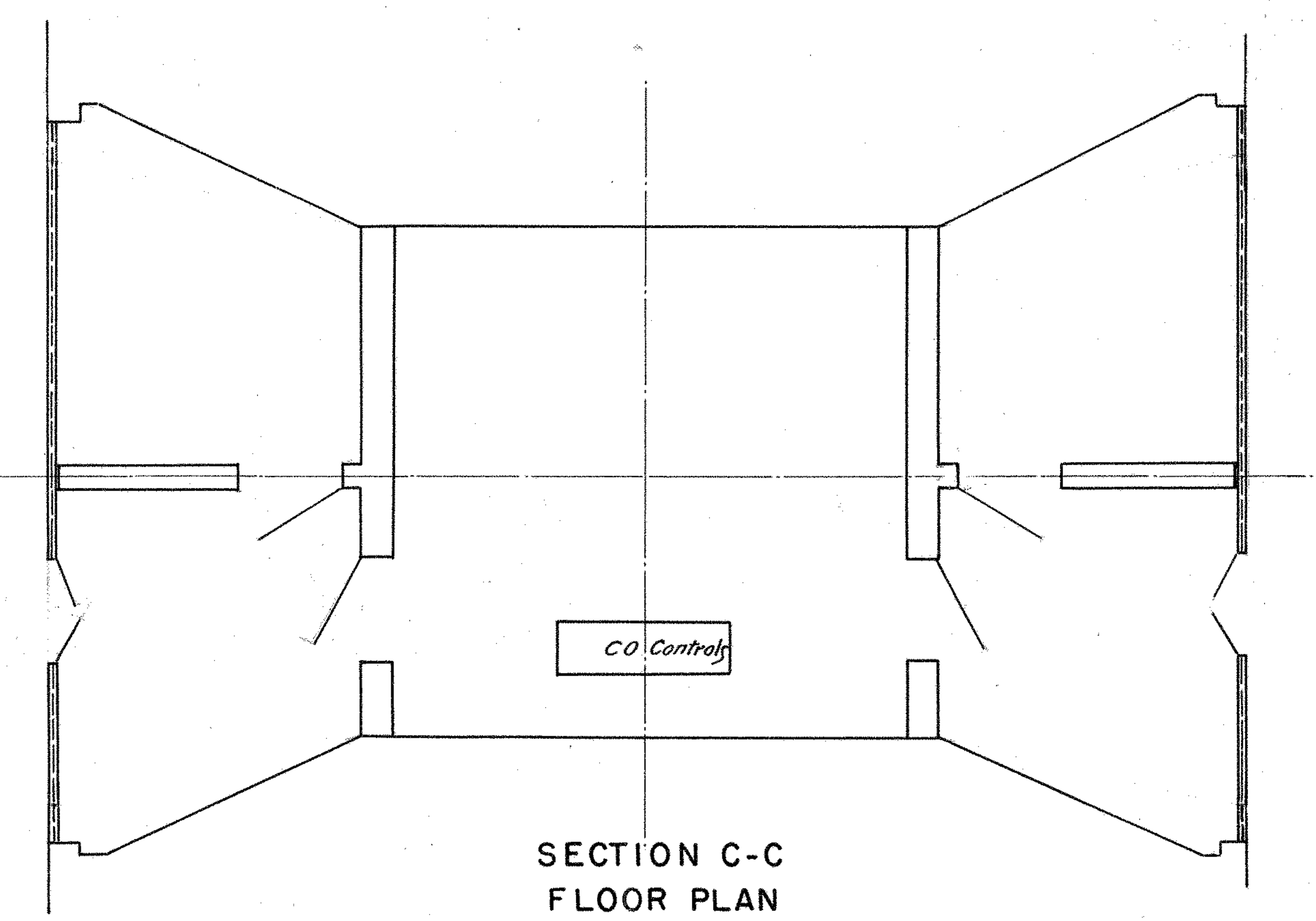
185 90
147 03
45

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		46	73

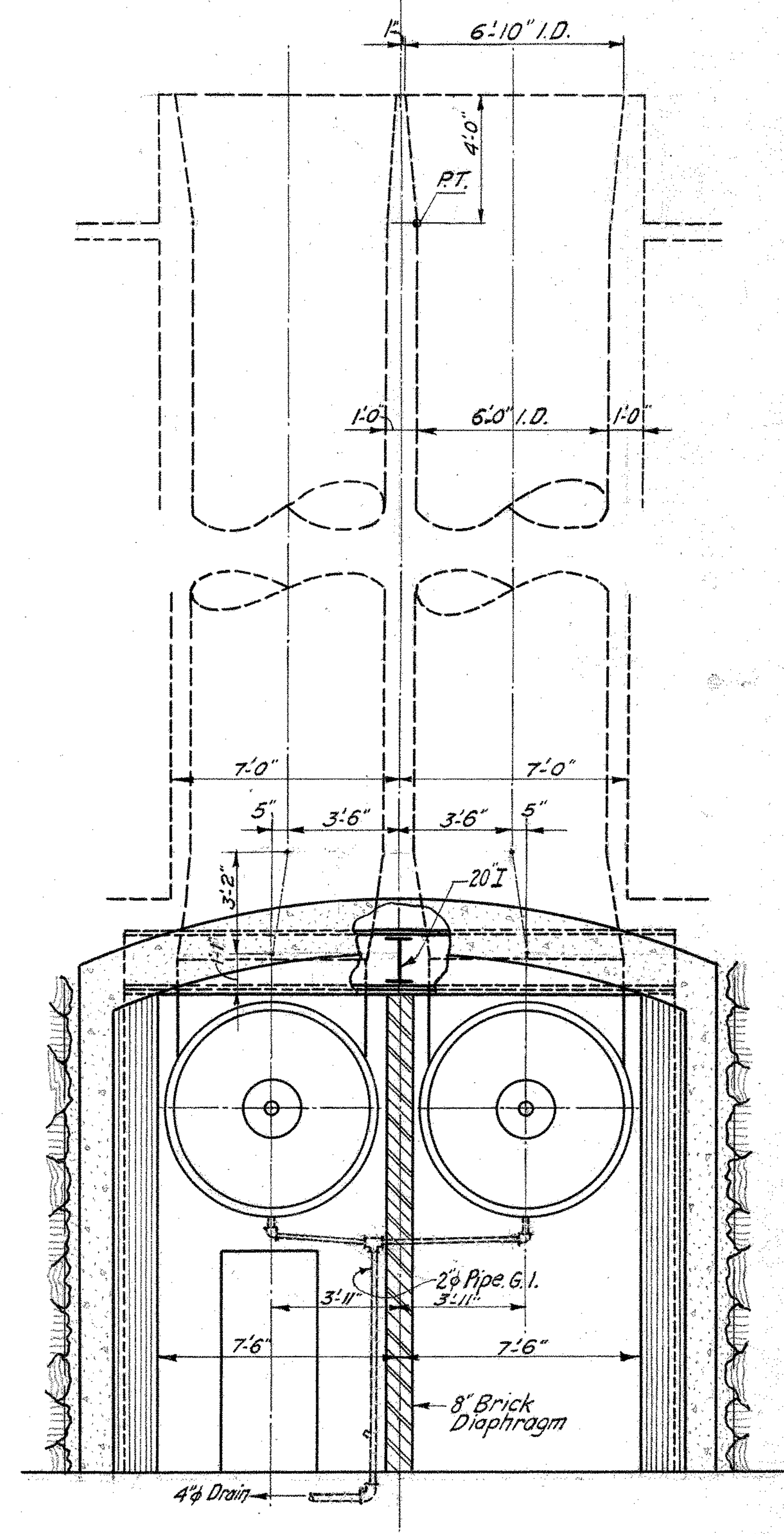
PROJECT NO. 185-90

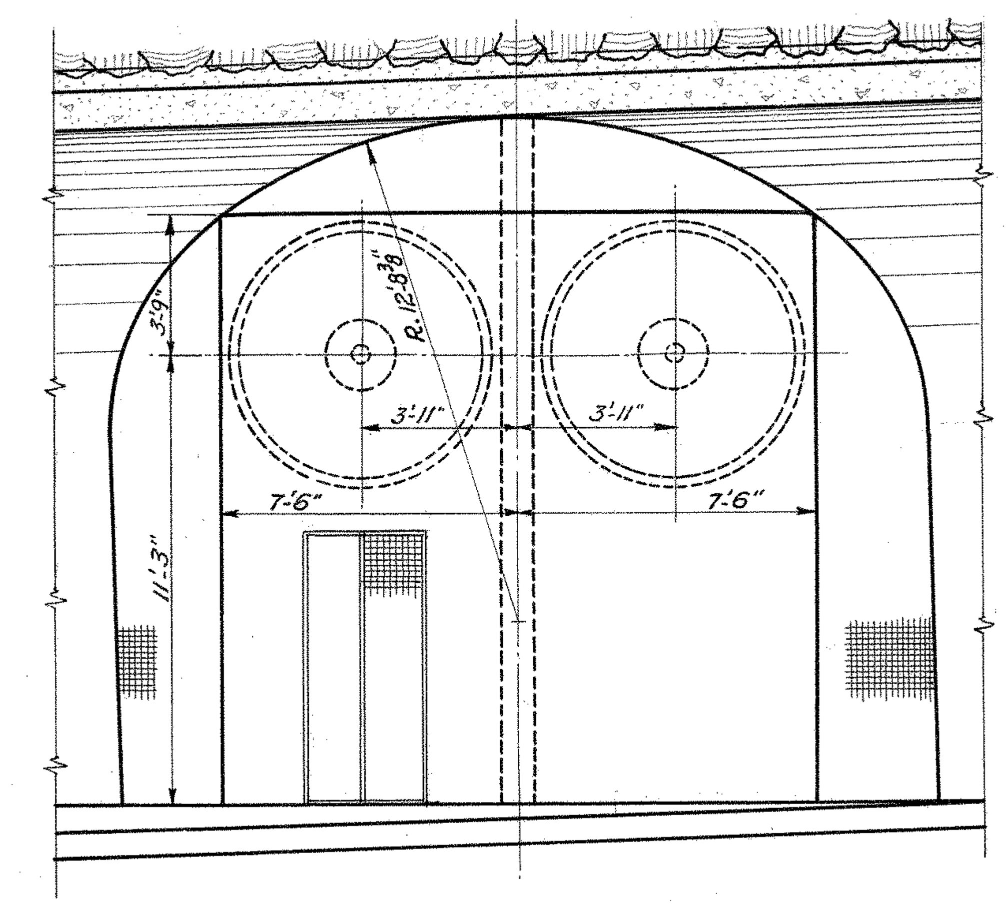


PLAN



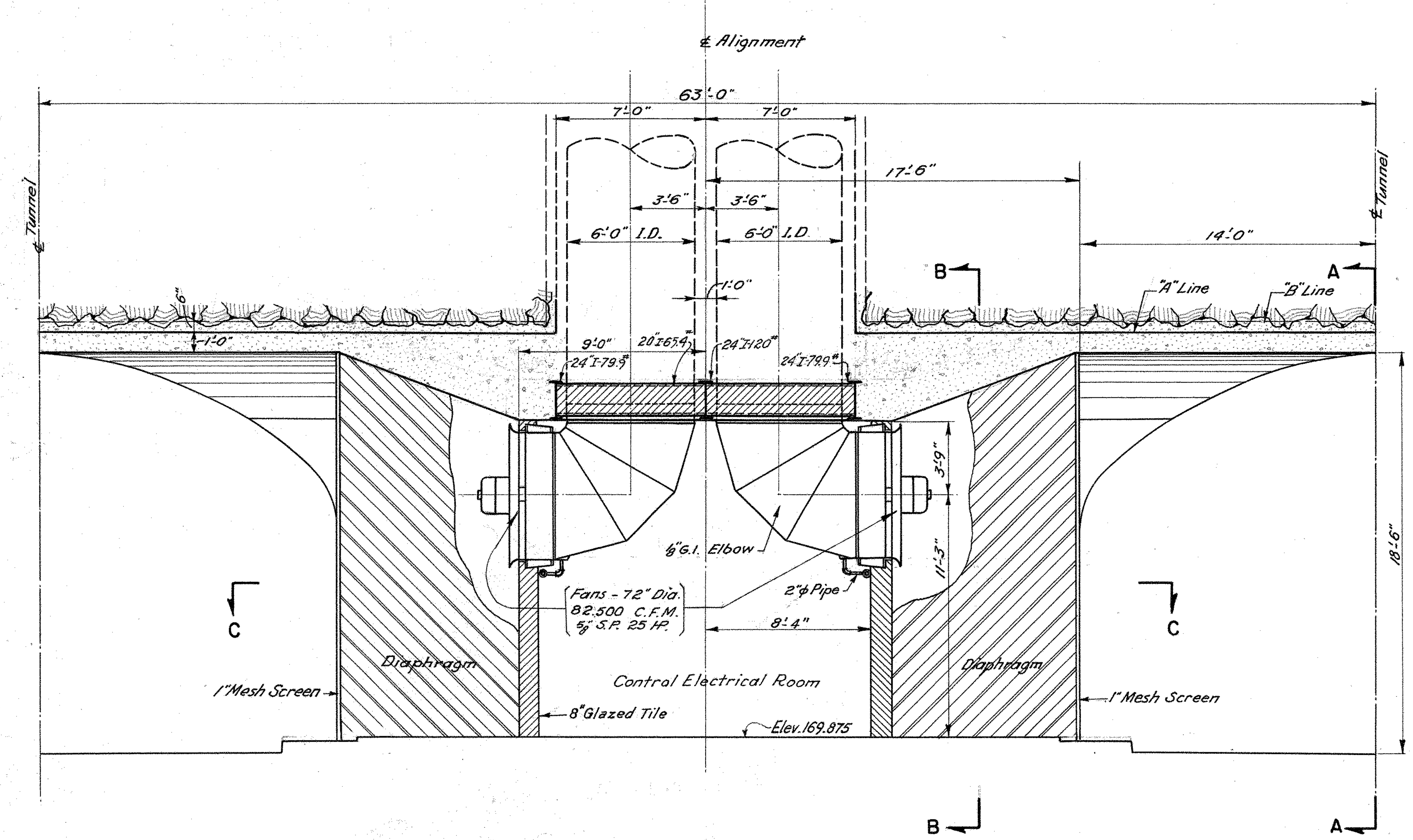
SECTION C-C
FLOOR PLAN





SECTION A-A

SECTION B-B



SECTION D-D

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
CONTROL ROOM

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1/4" = 1'-0"
MADE BY J. P.
CHECKED BY S.R.Apt
APPROVED DATE

PROJECT NO.
TUNNEL SHEET NO. 33 OF 44

185 90 147 03 46

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		47	73

PROJECT NO. 185-90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
DRAINAGE

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE: AS NOTED
MADE BY J.P.
CHECKED BY S.R. Apt
APPROVED DATE

PROJECT NO.

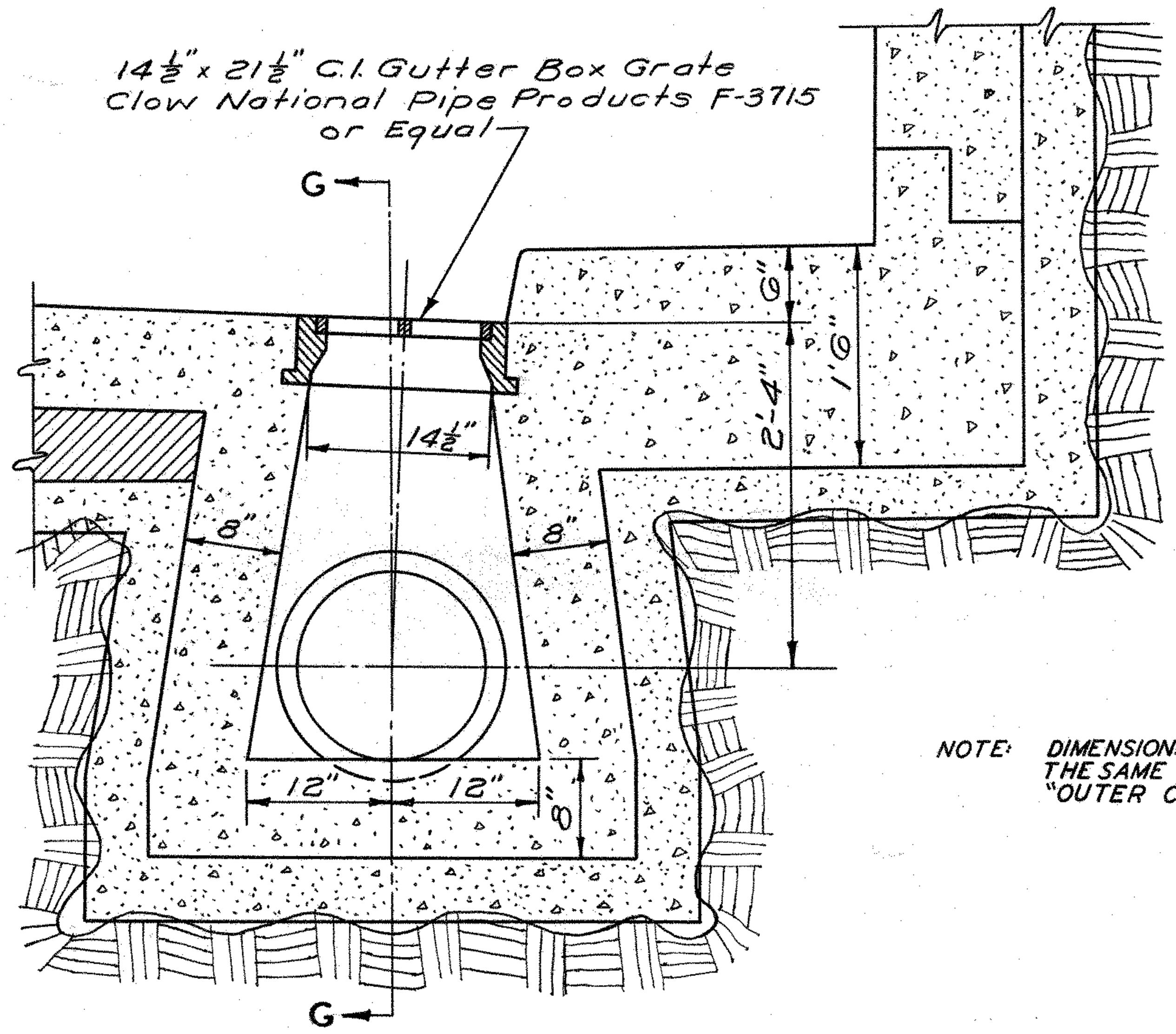
TUNNEL SHEET NO. 34 OF 44

185 90

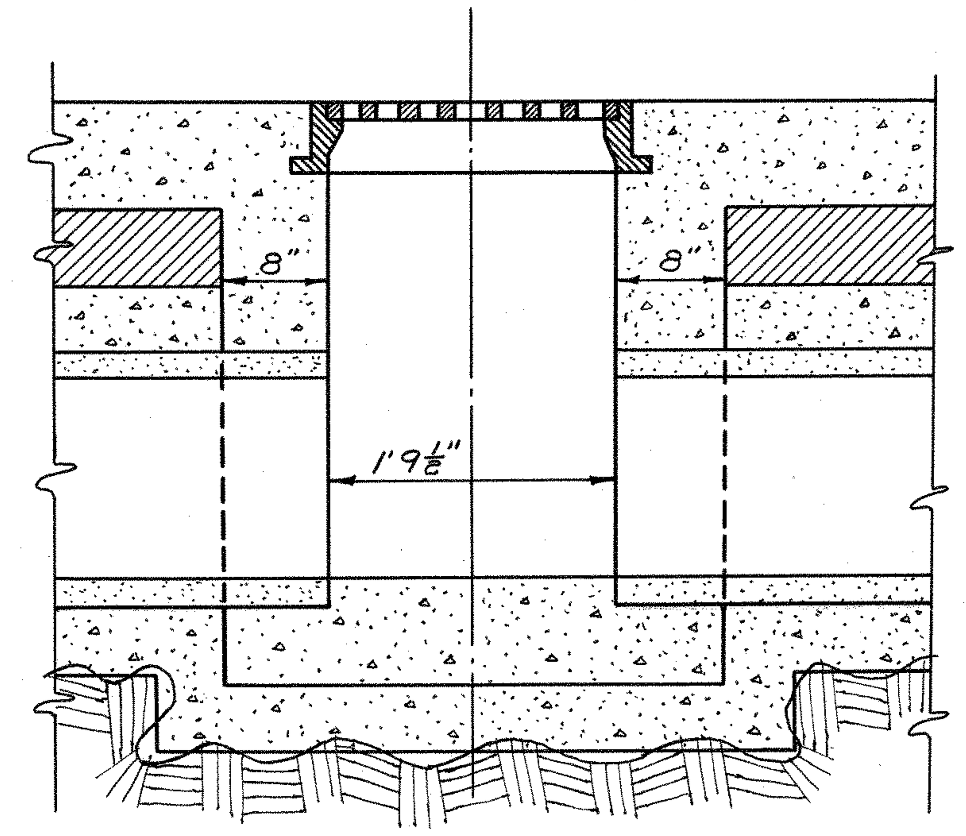
147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		47A	73

PROJECT NO. 185-90

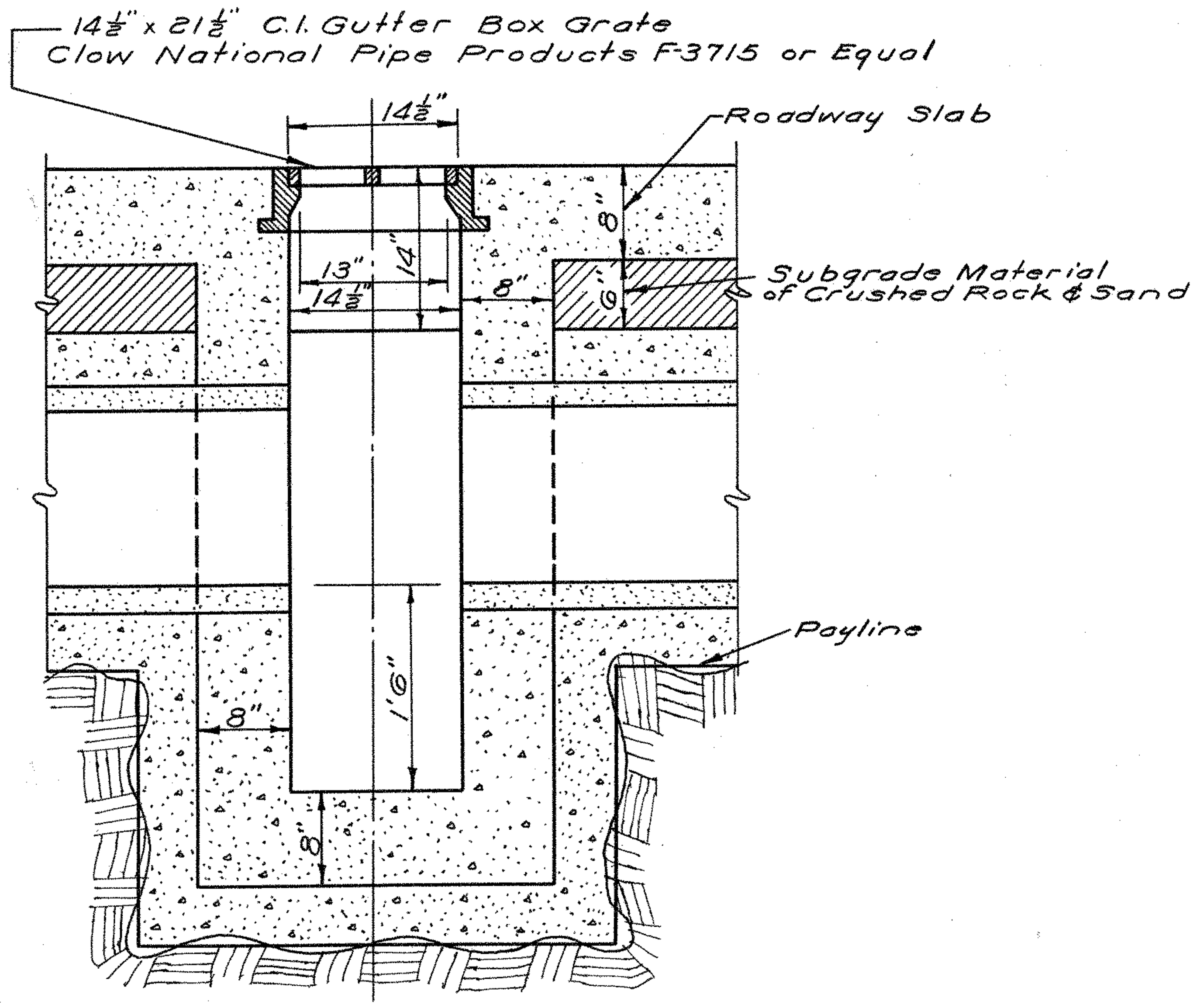


NOTE: DIMENSIONS NOT SHOWN ARE THE SAME AS IN DRAWING FOR "OUTER CURB."

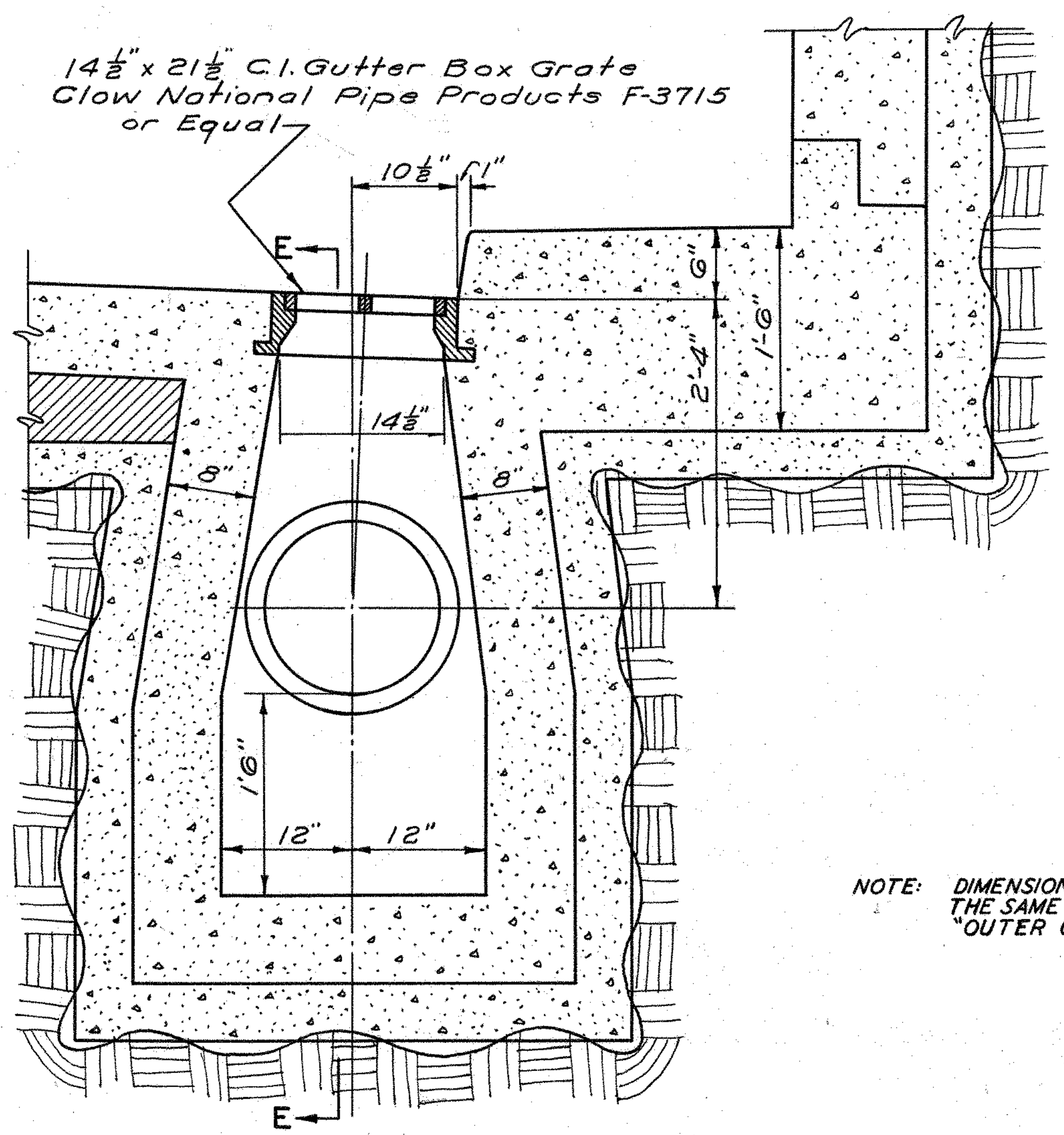


SECTION G-G

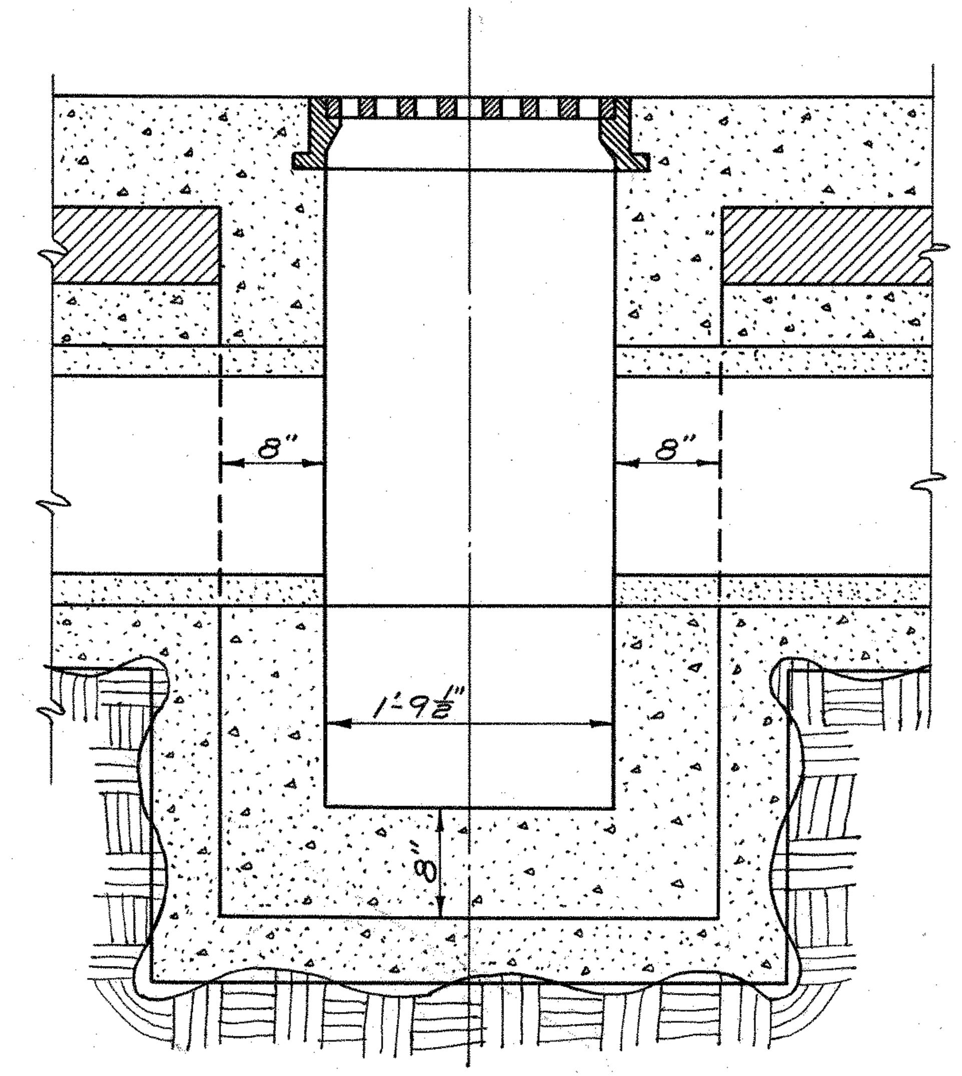
DETAIL OF CATCH BASIN WITHOUT SUMP
Scale 1" = 1'-0"



SECTION F-F
Scale 1" = 1'-0"

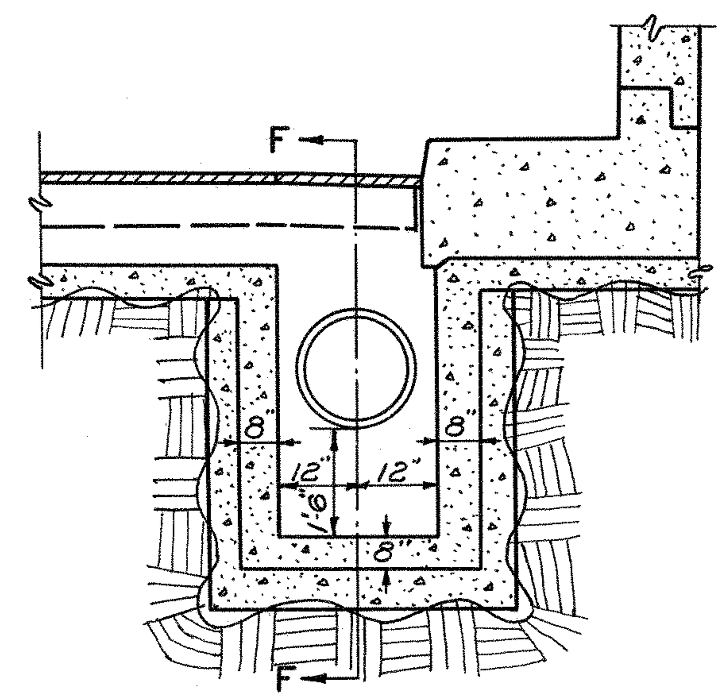


NOTE: DIMENSIONS NOT SHOWN ARE THE SAME AS IN DRAWING FOR "OUTER CURB".



SECTION E-E

DETAIL OF CATCH BASIN WITH SUMP
Scale 1" = 1'-0"



DETAIL OF SUMP FOR RAMP DRAIN
Scale ½" = 1'-0"

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

DRAINAGE REVISIONS

SCALES *AS NOTED*
MADE BY *M. Kramer* DATE *12-22-47*
CHECKED BY ______ DATE ______
APPROVED ______ DATE ______

NUMBER 185-90
SHEET NO. 34A OF 44

Printed in U.S.A. on Arkwright Tracing Cloth
Gustave Fischer Co., Hartford, Conn.

185 90

147 03

STANDARD No. 47A

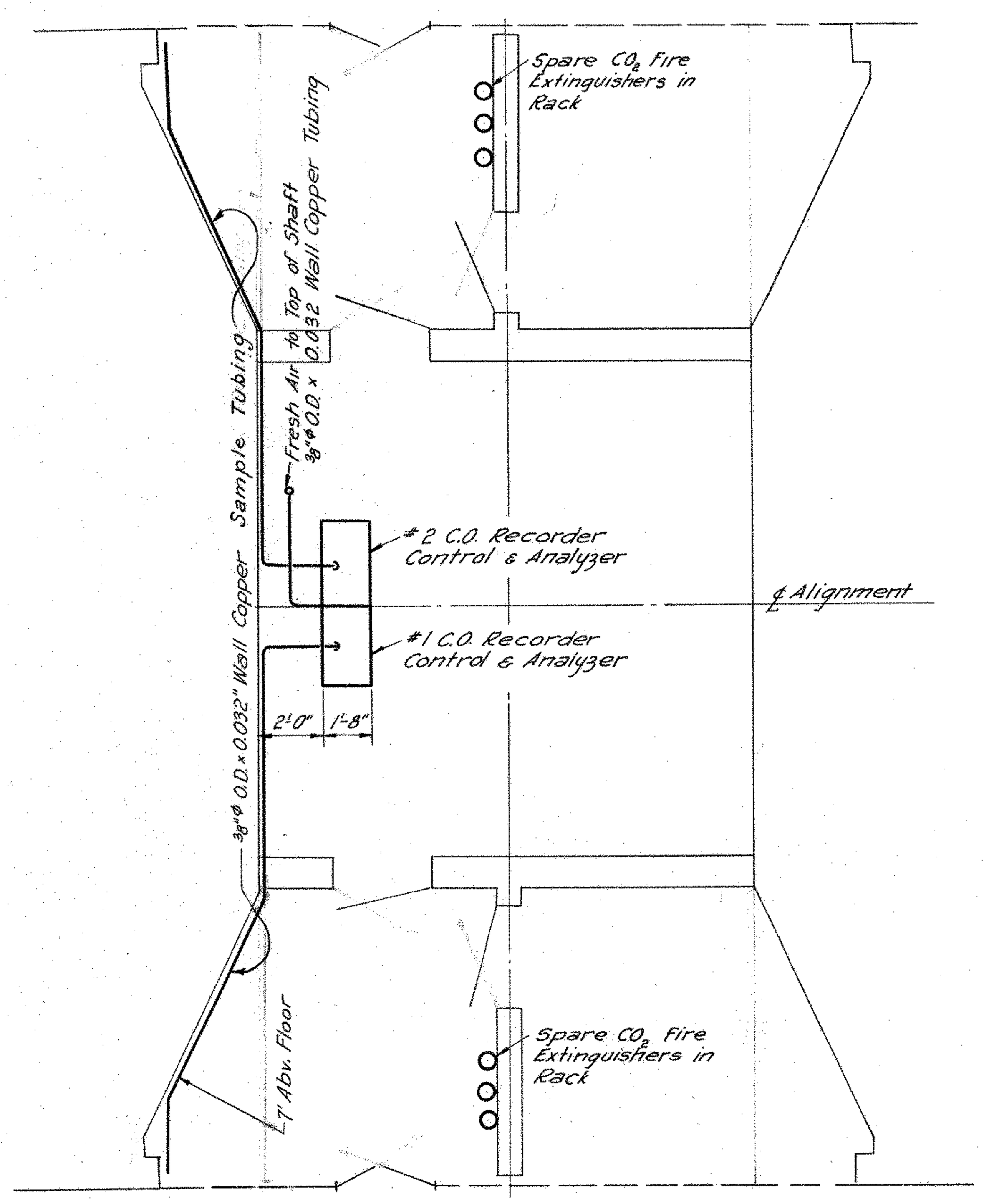
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		48	73

PROJECT NO. 185-90

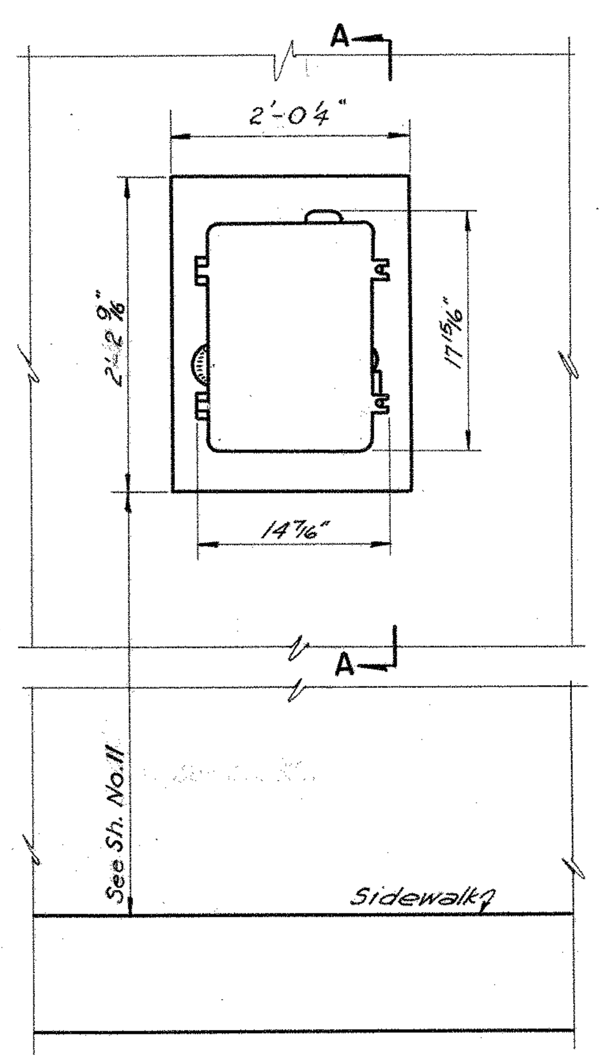
GENERAL PLAN

40 0 40 80

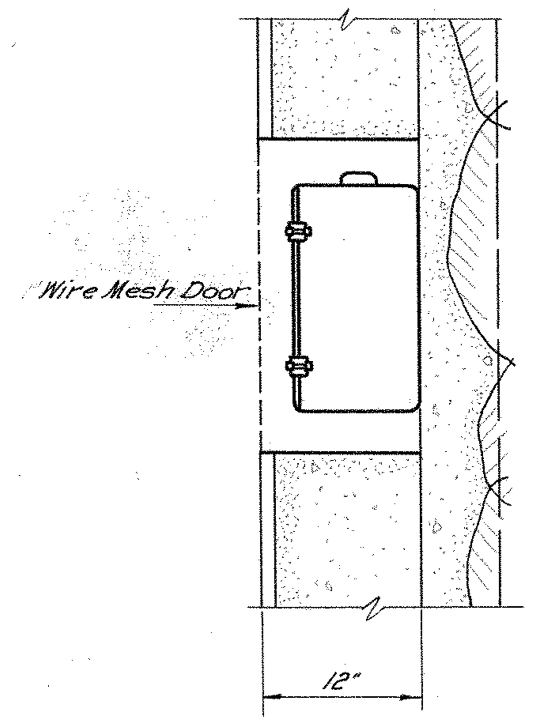
SCALE IN FEET



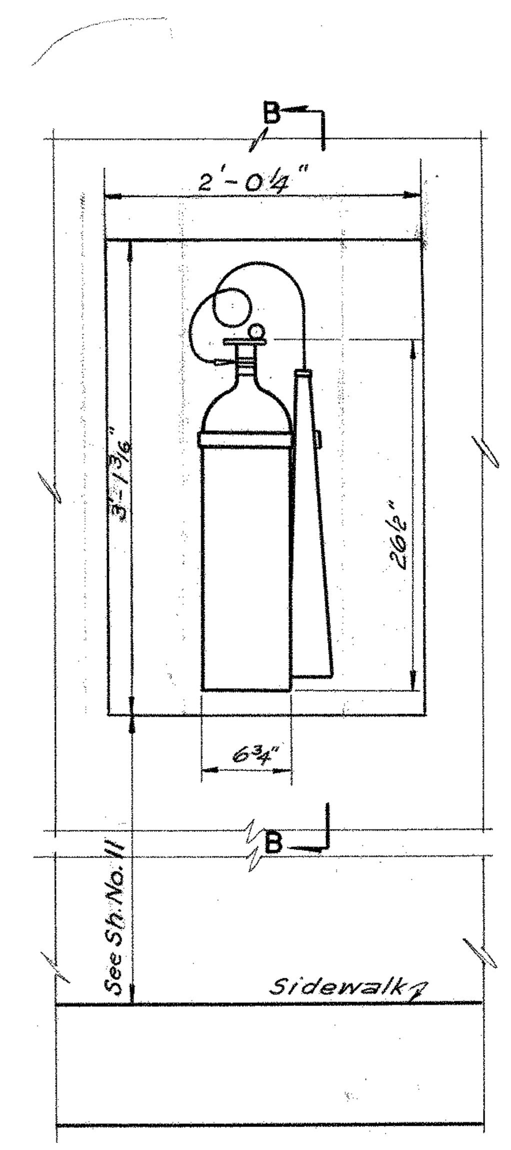
PLAN
CONTROL ROOM
Scale: 1/4" = 1'-0"



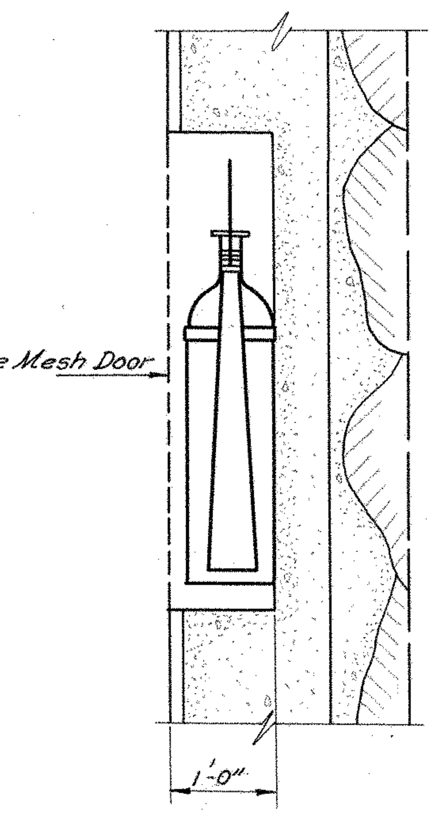
DETAIL OF C.O. VENTILATION CONTROL NICHE
Scale: 1" = 1'-0"



SECTION A-A



DETAIL OF CO_2 FIRE EXTINGUISHER NICHE
Scale: 1" = 1'-0"



SECTION B-B

For Detail of Doors for Niches See Sheet No. 11

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
VENTILATION

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE: AS NOTED
MADE BY S.S.
CHECKED BY S.R.Apt
APPROVED
DATE

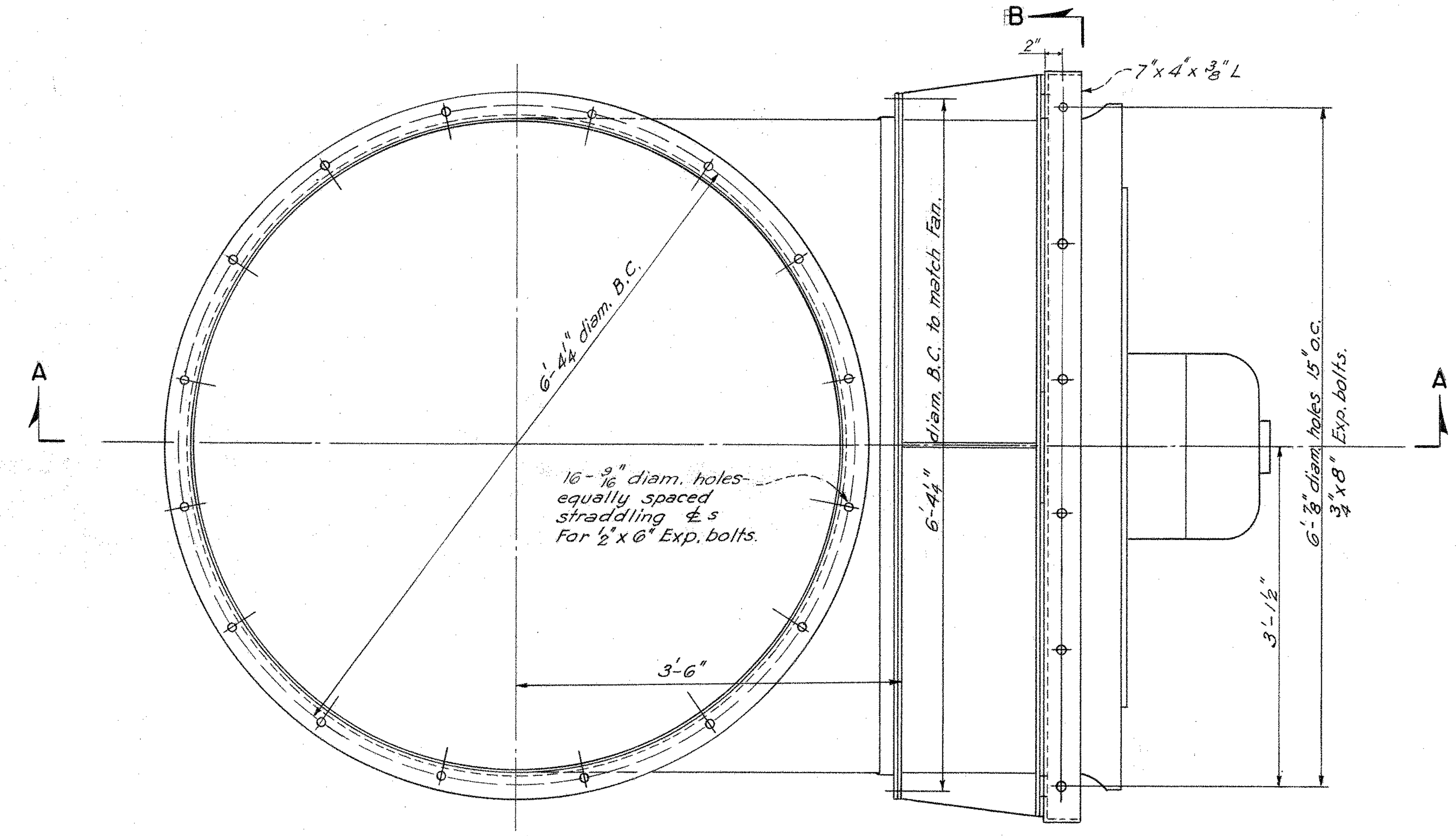
PROJECT NO.
TUNNEL SHEET NO. 35 OF 44

185 90 147 03 48

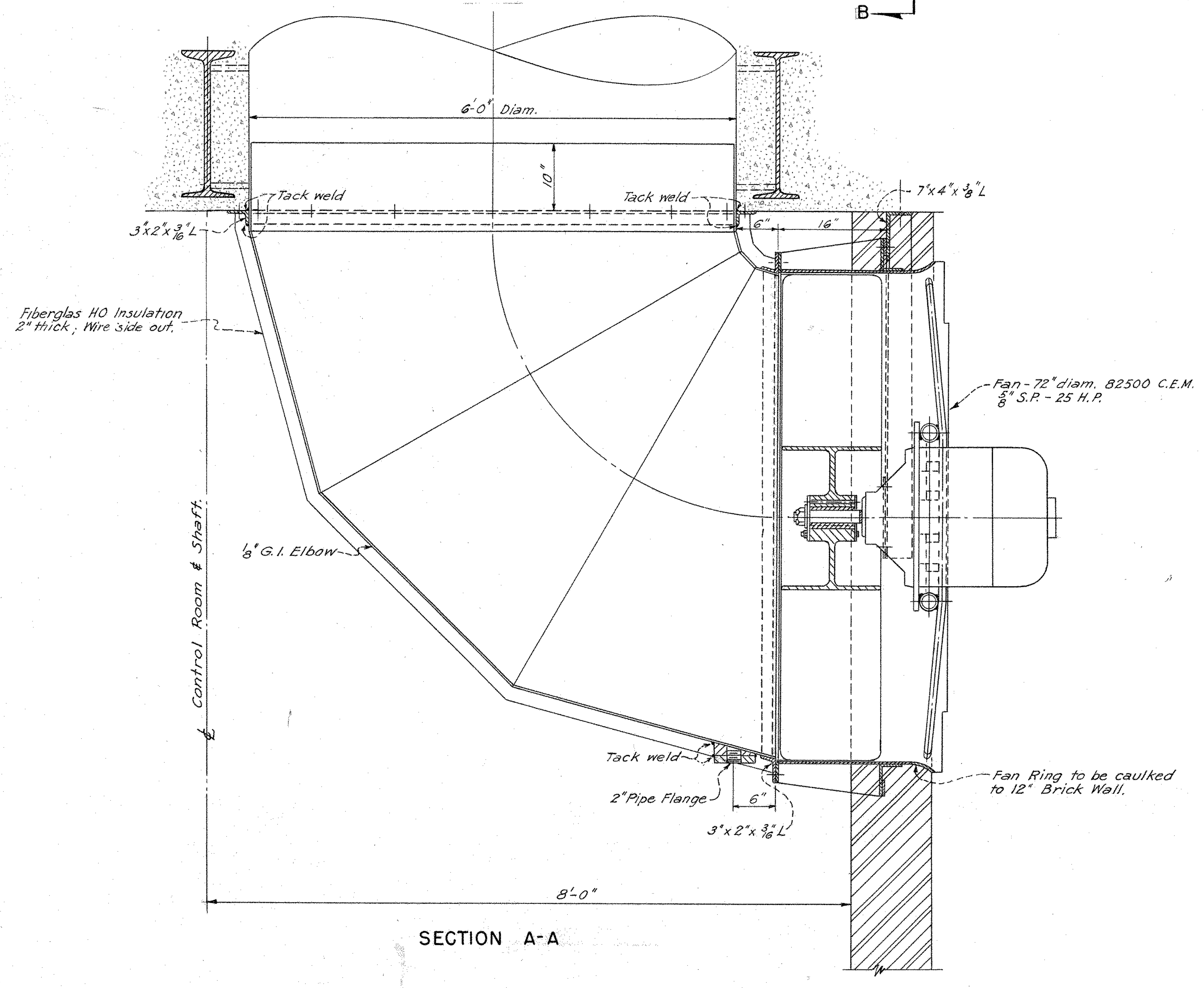
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		49	73

PROJECT NO. 185-90

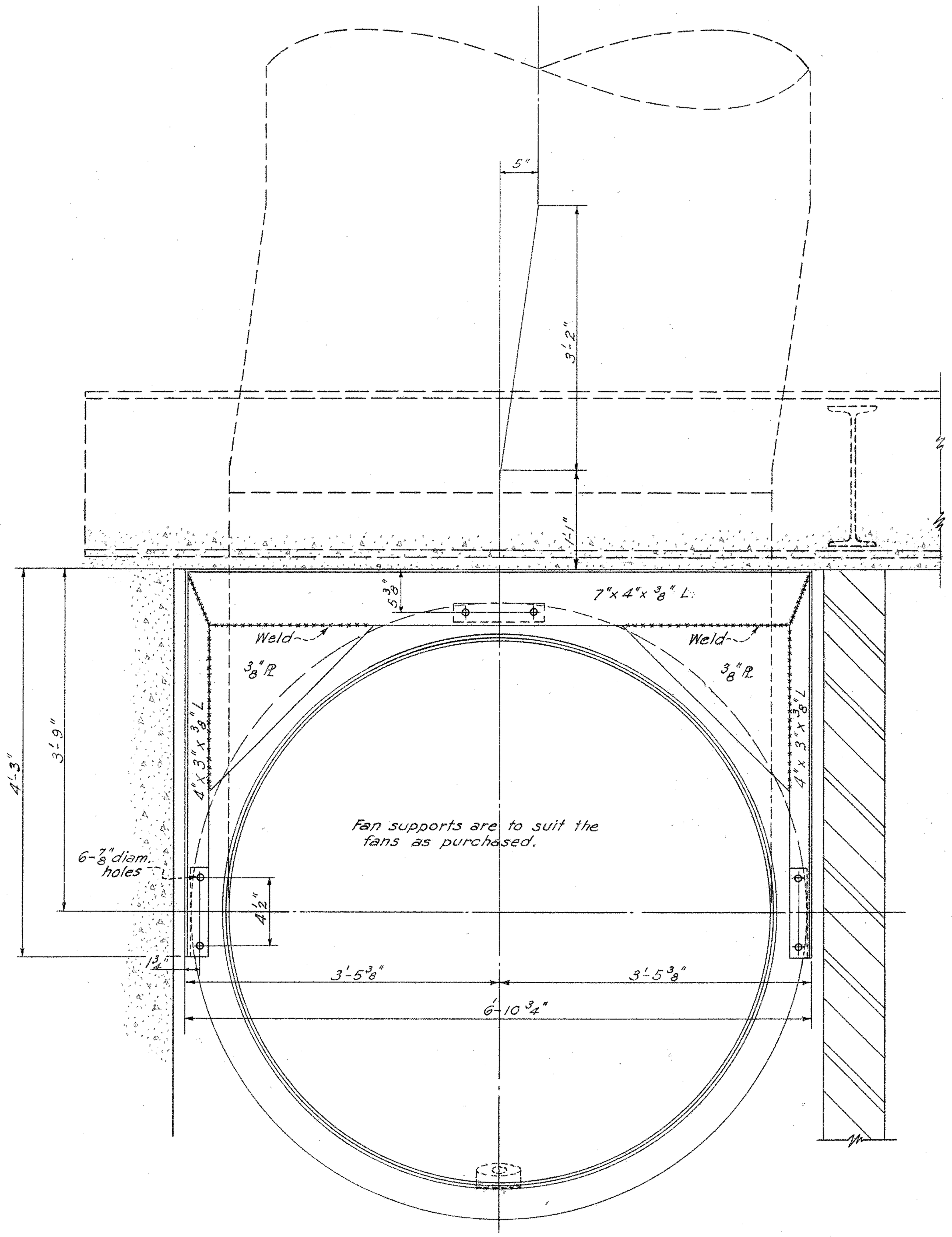
NO REVISIONS SUBMITTED FOR THIS SHEET



PLAN



SECTION A-A



SECTION B-B

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
DETAILS OF FAN

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE: 1" = 1'-0"
MADE BY S.S.
CHECKED BY S.R.Apt
APPROVED ______ DATE ______

PROJECT NO.
TUNNEL SHEET NO. 36 OF 44

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		50	73

PROJECT NO. 185 - 90

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES O[F WORK], SHOWN ON THESE SHEETS IS BASED ON LIMITED INVES[TIG]ATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO [IN]DICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR [DI]STRIBUTION OF QUANTITIES OF WORK WHICH WILL BE [RE]QUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
WIRING DIAGRAM

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

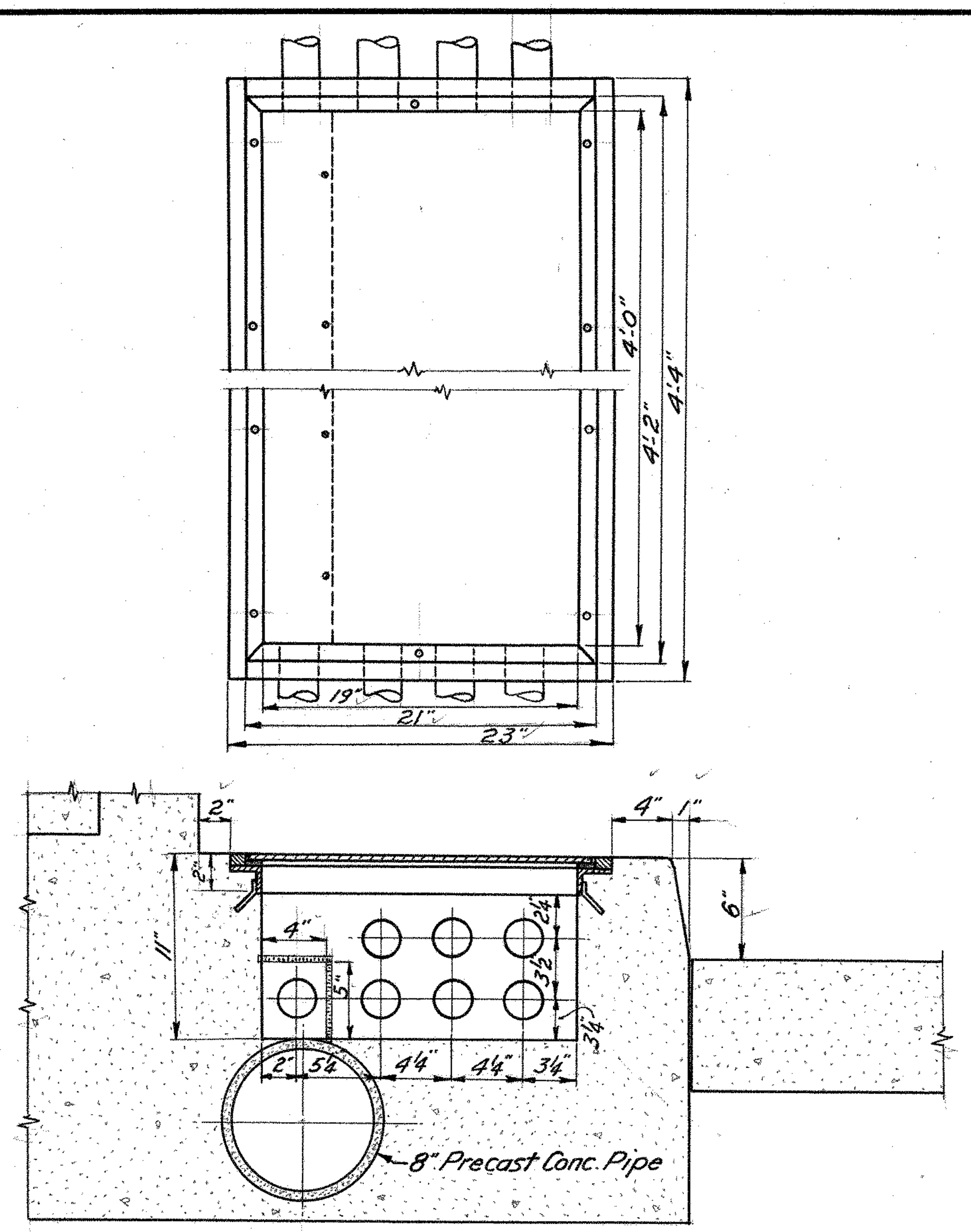
SCALE —
MADE BY R.J.T.
CHECKED BY H.K.A.
APPROVED
DATE

PROJECT NO.
TUNNEL SHEET NO. 37 OF 44

185 90
147 03
50

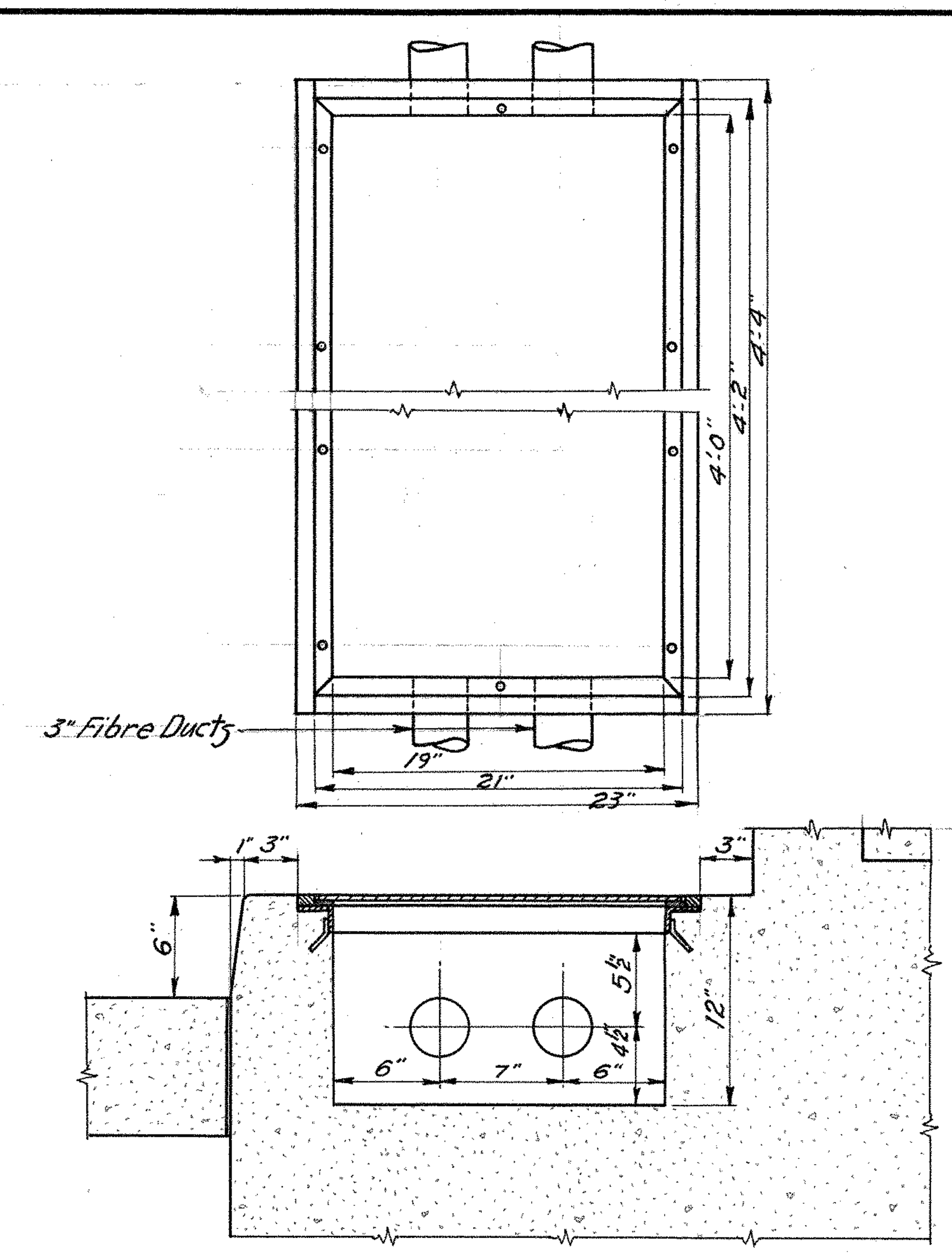
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		51	73

PROJECT NO. 185-90



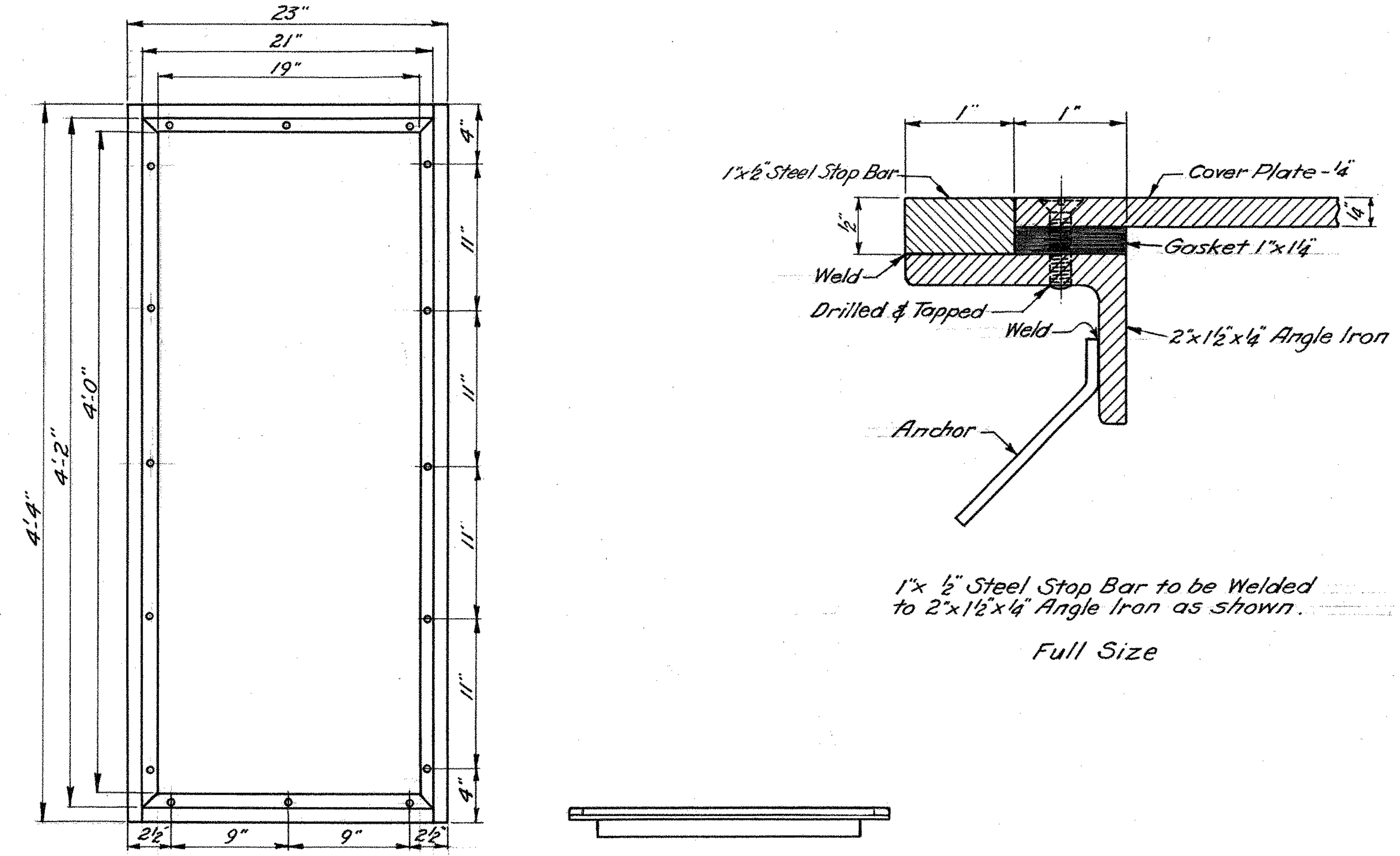
TYPICAL DETAILS OF TYPE "A" PULL BOX

Scale: 1½" = 1'-0"



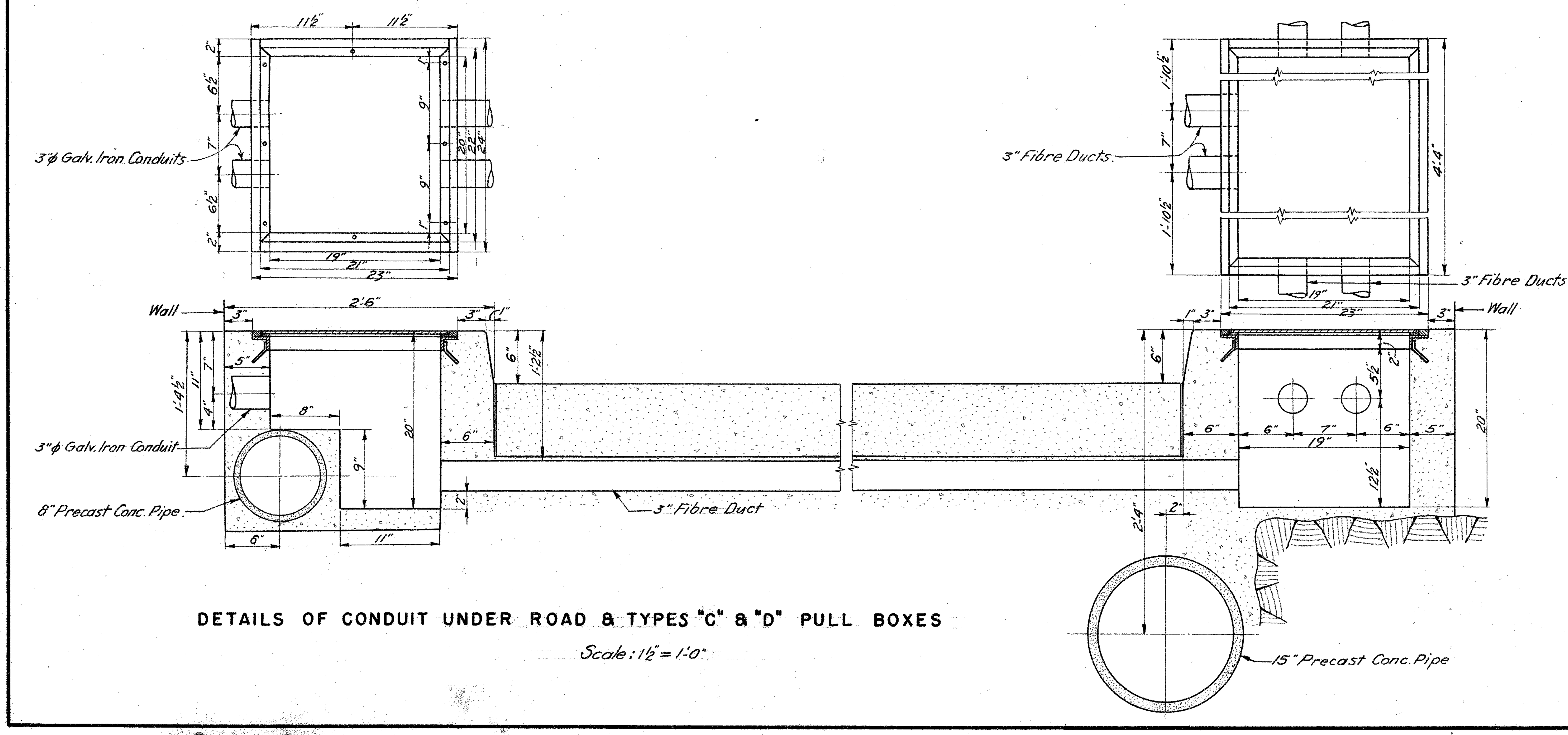
TYPICAL DETAILS OF TYPE "B" PULL BOX

Scale: 1½" = 1'-0"



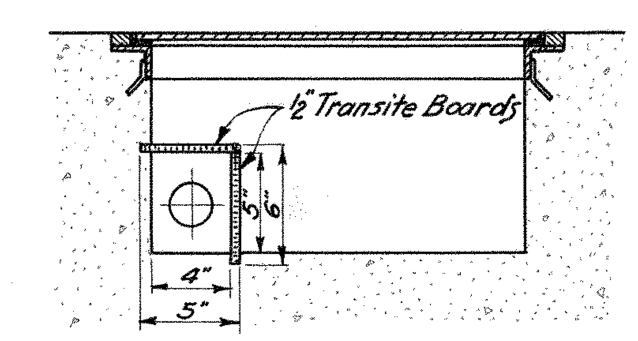
TYPICAL DETAILS OF FRAME & COVER OF PULL BOXES

Scale: 1½" = 1'-0"



DETAILS OF CONDUIT UNDER ROAD & TYPES "C" & "D" PULL BOXES

Scale: 1½" = 1'-0"



TYPICAL DETAILS OF ISOLATING TELEPHONE LINE IN PULL BOX

Scale: 1½" = 1'-0"

NOTES:

1 - See Conduit Plan before pouring Concrete.
2 - Transite Board Shall be fastened by 1⅛" No. 8 Parker-Kalon Screws.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
PULL BOX DETAILS

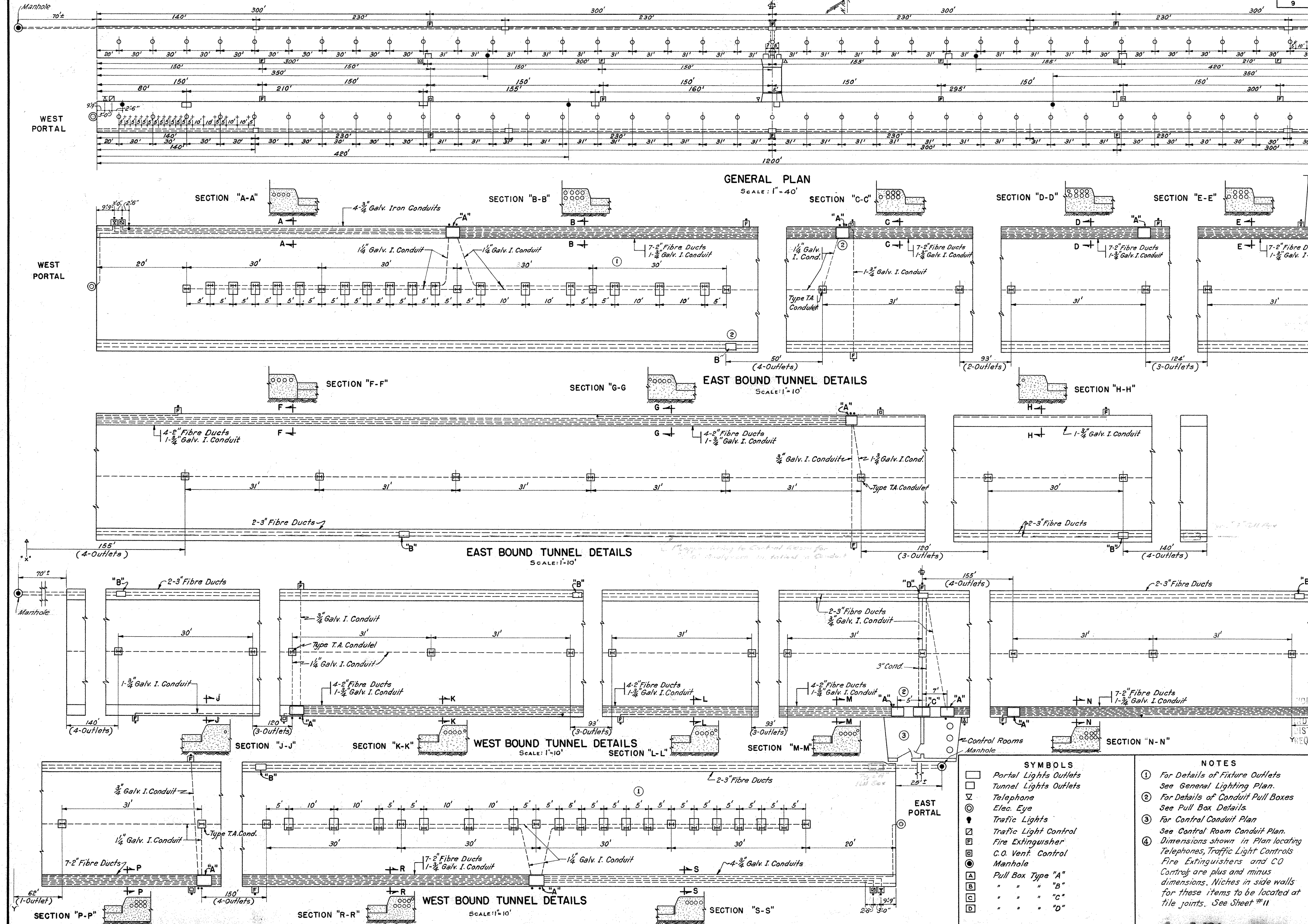
PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE As Shown
MADE BY M.W.S.
CHECKED BY H.K.B.
APPROVED DATE

PROJECT NO.
TUNNEL SHEET NO. 38 OF 44

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		52	73

PROJECT NO. 185-90



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SYMBOLS

- ▭ Portal Lights Outlets
- ▭ Tunnel Lights Outlets
- ▽ Telephone
- ◎ Elec. Eye
- ● Trafic Lights
- ☒ Trafic Light Control
- F Fire Extinguisher
- C.O. Vent. Control
- ◉ Manhole
- A Pull Box Type "A"
- B " " " "B"
- C " " " "C"
- D " " " "D"

NOTES

1. For Details of Fixture Outlets See General Lighting Plan.
2. For Details of Conduit Pull Boxes See Pull Box Details.
3. For Control Conduit Plan See Control Room Conduit Plan.
4. Dimensions shown in Plan locating Telephones, Traffic Light Controls Fire Extinguishers and CO Controls are plus and minus dimensions. Niches in side walls for these items to be located at tile joints. See Sheet #11

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
CONDUIT PLAN-TUNNEL

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

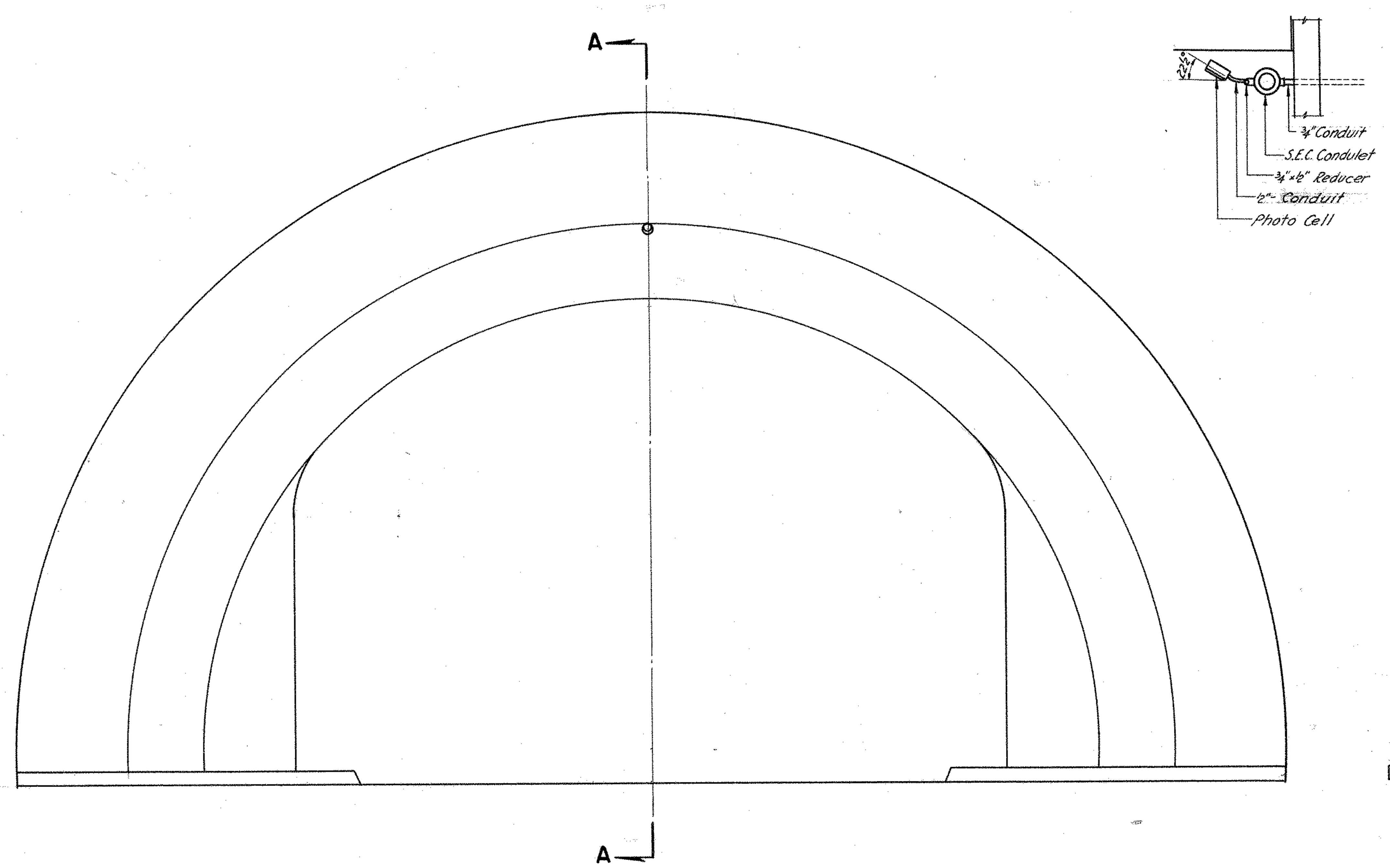
SCALE As Shown
MADE BY M.W.S.
CHECKED BY H.H.B.
APPROVED
DATE

PROJECT NO.
TUNNEL SHEET NO. 39 OF 44

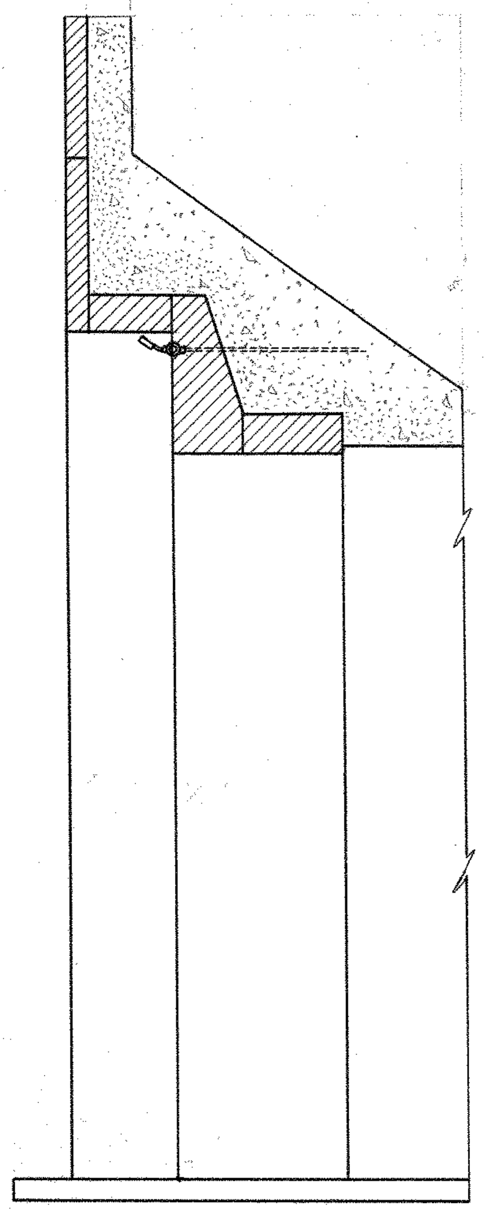
185 90 147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		53	73

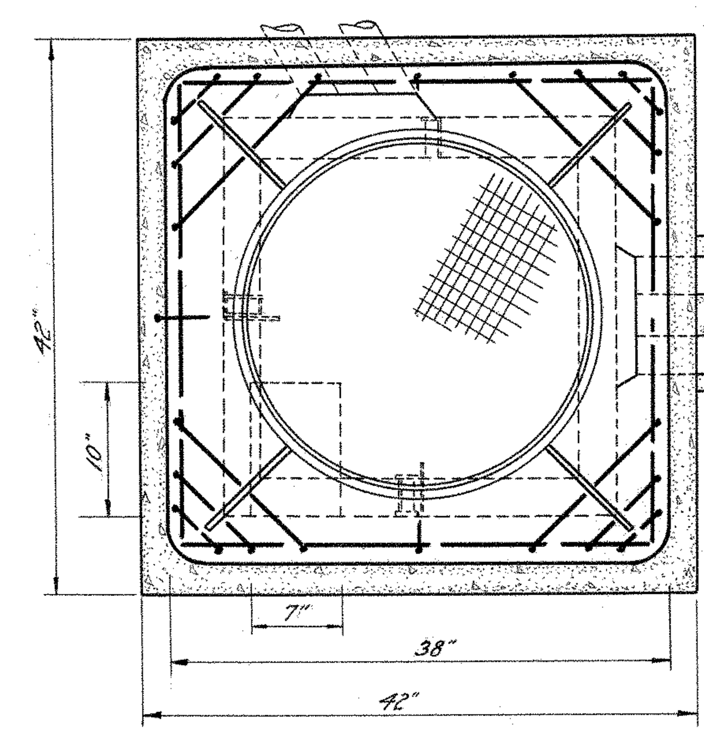
PROJECT NO. 185 - 90

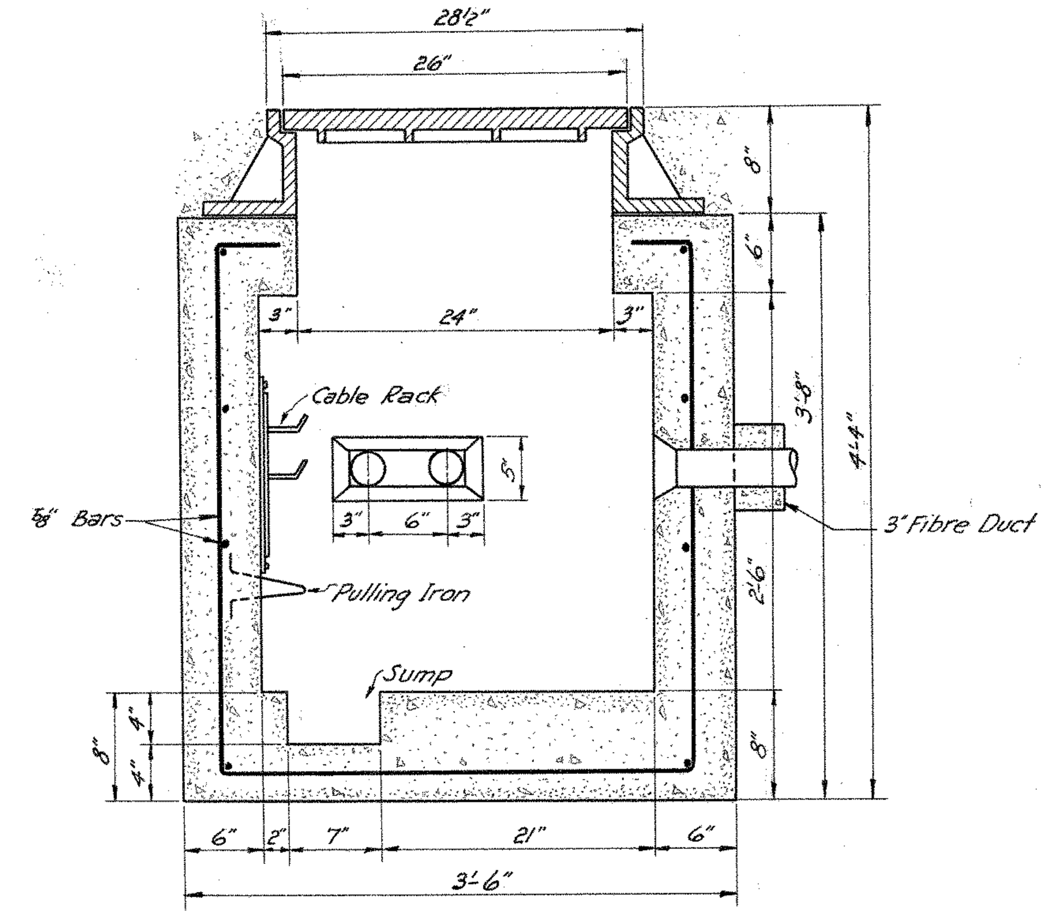


ELEVATION OF WEST PORTAL OF EAST BOUND TUNNEL
Scale: ¼"=1'-0"

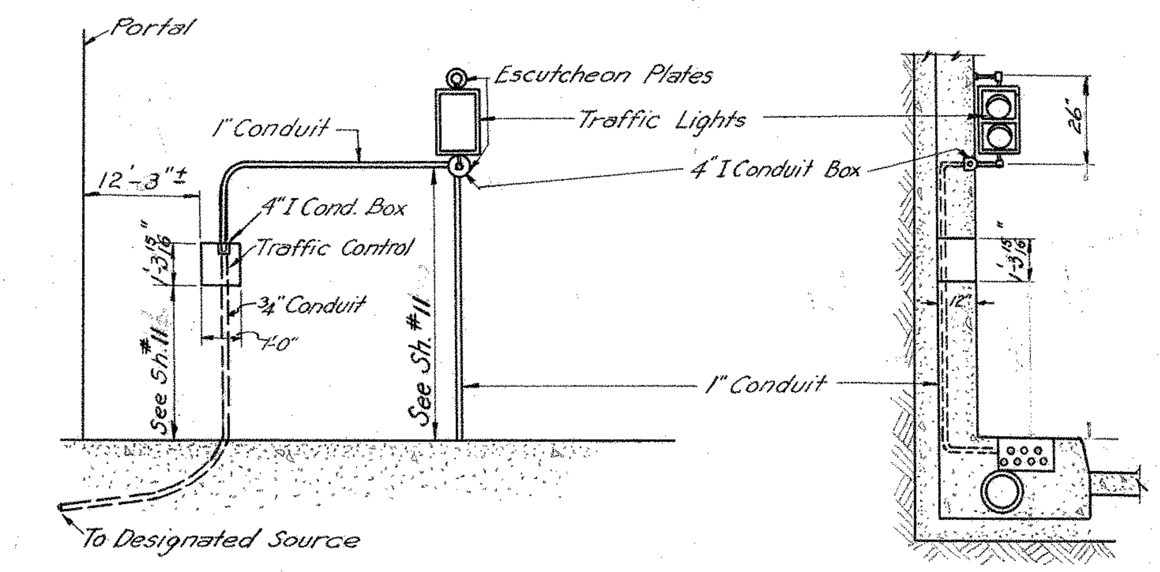


SECTION "A-A"

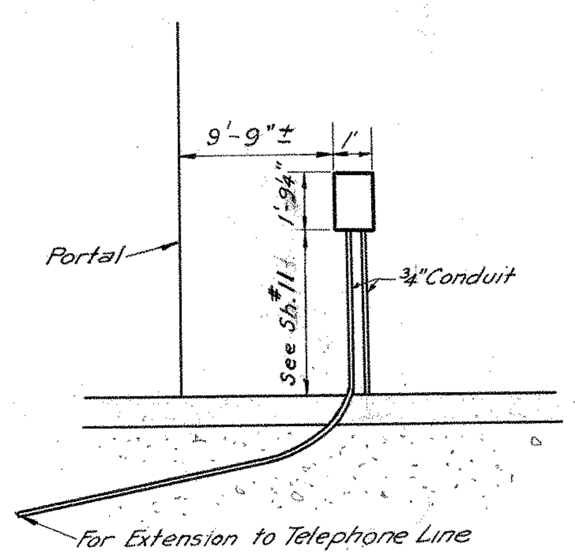


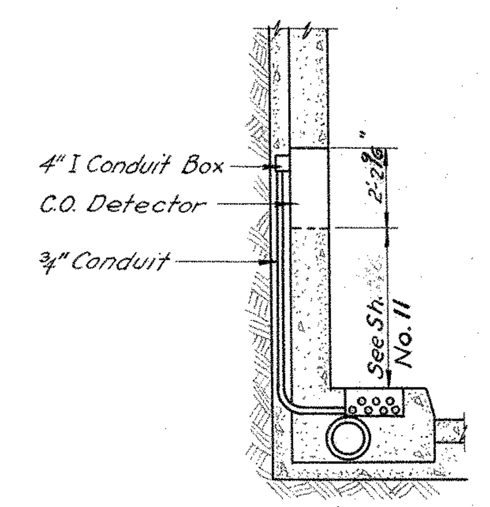


TYPICAL DETAIL OF MANHOLE & COVER
Scale: 1"=1'-0"

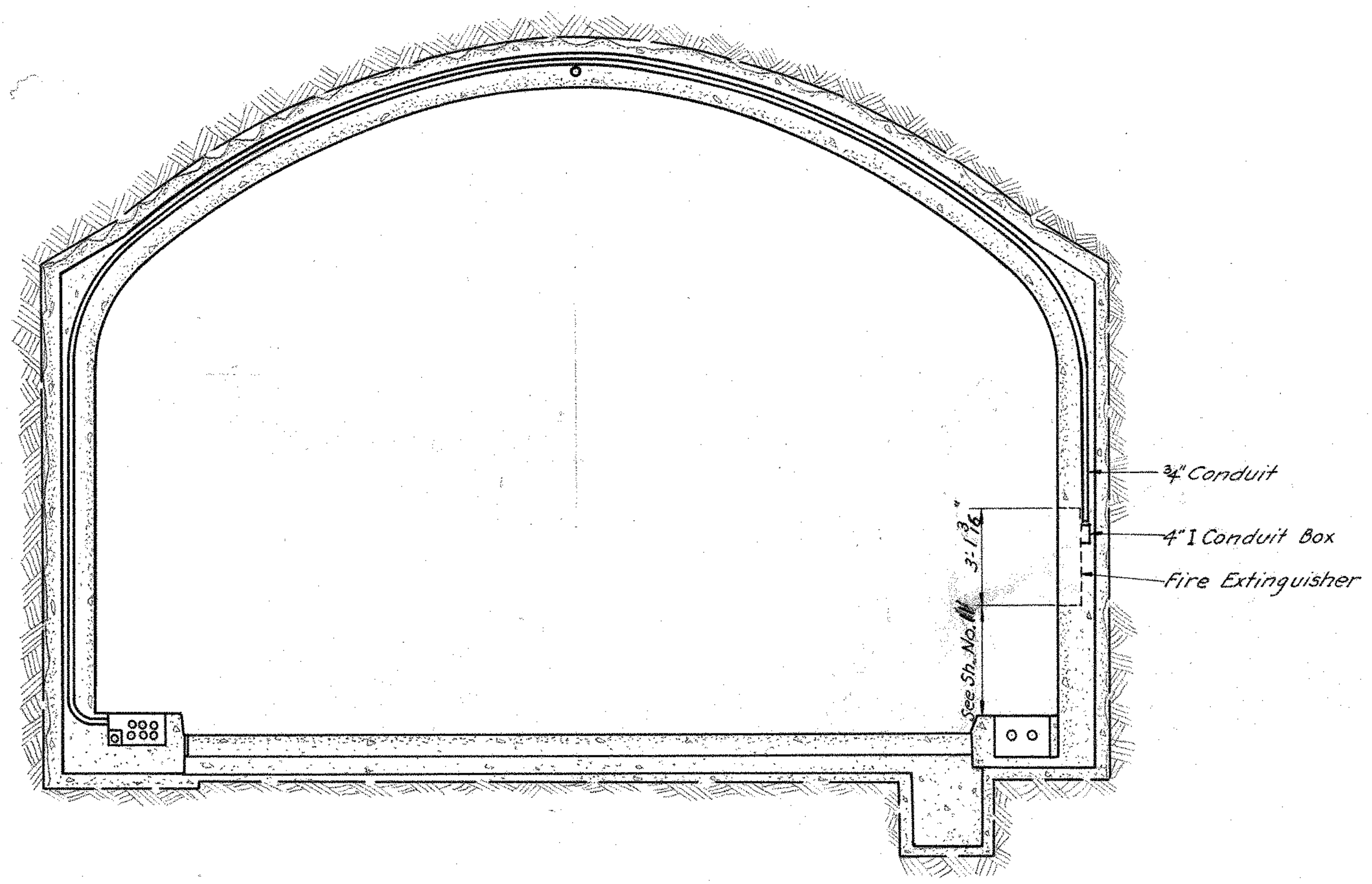


TYPICAL DETAIL OF
TRAFFIC LIGHTS & TRAFFIC CONTROL INSTALLATION
Scale: ¼"=1'-0"

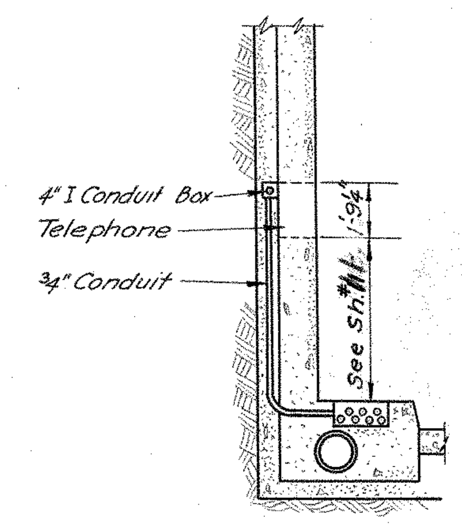




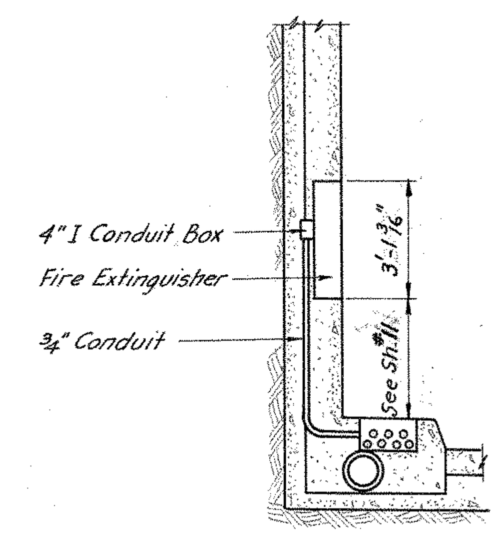
TYPICAL DETAIL OF
C.O. DETECTOR INSTALLATION
Scale: ¼"=1'-0"



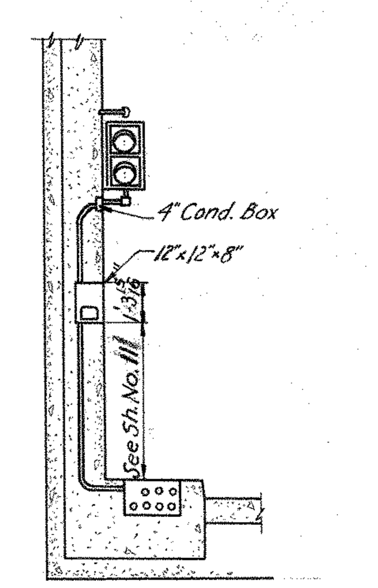
CROSS SECTION VIEW OF INSTALLATION OF OVERHEAD CONDUIT
FOR FIRE EXTINGUISHER
Scale: ¼"=1'-0"



TYPICAL DETAIL OF
TELEPHONE CONDUIT INSTALLATION
Scale: ¼"=1'-0"



TYPICAL DETAIL OF
FIRE EXTINGUISHER INSTALLATION
Scale: ¼"=1'-0"



DETAILS OF TRAFFIC LIGHTS WITH FLASHER

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
CONDUIT DETAILS

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

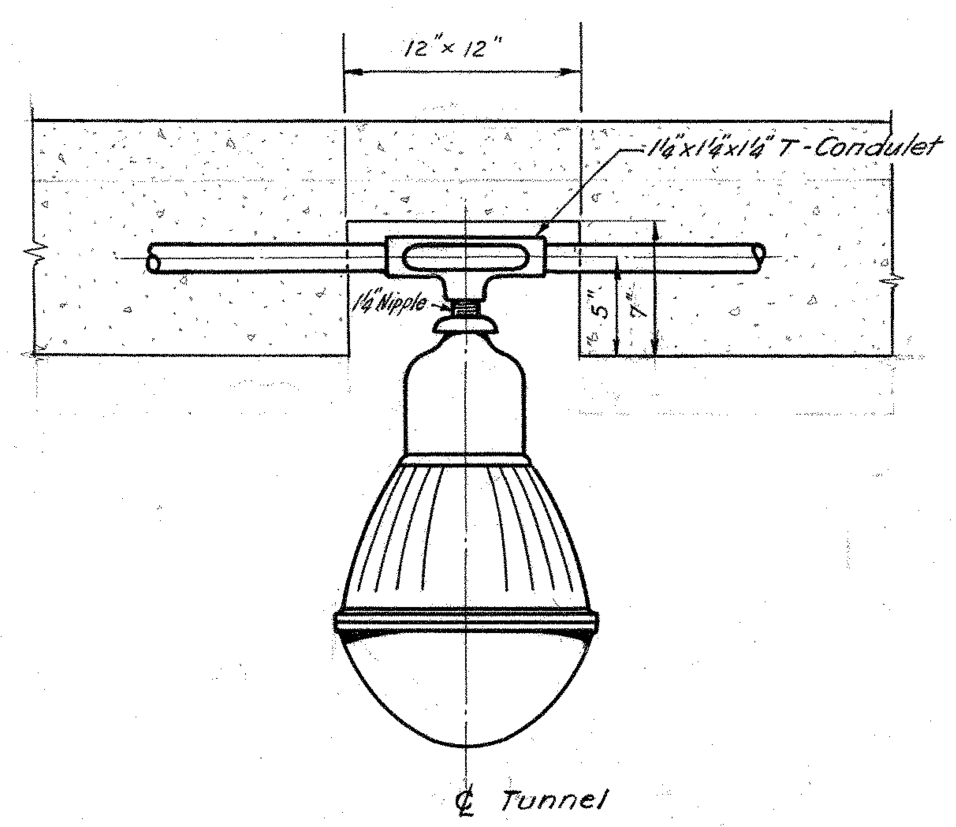
SCALE As Shown
MADE BY M.W.S.
CHECKED BY H.K.B.
APPROVED
DATE

PROJECT NO.
TUNNEL SHEET NO. 40 OF 44

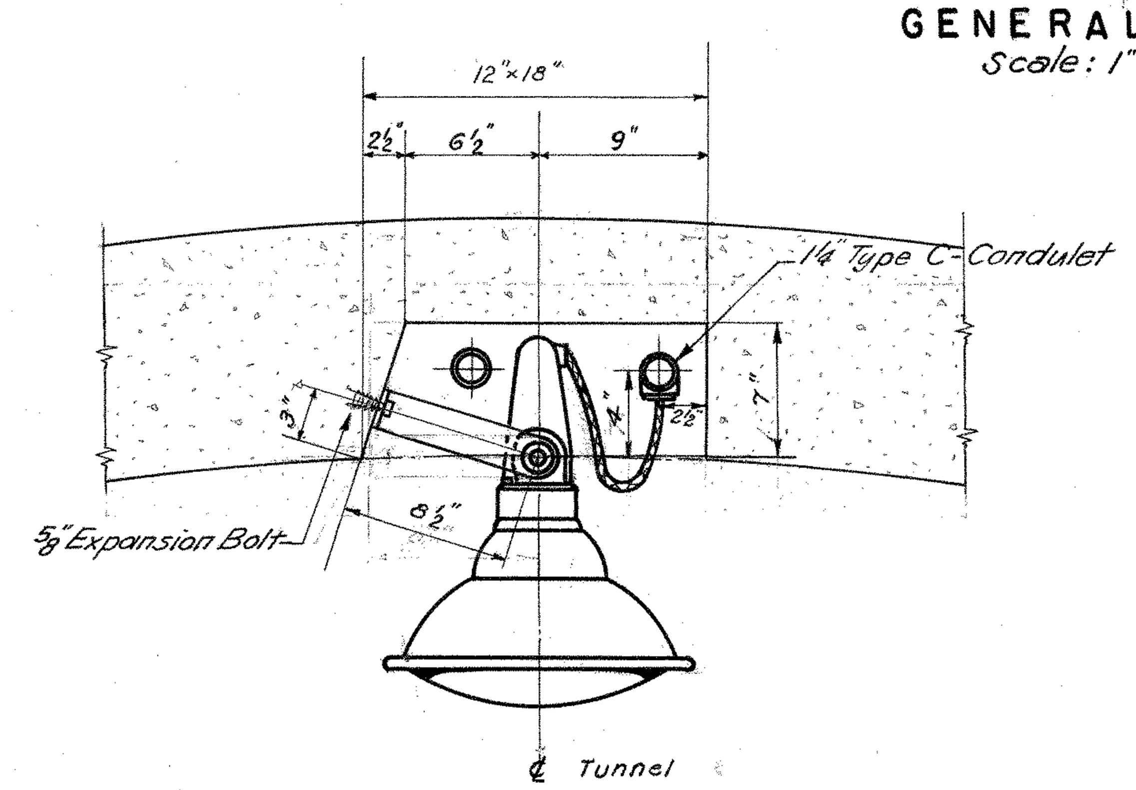
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		54	73

PROJECT NO. 185-90

GENERAL PLAN
Scale: 1" = 40'



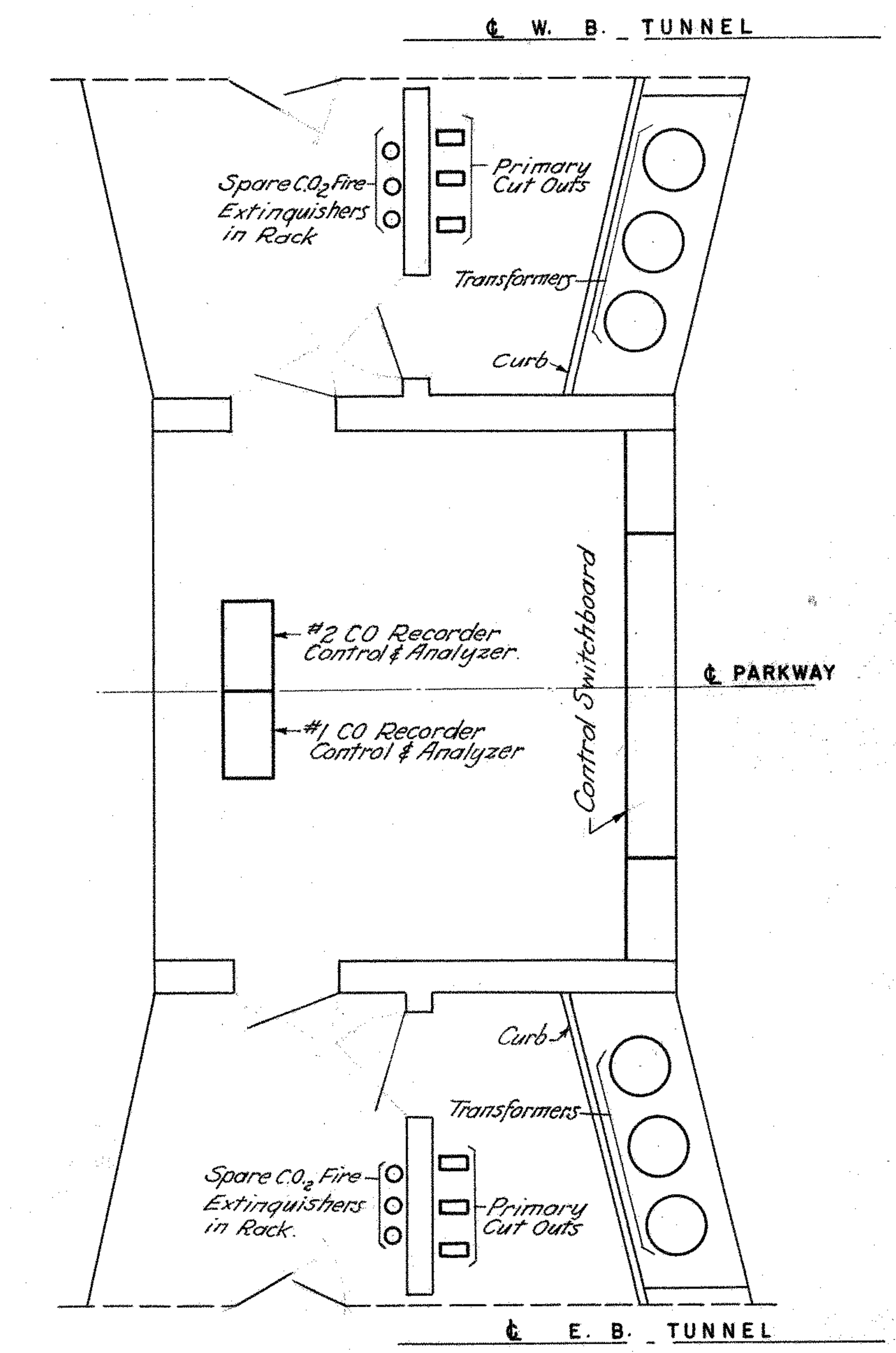
TUNNEL LIGHTING FIXTURE
FORM 79 – 300 W
Scale: 1½" = 1'-0"



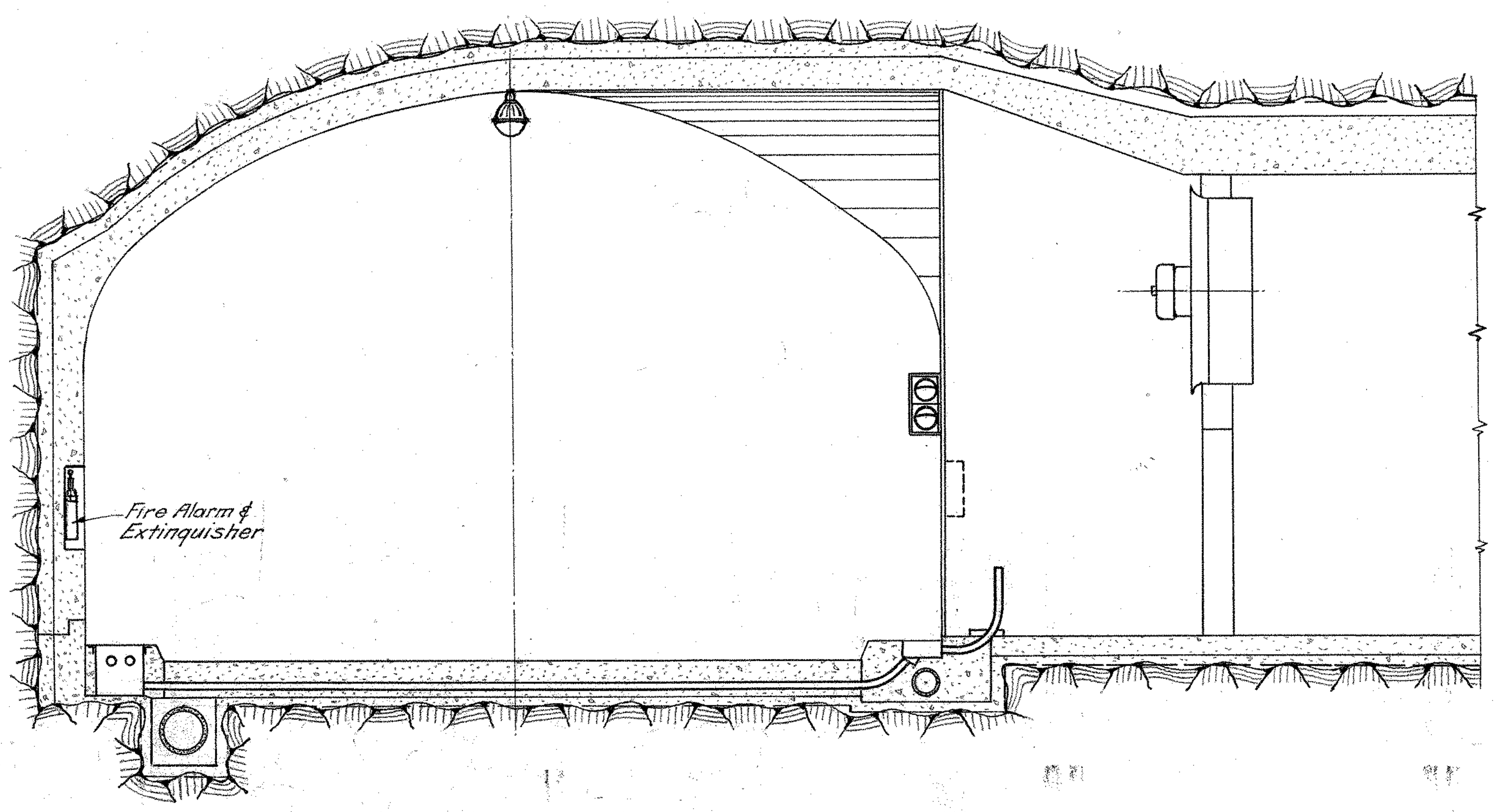
PORTAL LIGHTING FIXTURE
TYPE L-43 – 750 W
Scale: 1½" = 1'-0"

SYMBOLS

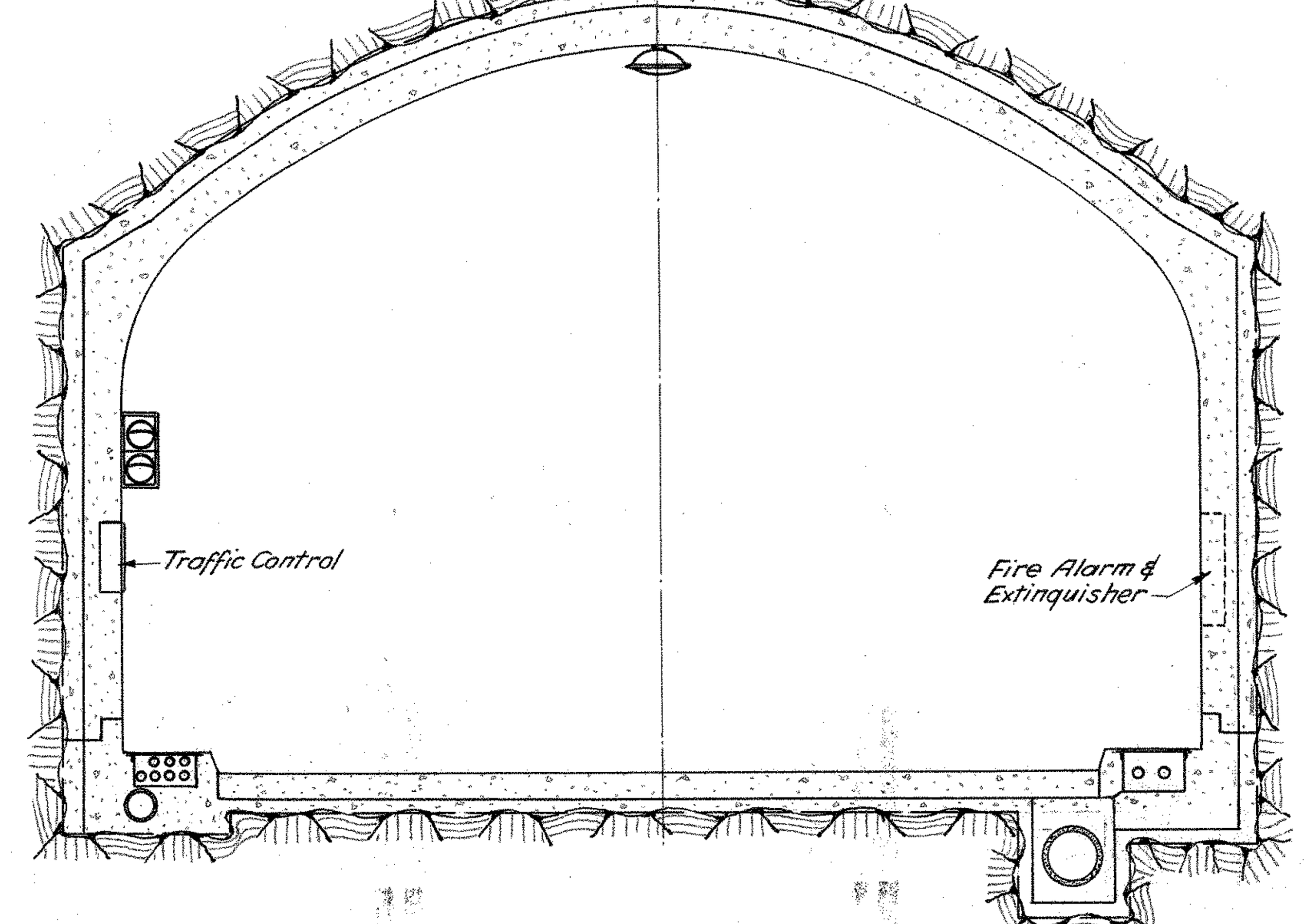
- Tunnel Lights 300 W.
- Portal Lights 750 W.
- Telephone
- Electric Eye
- Traffic Lights
- Traffic Light Control
- Fire Alarm & CO_2 Fire Extinguisher
- Power Supply
- C.O. Ventilation Control



PLAN OF CONTROL ROOM
Scale: ¼" = 1'-0"



SECTION "A-A"
Scale: ¼" = 1'-0"



SECTION "B-B"
Scale: ¼" = 1'-0"

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

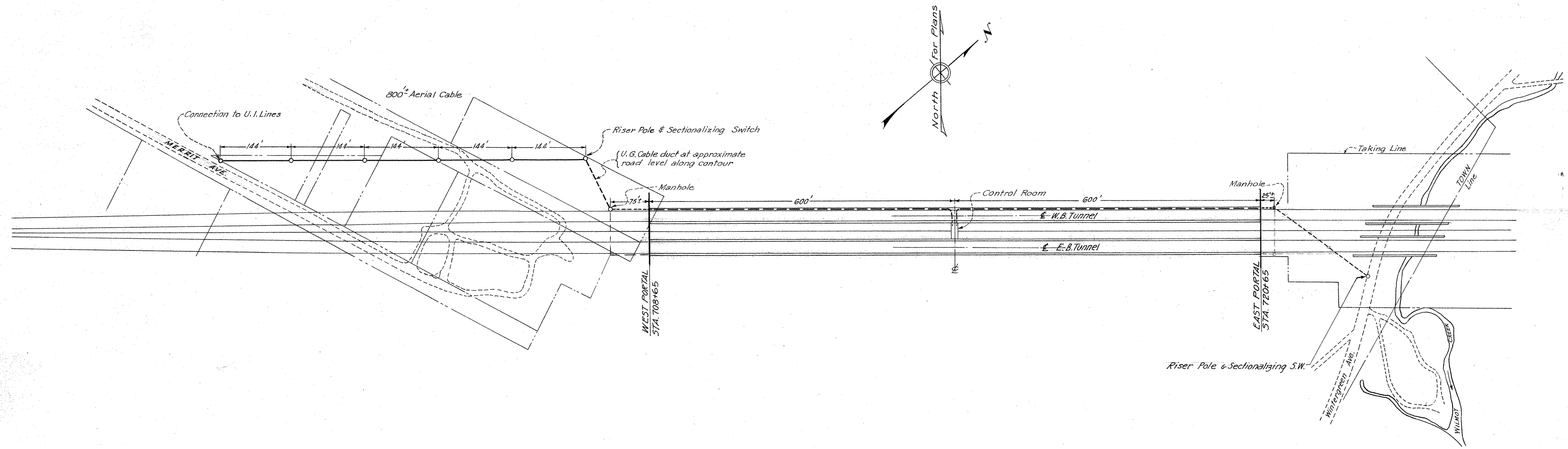
WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
LIGHTING

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS — NEW YORK, N.Y.

SCALE As Shown
MADE BY M.W.S.
CHECKED BY H.K.B.
APPROVED ______ DATE ______
PROJECT NO.
TUNNEL SHEET NO. 41 OF 44

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		55	73

PROJECT NO. 185 - 90



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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL

FEEDER CABLE PLAN

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE 1"=100'
MADE BY M.W.S.
CHECKED BY
APPROVED DATE

PROJECT NO.
TUNNEL SHEET NO. 42 OF 44

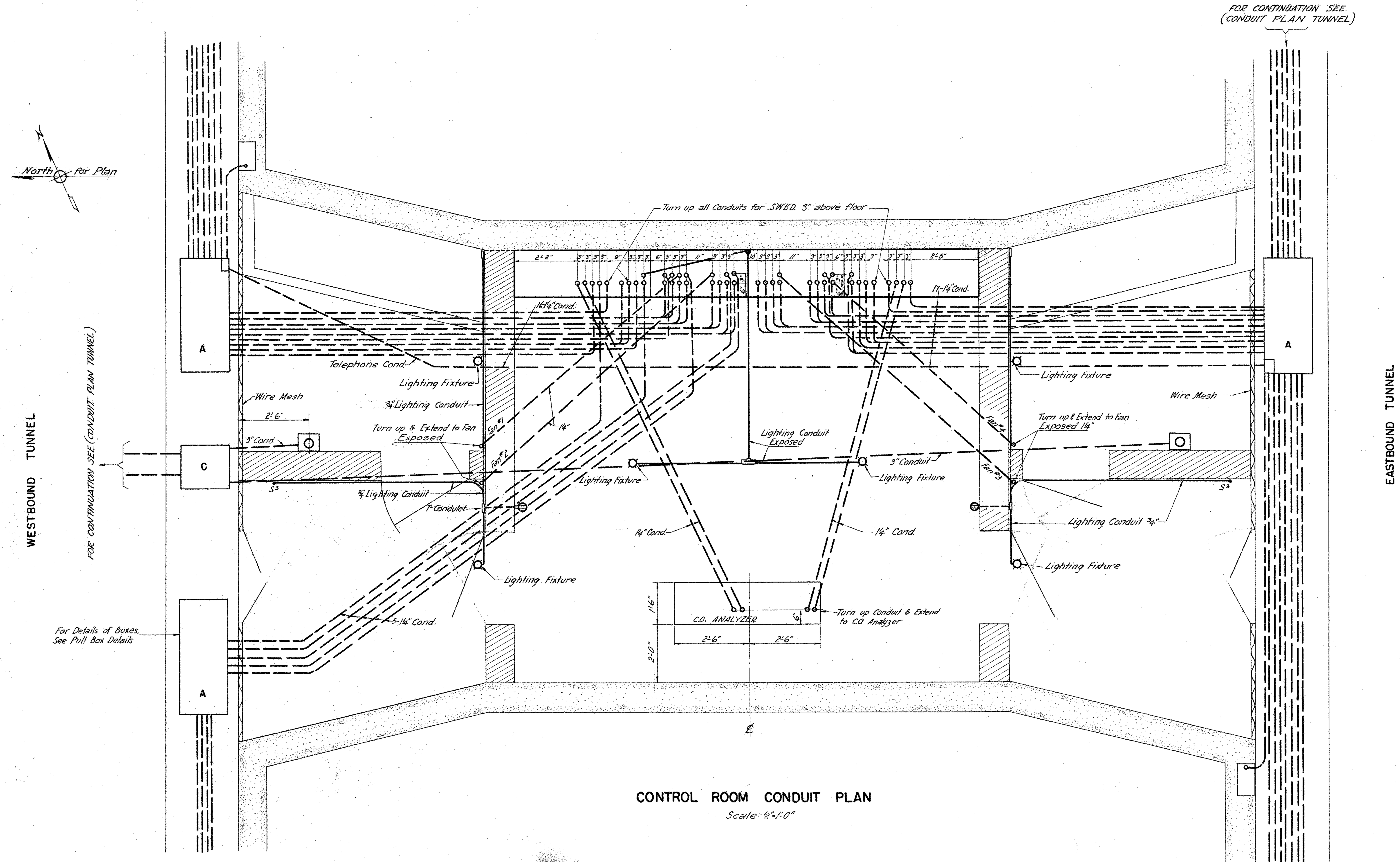
Traced by A.L.M.

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		56	73

PROJECT NO. 185-90



CONTROL ROOM CONDUIT PLAN

Scale ½" = 1'-0"

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
CONTROL ROOM CONDUIT PLAN

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE ½" = 1'-0"
MADE BY M.W.S.
CHECKED BY H.A.B.
APPROVED
DATE

PROJECT NO.

TUNNEL SHEET NO. 43 OF 44

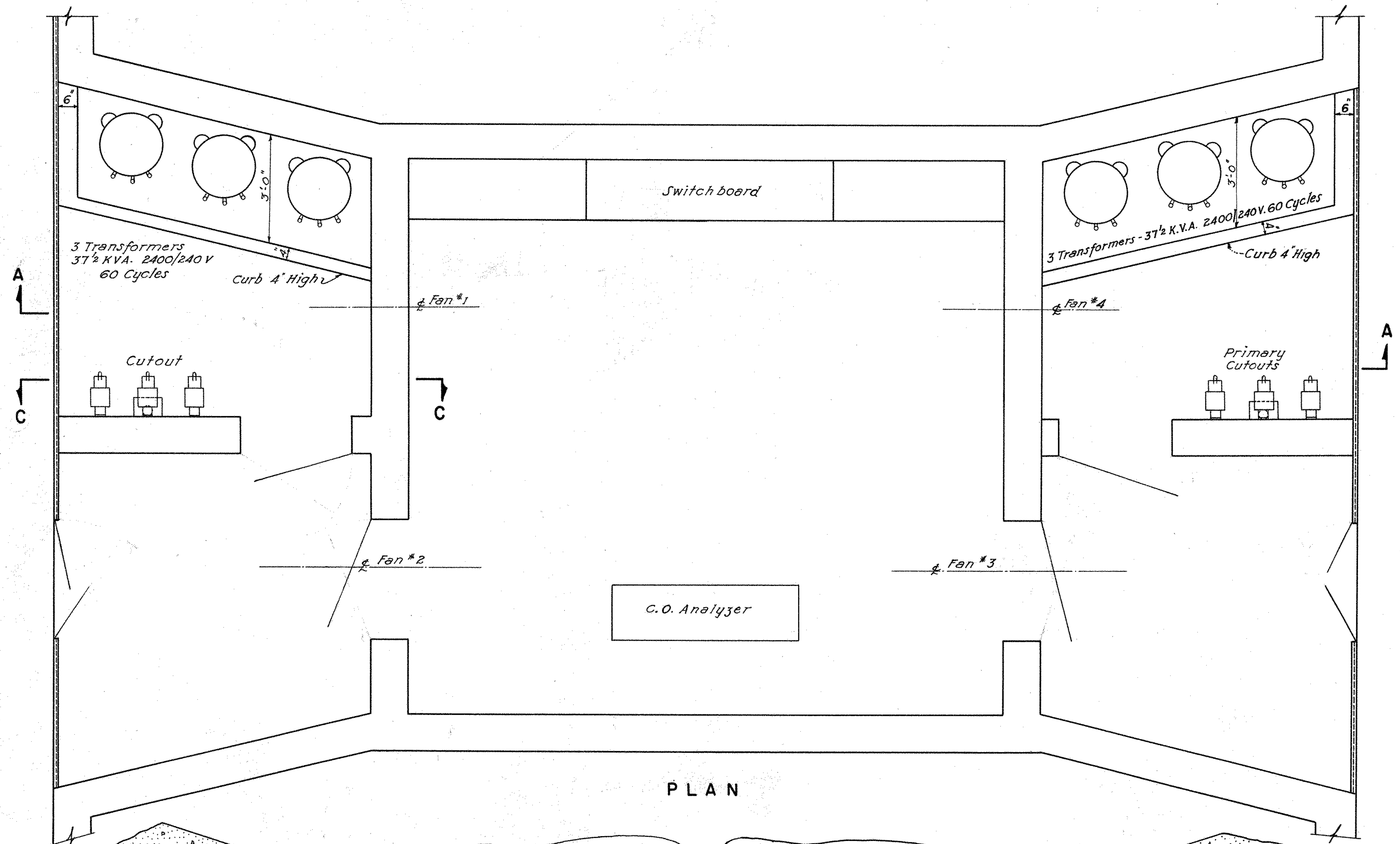
185 90

147 03

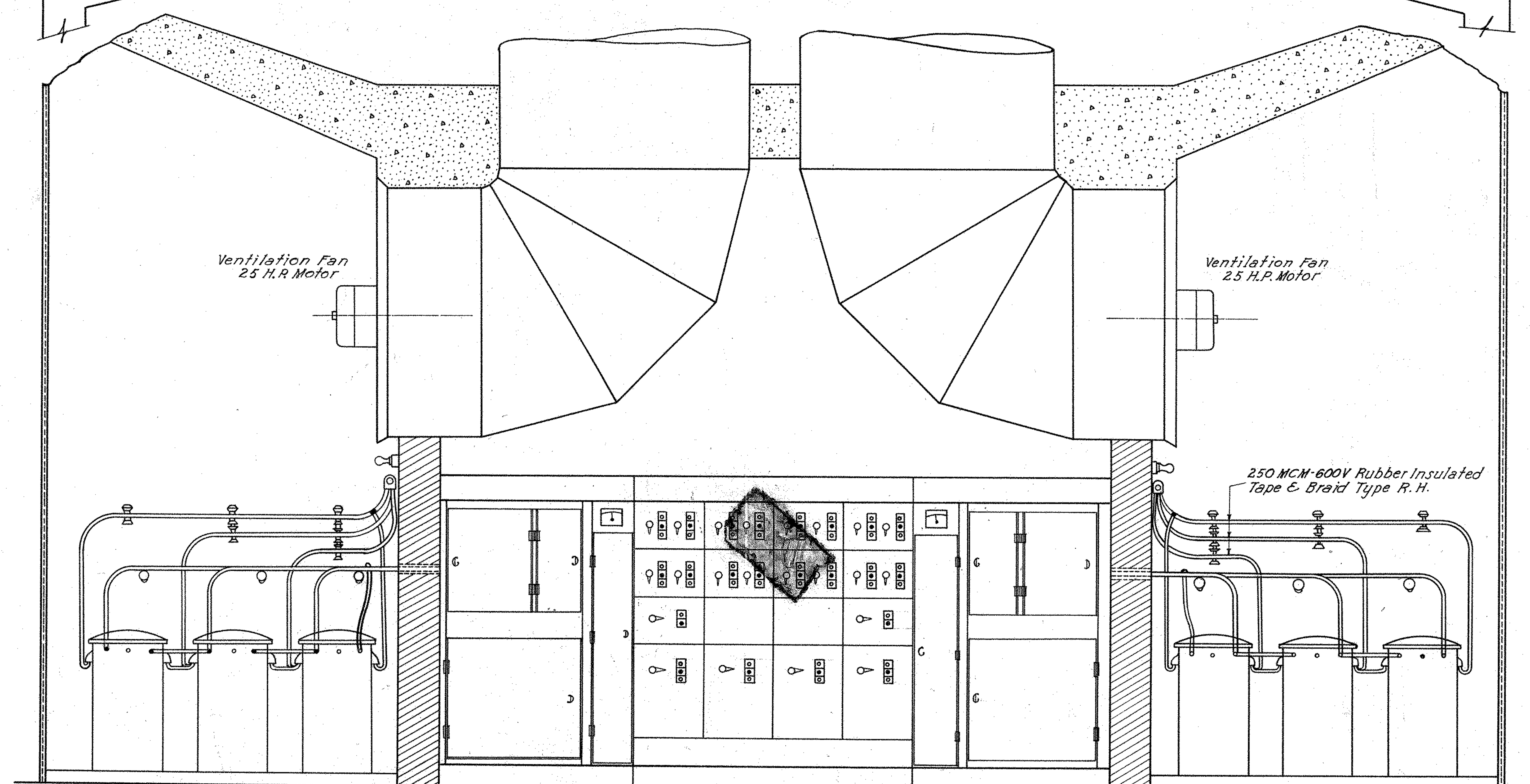
FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		57	73

PROJECT NO. 185-90

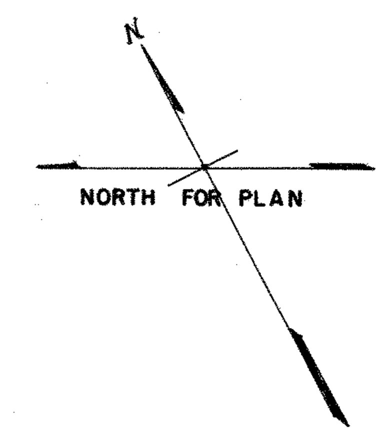
NO REVISIONS SUBMITTED FOR THIS SHEET

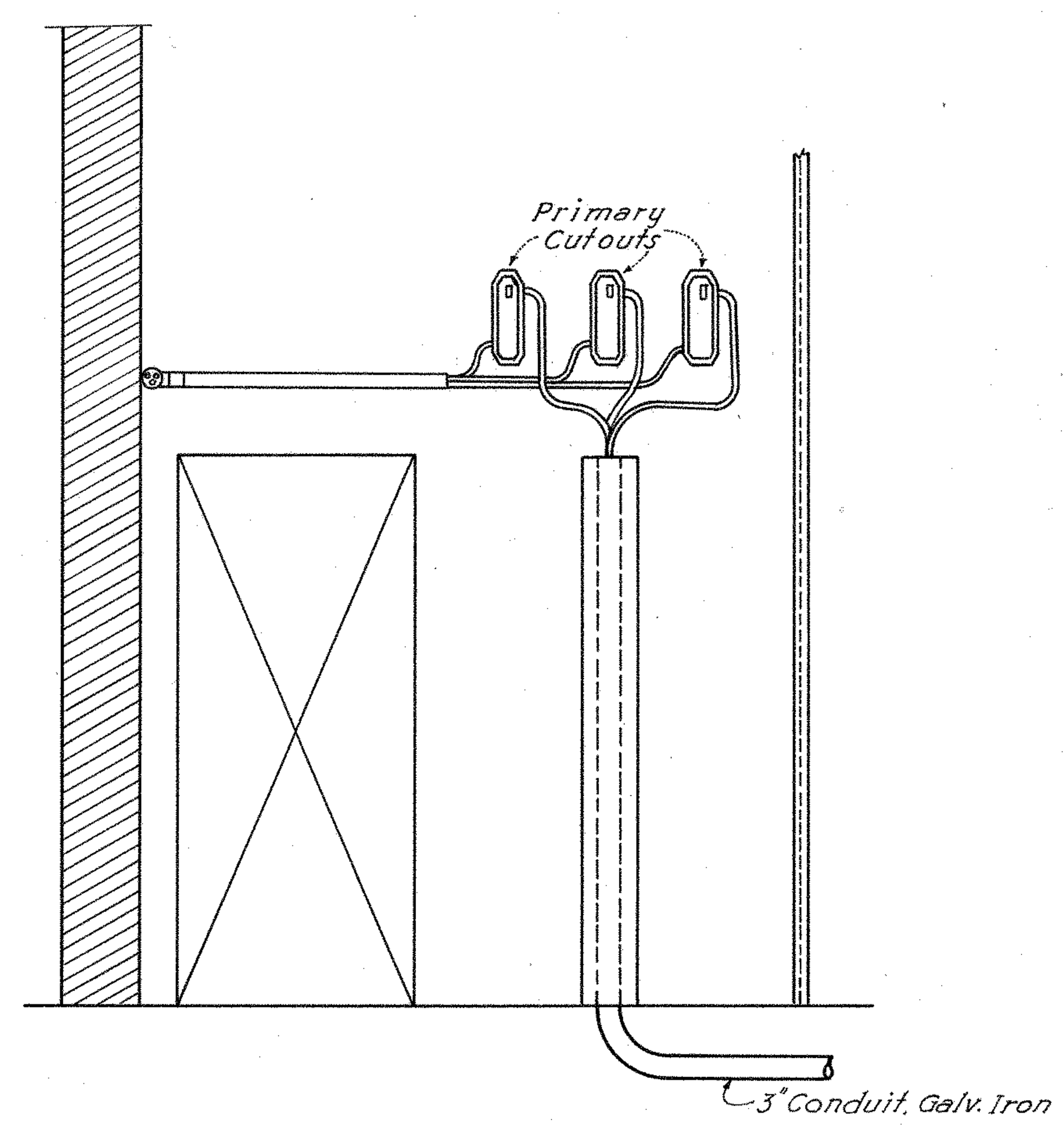


PLAN

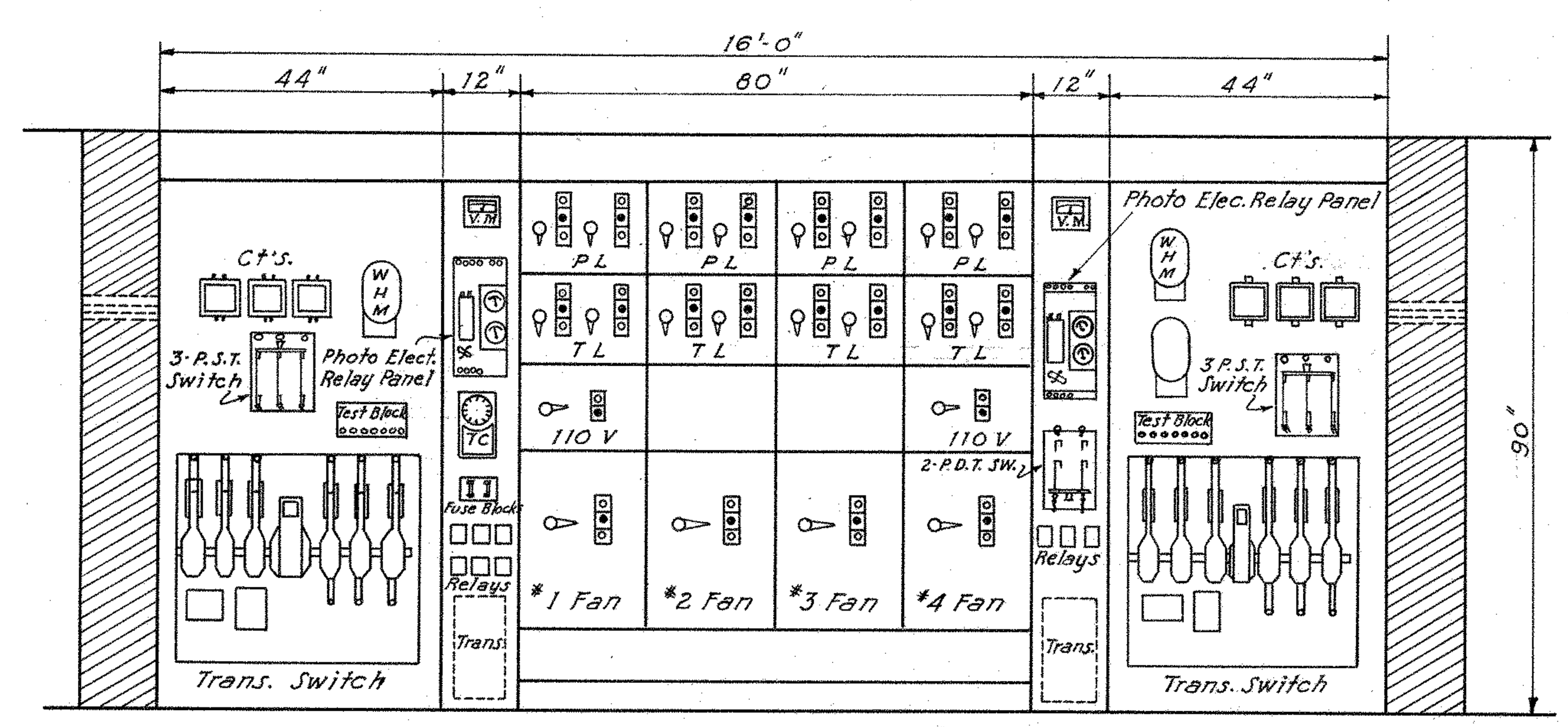


SECTION A-A





SECTION C-C



ELEVATION OF SWITCHBOARD

(DOORS REMOVED)

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CONNECTICUT
STATE HIGHWAY DEPARTMENT

WILBUR CROSS PARKWAY
WEST ROCK TUNNEL
GENERAL ARRANGEMENT PLAN
CONTROL ROOM

PARSONS, BRINCKERHOFF, HOGAN & MACDONALD
ENGINEERS NEW YORK, N.Y.

SCALE ½" = 1'-0"
MADE BY M.W.S.
CHECKED BY H.K.B.
APPROVED
DATE

PROJECT NO.

TUNNEL SHEET NO. 44 OF 44

CROSS SECTIONS

SCALE 1 INCH = 10 FEET

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		58	73

NOTE BOOK NO. A-185-05-02	
Ground Surface Platted by	S.B.
" " Checked by	H.A.M.
Template Sections Platted by	H.T.D.
" " Checked by	L.B.W.
Areas by	H.J.T.
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185-90

147 03

CROSS SECTIONS

Scale 1 inch=10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		59	73

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NOTE BOOK NO. A-185-05-02

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" " Checked by
Quantity Transferred and Inked by

185 90   147 03   59

CROSS SECTIONS

Scale 1 inch=10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		60	73

NOTE BOOK NO. A-185-05-02

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CROSS SECTIONS

Scale 1 inch=10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE		1947		61	73

WILBUR CROSS PARKWAY
PROJECT 185-90

NOTE BOOK NO. 185-23 A

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" Checked by M.J.S.
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" " Checked by
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185-90 147 03

CROSS SECTIONS

Scale 1 inch = 10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE		1947		62	73

WILBUR CROSS PARKWAY
PROJECT 185-90

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NOTE BOOK NO. 185-23-"A"

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185 90

147 03

CROSS SECTIONS

Scale 1 inch = 10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE		1947		63	73

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

NOTE BOOK NO. 185-23-"A"

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Template Sections Platted by L.B.W.
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Areas by H.W.G.
" Checked by M.J.S.
Template Sections Revised by
" " Checked by
Final Areas by
" " Checked by
Quantity Transferred and Inked by

185 90

147 03

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE		1947		64	73

CROSS SECTIONS

Scale 1 inch = 10 feet

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE TRUE CONDITIONS OR ACTUAL QUANTITIES OR DISTRIBUTION OF QUANTITIES OF WORK WHICH WILL BE REQUIRED.

NOTE BOOK NO. 185-23-A

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Template Sections Platted by L.B.W.
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Areas by D.A.P.
" Checked by H.W.G.
Template Sections Revised by ______
" " Checked by ______
Final Areas by ______
" " Checked by ______
Quantity Transferred and Inked by ______

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185 90

147 03

CROSS SECTIONS

SCALE 1 INCH = 10 FEET

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	WOODBRIDGE		1947		65	73

WILBUR CROSS PARKWAY
PROJECT 185-90

NOTE BOOK NO. 185-23-"A"	
Ground Surface Platted by	S.S.W.
" " Checked by	L.Z.
Template Sections Platted by	T.S.
" " Checked by	
Areas by	D.A.P.
" Checked by	M.J.S.
Template Sections Revised by	
" " Checked by	
Final Areas by	
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CROSS SECTIONS

Scale 1 inch = 10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		66	73

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Areas by H.W.G.
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Template Sections Revised by
" " Checked by
Final Areas by H.J.T.
" " Checked by T.R.
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185 90

147-03

66

CROSS SECTIONS

Scale 1 inch=10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	NEW HAVEN		1947		67	73

WILBUR CROSS PARKWAY

PROJECT 185-90

NOTE BOOK NO. 185-23-"A"	
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" " Checked by	L.B.W.
Areas by	H.W.G.
" Checked by	L.B.W.
Template Sections Revised by	
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185-904

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CROSS SECTIONS

Scale 1 inch = 10 feet

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	HAMDEN		1947		68	73

WILBUR CROSS PARKWAY
Project 185-90

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68

CROSS SECTIONS
SCALE 1 INCH = 10 FEET

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	FISCAL YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	HAMDEN		1947		69	73

NOTE BOOK NO. 185-23 A

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Areas by T.R.
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" " Checked by
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185 90 117 03

CROSS SECTIONS

SCALE 1 INCH = 5 FEET

FORM NO. ENG. 13 ED. 6-45

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	STATE PROJ. NO.	YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	New Haven and Woodbridge		185-90	1947		70	73

WILBUR CROSS PARKWAY

PROJECT NO. 185-90

POND LILY AVE. RAMP

NOTE BOOK NO. 185-66-A	
Ground Surface Plotted by	G.S. Koch
" " Checked by	L.E. Fitts
Template Sections Plotted by	L. Osterling
" " Checked by	J.J. O'Brien
Areas by	H. Cahoon
" Checked by	J.J. O'Brien
Final Sections Plotted by	
" " Checked by	
Final Areas by	
" " Checked by	
Quantity Transferred and Inked by	

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70

CROSS SECTIONS

SCALE 1 INCH=5 FEET

FORM NO. ENG. 13 ED. 6-45

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	STATE PROJ. NO.	YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	New Haven and Woodbridge		185-90	1947		71	73

NOTE BOOK NO. 185-66A

Ground Surface Plotted by G. S. Koch
" " Checked by L.E.Fitts
Template Sections Plotted by L. Osterling
" " Checked by J.J.O'Brien
Areas by J.J. O'Brien
" Checked by H. Cahoon

Final Sections Plotted by
" " Checked by
Final Areas by Conkey
" " Checked by Raymond
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CROSS SECTIONS

SCALE 1 INCH=5 FEET

FORM NO. ENG. 13 ED. 6-45

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	STATE PROJ. NO.	YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	New Haven and Woodbridge		185-90	1947		72	73

WILBUR CROSS PARKWAY

PROJECT NO. 185-90

POND LILY AVE. RAMP

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Template Sections Plotted by L. Osterling
" " Checked by J.J. O'Brien
Areas by J.J. O'Brien
" Checked by H. Cahoon

Final Sections Plotted by ______
" " Checked by ______
Final Areas by ______
" " Checked by ______
Quantity Transferred and Inked by ______

185 90

147 03

72

CROSS SECTIONS

SCALE 1 INCH=5 FEET

FORM NO. ENG. 13 ED. 6-45

FED. ROAD DIST. NO.	STATE	TOWN	FED. AID PROJ. NO.	STATE PROJ. NO.	YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
9	CONN.	New Haven and Woodbridge		185-90	1947		73	73

WILBUR CROSS PARKWAY
PROJECT NO. 185-90

POND LILY AVE. RAMP

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Template Sections Plotted by L. Osterling
" " Checked by J. J. O'Brien
Areas by J. J. O'Brien
" Checked by H. Cahoon

Final Sections Plotted by
" " Checked by
Final Areas by
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Quantity Transferred and Inked by

185 90

147 03

73

WEST ROCK TUNNELS

CONSTRUCTED UNDER THE SUPERVISION
OF THE
CONNECTICUT STATE HIGHWAY DEPARTMENT
COMPLETED — NOVEMBER 1949

GOVERNORS

RAYMOND E. BALDWIN JAMES L. McCONAUGHY
WILBERT SNOW JAMES J. SHANNON
CHESTER BOWLES

HIGHWAY COMMISSIONERS

WILLIAM J. COX G. ALBERT HILL

DEPUTY HIGHWAY COMMISSIONERS

ARTHUR W. BUSHELL ROY E. JORGENSEN

CONSULTING ENGINEERS

PARSONS BRINCKERHOFF HALL AND MACDONALD

CONTRACTORS

GULL CONTRACTING CO. INC AND L. G. DEFELICE & SON INC. NEW YORK N.Y.

3-6

4-8

Scale - 4" = 1'-0"

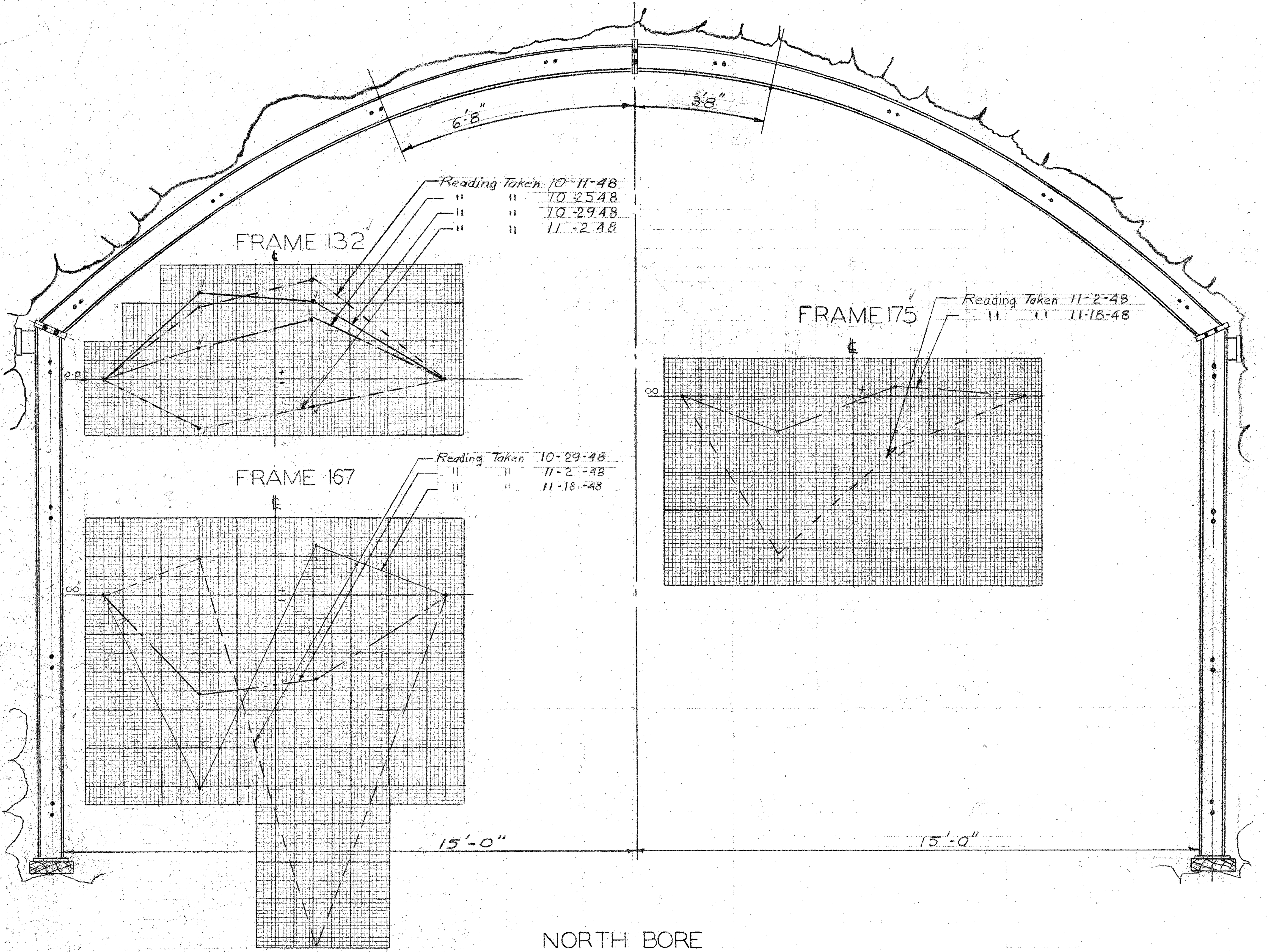
0 3 6 9 12

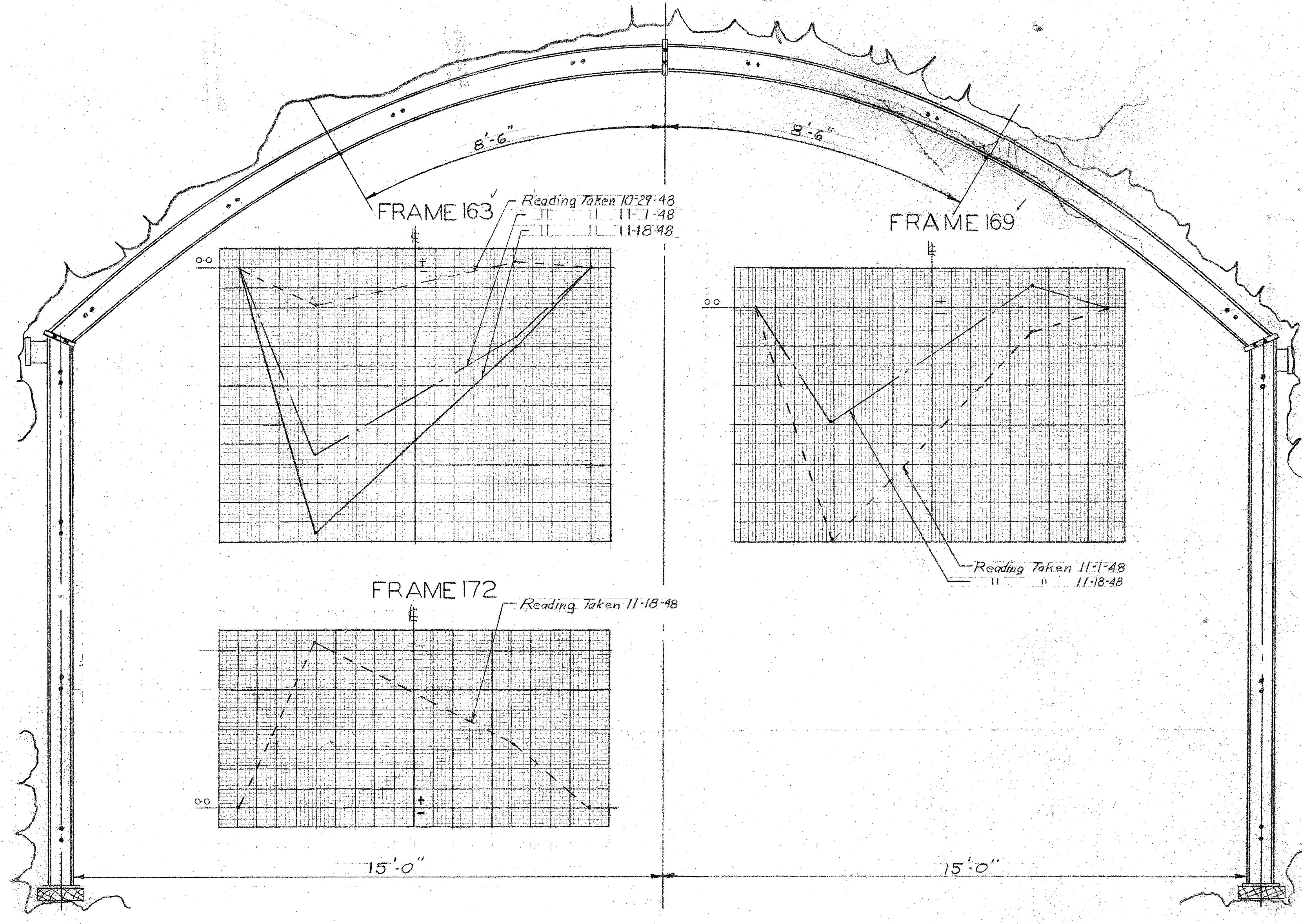
PROPOSED COMMEMORATIVE TABLET
WEST ROCK TUNNEL - NEW HAVEN CONN
CONNECTICUT STATE HIGHWAY DEPARTMENT
165 Capitol Avenue Hartford Conn.
Sept 2-1949 Drawn by G.L.D.

Material - Bronze - SHOT BLASTED
LETTERS - ROMAN - STOCK - Polished Faces
Fastenings - 4 - Exp. Bolts of Bronze.

One Required - Mounted on one Face.
Completely erected - by - Oct 15-1949.

147 03





NORTH BORE

NORTH HALF

Frame No	Date Taken	Cond. of Frame	Avg. Rdg.	Avg. Diff	Stress
132	10-4	Unloaded	.0636	-	-
	10-11	Loaded	.0655	+.0019	+5700
	10-25	"	.06445	+.00085	+2550
	10-29	"	.06587	+.00227	+6810
	11-2	"	.0623	-.0013	-3900
167	10-25	Unloaded	.07115	-	-
	10-29	Loaded	.0721	+.00095	+2805
	11-2	"	.06863	-.00252	-7560
	11-18	"	.0661 H	-.00505	-15150
175	10-29	Unloaded	.06505	-	-
	11-2	Loaded	.0609	-.00415	-12450
	11-18	"	.0641 B	-.00095	-2850

H-Blocked and Hid by Rock
B-Blocked

SOUTH HALF

Frame No	Date Taken	Cond. of Frame	Avg. Rdg.	Avg. Diff.	Stress
132	10-4	Unloaded	.07125	-	-
	10-11	Loaded	.07385	+.0026	+7800
	10-25	"	.0729	+.00165	+4950
	10-29	"	.07333	+.00208	+6240
	11-2	"	.0705	-.00075	-2250
167	10-25	Unloaded	.06653	-	-
	10-29	Loaded	.05733	-.0092	-27600
	11-2	"	.0644	-.00213	-6390
	11-18	"	.06783H	+.0013	+3900
175	10-29	Unloaded	.06967	-	-
	11-2	Loaded	.06827	-.0014	-4200
	11-18	"	.06993B	+.00026	+780

SOUTH BORE

NORTH HALF

Frame No.	Date Taken	Cond. of Frame	Avg. Rdg.	Avg. Diff.	Stress
163	10-26	Unloaded	.06567	—	—
	10-29	Loaded	.06473	-.00094	-2820
	11-1	"	.06083	-.00484	-14520
	11-18	"	.05892	-.00675	-20250
169	10-29	Unloaded	.06263	—	—
	11-1	Loaded	.0567 *	-.00593	-17790
	11-18	"	.05966	-.00297	-8910
172	11-1	Unloaded	.06473	—	—
	11-18	Loaded	.06903	+.0043	+12900

SOUTH HALF

Frame No.	Date Taken	Cond. of Frame	Avg. Rdg.	Avg. Diff.	Stress
163	10-26	Unloaded	.0677	—	—
	10-29	Loaded	.06787	+.00017	+510
	11-1	"	.06595	-.00175	-5250
	11-18	"	.0657	-.0020	-6000
169	10-29	Unloaded	.0699	—	—
	11-1	Loaded	.0693 *	-.0006	-1800
	11-18	"	.07047	+.00057	+1710
172	11-1	Unloaded	.07385	—	—
	11-18	Loaded	.0755	+.00165	+4950

*-Roof of Frame Shifted South

Deformation Readings taken by C.L. Nord
Check " " " W. Brandt
& Aug. Ehrenfels
Recording made by Aug. Ehenfels

CONNECTICUT
STATE HIGHWAY DEPT.

WEST ROCK TUNNEL

Stress Readings on Steel Frames

Scale 1/2" = 1'-0"
Made By H.S.F.
Checked By [signature]
App. By
Date 11-23-48

Project No.
Sheet No. 1 of 1

185-90 185 90

147 03 147-03

Appendix B

Reference Documents – NCHRP 216

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP

Web-Only Document 216:

Emergency Exit Signs and Marking Systems for Highway Tunnels

Laura Higgins
Paul Carlson
Jeff Miles
Texas A&M Transportation Institute
The Texas A&M University System
College Station, TX

Stephen Rozyckie
Martha Averso
David Graham
Brian Seip
Gannett Fleming, Inc.
Harrisburg, PA

Gunnar Jenssen
SINTEF Technology and Society
Trondheim, Norway

Contractor's Final Report for NCHRP Project 20-59(47)
Submitted August 2015

TRB TRANSPORTATION RESEARCH BOARD
The National Academies of
SCIENCES · ENGINEERING · MEDICINE

ACKNOWLEDGMENT

This work was sponsored by the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program (NCHRP), which is administered by the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine.

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, non-governmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Ralph J. Cicerone is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. C. D. Mote, Jr., is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.national-academies.org**.

The **Transportation Research Board** is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to increase the benefits that transportation contributes to society by providing leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

Learn more about the Transportation Research Board at **www.TRB.org**.

CONTENTS

The proposed set of guidelines, published as a brochure, can be found at http://www.trb.org/Main/Blurbs/173414.aspx.

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 20-59(47) by the Texas A&M Transportation Institute (TTI), a member of The Texas A&M University System. The research team gratefully acknowledges the input of the Regulatory and Warning Signs Technical Committee of the National Committee on Uniform Traffic Control Devices, as well as that provided by the 20-59(47) project panel. Thanks also go to Jeremy Johnson, Dan Walker, Ivan Lorenz, Kai Johnson, Sarah Hammond, Christine Yager, Sarah Badillo, Paige Ericson, David Dobrovolsky, Neal Johnson, and Rod Cavness, all of TTI, for their valuable help with preparing for and conducting data collection for the human factors studies, and to Dr. Srinivas Geedipally of TTI for his input on data analysis.

ABSTRACT

This research project focused on determining effective messages for encouraging drivers to leave their vehicles and evacuate a tunnel on foot; determining sign and marking formats that most effectively lead people to emergency tunnel exits; and determining the most visible sign and marking materials and technologies for use in highway tunnel environments.

Focus groups were conducted to explore potential evacuation messages and delivery methods. Next, a simulated tunnel environment was used to test driver responses to emergency messages, and to test visibility and comprehension of selected emergency exit signs and markings, including the running man pictogram prescribed in the International Organization for Standardization's 7010 guidelines. Results indicate that the running man pictogram was correctly or partially understood as indicating an exit by a majority of participants, and that a directional sign with the pictogram, "EXIT" text, a directional arrow, and distance in feet was correctly understood by virtually all participants. Visibility distances of tested internally illuminated signs were somewhat longer than those of tested photoluminescent signs; visibility for all sign technologies dropped sharply when viewed through smoke. The final product is a proposed set of guidelines for emergency exit signs, markings, and messages for use in tunnels in the United States, published as a brochure, which can be found at http://www.trb.org/Main/Blurbs/173414.aspx.

EXECUTIVE SUMMARY

Emergencies such as vehicle crashes, fires, hazardous waste spills, or terrorist activities can be particularly hazardous when they occur inside long underground tunnels. The enclosed environment of a highway tunnel can concentrate heat, smoke, or other toxic gases resulting from the incident; limited right-of-way means that even a partially blocked lane can potentially trap vehicles and hinder access for emergency responders. As a result, tunnel users may need to evacuate themselves on foot via emergency exits. This research study examined emergency exit signs, markings, and messages intended for use in highway tunnels. The study's three primary objectives were as follows:

- To evaluate the effectiveness of emergency messages and their delivery methods (i.e., visual, audible, or both) to encourage drivers to leave their vehicles and evacuate a tunnel on foot.
- To evaluate the effectiveness of sign messages, as well as signing and marking formats, to lead people to emergency tunnel exits.
- To evaluate the visibility of different sign and marking materials and technologies for use in highway tunnel environments, in particular when a tunnel is filled with smoke.

BACKGROUND

Studies of past tunnel emergencies have found that tunnel users often do not act independently to evacuate themselves on foot, instead choosing to remain in or near their vehicles. Some reasons for making the potentially fatal decision not to evacuate are the lack of awareness of an unfolding hazard, uncertainty about the appropriate course of action, reluctance to leave the perceived safety of the vehicle, and reluctance to abandon property. During an emergency, people have a tendency to wait for information or instruction rather than seeking it out. If and when people do decide to exit a tunnel in the face of a recognized danger, a common tendency is to try to reach the main tunnel portal entrance through which they drove into the tunnel, rather than emergency exits for pedestrians, which may be nearer. In fact, drivers may not be aware of the existence of emergency exits or cross passageways and therefore may not recognize the purpose of exit doors along the tunnel wall. Additionally, people tend to overestimate the amount of time they have to evacuate during a fire, a potentially fatal mistake since fire and smoke can spread more quickly in a tunnel fire than in a building.

In the absence of emergency responders to give directions, in-tunnel signs, marking systems, lighting, and/or audible signals must provide direction to tunnel users. Both the need to evacuate and the location of the nearest emergency exits must be clearly communicated. Additionally, the signs and markings must be visible to pedestrians under potentially adverse viewing conditions, including darkness and smoke. Existing guidelines that address aspects of emergency exit signs and markings for highway tunnels include the following:

- Directive 2004/54/EG of the European Parliament establishes minimum safety requirements for all roadway tunnels on the Trans European Roadway Network that are longer than 500 meters. One of the objectives of the guidelines is to improve conditions for self-rescue from a tunnel in an emergency, including guidelines for evacuation lighting and signing.

- The National Fire Protection Association (NFPA) is a nonprofit organization with members from nearly 100 nations. As part of its mission, NFPA has developed approximately 300 codes and standards for mitigating the risk and effects of fires. Three NFPA codes that directly address emergency exit signs and markings for highway tunnels are NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*; NFPA 170, *Standard for Fire Safety and Emergency Symbols*; and NFPA 101, *Life Safety Code*.
- The International Building Code's (IBC's) guidelines do not directly apply to exit door and exit pathway signs and markings in tunnels; however, they represent a standard for exit signing in buildings that is consistent and recognized throughout the United States.
- The International Commission on Illumination's (CIE's) 193-2010 Emergency Lighting in Road Tunnels provides guidelines for emergency lights and markings for pedestrians in highway tunnels, including marking recommendations for emergency exit doors.

RESEARCH APPROACH AND RESULTS

Building on prior research and existing U.S., European, and international standards for emergency exit signs and markings, researchers tested selected messages, sign and marking formats, and sign and marking technologies with volunteer participants. Research activities included focus group discussions and a simulation of a tunnel emergency situation involving smoke. The expert panel discussion included tunnel operators and emergency responders, and their responses were used to revise the focus group discussion and tunnel fire simulation, as well as to identify potential maintenance or other technical issues associated with signs and markings.

Focus Group Discussions

Two focus group discussions were conducted to gain a better understanding of how tunnel users might respond to various tunnel incident scenarios and warnings. Participants were presented with pictures, videos, and audio clips pertaining to a hypothetical emergency involving fire inside a highway tunnel. Participants discussed how they might react to a similar situation, what types of information and messages would be most effective, and what might influence their decisions to either stay in their vehicle or evacuate the tunnel on foot. The results of the focus group discussions included the following:

- Participants indicated that uncertainty about what is happening might lead to a delayed or incorrect response, so it would be important to relay to tunnel occupants details about the emergency or at least instruct the drivers to evacuate the tunnel.
- The messages that participants found most useful included a brief statement about the emergency, followed by a direct action statement. Examples of this type of message, displayed on an electronic message sign, included "Emergency—walk to exits" and "Fire in tunnel—walk to exits." Audio messages including the same information elements were also considered effective.

Tunnel Simulation

The tunnel simulation tested individual responses to a tunnel emergency scenario similar to those discussed by the focus groups and tested several sign and marking formats and technologies within the simulated tunnel environment, both for participants’ comprehension of and confidence in various formats and for detection and legibility distances through smoke.

Response to Emergency Situation and Messages

Stage 1 of the tunnel exercise simulated a vehicle trip through a highway tunnel that was stopped by a traffic jam, followed by the appearance of smoke in the tunnel and sounds of stopped traffic and tunnel ventilation. One-third of participants received only these visual and auditory cues to the situation, another one-third also saw a dynamic message sign (DMS) with the message “Fire in tunnel—walk to exits,” and a final one-third heard a longer audio message: “Attention—there is a vehicle fire in the tunnel. Turn off your engine and leave your keys in the vehicle so that it can be moved by emergency personnel. Leave your vehicle and walk quickly to emergency exits.” Results of Stage 1 included the following:

- While all three groups included participants who indicated that they would stay in their vehicle as well as participants who indicated they would leave the vehicle, the two groups of participants who received a message about the incident (either visually or audibly) were much more likely to say they would leave the vehicle and exit on foot (81 percent of those who saw the DMS and 73 percent of those who heard the audio announcement) versus the group who received no message (20 percent).
- When asked what additional information they would want or need regarding the situation, participants who had not received a message were most likely to request information about the nature and seriousness of the situation, as well as instructions about what they should do. Participants who had received either of the two messages were most likely to ask about the locations of the exits and how to identify them.

Sign Comprehension

Participants viewed nine signs. Three of the signs were symbol-only signs: a “running man” symbol-only sign, a “refuge point” sign, and an emergency telephone sign. Researchers asked participants what they thought each of these signs meant. The other six signs all incorporated the word “EXIT,” and participants were asked where they would expect to find an exit door based on each sign. Some of the principal results from the comprehension testing included the following:

- The stand-alone running man symbol was identified correctly by 48 percent of participants as an exit sign, while another 38 percent assumed that the sign indicated a direction or path for them to follow.
- All signs that included the word “EXIT” were correctly identified by all participants as indicating a tunnel exit. Comprehension scores for signs with “EXIT” text, therefore, measured participants’ understanding of an exit’s location relative to the location of the sign.
- Once the running man symbol was paired with the word “EXIT,” most participants thought that the running man sign (with or without the word “EXIT”) indicated a direction, even without a supplemental arrow. Therefore, participants most frequently assumed that the running man symbol indicated an exit to the side of the sign or farther away in the direction that the running figure was facing. However, participants saw the

test signs in the context of a wall-mounted frame and so did not have the added context of a visible doorway.

- A small number of participants did not recognize the chevron arrows on a text-only EXIT sign as directional arrows. All participants recognized tailed arrows as indicating a direction.
- When the running man sign was paired with a (tailed) directional arrow and a distance, comprehension of the exit's location relative to the sign was perfect among nearly all participants.
- When a running man exit sign included an arrow but no specified distance, many participants assumed that an exit was nearby in the direction of the arrow; if no distance was provided, they assumed the distance to the exit was very short.

Path Marking Preferences

Participants were presented with four pairs of exit path/door marking formats and asked to select the option from each pair that they would feel most confident about following to an exit:

- Steady-state light-emitting diode (LED) lights vs. LED lights flashing in unison.
- Unison-flash LED lights alone vs. unison-flash LED lights plus an audio beacon saying, "Exit here."
- Unison-flash LED lights vs. traveling LED lights that illuminated in a left-to-right sequence.
- Unison-flash LED lights plus an "exit here" audio beacon vs. traveling LED lights.

In general, participants preferred flashing lights over steady-state lights, and traveling lights that indicated a direction over unison-flash lights. An audio beacon was a favored option to indicate the location of doorway; however, when the audio beacon was compared against traveling/directional pathway lights, many participants indicated that the traveling lights would be more useful farther away from an exit door, and the audio beacon would be helpful close to the door.

Sign Visibility

To assess the visibility of the signs tested, researchers measured the luminance of each sign's positive (brighter) and negative (darker) areas, as well as of the gray walls and frames surrounding the signs. Measurements were conducted in clear conditions and in smoky conditions with smoke opacity levels of 4, 5, 10, 12 and 23 percent, and in both low ambient light and darkness. The measurements were used to calculate the contrast ratio of each sign compared to the tunnel wall, and also the contrast ratio of each sign's positive and negative elements, i.e., sign legend versus sign background. Sign visibility was also measured during participant testing in the tunnel simulation by recording the distances at which participants could detect and read each sign. Some of the signs were internally illuminated by LEDs, while others were photoluminescent (PL).

Luminance and Contrast in Smoke

The luminance measurements showed that the overall luminance levels and the contrast ratios between signs and the tunnel wall, and between the sign legends and background, all diminished sharply when the signs were viewed through smoke. This significantly affected how far away signs could be seen and also reduced the contrast between their light and dark areas, which made text and symbols more difficult to read. The principal findings from the luminance measurements included the following:

- In general, LED signs in clear conditions had much higher luminance levels than PL signs, and this difference continued when signs were measured in smoky conditions. However, these differences in luminance diminished as smoke opacity increased.
- Under low levels of ambient light, the contrast of sign luminance with the tunnel wall diminished rapidly as smoke opacity increased. In general, LED signs slightly outperformed PL signs. When there was no ambient light, contrast between the tested signs and the tunnel walls was much higher, and PL signs displayed higher contrast ratios than LED signs.
- Contrast ratios between sign legends and backgrounds were consistently higher for PL signs than for LED signs. This was the case with low levels of ambient light and was even more pronounced without ambient light.

Detection and Legibility Distances

During the tunnel simulation, detection and legibility distances were recorded for each sign that participants viewed, as well as for a photoluminescent path marking square. Some of the findings from visibility testing of the signs with study participants included the following:

- For all of the signs, smoke density/opacity was a significant factor in detection and visibility distances, as would be expected from the sharp drop in sign/marking luminance and contrast that was seen in the photometric measurements.
- The LED signs that were tested could be seen from farther away than the tested PL signs, as would be expected from the LED signs' higher luminance values.

PROPOSED GUIDELINES

The findings from the study are summarized in a set of proposed guidelines for the format and placement of emergency exit signs and markings for highway tunnels. The guidelines also address considerations for selecting sign and marking materials and technologies, as well as some preliminary recommendations for public outreach and education pertaining to tunnel emergencies and exit plans. Highlights from the proposed guidelines include the following:

- **Emergency Exit Sign Formats.** Emergency exit door and directional signs should include the running man symbol in combination with the word "EXIT," as shown in Figure 1. Sign colors should be green and white. This sign should be placed on the exit door if possible, or on the tunnel wall immediately to the right or left of the door, preferably with the midpoint of the sign no higher than 1.5 meters (4.9 feet) above the floor.

Figure 1. Exit door sign format.

- **Emergency Exit Directional Sign Formats.** Signs indicating directions to emergency exits should be placed at least every 25 meters (82 feet) along the tunnel wall. These signs should include the running symbol and "EXIT" text, with the addition of a tailed directional arrow and the distance to the nearest exit in feet (see Figure 2). If exits are located in two directions relative to the location of the sign, two signs should be placed side by side to indicate the directions and respective distances to the two exits.

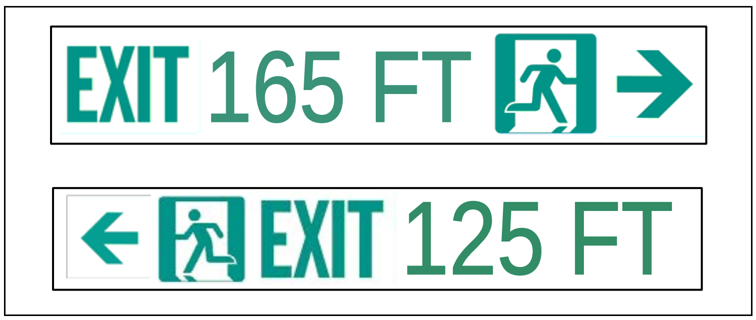


Figure 2. Sample exit directional sign formats.

- **Exit Door Markings.** The area around each exit door should be illuminated at a level that is three to five times brighter than the illumination of the adjacent walls. In addition, exit doors should be marked with strobe lights that activate only during an emergency. The lights should strobe at a frequency of between 1 Hertz and 2 Hertz; white strobe lights are specified under current NFPA guidelines, though further research may be warranted to compare white versus green strobe lights (recommended by some international guidelines) for this purpose.

- **Exit Door Audio Beacons.** Auditory beacons may be used to supplement (not replace) illuminated exit door lighting. When used, auditory beacons should only contain a single message, such as "exit here" or "refuge shelter," and may be in more than one language in addition to English. The primary benefit of an audible exit door beacon will be realized in the area close to the door. The decibel level used for the beacon should be calibrated to be audible to listeners within a relatively short radius of the door itself, and the use and type of auditory beacons should take into account the specific acoustic characteristics of the location in which it is used.

- **Exit Path Markings.** Exit path markings can be static or dynamic. If feasible, path markers should indicate a direction to an exit door. This may be accomplished with a dynamic light array, controlled automatically or manually by tunnel operations staff, that lights sequentially to indicate a direction. If directional/sequential LED arrays are not a feasible option, LED lights that can be activated to flash in unison during emergency situations seem to be slightly more effective than steady-state lights for indicating an emergency exit path. Path direction to exit doors can also be accomplished with static markers that include a directional arrow. Pathway markings should be placed no more than 1 meter (3 feet) above the pathway floor.

- **Emergency Messages.** In the event of an in-tunnel emergency or disruptive incident, it is beneficial to broadcast a message to drivers if possible, visually and/or audibly. In the case of an emergency that requires drivers to evacuate the tunnel on foot, an emergency message can be especially important for encouraging the evacuation. The message should contain, at minimum, the following pieces of information:
    - A brief statement about the nature of the emergency, e.g., "fire in tunnel" or "vehicle fire ahead."
    - Direct instructions about the action to take, e.g., "walk to exits" or "leave vehicles, walk to exits," if evacuation on foot is warranted. An evacuation direction (e.g., upstream of the fire) should be specified, if applicable.

  An emergency message broadcast via a dynamic message sign should be no more than two phases long, with a maximum of three lines/three bits of information per phase. Auditory messages may permit slightly longer messages than dynamic message signs; however, both loudspeakers and radio override systems can be problematic in a tunnel environment. Wireless emergency alerts may have potential for delivering emergency messages via driver cell phones.

- **Sign Material and Technology Considerations.** Internally lit, externally lit, or photoluminescent signs are all options for tunnel environments. Sign spacing should take sign luminance and associated visibility distance into consideration. Any sign or marking must be capable of withstanding environmental and traffic conditions in a highway tunnel, as well as tunnel cleaning procedures (or should be capable of being removed prior to tunnel cleaning). This can mean waterproofing the housings around electrical components for internally illuminated signs and selecting water-resistant and corrosion-resistant materials and coatings. Photoluminescent signs should be selected according to the availability of ambient light to charge them.

- **Public Education and Outreach.** Public service announcements and/or other public outreach materials may be useful for educating drivers about safe behaviors associated with driving in highway tunnels, including information about tunnel incident procedures and tunnel emergency exits, such as cross passageways and refuge areas as applicable. This type of advance education may improve the responses of drivers in the event of a tunnel-related emergency and may also predispose them to look or listen for emergency announcements during an incident.

CHAPTER 1. INTRODUCTION

Emergencies such as vehicle crashes, fires, hazardous waste spills, or terrorist activities can be particularly hazardous when they occur inside underground tunnels. Because stopped or trapped vehicles can make it difficult or impossible for emergency responders to quickly reach or respond to an emergency situation in a tunnel, tunnel users must often evacuate themselves. A 2006 scan tour of underground tunnels in Europe found consistent signing in use from country to country for the purpose of directing tunnel users to emergency exits (Ernst et al. 2006). This research project sought to evaluate signs, markings, and auditory messages in order to develop guidelines for use in tunnels in the United States.

The work plan for this project focused on researching three critical issues in order to develop an objective set of guidelines for tunnel emergency exit signs and markings:

1. Determine the messages and delivery methods (visual, audible, or both) that will encourage drivers to leave their cars and exit a tunnel on foot when conditions warrant such an evacuation.
2. Determine the sign graphics and colors, sign messages, marking types and colors, and auditory messages that most effectively lead people to emergency tunnel exits.
3. Determine the most visible sign and marking materials and technologies for dark and smoky conditions.

The project was conducted in four phases. In Phase I, the research team conducted a review of published studies and existing standards pertaining to emergency exit signs and markings, and developed a final research plan for conducting human factors studies. In Phase II, focus group discussions and a simulation of a tunnel environment under emergency conditions were used to measure human response to various signs and markings intended to lead pedestrians safely out of tunnels during emergency situations. A proposed guide for emergency exit signs and marking systems was developed in Phase III. This research report, including the proposed guidelines and an implementation plan for the guidelines, were developed during Phase IV.

CHAPTER 2. BACKGROUND

Vehicle crashes, fires, and other emergency situations pose particular dangers when they occur in long roadway tunnels; the limited space available for vehicle mobility means that a fully or partially blocked travel lane can quickly trap vehicles, and the confined space within a tunnel can also concentrate heat, smoke, or other toxic gases resulting from the incident. An added danger is that emergency responders will be delayed in responding due to the time needed to reach the tunnel and to access the incident scene inside the tunnel, making it necessary for travelers inside the tunnel to evacuate themselves, often on foot. In the absence of emergency responders to provide direction, in-tunnel signs, marking systems, lighting, and/or audible signals must communicate to tunnel users both the need to evacuate and the location of the nearest emergency exits.

HUMAN RESPONSES IN TUNNEL-RELATED EMERGENCIES

Studies of past tunnel emergencies have found that tunnel users often do not act independently to evacuate themselves on foot, instead choosing to remain in or near their vehicles. If and when people do decide to exit a tunnel in the face of a recognized danger, a common tendency is to try to reach the main (vehicular) tunnel portal, rather than emergency exits for pedestrians, which may be nearer. The reasons for these potentially fatal courses of action can include lack of awareness of an unfolding hazard, uncertainty about the appropriate course of action, reluctance to leave the perceived safety of the vehicle, reluctance to abandon property, and (in the case of fire) incorrect assumptions or estimations regarding how quickly the fire and smoke will spread (van Waterschoot et al. 2008, Nilsson et al. 2009).

Lessons Learned from Past Tunnel Disasters

A review of 26 tunnel fires that occurred between 1970 and 2003 found some commonalities in the behaviors and responses of the public. Observations of frequent driver responses to those incidents included the following:

- During an emergency, people have a tendency to wait for information or instruction rather than seeking it out.
- Motorists often do not recognize they are in danger. On an open roadway, stopped traffic or even a vehicle fire is not usually an emergency situation for other vehicles on the road; therefore, motorists without prior education about tunnel fires/hazards may not recognize an unfolding emergency until it is communicated by announcements, message signs, or other signals.
- Drivers are reluctant to abandon their vehicles and personal items.
- The exit that people are most likely to try to reach is the main tunnel portal—that is, the roadway entrance through which they drove into the tunnel. Emergency exits may be missed or disregarded in favor of the more familiar main portal.
- People tend to overestimate the amount of time they have to evacuate during a fire (van Waterschoot et al. 2008).

Several of these observations were tragically illustrated in the Mont Blanc (France-Italy) and Tauern (Austria) tunnel fires in 1999 and the St. Gotthard (Switzerland) tunnel fire of 2001.

The Mont Blanc fire, which began when a truck carrying flour and margarine caught fire inside the 7-mile-long tunnel, resulted in a 53-hour blaze that destroyed 36 vehicles. Of the 39 people who died in the fire, 29 were found still inside their vehicles; others tried to leave but were too late to escape the spread of fire and smoke, or fled to refuge chambers within the tunnel that ultimately failed due to the heat and duration of the fire. The Tauern tunnel fire, the result of a vehicle collision that in turn exploded a truck's cargo of spray paint cans, killed eight people in the initial crash and another four in the fire that followed. The St. Gotthard tunnel fire, which also resulted from a vehicle collision inside the tunnel, resulted in 11 deaths, again including some people who might have been able to escape before the fire spread. In all three cases, the seriousness of the developing fire was not immediately realized by other drivers in the tunnel, particularly those who were farther from the initial accident and could not see what had happened, and so crucial escape time was lost (Jenssen 2007, Eder et al. 2013, OECD 2006).

Laboratory Studies and Simulations

A driving simulation conducted by Netherlands Organization for Applied Scientific Research (TNO) observed the reactions of drivers when they were confronted by an in-tunnel traffic jam followed by approaching smoke. Drivers in the study were provided with one of three different information conditions:

- Drivers in Condition 1 were provided no information on how to respond to the situation shown.
- Drivers in Condition 2 were given an information leaflet containing information on safe behavior in tunnels prior to beginning the simulation.
- Drivers in Condition 3 were provided the same information leaflet prior to the simulation and also heard two messages from a virtual tunnel operator during the simulation. The first of these messages ("Please turn off the engine") was played 2.5 minutes after the simulated traffic accident, which was also 1 minute before smoke appeared in the tunnel. The second message ("Please go to the escape exits") played 1.5 minutes after the first message, which was 30 seconds after the appearance of smoke.

The study's results showed that increasing the information provided to drivers markedly affected their decisions to leave (or to state their intention to leave) the simulated vehicle in response to the unfolding tunnel fire. With no information other than the visual cues shown during the simulation, 65 percent of drivers in Condition 1 ultimately indicated their intention to leave the vehicle, compared to 75 percent of drivers in Condition 2 and 94 percent of drivers in Condition 3. Additionally, the three information conditions influenced the time that drivers took to decide to leave the vehicle. Measured from the time that traffic came to a stop in the simulated tunnel, Condition 1 drivers took an average of 3.16 minutes to leave the vehicle (if they left at all), the average time for Condition 2 drivers was 2.54 minutes, and the average time for Condition 3 drivers was 2.23 minutes. For Condition 3 drivers, this evacuation time equated to approximately 0.23 minutes following the voice announcement (Jenssen 2008).

A similar study in Sweden in 2007 used a simulated emergency scenario in an actual roadway tunnel to examine motorist behaviors when confronted with a tunnel fire, and to assess the influence of various types of evacuation information on those behaviors. The 29 participants in the experiment all drove (as a queue of 29 vehicles) into a dual-bore tunnel in which a simulated accident scene blocked their path. Two and a half minutes after the first vehicle in the queue stopped, information signs began displaying a message instructing drivers to turn off their engines and evacuate the tunnel, and a prerecorded alarm began providing a similar message in three languages. At the same time, green flashing lights were activated at emergency exits close to the simulated accident site. In this experiment, the 19 participants at the head of the queue (i.e., within view of the accident site) left their vehicles and had reached or were en route to emergency exits before the alarms and flashing lights activated; for this group, seeing others begin to evacuate was a common factor in their decision to do the same. The remaining participants, who were farther back and therefore could not see the accident site, opened their vehicle doors within a few seconds of alarm activation; while these participants found the audio message difficult to understand, nine out of 10 of them cited it as a factor in their decision to leave their vehicle. Some also mentioned the signs as a factor, while others indicated that they did not notice them. The flashing lights at exit doors were seen only by members of this latter group (Participants 20–29); three recalled the flashing lights as being important to their identification of the door, while the others did not (Nilsson, Johansson, and Frantzich 2009).

SIGN AND MARKING COMPREHENSION

Studies of emergency exit way-finding guidance in the literature include evaluations of signs and visible markings and beacons, as well as of audible signals and messages.

In a high-anxiety situation, a person's focus narrows and cognitive ability is reduced. For this reason, it is important to provide simple, straightforward instructions about what to do and where to go in the event of an emergency. Alarms that include specific messages to leave vehicles and exit the tunnel may help to reduce delayed responses; signs and markings that are easy to see and understand can help to direct people to the closest exit (Nilsson et al. 2009, Morley and Corbett 1997). Since most tunnel users cannot be expected to have specific knowledge or training for evacuating themselves from their vehicles and from the tunnel, the guidance offered by signs, markings, and auditory messages must be straightforward and intuitive.

Running man graphical exit signs were tested with airline passengers at Schipol Airport in Amsterdam to evaluate the comprehensibility of graphical sign messages including the identification of the exit door and an indication that an exit door is located to the left or right of the sign. The signs were tested with people traveling to and from all regions of the world to compare comprehension across different nationalities and languages. Comprehension of these graphical signs was above 66 percent for survey participants who were from Western Europe, North America, and Australia/New Zealand; it was lower for participants from Eastern Europe, Asia, Africa, Latin America, and the Middle East (Morley and Corbett 1997).

In a similar comprehension study conducted by the Federal Aviation Administration, approximately 50 percent of study participants correctly identified the meaning of the running man symbolic exit sign when the sign was viewed in isolation, compared to 97 percent who correctly identified the meaning of a text EXIT sign; symbolic signs indicating the direction to an exit were correctly identified by about 43 percent of participants. When the signs were viewed in context (pictures showing exit doors from the interior of an airplane), comprehension of signs using the running man symbol rose to an average of 70 percent. The study concluded that the symbolic exit signs were not equivalent to the traditional (in the United States) EXIT text sign and would need "additional compensating factors" to provide an equivalent level of safety for people needing an emergency exit (McLean and Corbett 2007).

A series of experiments in Sweden testing exit markings for tunnels found that green flashing lights at exit doors, particularly lights that activate at the onset of a fire alarm, were the most successful for catching the attention of study participants and communicating the intended "exit here" message. Orange flashing lights were also attention getting, but were more likely to be interpreted by participants as signaling danger rather than a safe exit (Nilsson 2009, Ronchi et al. 2012).

A 2013 tunnel evacuation study compared the effects of five different combinations of emergency exit markings on participants' evacuation speed and exit choice within a smoke-filled tunnel. The test exit door treatments included the following combinations:

1. A backlit emergency exit sign.
2. The exit sign plus green flashing lights on either side of the door.
3. The exit sign, a non-flashing white halogen light above the door, and non-flashing green and white lights on either side of the door.
4. The exit sign plus a loudspeaker that broadcast an audible signal/message instructing participants to exit at that location.
5. The exit sign, plus all of the light options from Scenarios 2 and 3 (white halogen light above the door, green flashing lights on either side of the door, green and white non-flashing lights on either side of the door).

The five different exit treatments did not, in general, change the frequency of correct exit selection when participants were on the same side of the tunnel as the exit door. Under Treatment Conditions 1, 2, 4, and 5, the designated emergency exit was successfully found by 100 percent of the study participants whose starting point in the tunnel was on the same side of the tunnel as the exit door. However, for participants who started on the opposite wall of the tunnel (meaning that they would have to cross the width of the tunnel to reach the exit door), exit door treatments became more significant, with the green flashing lights and the audible signal producing more consistent results than the exit sign alone or the exit sign with any of the steady-state lights. In Treatment Condition 3, the steady-state white and green lights actually deterred a few participants from approaching the exit door from either the same or the opposite wall. Statements made by participants indicate that some thought the arrangement of green and white lights represented the outline of a train rather than an exit door (Fridolph et al. 2013).

VISIBILITY OF SIGN AND MARKING TECHNOLOGIES

Signs and markings intended to guide tunnel users on foot to exits in the event of an emergency must be visible to pedestrians under potentially adverse viewing conditions, including darkness and smoke. Because some types of tunnel-related emergencies may affect electrical systems, emergency signs and markings should be able to operate at least temporarily on independent power sources, or operate without the need for electrical power (e.g., photoluminescent materials).

A series of studies on visibility of signs through various types of smoke found that the smoke density, light scatter off smoke particles, and brightness and contrast threshold of the sign were the most significant factors determining how far away the sign could be seen. However, smoke's irritant effects, especially at higher densities, also affected visibility. Tests found that visibility distance of a given object in non-irritant smoke was a linear function of smoke density, and visibility dropped off sharply and non-linearly in irritant smoke (Jin 1997). An earlier study also examined the effects of sign luminance on visibility through smoke, finding that smoke had to reach an optical density of between 0.07 and 0.16 od/m to obscure signs with average luminances over 70 cd/m^2; signs with lower average luminances were obscured at lower smoke densities (Collins et al. 1992).

A study comparing laser diodes, xenon discharge tubes, and high-intensity LEDs as visual beacons for tunnel evacuations found that high-intensity LEDs provided the best visibility through smoke. A subsequent emergency evacuation guidance system was developed that used high-intensity LEDs configured as a flashing arrow to indicate the direction of an exit (Ellis et al. 2008). Similar systems have been implemented in Austria, coupled with LEDs to highlight the exit doors themselves. LED beacons, markings, and illuminated signs require relatively low levels of electrical power and can be operated using backup battery power if the main power in a tunnel is lost (Eigentler 2006).

A study by the University of Reading in the United Kingdom examined the visibility and legibility of exit route signs for people with visual impairments such as macular degeneration and cataracts. Participants viewed signs under normal lighting and emergency lighting conditions. In the initial data analysis (comparing four out of the total 24 signs evaluated), legibility distances were greater for two LED signs compared to two externally illuminated signs (Cook et al. 2005).

Photoluminescent signs and markings charge via exposure to a light source, and once charged, will glow in the dark. Because they do not need electrical power to operate, they offer a fail-safe in case of a widespread power loss. Another advantage of photoluminescent signs and markings is the ability to mount them completely flush to a wall, unlike powered signs or lights. Photoluminescent signs have been adopted in Canada for building exits and are required by city ordinance in New York for buildings over 75 feet tall (Carss 2010, Windle 2005). Photoluminescent materials can fail to fully illuminate, however, if they are inadequately charged by ambient light; some types may also degrade with exposure to ultraviolet radiation or moisture (Amy 2008).

AUDIO BEACONS AND MESSAGES

Auditory beacons can provide guidance in poor visibility conditions and for visually disabled pedestrians; they can also help to attract attention to emergency exits even when visibility is good. A study of an emergency evacuation system for mine workers, however, found that auditory beacons used alone as a way-finding system resulted in slower walking speeds and longer evacuation times than auditory beacons coupled with visual beacons (*14*). In two studies conducted by Boer and Wijngaarden, auditory beacons that included a chiming sound followed by the words “exit here” resulted in significantly more test participants following the correct route to a designated exit, compared to auditory beacons that used a nonverbal sound only. Participants also walked more rapidly toward the self-explaining auditory beacon than they did toward a nonverbal sound (Boer and van Wijngaarden 2004, Boer and van Wijngaarden 2008).

A series of studies by Lund University in Sweden examined how emergency exit messages should be formulated and conveyed in order to facilitate efficient egress. In the first study, customers at IKEA in Gothenburg were presented with spoken emergency exit messages and then questioned about the messages they had heard. Next, an experiment was conducted at the University of Lund with three selected types of verbal messages. The study was conducted with uninformed university students. All trials were video filmed to determine decision and reaction time to the messages. Both artificial and natural speech were used, with no notable difference in comprehension. The study noted that the artificial voice was very close to a natural voice in sound (Nilsson 2006).

Results of these two studies indicated that people remember less of the important information from a message if the message is too long. Based on the results, it is recommended that messages should not contain more than five information bits. One information bit is in this case a series of words that together build a single concept. Another finding is that people want to know the reason for the alarm. Since the initial phase of the emergency egress is characterized by indecision and information search, it is recommended to include a reason for the alarm in the speech message. Further, hearing that there is a fire leads to less misunderstanding. Hence, it is recommended that "fire" be included in the verbal message.

Comprehensible loudspeaker announcements contribute to proper motorist behavior in the event of fire and other road tunnel incidents. This is especially important for enabling self-rescue but also to ensure smooth traffic flow in case of traffic accidents, vehicle breakdowns, or other closed or blocked lanes. A research study in 2011 found that audible beacons using synchronized longitudinal sound resulted in considerably better speech comprehension inside tunnels compared to previous sound beacon technologies. This technology has been selected for use in highway tunnels in Germany; acoustic beacons using synchronized longitudinal sound are already installed in 10 German road tunnels. Further research is needed in order to develop and improve electro-acoustic sound beacons in tunnels even further. Topics that the 2011 study identified to be explored further included the following:

- Efficient adaptation of sound volumes to changing noise levels.
- Inclusion of escape ways and portal zones.
- Delivery of speech announcement text.
- Standardized ergonomic operation of speech announcements (Mayer et al. 2011).

EXISTING STANDARDS FOR TUNNEL EMERGENCY EXIT SIGNS AND MARKINGS

A number of existing standards in the United States and elsewhere in the world address requirements for emergency exits and associated signage, markings, and audio signals. Some of these are specific to highway tunnels, while others were developed for building exits but may have application, with or without modification, to the highway tunnel environment. Directive 2004/54/EG of the European Parliament establishes minimum safety requirements for all roadway tunnels on the Trans European Roadway Network that are longer than 500 meters. One of the objectives of the guidelines is to improve conditions for self-rescue from a tunnel in an emergency, including guidelines for evacuation lighting and signing.

The National Fire Protection Association is a nonprofit organization with members from nearly 100 nations. As part of its mission, NFPA has developed approximately 300 codes and standards for mitigating the risk and effects of fires. Two NFPA codes that directly address emergency exit signs and markings for highway tunnels are NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways,* and NFPA 170, *Standard for Fire Safety and Emergency Symbols.*

The International Building Code's guidelines do not directly apply to exit door and exit pathway signs and markings in tunnels; however, they represent a standard for exit signing in buildings that is consistent and recognized throughout the United States.

The following sections summarize guidelines from these and other U.S. and European standards for emergency exit signs, markings, lighting, and audio signals.

Exit Sign Formats and Graphics

Symbolic signs showing a running man exiting through a door were adopted for use in Europe in 1985 (Ernst et al. 2006, Turner 2010). The use of pictograms to replace text for emergency exit and other signs began to gain momentum across Europe in the early 1990s. Since that time, more than one version of a running man pictogram has been in use for exit signs across Europe. The International Organization for Standardization (ISO) 3864 (*27*) established one version of the pictogram as the standard for fire exit/escape signs, and this pictogram has also been adopted in ISO 7010, which provides guidelines for graphical symbols and colors for safety signs in general. The ISO 7010 exit sign, established in 2013, is a green sign with "EXIT" in white lettering in front of a man running into a door (see Figure 3).

A version of the running man symbol is the recommended exit sign format in Directive 2004/54/EG, Annex III. NFPA 170, Chapter 4, "Symbols for General Use," provides guidance concerning the shape, colors, and use of symbols for general fire safety information. Table 4.2, "Symbols for General Use", includes exit door signs and directional signs that incorporate the ISO 7010 running man symbol. Annex A, Section A.12.6.8 of NFPA 502 references this recommendation of NFPA 170.

Figure 3. Running man exit symbol, from ISO 7010.

Sign Size

Several national and international standards provide guidelines for the sizes of exit signs and/or sign elements. NFPA 101 recommends a minimum character height of 6 inches for text EXIT signs. The Norwegian Public Roads Association Standard for Road Tunnels recommends a 400 mm by 400 mm (15.75 inches square) running man symbol sign for tunnel exit doors. IBC requires "EXIT" letters that are at least 6 inches tall and 2 inches wide (with the exception of the letter "I"), with a stroke width of at least 0.75 inches. Finally, British Standard 5499-4:2000 provides the equation $D = hZ$ for calculating minimum sign height and minimum letter height for running man exit path signs, where:

- D = maximum viewing distance in meters.
- h = overall height of the sign's printed area in millimeters.
- Z = a distance factor based on the illumination of the sign and the level of detail included in the sign's legend. For exit path signs with the running man symbol, Z is generally assumed to be 170.

Sign Placement

Annex III of Directive 2004/54/EG requires directional signs (running man exit symbol, directional arrows, distances in meters) to be placed every 25 meters (82 feet) along the tunnel wall, pointing to the two nearest emergency exits; the prescribed height of the signs is between 1 and 1.5 meters (between 3.3 and 4.9 feet) from the walking surface.

NFPA 502, Section 7.15 similarly prescribes that directional signs be placed every 25 meters (82 feet) or less on the side walls of a tunnel to indicate the distances to the two nearest exits. While the height of these signs from the ground or path is not specified, the guidelines state that the mounting height should take into account the signs' visibility during a fire.

Sign Luminance and Visibility

Section 12.6.8 of NFPA 502 prescribes minimum illuminance levels for externally illuminated exit signs (5 foot-candles) and minimum luminance levels for internally illuminated exit signs (2.5 foot-lamberts). IBC requires that exit signs must be illuminated at all times, and that they have their own power source that is not dependent on the main power for the building or structure and that will keep the signs illuminated for at least 90 minutes in the event of a main power failure. Like NFPA 502, IBC requires that externally illuminated exit signs must be illuminated at an intensity of at least 5 foot-candles or 54 lux.

While NFPA 502 does not mention photoluminescent signs, NFPA 101 requires radioluminescent or electroluminescent signs to have a minimum luminance of 0.06 fL or 0.21 c/m2 (*37*). ASTM Standard E 2072 similarly provides minimum luminance requirements for photoluminescent safety markings:

- In laboratory testing conditions:
  - 20 mcd/m2 after 10 minutes in the dark.
  - 2.8 mcd/m2 after 60 minutes in the dark.
- On site (4-inch-wide safety marking):
  - 15 mcd/m2 after 10 minutes in the dark.
  - 2.2 mcd/m2 after 60 minutes in the dark.

Emergency Exit Path and Door Lighting

Directive 2004/54/EG requires general safety lighting to provide a minimum level of visibility in case of a power outage, as well as evacuation marker lights placed at a maximum height of 1.5 meters (4.9 feet) above the floor to help guide pedestrians who are evacuating the tunnel.

CIE 193-2010, *Emergency Lighting in Road Tunnels*, also provides guidelines for emergency lights and markings for pedestrians in highway tunnels. Section 2.3 of this standard sets the maximum height of evacuation-route pathway markers at 1 meter (3.3 feet) above the carriageway, with a maximum spacing of 10 meters (33 feet). Pathway markers may be permanently illuminated or activated only in the event of an emergency. CIE 193-2010 also provides detailed guidance regarding the illumination and marking of emergency exit doors, intended to encourage vehicle drivers and passengers to leave vehicles and exit on foot if needed. Exit door illumination is intended to make the doors visible and conspicuous to tunnel users at all times (not just during an emergency); CIE guidelines prescribe a doorway illuminance level three to five times higher than the average illuminance of the surrounding walls, extending out from the door frame for 2 meters (approximately 6 feet) in all directions. Exit door markers are lights intended to act as signals to tunnel users during an emergency; the guidelines recommend flashing green marker lights arranged around the exit door that are activated only in emergency situations. Recommended minimum intensity of the green marker lights is 150 cd, and recommended flash rate is from 1 Hz to 2 Hz.

NFPA 72, *National Fire Alarm and Signaling Code*, Section 18.5.3, recommends the same flash rate (1 Hz to 2 Hz) for emergency strobe lights but recommends white or clear lights rather than green.

Audio Signals

NFPA 72 provides guidance for audible alarms and evacuation messages for buildings, some of which may have some application for audible alarms and verbal messages in tunnels. Section 18.4 establishes auditory requirements for evacuation signals, including sound levels and signal characteristics. Some of NFPA 72's recommendations that may inform audio signal recommendations for highway tunnels include the following:

- Section 18.4.1 establishes maximum sound pressure levels from the combination of ambient noise with the sounds created by audio signals. Maximum peak sound pressure is limited to 110 A-weighted decibels (dBA) and maximum average sound pressure to 92 dBA.
- Section 18.4.2 describes a three-tone temporal alarm used to notify building occupants to evacuate.
- Section 18.4.3 establishes minimum sound level requirements for public-mode audible signals as 15 dB above the average ambient sound level.
- Section 18.4.6 outlines procedures for calculating minimum sound pressure levels needed to overcome a particular masking noise and may be applicable to certain emergency situations in tunnels, such as when jet fans are activated for ventilation.
- Section 18.4.7 provides recommendations for audible signals at exit doors.
- Section 18.4.10 describes voice intelligibility requirements for voice messages.

NFPA 502 Annex B, Section B.2.5 specifies maximum peak noise levels along highway tunnel evacuation paths of 115 dBA and maximum average levels of 92 dBA. This represents a 5 dBA increase in the maximum peak-level sound pressure specified in NFPA 72 for buildings, while the maximum average sound pressure is the same for both standards.

EXPERT INPUT

Input was sought from experts in roadway signage, tunnel operations, and emergency response at various points throughout the project. First, members of the Regulatory and Warning Signs Technical Committee (RWSTC) of the NCUTCD were asked for their input regarding emergency exit signs and markings. Next, a subject matter expert (SME) panel of experienced tunnel facility responders in the law enforcement, fire/EMS, department of transportation (DOT), towing and recovery, and traffic incident management communities was assembled via WebEx on June 26, 2014, to discuss practices and experiences pertaining to tunnel incidents and emergencies. Finally, some additional tunnel operators were interviewed via telephone in

February 2015 regarding their emergency procedures, including communication to tunnel users. Table 1 lists the tunnel facility experts who provided input to this study.

Table 1. Participating Subject Matter Experts.

Participant		Agency/Committee	Title
NCUTCD	Bruce Ibarguen	Maine DOT	State Traffic Engineer
	Tom Heydel	Wisconsin DOT	Regional Traffic Engineer
	James Pline	Institute of Transportation Engineers (ITE)	Past ITE President
SME Panel	Michael Fitzpatrick	Massachusetts DOT	Highway Operations Center Manager
	Lorenzo Parra	Massachusetts DOT	Director of Highway Operations Center
	Lt. Dave Cain	Pennsylvania State Police	Commander, Central Patrol Section/Troop T, Everett
	Allen Baldwin	Winchester, VA Fire Department	Fire Chief
	Rusty Fitzhugh	Virginia DOT	Hampton Roads Bridges and Tunnels (HRBT) Operations Manager
	Tina Eley	Virginia DOT	HRBT Operations Supervisor
	Lisa Williams	Virginia DOT	Field Supervisor
	Eric Roberts	Virginia DOT	Field Supervisor
	Lynn Manges	Interstate Emergency Services, Towing and Recovery, Bedford, PA	Director of Towing Operations
Interviews	Todd Anselman	Colorado DOT, Hanging Lake Tunnels	Electronics Specialist
	Spencer Dickey	Colorado DOT, Hanging Lake Tunnels	Tunnel Operations Manager
	Douglas Haight	Washington DOT (WSDOT), Seattle Tunnel	WSDOT Project Engineer, Sound Transit Projects
	Chris Thomas	Washington DOT, Seattle Tunnel	Supervisor of Tunnel Operators

The following sections summarize the input received from the interviews and panel discussion.

Driver Responses to Tunnel Incidents

Many drivers view car fires and other potentially hazardous incidents in tunnels as just another traffic slowdown. Because sightlines in tunnels can be shorter than on open roadways, motorists may not even know what the incident is until or unless they are close to it. Frustration and anger are prevalent behaviors; drivers do not want to get stuck in an incident inside of a tunnel. A risky behavior that has been frequently observed is drivers speeding past the incident on their way out of the tunnel, risking everyone on the scene as well as themselves. Sometimes the opposite occurs, with drivers slowing down close to an incident to rubberneck, particularly drivers who are not accustomed to traveling in tunnel facilities.

When all lanes are blocked, motorists will sometimes exit their vehicles and linger around either in the tunnel tubes or on the surface prior to the incident. This causes the potential for further injury. The likelihood of additional incidents increases if traffic is diverted to other tunnel bores at crossings.

Emergency Procedures

Many tunnels have ventilation systems that are activated in response to events involving smoke or other hazardous materials. When this occurs, all tunnel areas upstream of the incident (where the stopped traffic sits) are put into positive pressure. Exhaust fans activate downstream of the event, removing smoke and gases through the end of the tunnel and up vent building stacks. Motorists downstream of an incident do not tend to linger; they continue out of the tunnel.

Advanced monitoring and incident management systems are becoming more common in newly constructed or refurbished tunnels. These systems can include video and thermal cameras to enable operators to see the exact location and nature of an incident, including the presence and extent of smoke, and can automate response sequences including the activation of emergency signs and markings.

Emergency Announcements and Exit Guidance

Planned and rehearsed strategies are important for clearing in-tunnel incidents quickly. Communication with the motorists approaching the incident is very important in allowing the opportunity to divert, if possible. On-scene temporary traffic control for intermediate and major incidents is one approach to this problem, and several of the agencies represented by the expert participants have developed and practiced procedures for getting first responders on scene as quickly as possible.

The represented agencies also use a variety of other techniques for communicating with drivers during an incident, including dynamic message signs, strobe lights at exit doors, and static signs; one agency also sends alerts out via Web feed and Twitter. A radio override system is in use at the Seattle Tunnel. Issues and limitations that the expert participants have experienced with various communication methods include the following:

- Dynamic/variable message signs, some with canned messages and some that can be manually programmed with a customized message, are in use in several of the tunnels represented by the participants. The Seattle Tunnel, as one example, contains some fixed variable message signs (VMSs) for lane control, alternating with VMSs that can display one of 110 preprogrammed messages as needed. The signs can be activated with appropriate messages as part of an automated incident management system that allows a tunnel operator to specify whether an evacuation is advised. The primary limitation of DMSs/VMSs is the short message length.

- Highway advisory radio and radio override systems are older technologies, and many tunnel operations are moving to or considering other options. Many override systems were designed for AM/FM radio frequencies, and with the rising prevalence of satellite radio and smartphone-based entertainment, the number of drivers that are likely to hear messages broadcast via radio override is diminishing. Radio override systems can also bleed into tunnel bores beyond the one affected, potentially causing confusion.
- Loudspeakers are not currently in use in the tunnels represented by the expert participants, due to problems with reverberation and resultant low intelligibility.

Exit Sign and Marking Considerations

Each sign must convey a very specific message. The message must be brief, as the user will be in a stressful situation and will need to interpret the message immediately. Easily recognizable sign legends are important for exit door signs and for signs and markings that will direct the evacuee to the exit doors. Consideration must be given to which exit is nearest to the evacuee at any point along the tunnel. Static running man symbols are widely recognized, but a static sign could be pointing toward the hazard.

Assuming that the evacuee is unable to stay in his or her vehicle, emergency exit signs only need to be legible for a walking (or perhaps running) speed. Tunnel lighting is present in most highway tunnels. Therefore, the sign will have some ambient light on it already. However, if the emergency has knocked out power to the lighting, then the signs may need battery backup to allow the evacuee to see them. This would be true if the light were external or internal to the sign.

It will be important to convince people to get out of their vehicles and walk. LED edge markings, similar to those in the aisles of airplanes, could help provide guidance to the nearest exit. It will probably be necessary to have segmented sections of the tunnel with various controls for emergency path markings dependent on where the emergency occurs. An advantage of lighting in or near the pavement is that usually smoke is not as thick near the ground.

Strobe lighting is being used in some tunnels to identify exit doors, but more research may be needed to determine whether people interpret strobe lighting to mean “come this way” or “do not come this way.”

Signs and markings need to be able to withstand environmental and traffic conditions within a highway tunnel, as well as tunnel cleaning procedures (or should be removable during tunnel cleaning). Tunnel cleaning can involve pressure washing with water and/or rotating brushes.

Current U.S. tunnel designs and types of exits should be considered when recommending sign placement. To know what to develop for a sign layout, it is necessary to know where and to what the evacuee is being sent.

CHAPTER 3. FOCUS GROUPS—RESEARCH APPROACH AND RESULTS

Two focus groups were conducted with drivers to gain a better understanding of how tunnel users might respond to various tunnel incident scenarios and warnings.

Focus group discussions were held on June 12, 2014, in a conference room at the Texas A&M Transportation Institute (TTI) office in Houston, Texas. The first group met at 1:00 p.m., and the second group met at 5:30 p.m. Each session lasted approximately 70 minutes. The demographics of the focus group participants are shown in Table 2.

Table 2. Focus Group Participant Demographics.

Group 1		**Group 2**	
Gender	*Age*	*Gender*	*Age*
M	23	M	20
M	54	M	41
M	61	M	56
M	64	M	58
F	18	M	68
F	22	F	20
F	24	F	25
F	27	F	39
F	43	F	56
F	53		
F	62		

PROCEDURE AND RESULTS

A PowerPoint presentation was used to present the groups with pictures, video, and audio as stimuli for the discussion questions. Each of the moderated discussions began with an introduction by the moderator about focus group protocol and etiquette, followed by some icebreaker questions to give participants a chance to introduce themselves and to become comfortable participating in the discussion. Participants were asked to tell the group their first name, whether or not they had experience driving in tunnels, and (if applicable) what they liked best or least about driving in tunnels.

Of the 11 participants in Group 1, seven reported having driven through highway tunnels. In Group 2, six out of the nine participants have driven through tunnels. The results are presented in the rest of this section with respect to how the conditions were presented to the focus group participants.

Slowing/Stopping Traffic in a Tunnel

Participants viewed a brief video clip of a vehicle entering a highway tunnel, proceeding a distance into the tunnel, and then slowing as other traffic in the tunnel began braking. Following this video, participants were asked, “If you were driving through a tunnel and traffic slowed or stopped, what would you guess might be the reason?”

Participants in both groups identified possible reasons including ordinary rush-hour traffic congestion, road construction, a stalled vehicle, a traffic accident ahead, and a structural failure within the tunnel.

When asked what their initial reaction would be to this scenario, most participants indicated that they would wait for traffic to start moving again. One participant said that he would turn on his hazard lights to alert traffic behind him that he was stopped, and another said that she would try to maneuver her vehicle to an open space in the adjacent lane and try to keep moving toward the tunnel exit. A few participants indicated that they would feel frustrated or anxious about being stopped inside a tunnel. One or two participants in each group said that they would turn on the vehicle's radio to listen for messages about what was happening in the tunnel, and one participant in Group 1 commented that there should be signs throughout the tunnel to provide real-time messages.

Stopped Traffic, Drivers Exiting Vehicles

Participants next viewed a still photo of traffic stopped inside a tunnel, with some of the drivers outside their vehicles standing or walking. When asked what might be happening in a scenario that looked like this, some participants speculated that there might be something more dangerous or unusual than an ordinary traffic jam farther ahead in the tunnel. Participants in both groups had mixed opinions about appropriate actions to take, with some saying they would want to exit their vehicle to find out what was happening and others believing that leaving their vehicles would place them at additional risk. Some sample comments were as follows:

- *Whatever it is, it's not good. If people are getting out of their cars, it's not good.*
- *But also those people getting out of their cars causes a problem, because once the traffic starts moving, someone might get hit. It's a hazard.*
- *I think it might be dangerous to stay in the car. If something's coming, you might not see it, and then you can't run.*
- *I think I'd get out of my car for a few seconds and stand up, to see if I could see any farther ahead, and get some sort of clue as to what's happening, as to why traffic isn't moving.*
- *I think in this situation, where people are out of their vehicles and talking, at least you're informed as to what is taking place, to put your mind at ease and not panic or get anxious about what's happening.*

While the specific action that participants said they might take varied, most participants agreed that they would be seeking additional information about the situation, such as the following:

- *Signs on the top and sides of the tunnel.*
- *Something similar to the signs you see on freeways, telling you about accidents or delays ahead.*
- *Ideally, the sign would be before you ever entered the tunnel. That way, it can divert traffic, or you can make the decision about whether to wait outside the tunnel or take a different route.*
- *If traffic is backed up, emergency personnel might not be able to get there. [They need] a way to communicate without needing someone to get in to the spot where the trouble is.*
- *[Message via] the radio.*

- *I would get out and try to find out from others who are walking around. Someone's bound to know what's going on.*

Stopped Traffic, Smoke

Participants viewed a still picture showing vehicles in a tunnel surrounded by smoke. Most of the participants identified the haze in the photo as smoke, and some speculated it could be coming from a vehicle fire; one participant in each group thought it might be fog.

Reactions to a possible fire or similar emergency situation varied, with some participants saying that they would leave the tunnel as quickly as possible, on foot if necessary, and others commenting that they would be more likely to seek more information about the situation first. Two participants in Group 1 said that their first action, if they were close enough to see a burning vehicle or similar situation, would be to try to help whoever was in the vehicle or otherwise in immediate danger. Comments about this situation included the following:

- *Get out!*
- *I would ask cars behind me to back up.*
- *If I was close enough to see what was going on and I could possibly help, I think I would try to help.*
- *If I was behind the place in the tunnel where there was a fire going on, then my first reaction would be to get out of there.*
- *[My response] depends on how far it is to get out, and on what exactly is going on. Is there a fire? What kind of fire is it?*
- *[I might not leave] at this point, unless other people are leaving. If I see that others are exiting on foot or running, then I'm going too—I don't know if there are emergency exits or if I'm going all the way back [to the portal], but I'm getting out of there.*
- *The first thing would be to determine if it's smoke or if it's fog. If I smelled something burning, then I would try to exit.*
- *But on the other hand, if you and a lot of other people left their vehicles there, it could hinder emergency vehicles trying to get to the car that's on fire or to the person that's hurt.*
- *The key is signage…[that] could tell you to stay or exit.*

Finally, participants were asked where they would start looking for an exit if they did decide to leave their vehicle and walk. One participant said she would start heading "back the way I came," indicating the tunnel's main portal. Others speculated that there might be side doors, with ladders or staircases going up.

DMS Messages

Participants viewed a series of three messages on a simulated dynamic message sign. Each message consisted of two phases, each consisting of a word or phrase that totaled 18 characters or fewer; the phases were animated on the slide so that they alternated on the screen every 2 seconds. This length of message was selected based on a typical DMS width for a two-lane tunnel (according to a tunnel operator and a DMS vendor who were consulted during the preparation of the focus group presentation). Two phases is the maximum recommended by the *Manual on Uniform Control Devices* (MUTCD) for DMS messages. This format was chosen in part to assess the effectiveness of fairly short messages in conveying useful information and an appropriate sense of urgency.

"Emergency—Walk to Exits"

The first message tested was "Emergency—Walk to Exits," displayed in two phases (in the preceding text, the dash separated the two phases). Participants were asked, "What would be your reaction to seeing this message?"

Within Group 1, most participants indicated that they would follow the sign's instructions. In Group 2, some participants said they would immediately follow the instructions, but others indicated that they might be slower to respond. Participant comments included the following:

- *That's all the information I need.*
- *I would want to know why but would still exit because it says "emergency."*
- *I'd think "okay, let's go."*
- *"Emergency" would slow me down if I was driving.*
- *If it's at the beginning of the tunnel, I would still be trying to get my car out of there. But if it were in the middle of the tunnel, and traffic is stopped, and this came on, then I'm getting out of the car.*
- *I probably would panic. I would be nervous to walk in the tunnels I've been in; I'd be afraid to get hit.*

"Leave Vehicle—Walk to Exits"

The second message tested was "Leave Vehicle—Walk to Exits." Participants were again asked, "What would be your reaction to seeing this message?" Participants were also asked whether this message provided them with more or less useful information compared to the first message.

While some participants appreciated having the "leave vehicle" directive prior to "walk to exits," most felt that receiving instructions without a reason being provided was less informative overall. Participants who preferred "leave vehicle" to "emergency" felt that the two-part directive provided extra guidance that might be useful in a stressful situation and also conveyed the message that leaving in a vehicle was not possible; participants who preferred "emergency" as the first part of the message felt that it was more important to provide context for the "walk to exits" command. Participant comments included the following:

- *I'd be suspicious [of "leave your vehicle"]. Why do I need to leave my vehicle? What are you trying to do?*
- *Not enough information.*
- *"Emergency, walk to exits" is better for me. The word "emergency" sticks out.*
- *I'd probably keep driving until I see more information rather than just leave my vehicle. Would like information that tells me the next step, like "get out and walk."*
- *It gives specific commands. The other one just said "emergency," so if I was driving I might slow down, but this one says, "Leave your vehicle, there's a major problem." Which means I'm going to leave my vehicle, I'm not going to question it.*

- *I would say that the "leave vehicle" is better for me; I see that word "emergency" and I'm scared. "Leave vehicle" doesn't get me excited or upset, where "emergency" might make me anxious.*

"Fire in Tunnel—Walk to Exits"

The third message tested was "Fire in Tunnel—Walk to Exits." This was the least preferred message among both groups of participants. Participants expressed concern that seeing a "fire in tunnel" message might cause anxiety or panic that would impede safe evacuation. Comments on this message included the following:

- *Here's my initial reaction to that: mayhem. I don't think people would see that and walk to the exits. I think people would freak out and would run instead of walking. I would much prefer "leave vehicle" or "emergency" to "there's a fire" because a bunch of people are going to freak out and run for the exits.*
- *As long as I'm being cautioned to get out of harm's way, I can find out what happened after I'm safe.*
- *This is definitely my least favorite. It's informative, which is awesome, but I would be more anxious, and nervous, and more inclined to run if this was the sign.*

In the following portions of the discussion, however, some participants expressed support for the specific hazard information provided by the phrase "fire in tunnel."

Preferred Phrases

Participants viewed a list of phrases that could be used in a DMS message and asked which phrases they felt would be the most useful to include in a message advising drivers to evacuate a tunnel on foot. Phrases shown included "Emergency," "Fire in Tunnel," "Turn off Vehicle," "Leave Vehicle," "Walk to Exits," and "Exit on Foot." Participants were also invited to modify these phrases or add different phrases to the list.

Nearly all participants agreed that "Walk to Exits" or "Exit on Foot" was an essential phrase. Participants were split on whether a description of the situation (e.g., "emergency") or a supplemental command statement (e.g., "turn off vehicle" or "leave vehicle") was more important to include; a slight majority preferred knowing something about the situation as a reason for the "walk to exits" or "exit on foot" directive. While most participants were still opposed to using "fire in tunnel" as the situation description, one participant supported its use. Participant comments included the following:

- *NOT "fire in tunnel." The others are okay. I think "turn off vehicle" and "leave vehicle" are implied already by "walk to exits." If there's not an immediate need to leave (maybe an incident ahead but not an emergency), then "caution," maybe even "stay in your vehicle" in that case. "Accident ahead, stay in vehicle."*
- *Even though it would cause the most panic, I would like "fire in tunnel, walk to exits" if there really is a fire in there. I don't want to be strolling through, not hurrying because I don't know how dangerous it is. If there's a fire, I would want to know right away before things start blowing up. If there is a fire, that information is essential, then after that "walk to exits."*

- *"Turn off vehicle" because people in a panic would likely forget to do that and it could cause problems like a buildup of carbon monoxide, then "walk to exits." That would get my attention.*
- *"Walk to exits" is most important. "Leave vehicle" is also good, because it means that the situation is urgent.*
- *I like "exit on foot" because it tells you that you can't go in your car.*
- *They should go hand in hand. You need the situation plus the command so you don't think you can stay in your vehicle if you shouldn't. "This is what's happening, now this is what you do." That cuts down on the likelihood that you'll panic, and you'll know how to react. Is it giving me an option to leave, or telling me I need to leave now?*

Audio Announcement

Participants listened to a recording of the following voice announcement: "Attention—there is a fire in the tunnel. Turn off your engine, leave the keys in your vehicle, and walk to emergency exits immediately." Reactions to the announcement were slightly different between the two groups. In Group 1, most participants indicated that the announcement would encourage them to leave, though most said that they would not leave their vehicle keys behind and questioned the reason behind that request. As with the DMS announcements, some participants were opposed to specifying a tunnel fire as part of the announcement, rather than a more general "emergency," but others supported the more specific description to convey the urgency of the situation. One Group 1 participant commented that the announcer's voice was too emotional and could increase anxiety.

Comments from Group 1 participants about this message included the following:

- *Don't say "fire in tunnel."*
- *If you're told to get out of your car and leave your keys, you want to know why.*
- *If there's a fire, in most cases you won't die from the fire, you'll die from the carbon monoxide. If it says "fire" people know they could die so they will leave. Damn the car! The car and the keys aren't going to do any good if you die.*
- *Need a calmer announcer's voice. The announcer should not be sounding like he's panicked. If he's panicking, I'm going to panic.*
- *So maybe they should tell you, very calmly, that there's a fire in the tunnel and you need to leave now. Take your keys, leave your keys, whatever, just leave.*

The reaction to the announcement among most Group 2 participants was more skeptical. They also questioned the request to leave vehicle keys behind, to the extent that some expressed their suspicions about the motivation of the entire announcement. The perception of the tone of the recorded announcement was also different than in Group 1; a Group 2 participant commented that the announcer's voice was too monotone and needed more urgency to make the message believable. Overall, the participants in Group 2 indicated much more resistance to leaving their vehicles and exiting based on the information provided in the voice announcement. One older male in Group 2, however, commented that the mere fact that an emergency was important enough to warrant an announcement should be enough of a reason to pay attention to it.

Comments from Group 2 participants about the audio message included the following:

- *I would turn off my car and exit the tunnel, but I wouldn't leave my keys. I'm always skeptical; if it's coming over a loudspeaker it could have been hacked, they could be trying to steal my car. If I can't see smoke, I'm definitely not leaving my keys.*
- *Asking me to leave my keys now has me questioning the whole message. Had you just said "cut off engine, head to doors" I would pay attention. But because you're now asking me to leave my keys, I want to know what's going on.*
- *"Leave keys" is a red flag for me.*
- *Usually you don't hear an announcement or see something displayed unless there's an emergency… We may not know exactly what's going on, but the alarm says there's something happening. You don't know the degree of emergency, but something's happening or the alarm wouldn't be sounding, so beware.*

Other comments received in the two groups about emergency messages and delivery included the following:

- *Maybe use a scale for the urgency of the problem, like the hurricane rating system. "This is how much panic you should have, this is how much urgency."*
- *Provide the message in different languages, not just English.*
- *If I'm in a strange city and I don't know how long the tunnel is or where the exits are, other than the one behind me, I'd like something to tell me where the exit is.*
- *Say which exit to take.*
- *Hearing the announcement is better than seeing a flashing message.*
- *Should have a combination of signs and audio. If someone's playing music, they could miss an audio announcement.*

Leaving Vehicle and Subsequent Actions

Participants were asked, "Would you take your car keys?" and "What other items would you try to take with you?" Nearly all participants indicated that they would take their car keys, most of them simply due to habit or because of the time delay involved in detaching a vehicle key from the rest of their keys. Two participants (both in Group 1) said they might leave the vehicle key so that emergency crews could move their vehicle if needed. Other items that participants indicated they would try to take included purses/wallets, phones, and personal/medical items. Two participants talked about taking children who were in the car, and one commented that if children were present, keeping calm and avoiding panic would become even more important.

The next question was, "If you saw other people who were staying in their vehicles, would that affect your decision to stay or leave? Would it change your actions in any other way?" Among the Group 1 participants, responses were very consistent: everyone in the group agreed that if there had been an announcement to leave, seeing other people still in their vehicles would not change their own decision to leave:

- *I would probably knock on their window and say, "It says to get out."*
- *If they didn't want to leave, I wouldn't waste my time and put myself in danger.*
- *I would encourage those people to leave, but I wouldn't stay there and argue with them.*

In Group 2, reactions were mixed, with some participants expressing more of a tendency to follow the lead of other drivers, and others opting to leave if prompted by warnings/announcements regardless of what others were doing:

- *If I saw that other people were staying in their vehicle, I would probably stay in mine. Worst-case scenario, I'd leave my car.*
- *I would go with the majority (if staying or leaving).*
- *I probably wouldn't walk as fast, if other people were staying. I would try to feel out the situation, question it more, but if everyone else is running towards exits I'd get out. I might walk toward the exit, but try to keep figuring out what's going on, maybe not go through the exit just yet.*
- *I would follow instructions given by sign or audio. They can't give you all the details about what's happening, but you need to follow directions or deal with the consequences.*
- *Here in Houston, we deal more with sudden flooding. There were people staying on the freeway during Hurricane Allison when the water was rushing toward them. If you hesitate for a few minutes, you could lose your life, so better safe than sorry. It's common sense.*
- *If there is a fire in a tunnel, you know it affects oxygen, so no matter what others are doing, if you know there's a fire, get out!*

Follow-Up Questions and Other Comments

Participants were asked if they had other suggestions or questions regarding emergency signs or announcements in highway tunnels. Most of the suggestions received were for signs pointing the way to emergency exits, and for lighting strategies to indicate emergency situations. Participant comments included the following:

- *Post emergency signs at intervals (maybe every mile or mile and a half) throughout the tunnel.*
- *Put DMS signs every 200 feet letting you know where next exit is.*
- *Directional signs to exits would be helpful, spaced pretty closely so that you don't miss seeing a sign that could show you the way out. I think lighted signs would be best.*
- *I'd think you'd want phosphorescent signs, in case of loss of power.*
- *Maybe use lights to provide visual color coding as you get closer to the incident (green if there's no problem, yellow if there's a problem ahead, then red as you get close to where the danger is).*
- *Red and flashing lights are best [to indicate an emergency].*
- *More than anything, flashing lights get your attention, so maybe something that only flashes during an emergency situation would help me know that there's something wrong. If I'm driving and see something flashing, that's a sign to me to slow down, survey the surroundings. Words are good, but you can't always see them; you can always see something flashing.*
- *Use multiple languages; we have all languages here now.*

As follow-up questions, participants were shown examples of some symbols for emergency signs such as the running man exit sign, a text EXIT sign, emergency telephone, fire extinguisher, disabled-access refuge point, and the running man symbol with a directional arrow and distance. Participants comprehended nearly all of these symbols without hesitation; there was some discussion about whether the refuge point sign indicated an exit, but most participants agreed that it probably indicated a safe place for people with disabilities to stay during an emergency until emergency responders could reach them.

When asked if the green running man exit sign and the red text EXIT sign conveyed the same or different meanings, most participants thought that the signs were more or less equivalent. A couple of participants felt that the running man symbol implied more urgency (because he appears to be running for the exit rather than walking), while two other participants felt that the red color of the text sign implied “emergency” more than the green color of the running man sign. However, all participants were confident that both indicated a way out of the tunnel.

FOCUS GROUP CONCLUSIONS

Individual participants’ responses during the discussion were not consistently correlated to age, gender, or prior experience driving in tunnels, except that the participants who had traveled in tunnels frequently were more likely to mention concerns about the confined space in a tunnel if an emergency were to occur (e.g., concerns about vehicle exhaust building up during a traffic jam or about the limited space available for a person to walk alongside the traffic).

While many participants indicated that they would likely consider leaving a tunnel on foot if they saw smoke and/or saw other people exiting, several also indicated that uncertainty about what might be happening or about the safest course of action might cause them to wait for further information or instructions. Even before signs and audio announcements were introduced in the discussion, several participants suggested that information about in-tunnel incidents should be communicated to drivers if possible.

Participants were generally resistant to the idea of leaving their vehicle keys behind, with most of their comments indicating a lack of awareness of why that request would be made. This indicates that public education efforts on highway tunnel safety may need to include an explanation of why emergency responders might need to move vehicles, and/or that an explanation should be included if drivers are requested to leave their vehicle keys behind.
There was a range of responses regarding the influence of other drivers’ behaviors on participants’ anticipated actions. In one focus group, there was a general tendency toward acting on provided information/announcements regardless of how others were perceived to be responding; in the other group, some participants weighed the crowd response as a significant factor in their own response. This indicates that public education efforts on highway tunnel safety in general may be warranted.

The emergency messages that the majority of participants found to be most helpful, as well as most likely to provoke the desired response, included an indication about the nature of the incident followed by a direct instruction. Of the instruction phrases presented, “walk to exits” was preferred by most participants, though “exit on foot” was also considered effective. “Turn off engine” and “leave vehicle” were considered to be useful supplemental instructions, but not as important as “walk to exits” for conveying the need to evacuate. The general term “emergency” was preferred over a more specific description such as “fire in tunnel,” due to participants’ concerns about possible anxiety or panic resulting from the term “fire;” however, some participants argued that a more specific description of the emergency would better communicate the urgency for an immediate evacuation.

The focus group results were used to finalize the emergency messages that were tested with participants in the tunnel simulation (described in the following chapter). Because “Fire in Tunnel—Walk to Exits” was parallel wording to the longer planned audio/text/Twitter message, and because earlier feedback from the project panel at the Phase I project meeting was in favor of specifying “fire” when fire is present, the DMS message subsequently tested in the tunnel simulation was “Fire in Tunnel—Walk to Exits.” Also, because of focus group feedback, the audio announcement used in the tunnel simulation included an explanation for the request to leave keys in vehicles.

CHAPTER 4. TUNNEL SIMULATION PROCEDURE AND RESULTS

The tunnel simulation first tested individual responses to a tunnel emergency scenario similar to those discussed by the focus groups, and then tested several sign and marking formats and technologies within the simulated tunnel environment, both for participants' comprehension of and confidence in various formats and for detection and legibility distances through smoke.

The tunnel simulation took place in College Station, Texas, and involved 63 participants. Potential participants included licensed drivers aged 18 and older, both men and women; as with the focus groups, recruiting targeted a mixture of younger, middle-aged, and older adults.

PARTICIPANT DEMOGRAPHICS

A total of 63 men and women from the Bryan-College Station area participated in the tunnel simulation. Participants ranged in age from 20 to 83. Table 3 summarizes the demographics of study participants.

Table 3. Tunnel Simulation Participant Demographics.

Age Groups	Males	Females
20–34	12	13
35–59	6	15
60+	9	8
Total	**27**	**36**

STUDY PROCEDURES

The simulation occurred in two stages. Stage 1 was intended to test participant responses to an unfolding hazardous situation in a highway tunnel and to emergency announcements telling them to leave their vehicle and evacuate on foot. Participants were told that the study procedure was examining traffic control devices for highway tunnels but were not told in advance of the simulation exercise that the devices being tested pertained to emergency exits.

Stage 2 of the simulation tested sign and marking formats and technologies for participant comprehension and visibility. The researcher presented each participant with a series of signs, markings, LED beacons, and audio beacons within the smoke-filled chamber, testing the following:

- Detection distance for signs and markings.
- Identification/legibility distance for signs and markings.
- Comprehension/interpretation and preference for sign, marking, and beacon formats.

Figure 4 shows the final layout of the tunnel simulation room. In Stage 1, the participant was seated in the driver's seat of the parked vehicle with the researcher seated in the passenger seat. For Stage 2, the participant and researcher viewed each sign and treatment combination one at a time, using a 60-foot corridor. Ambient lighting was set at 10 lux (measured at floor level), and the chamber was then filled with artificial smoke; the density of the smoke was measured continually and recorded on each participant's data sheet for each sign and beacon option. Having the density of the smoke vary from the beginning to the end of each participant's testing period allowed for the viewing distances of each sign and marking to be placed in the context of smoke density.

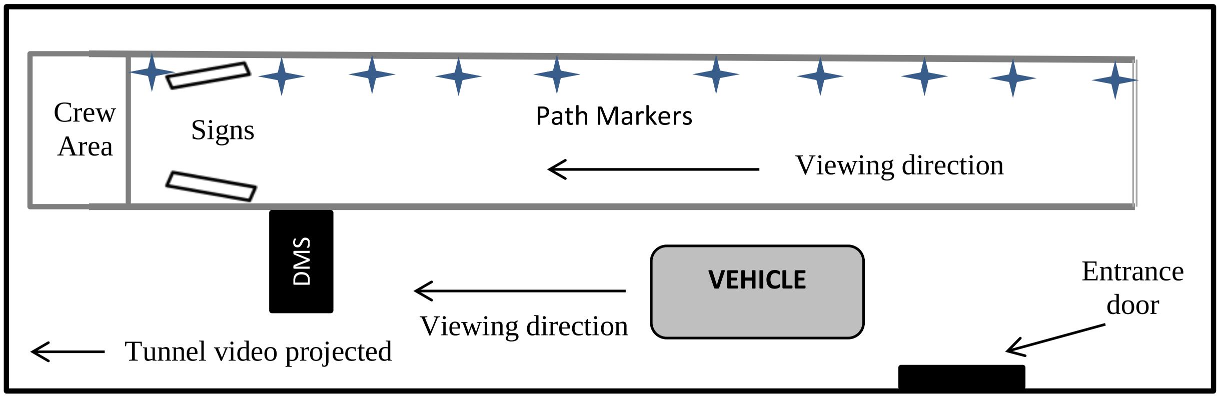


Figure 4. Layout for tunnel simulation.

Participants were divided into six groups, as shown in Table 4. This allowed for three different information conditions in Stage 1 and three different sign orders in Stage 2.

Table 4. Experimental Groups for Tunnel Simulation.

Group	Stage 1—Information Level	Stage 2—Sign Order
A	Ambient cues only	Sign order 1
B	Audio message	Sign order 2
C	DMS message	Sign order 3
D	Ambient cues only	Sign order 3
E	Audio message	Sign order 1
F	DMS message	Sign order 2

Stage 1: Response to Emergency Situation and Messages

The first few minutes of the Stage 1 exercise simulated a trip through a highway tunnel that was stopped by a traffic jam, followed by the appearance of smoke. The purpose of the exercise was to determine what type of message is most effective for encouraging drivers to leave their vehicle and evacuate the tunnel on foot, if such an evacuation is warranted. Participants were divided into three experimental groups (20 to 22 participants in each group) for Stage 1.

The Stage 1 study procedure provided the same introduction to all participants as follows:

- In the intake/preparation room, the greeter told participants that they would be seated in a vehicle, would view a short video clip, and would be asked to execute or describe the actions they would take that they believed were the most appropriate based on what they saw and heard.
- The researcher escorted the participant to the driver's seat of a parked car inside the tunnel simulation chamber. The researcher sat in the passenger seat of the same vehicle.
- Once the participant and the researcher were seated in the vehicle, the researcher repeated the instructions to the participant, began the video recording of the forward scene, and

played the simulation video. The video was projected on a wall in front of the vehicle to provide a near-full-size image of the simulated trip (see Figure 5). The clip showed a driver's view of a vehicle entering a highway tunnel and then encountering slowing and stopping traffic while inside the tunnel. The end of the clip was edited to show dark smoke streaming into the tunnel from ahead of the driver's vehicle and darkening the view of the tunnel. The soundtrack of the video was also edited to add the sounds of vehicle horns, engines, and a loud ventilation fan.

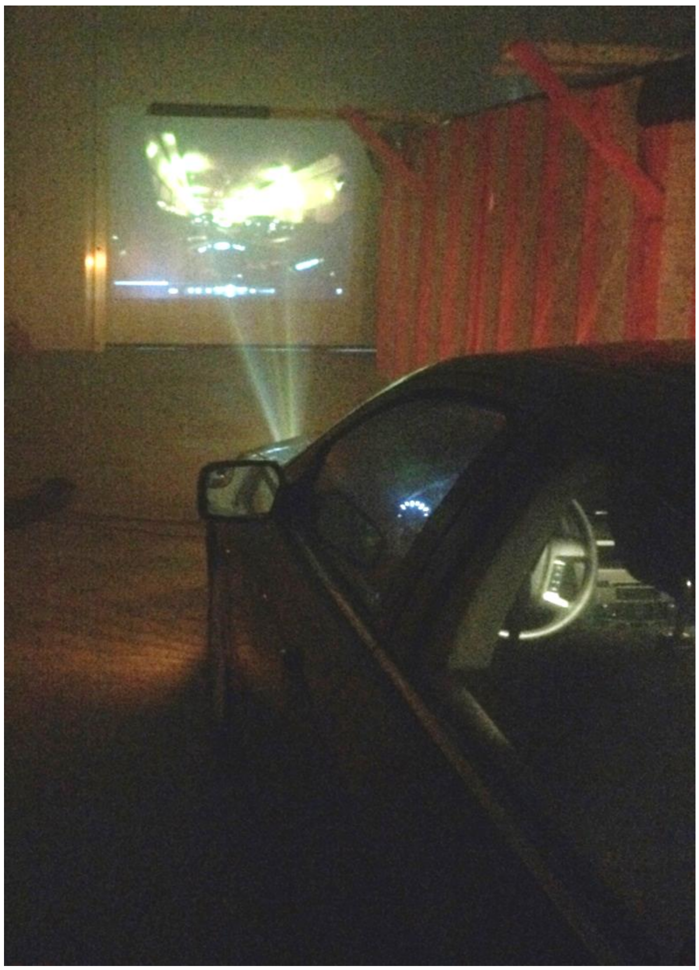


Figure 5. Tunnel simulation, Stage 1: video clip viewed from vehicle.

As the clip ended and the ambient sounds began, the experimental groups were provided information as follows:

- Group 1 participants were given no additional information beyond the ambient visual and audible cues from the video.
- Group 2 participants saw an overhead DMS displaying the message "FIRE IN TUNNEL—WALK TO EXITS."
- Group 3 participants heard the following recorded audio message (via an MP3 player and portable speaker inside the vehicle): "Attention—there is a vehicle fire in the tunnel. Turn

off your engine and leave your keys in the vehicle so that it can be moved by emergency personnel. Leave your vehicle and walk quickly to emergency exits."

Participant comments during the scenario were recorded. Following the video clip and any provided messages (DMS or audio), the researcher also prompted participants, as appropriate, with the following questions:

- "Given what you have observed so far, what would be your response at this point?"
- "What additional information would you look for?"

The researcher recorded all verbal responses to the questions, as well as any other participant actions in response to the simulated scenario. All participants, regardless of their experimental group and/or response to Stage 1, proceeded to Stage 2.

Stage 2: Sign/Marking Comprehension and Visibility

In Stage 2, participants viewed a selection of exit signs, pathway markings, and exit door markings and beacons. A total of six sign formats were tested:

- A running man symbol with no text (ISO 7010 version of the symbol). This sign was the first viewed by every participant and was shown only as an internally illuminated sign.
- A running man symbol plus the word "EXIT." Every participant saw this format twice, once as an internally illuminated sign and once as a photoluminescent sign.
- A running man symbol plus "EXIT" text, a directional arrow, and numerals identifying a distance in feet. Every participant saw this format twice. The internally illuminated version of the sign included a distance of 168 feet, and the photoluminescent version of the sign included a distance of 154 feet. These distance numbers were chosen deliberately to make participants less able to guess at a number before they could actually read it; in actual practice, it would be more typical to position signs at more predictable distances such as 150 feet or 175 feet.
- A text-only EXIT sign. Every participant saw two versions of this sign. The internally illuminated version of the sign also included chevron-type arrows on either side of the text, pointing right and left. The photoluminescent version of the sign did not include arrows.
- An emergency telephone symbol-only sign. Each participant saw this sign once; the sign was photoluminescent.
- A symbol-only sign designating an emergency refuge area for persons with disabilities. Each participant saw this sign once; the sign was photoluminescent.

Each participant also viewed a set of photoluminescent path markers. These included no text or graphics and were a non-electronic version of the LED path markers that were also tested during Stage 2. Table 5 summarizes the emergency exit signs and other devices that were tested during Stage 2.

Table 5. Signs, Markings, and Beacons Tested in Tunnel Simulation, Stage 2.

<table>
<tr><th colspan="2">Comprehension Questions and Visibility Distances</th><th>a. LED Version</th><th>b. PL Version</th></tr>
<tr><td colspan="2">
1. Running man (RM) symbol</td><td>X</td><td></td></tr>
<tr><td colspan="2">

2. Running man with EXIT text (exit door version)</td><td>X</td><td>X</td></tr>
<tr><td colspan="2">
3. Refuge area sign</td><td></td><td>X</td></tr>
<tr><td colspan="2">
4. Emergency telephone sign</td><td></td><td>X</td></tr>
<tr><td colspan="2">

5. EXIT text-only signs</td><td>X</td><td>X</td></tr>
<tr><td colspan="2">

6. Running man + EXIT text + arrow + distance</td><td>X</td><td>X</td></tr>
<tr><th colspan="2">Visibility Distance Only</th><th>a. LED Version</th><th>b. PL Version</th></tr>
<tr><td colspan="2">7. Pathway markers</td><td></td><td>X</td></tr>
<tr><th colspan="4">Exit Door Markers—Forced-Choice Preference/Confidence Pairs</th></tr>
<tr><td>8a. Flashing green</td><td>8b. Steady-state green</td><td>X</td><td></td></tr>
<tr><td>9a. Flashing green</td><td>9b. Flashing green + verbal audio beacon</td><td>X</td><td></td></tr>
<tr><td>10a. Flashing green</td><td>10b. Flashing green (traveling)</td><td>X</td><td></td></tr>
<tr><td>11a. Flashing green (traveling)</td><td>11b. Flashing green + verbal beacon</td><td>X</td><td></td></tr>
</table>

The signs were shown in three different sign orders, with approximately one-third of participants assigned to each of the three orders. Varying the orders in which the signs were presented served two purposes—to minimize the impact of learning effects on comprehension results and to ensure that the same signs were not always seen in thicker smoke (present at the beginning of each participant's test) or thinner smoke (present toward the end of each participant's test). The exception was the symbol-only running man sign, which was the first sign that every participant saw; this was to better test comprehension of the running man symbol (before participants saw the symbol in combination with the "EXIT" text. The sign orders are shown in Table 6.

Table 6. Viewing Orders of the Test Signs during Stage 2 of the Tunnel Simulation.

Sign Order 1	Sign Order 2	Sign Order 3
RM symbol	RM symbol	RM symbol
EXIT + arrows	RM + EXIT (LED)	Emergency phone
Emergency refuge	Markers (PL)	RM + EXIT + arrow + 154 ft
RM + EXIT (PL)	RM + EXIT + arrow + 168 ft	EXIT
Emergency phone	EXIT + arrows	RM + EXIT (LED)
RM + EXIT + arrow + 154 ft	Emergency refuge	Markers (PL)
EXIT	RM + EXIT (PL)	RM + EXIT + arrow + 168 ft
RM + EXIT (LED)	Emergency phone	EXIT + arrows
Markers (PL)	RM + EXIT + arrow + 154 ft	Emergency refuge
RM + EXIT + arrow + 168 ft	EXIT	RM + EXIT (PL)

Ambient lighting within the artificial tunnel was adjusted to approximately 10 lux (measured in smoke-free conditions at floor level) to approximate typical nighttime tunnel lighting levels, and the tunnel was then filled with artificial smoke, as shown in Figure 6. The density of the smoke was measured throughout each participant's testing session, recorded each time the participant viewed a sign.

Figure 6. View of simulated tunnel, with partially dissipated smoke.

Procedure for Sign and Marking Comprehension/Visibility

Each participant viewed each sign treatment one at a time, using the 60-foot corridor. Distances were pre-marked on the floor, and the researcher assisted the participant in finding and staying close to this marked path.

All signs were viewed at a height of 1.4 meters (4.5 feet) from the floor/walkway level. Signs were mounted at a 10-degree angle from the side walls of the corridor, to approximate a likely viewing angle of a pedestrian standing in the vehicle lane (i.e., standing next to his/her vehicle) and viewing a sign mounted flat on a tunnel wall from about 12 meters (40 feet) away. This slight angling of the test signs toward the participant helped to compensate for the much more constricted viewing angles possible in the 6-foot-wide artificial tunnel (see Figure 7 and Figure 8).

Pathway markings were viewed at a height of 1 meter (3 feet) from the floor/walkway level, in accordance with CIE 193-2010 (see Figure 9).

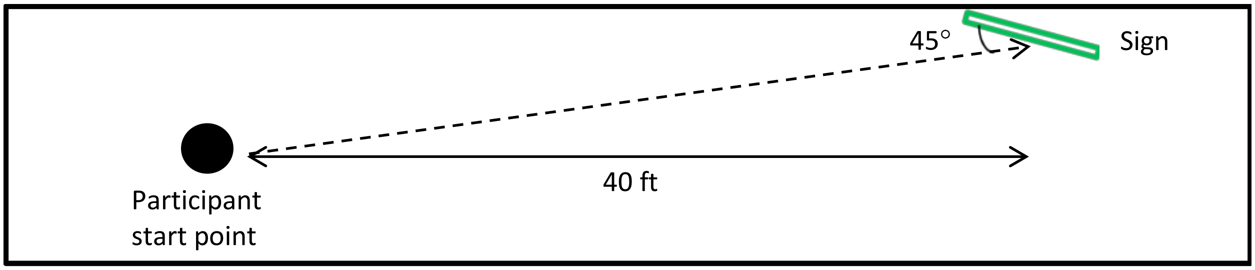


Figure 7. Viewing distance/angle for test signs.

Figure 8. Mounting brackets for test signs (shown without ambient smoke).

Figure 9. LED path lights in simulated tunnel.

This part of the simulation tested the following:

- **Detection distance**: For each of the sign and marking treatments, participants were asked to walk slowly forward from the start point marked in the corridor (a point at least 12 meters/40 feet away from the sign or marking) and to stop and tell the researcher when they could first see the sign or marking.   The researcher recorded this distance, using distance markings on the floor of the corridor.
- **Legibility distance** (signs only): Participants were asked to continue walking slowly forward and to stop and tell the researcher when they could read the text and/or describe the symbol shown on the sign. The researcher recorded this distance.
- **Comprehension** (signs only): Participants were asked the meaning/message of the sign; in the case of exit signs that featured the word "exit," participants were asked where they would expect to find the exit based on the sign. The researcher recorded the participants' responses to these questions.

Procedure for Pathway/Exit Door Treatments

In place of actual exit doors, LED lights were used to mark pathways extending in both directions from the center of the corridor. The first four LED markers were placed at a height of 1 meter (3.2 feet) above the floor, spaced approximately 1.8 meters (6 feet) apart. The final LED marker in each direction was placed high on the wall close to each end of the corridor, in positions that would be at the top of standard-height doorways. In addition to the LEDs, an audio speaker was mounted at one end of the corridor close to the final LED doorway light. Participants viewed (and sometimes heard) each pair of pathway/door treatments from the center point of the corridor; the researcher then asked, “Which direction would you be more confident about turning to find an exit?” and recorded the participants’ answers, along with the participants’ reasons for choosing as they did.

Exit Survey

Besides the sign comprehension questions that were asked in the simulated tunnel environment, participants answered questions about some additional symbol and color combinations in a brief exit survey conducted after they finished Stage 2. Pictures of the signs and symbols were presented to each participant on a laptop computer, and the researcher recorded the participant’s verbal responses.

RESULTS

Stage 1: Response to Emergency Situation and Messages

Information was collected for 63 participants in Stage 1. Only one participant physically left the vehicle in response to the simulation in Stage 1 (after hearing the audio message instructing drivers to leave vehicles). The rest of the participants responded only verbally regarding their response to the situation and the information presented. The comments offered by participants during and immediately following the simulated drive, as well as their responses to the questions, were used to categorize their probable reactions to the emergency situation as “more likely to stay in the vehicle” or “more likely to leave the vehicle.” Table 7 summarizes these two categories of responses across the three information conditions (ambient cues only, DMS message, audio message).

Table 7. Summary of Participant Responses to Tunnel Simulation, Stage 1.

Response	**Ambient Cues Only**	**DMS Message**	**Audio Message**	**Total**
Stay in the vehicle	16 (80%)	4 (19%)	6 (27%)	*28*
Leave the vehicle	4 (20%)	17 (81%)	16 (73%)	*35*
Total	*20*	*21*	*22*	*63*

Chi-square analysis of responses indicated that participants who received the DMS message were significantly more likely to indicate an intention to leave the vehicle versus participants who received ambient cues only: Chi-square critical value = 15.1; p(X^2>CV = 0.0001). Similarly, participants who received the audio message were significantly more likely to indicate an intention to leave the vehicle versus those who received ambient cues only: Chi-square critical value = 11.6; p(X^2>CV = 0.0007).

There was no significant difference in expressed intentions between the participants who heard the audio message versus those who saw the DMS message: Chi-square critical value = 0.43; p(X2 > CV= 0.51).

Staying or Leaving: Participant Comments

Participants who indicated that they would be more likely to stay in their vehicle tended to talk about needing more information, waiting to see what others would do, waiting to see if smoke or fire got closer to them, or simply feeling that remaining in the vehicle would be the safest course of action. Example comments from participants who indicated that they would be more likely to stay in the vehicle, at least until something else caused them to decide to leave, are listed below.

Comments from participants who received no warning message included:

- *I would stay in my car, maybe roll down my window to see if other people were getting out, but I definitely wouldn't get out first. Actually, I probably would just be wishing I had cell phone reception.*
- *I'd probably stay in my car, to be honest. I might eventually leave, would run in the opposite direction from the smoke.*
- *Can't get out because there are cars in front and back of me. If I left my vehicle it would be blocking the tunnel, or at least the lane. I would just sit and see if it was going to clear up and if the traffic would start moving again.*
- *I'd probably stay in the car unless things started getting hot. I might open the door to see if the smoke was all the way to the ground; if not, I might crawl out. If the whole tunnel is full of smoke, you're going to have to make a decision pretty fast.*
- *I'd stay in my car and see what might happen; if I had my phone I would call 911 and see if they could tell me what was happening. I might get out and talk to the person behind me to see if they know what's going on, but then might get back in my car—I feel like that might be safer.*
- *I would stop or slow down and see what is ahead and what options I have, either getting around it or getting out of it. Right now I think the only option I have is to stay with it, moving slowly or stopping as needed, and just work my way through it.*

Comments from participants who received a DMS or audio warning but still indicated they would be more likely to stay in the vehicle included the following:

- *I'm not going to get out without knowing what's out there. I'll wait for more information like what we heard on the radio. I would open it up to look, but I would stay in the car until I heard more about what to do. I'd want to wait until other cars were stopped, see what people in other cars were doing.*
- *Probably stay in my car and see what other people do.*
- *I'd be sitting in the car thinking "where the hell is an exit?" Because I hadn't seen any exit signs along the way that I'm aware of.*

Participants who indicated that they would be likely to leave their vehicle seemed either to recognize that smoke or fire in a tunnel presented an immediate hazard or to trust an official-sounding instruction to leave. Example comments are listed below.

Comments from participants who received no warning message but indicated they would leave their vehicle included:

- *I'd get out of my car and try to analyze by the available light how to exit and get out; the first place I would look is up, to see if there's any potential on those walls. I'm a brain-stormer, so I would get with some other drivers and start strategizing a way out of there. Forget the car; I would take my purse, I'd be trying to call 911. I'd be extremely worried* *for elderly and handicapped people, and would organize a search for anyone needing help inside the other vehicles. I'd be taking action.*

- *If it's smoke, I would think something is in danger of exploding and I would do my best to get away from it, if possible. If there was no way around in my car, I would probably get out to see, and run away if it looks dangerous. My life is more important than my car!*

Comments from participants who received a DMS or audio warning and indicated they would leave their vehicle were:

- *[DMS message] It says "walk to exit." I guess I'd walk to the exit. I'd head toward that sign. If I didn't have anything to carry with me, or any family to worry about, I'd probably make it.*
- *[DMS message] I remember passing the exit just several car lengths back, so I'm going to exit the car, go back and take that exit. It was kind of hard to see; I didn't see a lit exit sign. That would help, kind of like an exit sign in a building.*
- *[DMS message] I noticed when I was driving that there seems to be a railing to the left, so there's probably a walkway there. Assuming my cell phone was charged, I would turn it on and turn on the flashlight. Get out of the car, since that's what I'm being told to do, take my keys with me. If I knew the tunnel and had a good feeling for how long it was, I'd know which way to walk. If I didn't know the tunnel, I would probably walk back the way I came.*
- *[Audio message] If I hear someone telling me to get out of the car, I'm getting out of the car. I can guarantee you that's exactly what I'd do. I'd leave the key in the car. I'd probably try to grab my iPad, personal items, maybe grab some water if I had it in the car. And when I got out, I'd expect to see other people getting out too.*
- *[Audio message] I would probably listen to what he said and get out. Because that would be the emergency folks telling us what to do.*
- *[Audio message] I guess I'd get everyone out of the car and leave. I'm always attached to my keys, so leaving the keys in the car might be a challenge. I would assume that is what I'd do. If you see a fire in a tunnel, I'm not sure I would know what to do, so having a voice tell me what to do would be helpful, along with seeing other people getting out and leaving.*

Additional Information Needs

Participant responses regarding additional information they would want to have most often fell into one of the following categories:

- Location of emergency exits.
- Pathway or other emergency lighting.
- Cause of the incident.
- Seriousness of the incident/situation.
- Instructions about what to do.

Table 8 summarizes the number of requests that were made by participants for each type of information under each of the three conditions. These total more than the number of participants since many participants listed several types of information that they would want.

Table 8. Tunnel Simulation, Stage 1: Additional Information Wanted.

Additional Information Wanted	Frequency of Request for Each Participant Group		
	Ambient Cues Only *(20 participants)*	**Audio Message** *(21 participants)*	**DMS Message** *(22 participants)*
Location of exits	4	15	17
Lights/path	7	8	12
Instructions about next actions	11	4	3
Cause of incident	12	2	3
Seriousness of incident	11	1	3
Other	0	7	1
None	0	2	1

As can be seen in the table, there was a difference in the information needs most frequently identified by participants who received only ambient cues about the emergency, versus those identified by participants who received one of the two messages. Participants who received only ambient cues were more likely to ask for instructions about what to do and about the cause of the incident and the seriousness of the incident—information that had already been provided to the other groups of participants. Participants who received either of the two messages were more likely to ask about exit locations and how to find them.

Other information needs that were mentioned by some participants included instructions to drivers to stop and/or watch for pedestrians, information about where drivers should stop (e.g., within their current lane or on a specified side of the tunnel), information about who/what entity was making the announcements (e.g., tunnel operator, emergency services), whether there would be additional announcements that people should be listening for, what would happen to abandoned vehicles, and where people should gather once they were out of the tunnel.

Stage 2: Sign Comprehension

Each time a participant indicated that he or she could see/read the words and/or symbols on a sign, the researcher asked, "What is on the sign?" Once the participant had described the symbols and/or read the text on the sign, the researcher asked the participant about the meaning of the sign.

Symbol-Only Signs

For signs that displayed symbols only (no text), the researcher then asked, "What do you think the sign is telling you?" Participants' verbal responses to these questions were recorded and later scored according to how closely each participant's interpretation of each sign matched the intended meaning of the sign. The scores for symbol-only signs are summarized in Table 9 as "correct," "partially or near correct," and "incorrect or don't know." Descriptions of these scores for each sign type are described in the subsections below.

Table 9. Comprehension Scores for Symbol-Only Signs.

Sign		Correct Definition	Partially or Near Correct	Incorrect or Don’t Know
Running man symbol		29 (48%)	23 (38%)	9 (15%)
Refuge point		5 (8%)	46 (75%)	10 (16%)
Emergency phone		53 (87%)	7 (11%)	1 (2%)

Running Man Symbol. The running man symbol was the first sign each participant saw; this order was intended to gauge how well the symbol was comprehended as a stand-alone information element. Most participants identified the symbol as a “running person,” “running man,” “someone running,” or “pedestrian.” When asked what the sign meant, 29 participants (48 percent) said that it indicated an exit (scored as “correct” in Table 9); another 23 (38 percent) said that it indicated a walkway or path that they would follow (scored as “partially/near correct”).

The nine participants whose responses were scored as “incorrect” thought the sign was a pedestrian crossing sign, to warn drivers that someone may be crossing the roadway in front of them.

Emergency Phone Symbol. This sign was included in the comprehension testing primarily to reduce the expectation that every sign would have something to do with an exit from the tunnel. Sixty out of 61 participants (98 percent) identified the phone and flame symbols on the sign; 53 out of 61 (87 percent) specifically stated that the phone was an “emergency” phone or a “phone to report a fire.” Seven participants (11 percent) indicated that the sign indicated a phone, but not necessarily for emergencies; one of these stated that it might be a phone that is fire protected. One participant stated that he/she had “no idea” what the paired symbols might mean.

Refuge Point. This sign, which like the emergency telephone sign was included to indicate something other than an exit from the tunnel, was the least-recognized symbol among the participants. While all participants correctly identified the wheelchair symbol as indicating something pertaining to people with disabilities, only five (8 percent) stated that the sign identified a safe/refuge area. Ten participants guessed that the sign indicated something (but could not guess what) for a disabled person, or that it was warning drivers to watch for people with disabilities close to the road. The remaining 46 participants guessed that the sign marked an accessible exit door or ramp, or a stored wheelchair that could be used to transport a disabled person.

Signs Including "EXIT" Text

For signs that included the text "EXIT," the researcher asked the participants, "Where would you expect to find the exit, based on this sign?" Participant responses were scored as "correct" if their expectation for the sign location matched the customary use of the sign (i.e., a text EXIT sign or a running man sign with no directional arrow would be used on or above an exit door; signs with directional arrows would be used to indicate that an exit would be in the direction of the arrow or arrows). Table 10 summarizes the comprehension scores for the signs that included EXIT text as part of the legend.

It should be emphasized that the comprehension scores in Table 10 should be not considered as having identical meanings to the comprehension scores for the symbol-only signs shown in Table 9; it can be assumed that all participants recognized the signs containing EXIT text as representing exits. The correctness of participant responses for the signs containing text refers only to where participants expected to find exits, based on a given sign.

Table 10. Comprehension Scores for Signs with Text.

Sign		Correct Exit Location	Partially or Near Correct Location	Incorrect or Don't Know
Running man + EXIT text (1st viewing)		16 (26%)	45 (74%)	0 (0%)
Running man + EXIT text (2nd viewing)		11 (18%)	50 (82%)	0 (0%)
Running man + EXIT + distance + arrow (1st viewing)*		60 (98%)	1 (2%)	0 (0%)
Running man + EXIT + distance + arrow (2nd viewing)*		59 (97%)	1 (2%)	1 (2%)
EXIT text + arrows		46 (75%)	2 (3%)	13 (21%)
EXIT text only		51 (84%)	7 (11%)	3 (5%)

**Participants in Groups B and F saw the "154 ft" sign first; participants in Groups A, C, D, and E saw the "168 ft" sign first.*

Running Man with EXIT Text. Participants saw this sign format twice, once as an LED-illuminated sign and once as a photoluminescent sign. All participants identified this as an exit sign; most (74 percent on first viewing, 82 percent on second viewing) thought that it indicated an exit nearby but past the sign in the direction that the running man was facing (scored as partially or near correct in Table 10). A smaller percentage (26 percent on first viewing, 18 percent on second viewing) identified the sign as being an exit door sign; this was scored as "correct" in Table 10.

Running Man with EXIT Text, Arrow, and Distance. Participants saw one LED-illuminated sign showing an exit 168 feet to the right, and one photoluminescent sign showing an exit 154 feet to the left; Participant Groups B and F saw the 154 feet sign first, while the other groups saw the 168 feet sign first. Nearly all participants comprehended both of these signs correctly, stating that the exit was in the direction that the arrow was pointing, at the stated distance away. Some participants commented that while they were uncertain of how far 168 feet or 154 feet would be, the sign nonetheless provided them with the information that the exit was some distance away, not in the immediate area. A small number of participants stated the distance and then translated that distance into an approximate number of paces that would get them to the exit.

One partially correct response for this sign was a misreading of the number as 15.4 feet instead of 154 feet; the other was a statement that the exit was "to the left of that sign" (the direction of the arrow) without specifying a distance. The only incorrect interpretation of this sign was from one participant who thought that it could mean "exit here, then go 168 feet in the direction of the arrow."

EXIT Text Signs with Chevron Arrows (Two Directions). Participants saw two versions of an EXIT text-only sign: an LED internally illuminated sign that included two chevron arrows (indicating exits in either direction) and a photoluminescent EXIT sign without arrows. The EXIT sign with the bi-directional arrows was recognized by all participants as indicating one or more exits, but participants' expected locations of those exits were not as consistent. The correct answer, that the two arrows indicated exits in both directions, was stated by 46 of the 61 participants (75 percent). Two participants (3 percent) stated that the exit was next to the sign, implying an exit in one direction rather than two. The remaining 13 participants (21 percent) assumed that the exit would be directly below the sign; some of these, from their comments, seemed not to recognize the chevron arrows as representing directions (one participant said specifically that they looked like brackets).

EXIT Text Signs (No Arrows). All participants recognized the sign as identifying an exit, and 51 out of 61 (84 percent) expected that the sign would be hanging on or directly above the exit door. Another seven (11 percent) expected to find the exit door in close proximity to the sign. Three participants (5 percent) stated that they were uncertain where an exit would be in relation to the sign's location.

Stage 2: Sign Visibility

Results for the sign detection and legibility distances are included in Chapter 5, along with the luminance measurements for each sign.

Stage 2: Path Marking Preferences

Four formats of pathway/exit door beacons were tested. All of these formats included a series of green LED lights spaced approximately 1.2 meters (4 feet) apart along the wall at a height of 1 meter (3.2 feet). The final LED light at either end of the artificial tunnel structure was positioned high on the wall to simulate a light just above a doorway. The four formats included the following:

- Steady-state LEDs (no flashing).
- Unison flash, in which all of the LEDs along the path flashed on and off at the same time.

- Traveling flash, in which the LED lights flashed individually in a repeated sequence from left to right (from the perspective of the viewer) and thus appeared to travel to the right.
- Unison-flash LEDs plus an audio beacon at the door location.

As described in the procedures section, these four options were presented to participants in pairs, as shown in Table 11, with one option in each pair to the left of the participant and the other option to the right of the participant. The participant was then asked, “Which direction would you be more confident about going to find an exit (left or right)?” A follow-up question asked for the participant’s reason for his or her preference.

Table 11. Path/Door Marking Comparisons.

Comparison	Most Frequently Preferred	Number Preferring (out of 61)	Percent Preferring
Unison flash vs. steady state	Unison flash	37	61%
Unison flash vs. unison flash + audio	Unison flash + audio	56	92%
Unison flash vs. traveling flash	Traveling flash	49	80%
Unison flash + audio vs. traveling flash	Unison flash + audio	44	72%

Unison Flash versus Steady State

Participants viewed a series of steady-state (continuously lit) LED path markers to the right and a series of LED path markers to the left that flashed in unison. Sixty-one percent of participants preferred the unison-flash markers to the steady state. Comments from participants who preferred the unison-flash markers included the following:

- *The blinking draws attention.*
- *It indicates “emergency” and “attention.”*
- *The flashing says, “Move!”*
- *It seems like it’s active, that it’s trying to point out something.*
- *Steady lights are just lighting; the flashing lights are telling me to do something.*
- *You can tell it’s not just normal lighting; since it draws your attention, it must matter more.*

Comments from participants who preferred the steady-state markers included the following:

- *Sometimes blinking means “hazardous”; the solid [steady-state] markers look like an airplane exit path.*
- *The flashing almost seems like something’s wrong, while the steady lights are reassuring.*
- *I don’t particularly like strobe lights because they’re a little disorienting. Maybe a slower flash rate would be better.*

- *The flashing almost looks like "watch out, there's a problem."*
- *The steady lights are not as disorienting and provide easier depth perception in a smoky environment.*

Unison Flash versus Unison Flash plus Audio

In this comparison, both the left and the right series of LED path markers flashed in unison; in addition, an audio beacon to the left of the participant (approximately 8.5 meters or 28 feet away) repeated the phrase "exit here," alternating between English and Spanish. Ninety-two percent of participants preferred the addition of the audio message to the path markers alone. Comments from participants who preferred the addition of the audio message included the following:

- *I'd follow the sound.*
- *The voice is telling me to go that way.*
- *That's where the sound is coming from. In this case, the flashing lights call attention to the voice and the path.*

There were no participants who stated that they preferred the flashing lights without the audio beacon, but some had no preference between the two pathway directions. Comments from these participants included the following:

- *I wouldn't trust the direction of the voice; it's inadequate as a directional guide.*
- *I can't tell where the voice is coming from.*
- *I'd change the message to "follow my voice and exit here."*

Unison Flash versus Traveling Flash

Participants viewed a series of LED path markers to the left that flashed in unison, and a series to the right that flashed individually in a repeating sequence that began with the marker closest to the participant and traveled down the wall to the right. Eighty percent of participants preferred the traveling flash to the unison flash. Comments from participants who preferred the traveling flash option included the following:

- *I like the progression of the lights telling me the direction to go.*
- *It looks like an arrow.*
- *I see which direction it wants me to follow.*
- *It's a slower blink than the [unison flash]; it doesn't mess with my eyes as much. Besides, the lights imply "that way," like runway lights.*

Comments from participants who preferred the unison flash included the following:

- *The [unison flash] is more prominent.*
- *It seems to be blinking faster than the other direction.*
- *Both are good; [unison flash] is drawing me [toward it] more.*

Unison Flash plus Audio versus Traveling Flash

The unison-flash LED lights plus the "exit here" audio beacon were presented to the participants' left, while the traveling flash LED path (with no audio) was presented to the right. Seventy-two percent of participants preferred the unison flash plus audio to the traveling flash, but several of these commented that a combination of the two strategies would be ideal. Comments from participants who preferred the unison flash plus audio option included the following:

- *Easier to go toward the voice, especially if you're disoriented.*
- *The voice outweighs the [traveling] lights.*
- *The voice gives me immediate confidence to go that way.*
- *The voice is more prominent, but I would recommend using both.*
- *The voice is good, but [traveling] lights would also be powerful; the voice could be echoing more in a tunnel.*

Comments from participants who preferred the traveling flash option included the following:

- *"Exit here" may not mean anything if I'm disoriented; also [the traveling light path] is a little calmer.*
- *The arrow effect is good.*
- *In a tunnel, it might be hard to tell where the voice is coming from.*

Exit Survey Responses

The first question in the exit survey asked, "Does the direction the running figure is facing always indicate the direction of the exit?" (see Figure 10). Of the 63 participants, 58 (92 percent) answered "yes" to this question, which is consistent with how most participants interpreted the directionality of the running man signs during Stage 2.

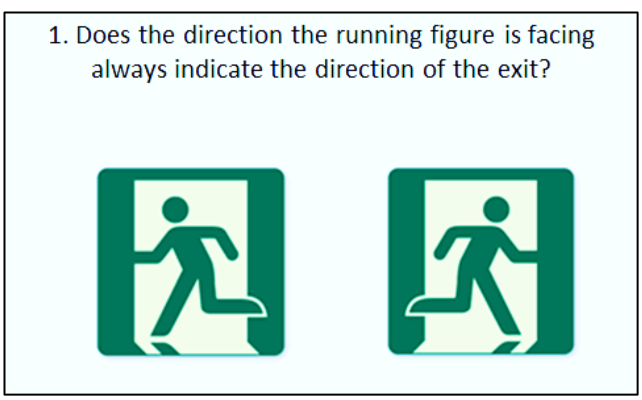


Figure 10. Exit survey, question 1.

Question 2 asked whether a running man symbol on a sign meant the same thing to participants as the symbol accompanied by the word "EXIT" (see Figure 11). Fifty participants (79 percent) answered that the two signs meant the same; of these, 48 nevertheless preferred the version that included the "EXIT" text, feeling it provided more clarity.

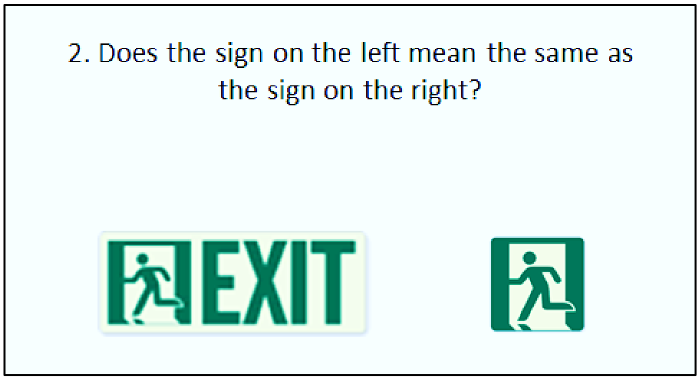


Figure 11. Exit survey, question 2.

Question 3 asked whether the running man symbol meant the same to participants as the traditional EXIT text sign (see Figure 12). Responses were mixed, with 30 participants (48 percent) answering that the two signs had the same meaning and 33 participants (52 percent) answering that the signs had different meanings. Of the 30 participants who felt that the two signs had equivalent meanings, 22 preferred the text EXIT sign, most often because they felt it was clearer and more familiar. Participants who answered that the two signs had different meanings tended to interpret the running man symbol as indicating an upcoming exit in the direction that the running man was facing, versus assuming that the text EXIT sign would be used at the location of the exit itself.

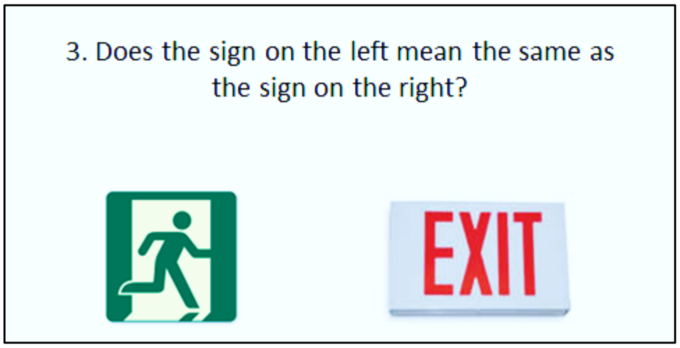


Figure 12. Exit survey, question 3.

Question 4 asked whether a red EXIT text sign meant the same to participants as a green text sign (see Figure 13). Fifty-seven participants (90 percent) answered that the two sign colors had the same meaning; of these, 31 preferred red and 16 preferred green. Participant comments about sign colors included the following:

- *Green means that you can exit this direction at any time. Red would mean it's an emergency exit only.*
- *In the tunnel, I could see green easier than red.*
- *I'm more accustomed to a red exit sign.*

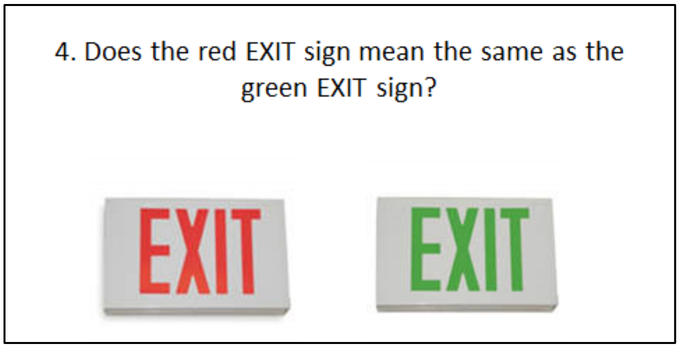


Figure 13. Exit survey, question 4.

Question 5 asked if a running man symbol alone meant the same thing to participants as a running man sign paired with a directional arrow (see Figure 14). Fifty participants (79 percent) answered that the addition of the arrow did not change the meaning of the sign (in actuality, the running man symbol by itself is generally used for an exit door, while the addition of an arrow indicates that the exit is in the direction of the arrow). This again underscores the prevailing view among the study participants that the running man symbol by itself indicated direction.

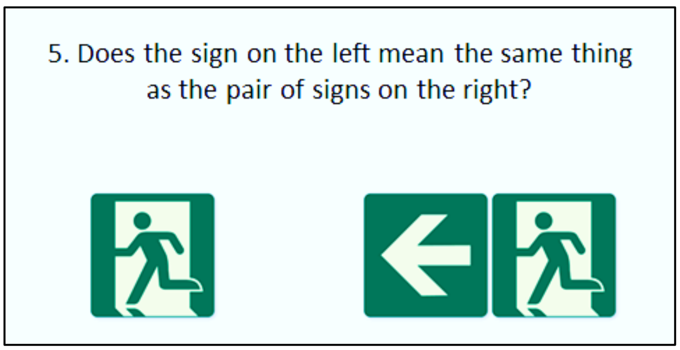


Figure 14. Exit survey, question 5.

Questions 6 and 7 paired a running man symbol with arrows pointing directly up and down, respectively, and asked what the symbol combinations would mean to participants (see Figure 15).

Twenty-two participants (35 percent) selected one of the two provided answers: that the down arrow likely meant “you are at the exit,” with some of these stipulating that they would expect this combination to be positioned above a doorway. Seven participants (11 percent) selected the answer “you need to keep going in your current direction for the exit.” The other 33 participants (52 percent) provided other definitions for this symbol combination, with most answering that the arrow would indicate a staircase, elevator, or downward slope.

The up arrow was also identified by the largest number of participants (26, or 41 percent) as indicating an upward staircase, ramp, or elevator. Twenty participants (32 percent) selected the provided answer “you need to keep going for the exit,” and eight selected the answer “you are at the exit.”

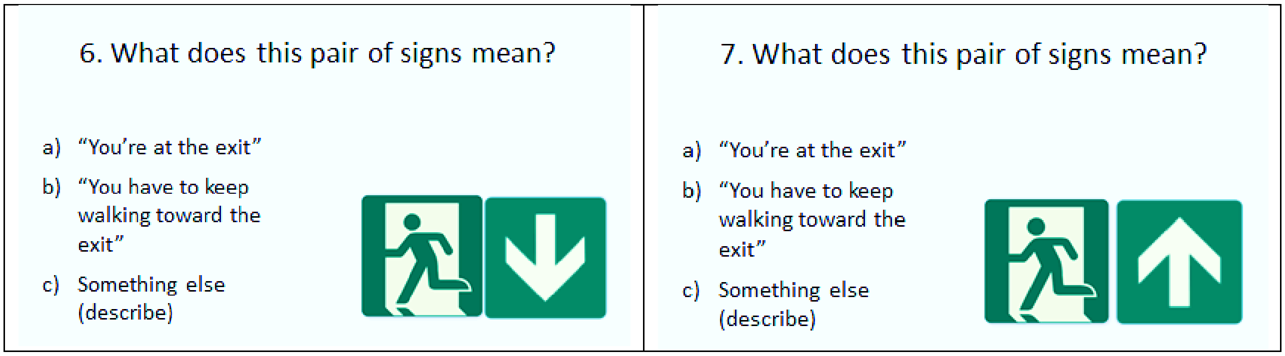


Figure 15. Exit survey, questions 6 and 7.

Questions 8 and 9 similarly paired a running man symbol with different directional arrows (an arrow pointing directly right versus an arrow pointing right but angled either up or down, as shown in Figure 16.) Most participants (57, or 90 percent, for the downward-angled arrow; 59, or 94 percent for the upward-angled arrow) believed that the arrow pointing directly right indicated that an exit would be on the same level as the pedestrian, while an angled arrow indicated that the pedestrian would have to go up or down, most likely via a staircase. A couple of participants thought the angled arrows could indicate an exit at the same vertical level, but in a diagonal direction or around a corner from the location of the sign.

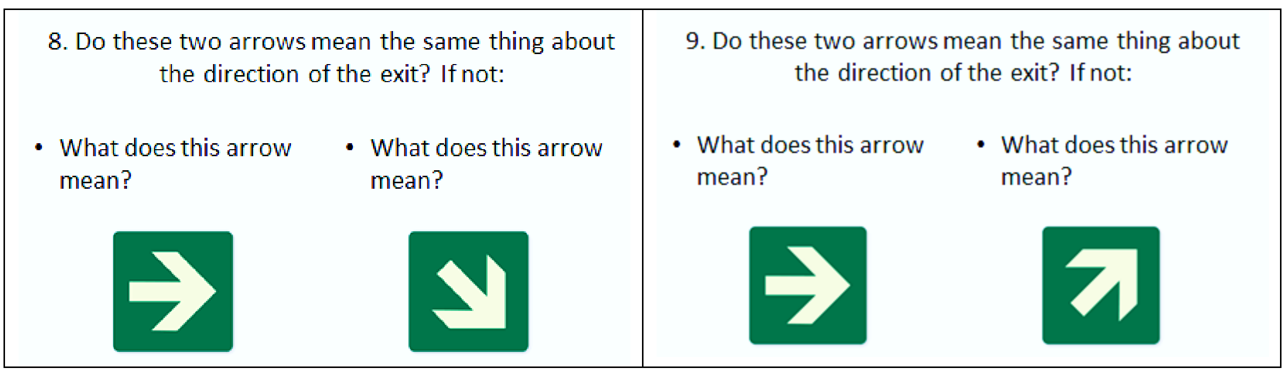


Figure 16. Exit survey, questions 8 and 9.

Question 10 asked participants if small chevron arrows and tailed arrows meant the same thing when used with exit signs (see Figure 17). Fifty-seven participants (90 percent) answered that the two arrows had the same meaning, though 47 of these preferred the tailed arrow to the chevron arrow for visibility and/or clarity. Comments from the small number of participants who indicated that the two arrows had two different meanings included the following:

- *The chevron arrow means that the exit is underneath the sign and to the right. The tailed arrow means that exit is coming up to the right, but you need to keep walking.*
- *The chevron doesn't look like an arrow, especially if it's on both sides. Maybe three chevrons in a row would look more like a direction.*

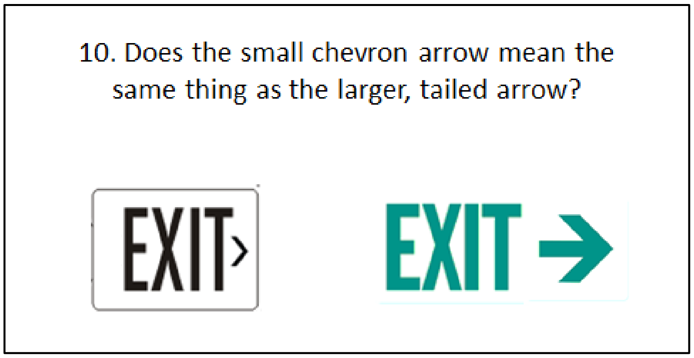


Figure 17. Exit survey, question 10.

Question 11 asked participants if a running man exit sign that included a distance along with a directional arrow meant the same as the directional sign without a distance (see Figure 18). Responses were mixed, with 37 participants (59 percent) answering that the two formats meant the same thing and 26 participants (41 percent) answering that the two signs provided different messages. Participants who indicated that the two signs provided different messages most frequently assumed that the sign without a specific distance included should indicate an exit that is only a short distance away. Participant comments, regardless of the answer selected, were very similar—most preferred the sign that included the distance, feeling that it provided clearer and more complete information to pedestrians.

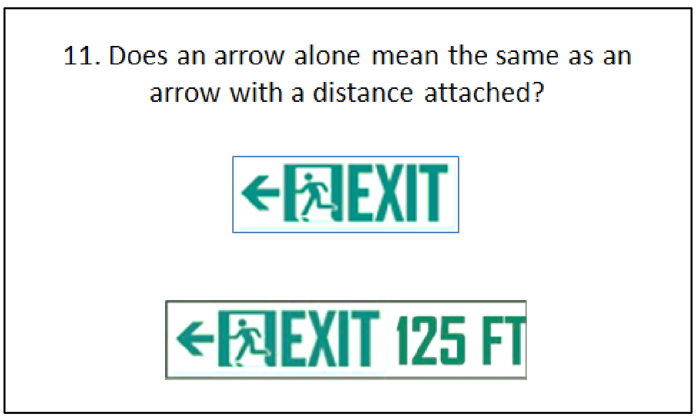


Figure 18. Exit survey, question 11.

TUNNEL SIMULATION CONCLUSIONS

Stage 1 of the tunnel simulation indicated that providing an evacuation message to drivers during an emergency situation increases the likelihood that they will leave their vehicle. The message mode (sign or audio) did not seem to greatly influence this result, as long as drivers received the information in one form or another. As seen in the focus group results, the most important message elements seemed to be an explanation of the situation and direct instruction; the drivers who did not receive a message in Stage 1 were most likely to ask for these pieces of information. Once drivers indicated their decision to leave the vehicle, their most frequent questions were about how to find and identify exits. One caveat that should be noted regarding the audio message is that participants heard this message via a small speaker inside the vehicle, not from a loudspeaker outside the vehicle. The sound quality and therefore the intelligibility of the audio message would be greatly reduced if it were broadcast over a loudspeaker inside a tunnel.

Exit Sign Comprehension

In Stage 2, participants had little or no trouble comprehending most of the exit signs. The stand-alone running man symbol that was presented first was identified correctly by 48 percent of participants as an exit sign, while another 38 percent assumed that the sign indicated a direction or path for them to follow. Once the running man symbol was paired with the word EXIT, the most common misconception by participants had to do with where they would expect to find the exit door in relation to the sign.

Most participants thought that the running man sign (with or without the word EXIT) indicated a direction, even without a supplemental arrow. Because of this inferred directionality, the most frequent assumption among participants was that the running man symbol indicated an exit that was to the side of the sign or farther away in the direction that the running figure was facing. It should be noted, however, that participants saw all signs in the context of a wall-mounted frame and so did not have the added context of a visible doorway.

Conversely, the only notable misconception about the text-only EXIT sign was related to the version of the sign that included chevron arrows in two directions; a small number of participants did not recognize the directionality of this sign and assumed that it must be above the exit door itself. The confusion among those participants seemed to lie with recognition of the chevrons as directional arrows, and the familiarity of seeing text EXIT signs above exit doors.

When the running man sign was paired with a (tailed) directional arrow and a distance, comprehension was perfect among nearly all participants. A directional arrow without a distance included (tested with a text EXIT sign in Stage 2 and with a running man sign in the exit survey) was generally understood to indicate that an exit would be found in the direction of the arrow, but most participants felt that specifying the distance to the exit provided clearer information. The assumption among many participants was that an arrow without a specified distance implied that the exit was nearby.

Tailed arrows were preferred by participants over chevron arrows for indicating a direction to an exit. Tailed arrows pointing directly left or right were clearly understood; arrows pointing or angled up or down required explanation.

Path Markings and Audio Beacons

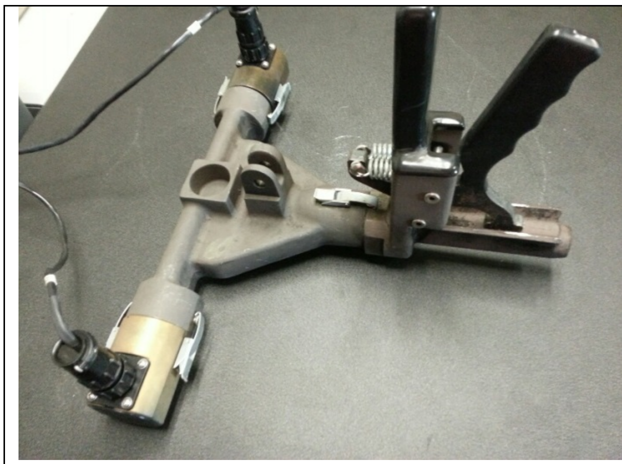
Directional/traveling path markers leading to an exit door and an audio beacon at the door location were the most preferred options among those presented to participants; when these two measures were placed opposite each other, more participants ultimately preferred the audio beacon as a directional aid. However, it should be noted that the audio beacon was less than 30 feet away, and acoustics in the artificial tunnel are not the same as in an actual tunnel (and a few participants still had trouble determining the direction the sound was coming from). Audio beacons would therefore be effective only at short distances (and in locations where ambient noise levels would not be likely to mask the sound), while the effectiveness of directional path lighting would extend over longer distances.

Non-directional path markings were also considered valuable; participant preferences were mixed about flashing versus steady-state markers, with a slight majority preferring flashing markers.

CHAPTER 5. PHOTOMETRIC MEASUREMENT PROCEDURE AND RESULTS

The researchers took photometric measurements to quantify the visibility for each of the study treatments using two different methods. First, they monitored the opacity of the smoke throughout the study to quantify the available visibility during testing. A Wager 6500 smoke meter (Figure 19a) provided a continuous output of smoke opacity in the vicinity of the signs in the artificial tunnel. The percent opacity was recorded each time a participant viewed a sign. Zero percent opacity would equate to a clear tunnel with no smoke; 100 percent opacity would prevent any transmission of light.

Separately from participant testing, luminance measurements of test signs were conducted using a calibrated Remax/Radiant Imaging PM-1600 charge-coupled device (CCD) photometer (Figure 19b).



(a) Wager 6500 Smoke Meter

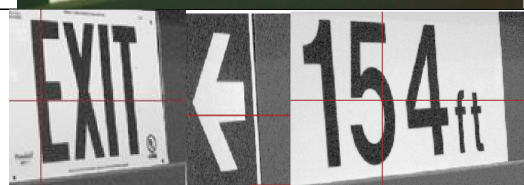
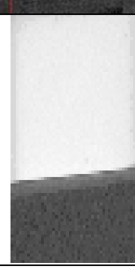
(b) PM-1600 CCD Photometer

Figure 19. Equipment used to measure smoke opacity, sign luminance and contrast.

LUMINANCE MEASUREMENT RESULTS

Table 12 describes the signs that were measured with the photometer. These signs represented two different types of sign technologies (internally LED-illuminated and photoluminescent) as well as positive versus negative contrast. Positive contrast signs typically consist of a light-colored legend against a darker background. The positive contrast signs tested in this study were the two text-only EXIT signs, one with text that was internally illuminated by LEDs and the other with photoluminescent text, both against non-illuminated backgrounds. (The LED and PL versions of the directional arrows, seen as part of the running man exit distance signs, were also positive contrast.) Negative contrast signs have a darker legend against a light (or illuminated/photoluminescent) background. The running man symbols and accompanying EXIT and distance text are all positive contrast sign elements. All of the signs that participants viewed in the tunnel simulation represented variations of the two technologies and the two contrast types shown in Table 12.

Table 12. Signs Measured with Photometric Equipment.

Sign		Comments
Running Man Exit Distance (LED)		Portions of the sign are covered by gray tunnel wall panels to provide background contrast
Sections of Running Man Exit Distance (PL)		Individual panels (EXIT, arrow, distance) are measured individually against a gray background
Text EXIT with Illuminated Letters (LED)		Sign background/casing is white but appears dark in low light levels when text is illuminated
Text EXIT with Glow Letters (PL)		Sign background is red but appears darker in low light
PL Marker		Photo shows PL marker (top) against gray background (bottom)

Each of these signs was measured under non-smoke and smoke conditions and under two ambient lighting conditions: with the emergency-level ambient lighting conditions used during the participant testing (set at approximately 10 lux) and with no ambient light. While luminance should not change with distance for most treatments under non-smoke conditions, it will under smoke conditions, so measurements were completed at multiple viewing distances and smoke opacity levels, as shown in Table 13. Measurements included the luminance levels of each treatment's positive (brighter) and negative (darker) elements, as well as the luminance of the gray painted background around each sign (representing the tunnel wall). This allowed researchers to calculate the luminance contrast of the positive and negative elements within each sign, as well as the contrast between each sign and the tunnel wall.

Table 13. Luminance Measurements and Conditions.

Luminance Measurements	Overhead Lighting	Viewing Distance	Opacity
• Positive (brighter) element of sign • Negative (darker) element of sign • Gray background behind sign	Yes	5 feet (1.5 meters)	0%
			12%
			23%
		10 feet (3 meters)	5%
			10%
		25 feet (7.6 meters)	4%
	No	5 feet (1.5 meters)	0%
			12%
			23%
		10 feet (3 meters)	5%
			10%
		25 feet (7.6 meters)	4%

Luminance and Contrast in Smoke

The photometric measurements quantified the effects of the artificial smoke on luminance and contrast levels of the test signs. As shown in Figure 20, the effective luminance of both LED and PL signs viewed from 10 feet (3 meters) away declined sharply at low levels of smoke opacity. The "EXIT" segment from the LED running man exit distance sign's measured luminance of 335 cd/m^2 (97.8 fL) in clear conditions dropped to 74.1 cd/m^2 (21.6 fL) with a smoke opacity of only 5 percent; at 10 percent smoke opacity, the effective luminance of the sign was 29.8 cd/m^2 (8.7 fL). A viewing distance of 5 feet (1.5 meters) reduced the effects of smoke opacity somewhat (93.6 cd/m^2 or 27.3 fL at 12 percent smoke opacity, 34.2 cd/m^2 or 10 fL at 23 percent opacity), but the effects were still dramatic. The PL sign began at a much lower luminance level (12 cd/m^2 or 3.5 fL with no smoke) and declined to 5.9 cd/m^2 (1.7 fL) at 5 percent smoke opacity and 4.7 cd/m^2 (1.4 fL) at 10 percent smoke opacity (both at a 10-foot/3 meter viewing distance).

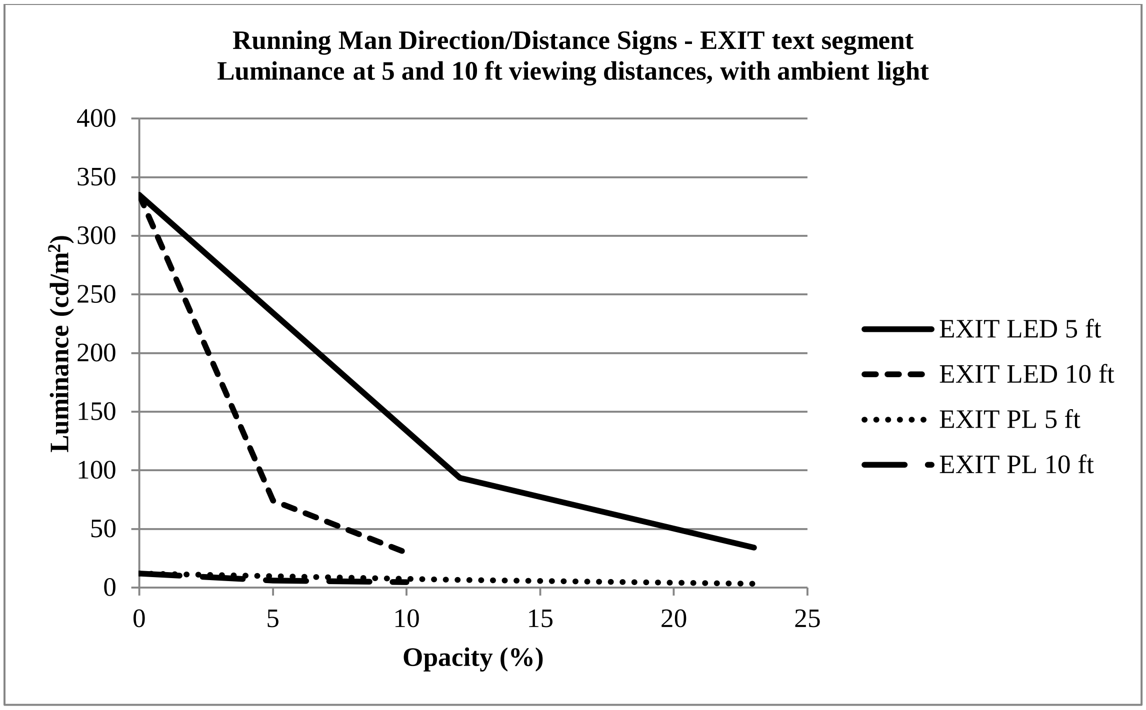


Figure 20. Luminance measurements of selected LED and PL negative contrast signs.

Besides the sharp drop in visible luminance from the test signs as smoke opacities increased, significant declines were seen in the contrasts between the signs and the tunnel wall and between the signs' positive and negative luminance areas. Figure 21 shows the contrast ratios of the LED and PL running man signs—specifically the contrast between the illuminated/glowing backgrounds of these signs with the gray tunnel wall panels under an ambient light level of approximately 10 lux. The luminance ratio of the LED sign backgrounds to the tunnel wall was approximately 72:1 in clear conditions; at a 10-foot viewing distance, this ratio dropped to 5:1 at 5 percent smoke opacity and less than 3:1 at 10 percent smoke opacity. The PL signs also declined in contrast with the wall background, from 9:1 with no smoke to 1.5:1 and then 1.1:1 at 5 percent and 10 percent smoke opacities, respectively.

When there was no ambient light, and therefore much less veiling luminance from light reflecting off smoke particles, contrast ratios between the signs and the tunnel walls improved. Figure 22 illustrates the contrast ratios at the same viewing distances and smoke opacity levels when no ambient light was present. The luminance contrast of the LED signs with the wall from 10 feet away was approximately 97:1 with no smoke, 7.6:1 at 5 percent smoke opacity, and 4.2:1 at 10 percent smoke opacity. The PL signs actually fared better than the LED signs in darkness, with contrast ratios of 137:1 in clear conditions, 9.6:1 at 5 percent smoke opacity, and 5.2:1 at 10 percent smoke opacity.

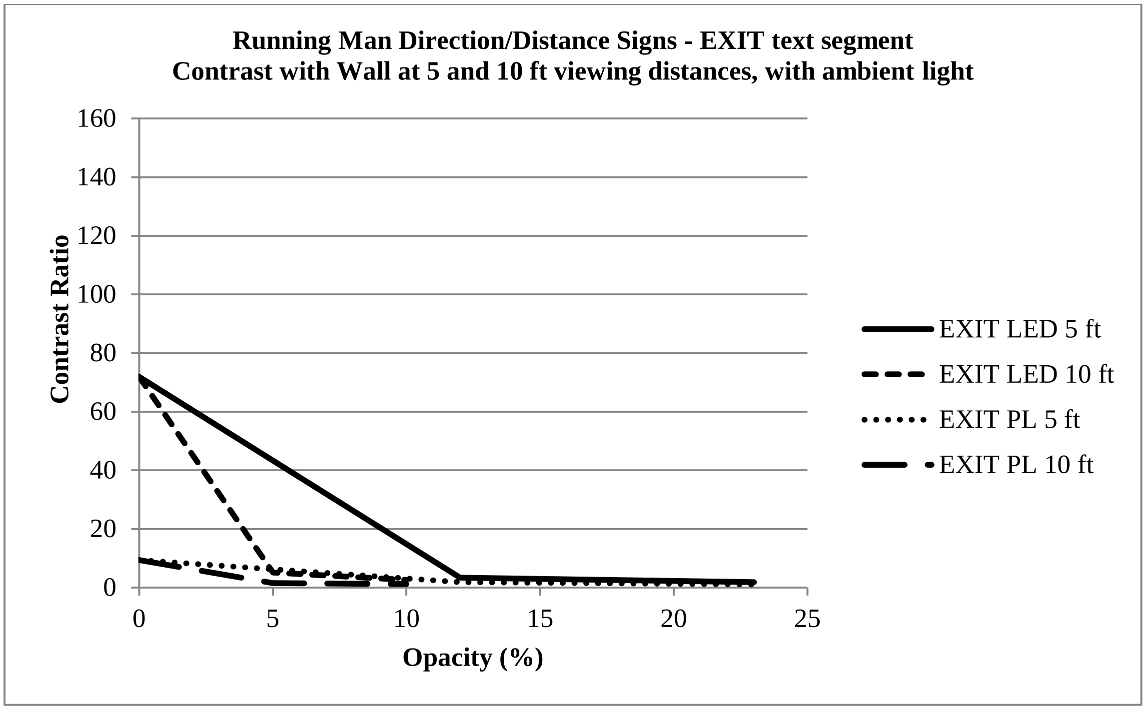


Figure 21. Contrast ratios: running man signs vs. tunnel wall, with ambient light.

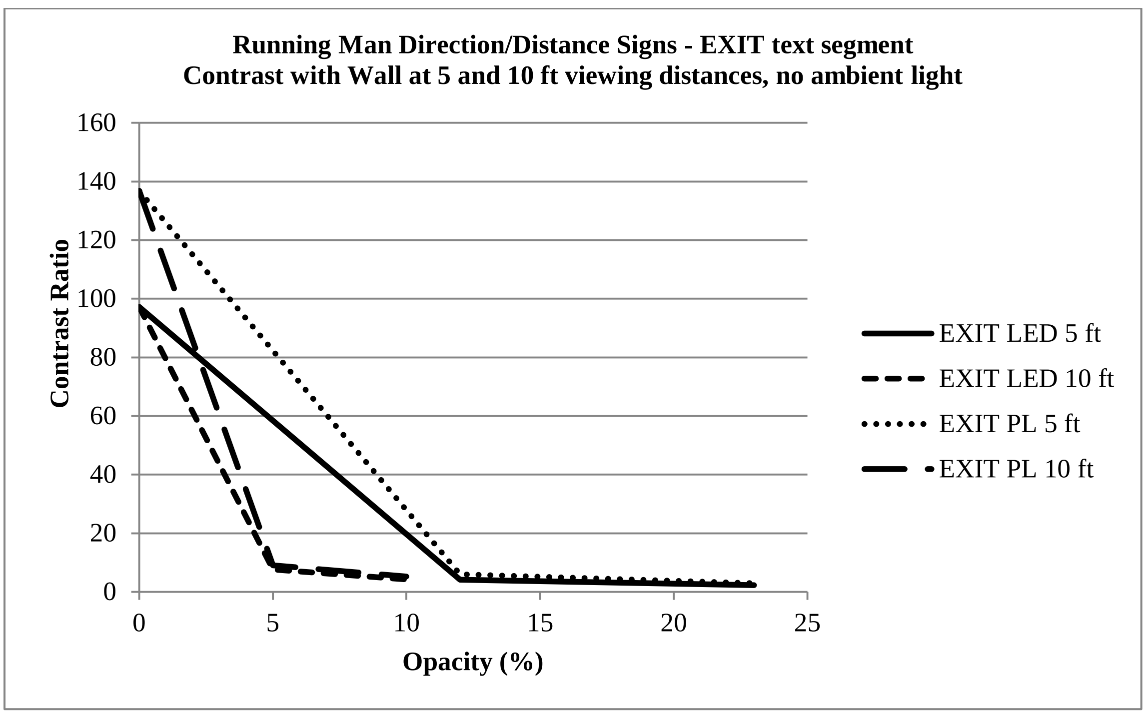


Figure 22. Contrast ratios: running man signs vs. tunnel wall, no ambient light.

Finally, the contrast ratios between the positive (brighter) and negative (darker) areas within each sign also declined with increasing smoke opacity, as shown in Figure 23. This is one metric in which PL signs surpassed LED signs in clear (no smoke) conditions when ambient light was present: the positive/negative contrast of the green "EXIT" text against the photoluminescent background was approximately 16:1. The corresponding contrast for the LED sign was approximately 4:1. At 5 percent smoke opacity, the contrast ratio for the PL sign dropped to 1.6:1; the corresponding contrast for the LED sign was 2.3:1.

The positive/negative ratios improved in the absence of ambient light, similar to the improvement seen in the sign/wall contrasts (see Figure 24). Again, the PL version of this sign had higher positive/negative element contrasts than the LED version (likely because even the dark portions of the LED signs were somewhat illuminated by the internal LEDs, while the dark portions of the PL signs had no such illumination).

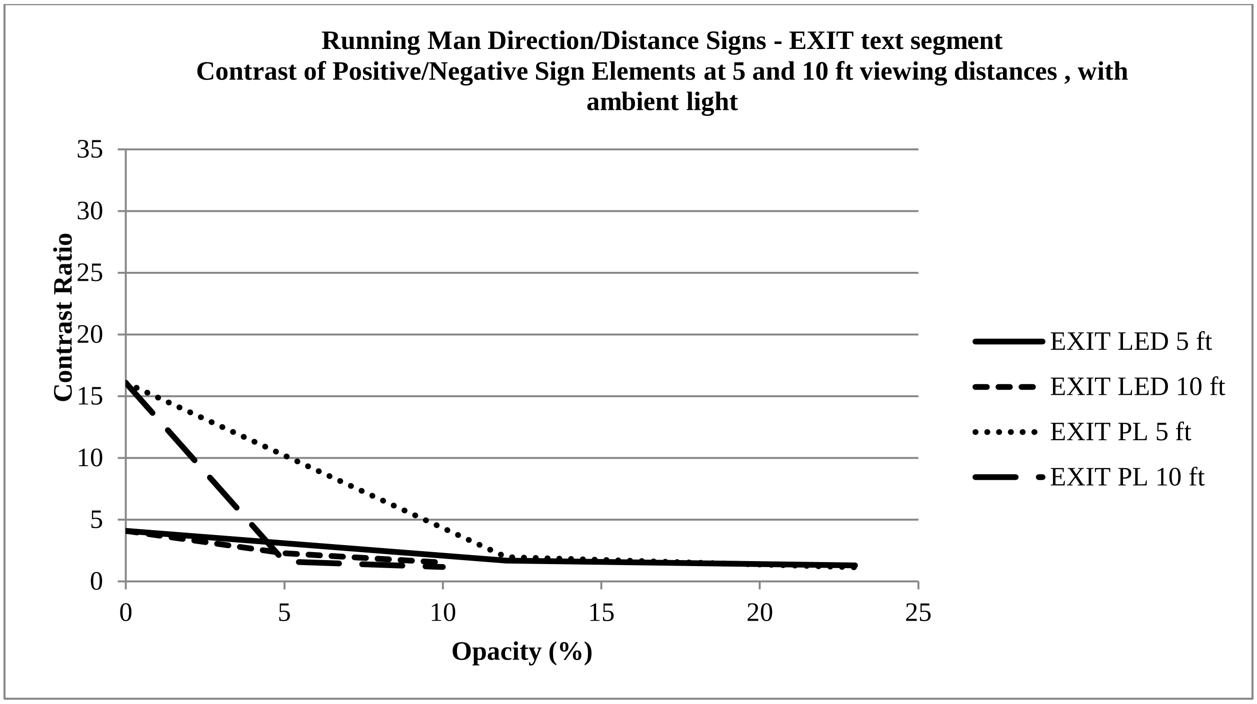


Figure 23. Contrast ratios: sign positive/negative luminance areas, with ambient light.

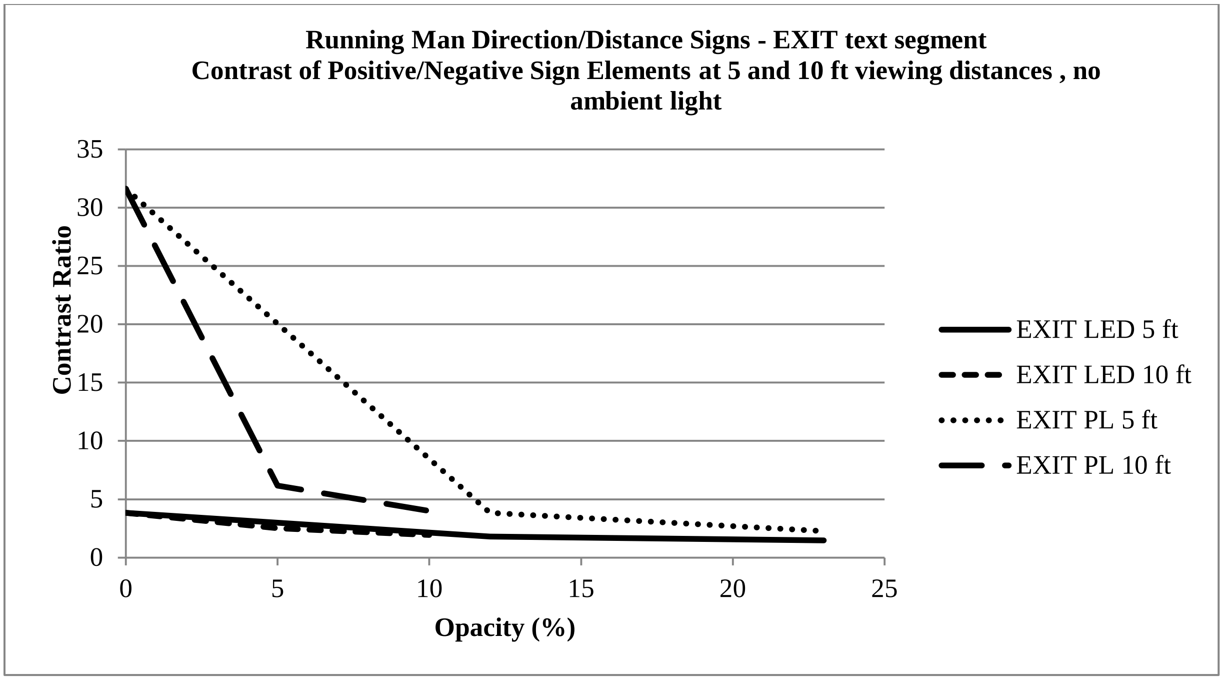


Figure 24. Contrast ratios: sign positive/negative luminance areas, with no ambient light.

All of the above descriptions focused on the negative contrast portions of the running man signs. Figure 25 compares the luminance of the LED and PL versions of the text-only EXIT signs with illuminated or photoluminescent text against a non-illuminated background. Figure 26 compares the contrast ratios of the positive and negative elements of these two signs.

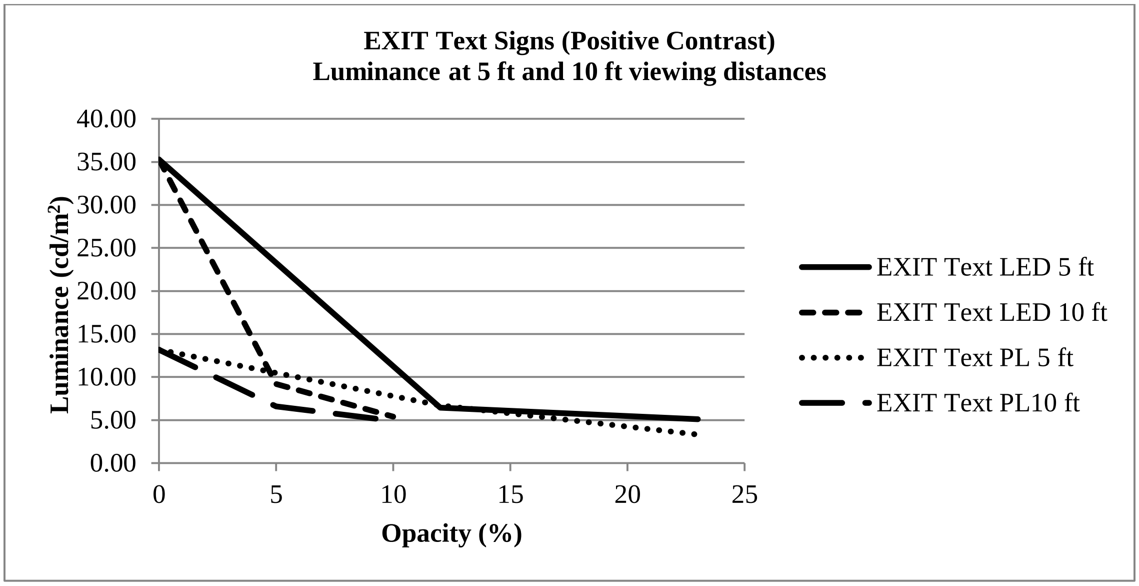


Figure 25. Luminance measurements of selected LED and PL positive contrast signs.

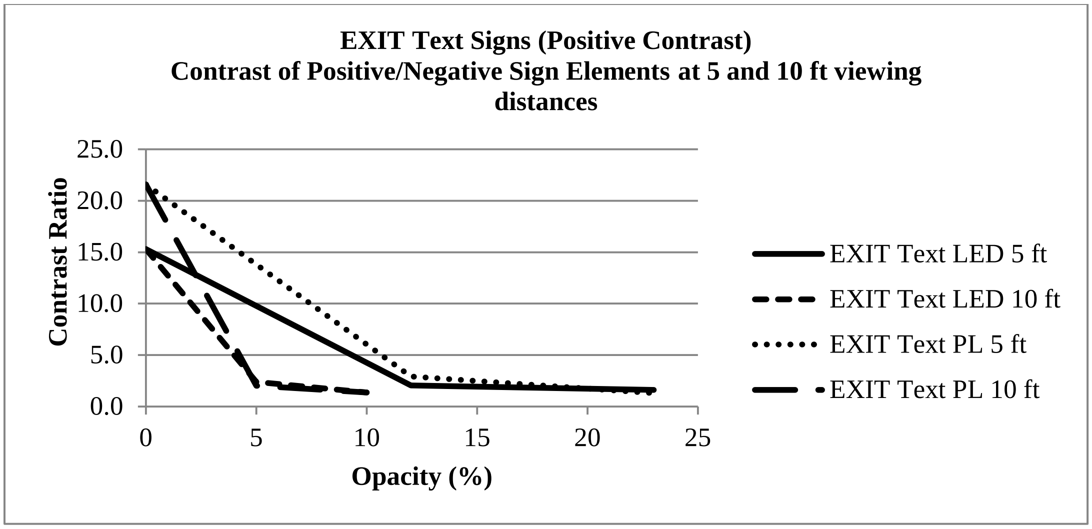


Figure 26. Contrast ratios: sign positive/negative luminance areas of EXIT text-only signs, with ambient light.

The luminance measurements all displayed some general trends that were echoed in the detection and legibility distance results in the tunnel simulation.

- All of the signs lost much of their effective luminance even with very low levels of smoke in the atmosphere. This affected how far away they could be seen and reduced the contrast between their light and dark areas, which made text and symbols more difficult to read.
- In general, PL signs began at much lower luminance levels than LED signs and remained at lower luminance levels compared to LED signs in smoky conditions. However, the differences in luminance between the PL and LED signs diminished as smoke opacity increased.
- Under low levels of ambient light, the contrast of sign luminance with the tunnel wall diminished rapidly as smoke opacity increased. In general, LED signs slightly outperformed PL signs. When there was no ambient light, contrast between the tested signs and the tunnel walls was much higher, and PL signs displayed higher contrast ratios than LED signs.
- Contrast ratios between lighter and darker regions of a sign (e.g., the contrast between a sign's legend and its background) were consistently higher for PL signs than for LED signs. This was the case with low levels of ambient light and was even more pronounced without ambient light.

DETECTION AND LEGIBILITY DISTANCES

Detection and legibility distances were recorded for each sign that participants viewed, as well as for a photoluminescent path marking square. In some cases, detection and legibility distances for a single sign were nearly identical; this happened most frequently with single-panel signs such as the text-only EXIT signs and the symbol-only running man sign.

Participants saw treatments at varying smoke opacities, despite efforts to maintain some consistency in smoke volume and density during participant testing. The output of the smoke machine could not be precisely regulated; in addition, smoke opacity gradually diminished within each participant's testing period due to the movement of the participant and researcher through the simulated tunnel. With the exception of the initial running man symbol sign, which was always presented first to participants, the test signs were presented in three different orders to help balance the effects of smoke opacity across the testing sessions; however, the exact opacity percentage at the moment each sign was viewed varied from participant to participant. Because of this variance in smoke opacity, a paired t-test of the detection distances and legibility distances could not be conducted between pairs of signs. Instead, a comparison of the scatter plots and trend lines of the detection and visibility distances for each sign was conducted.

A power regression was the best fit for most of the sign detection and visibility distances through the range of smoke opacity conditions. While smoke opacities ranged from 5.6 percent to 28.7 percent (a handful of measurements with smoke opacities less than 5 percent were removed from the data set as outliers), about two-thirds of the measured opacity levels during participant testing fell between 8 and 14 percent, with a mean opacity of 10.9 percent and a median of 10.4 percent. Table 14 summarizes the detection and legibility distances predicted by the regression equations for each of the tested signs at smoke opacities of 5, 10, 12, and 23 percent. Figure 27 extrapolates the predicted detection and legibility distances for the LED and PL versions of the running man exit distance signs at smoke opacities up to 40 percent.

Table 14. Detection and Legibility Distances Predicted at Varying Smoke Opacity Levels.

Sign		Opacity				***R^2 of Trend Line***
		5%	**10%**	**12%**	**23%**	
Predicted Detection Distance (in feet)	Running Man Exit (LED)	40.4	22.4	19.2	11.0	*0.84*
	Running Man Exit (PL)	21.6	11.1	9.4	5.0	*0.78*
	Running Man Exit Distance (LED)	44.9	24.6	21.0	11.9	*0.85*
	Running Man Exit Distance (PL)	23.6	11.9	10.0	5.3	*0.78*
	Text EXIT (LED)	28.8	15.7	13.3	7.5	*0.83*
	Text EXIT (PL)	22.0	10.6	8.7	4.4	*0.79*
	Running Man Symbol (LED)	39.1	19.2	15.9	8.2	*0.64*
	Phone (PL)	10.1	5.6	4.8	2.8	*0.36*
	Refuge (PL)	12.4	6.5	5.5	3.0	*0.34*
	Marker (PL)	22.2	12.1	10.3	5.8	*0.66*
Predicted Legibility Distance (in feet)	Running Man Exit (LED)	28.9	17.7	15.5	9.8	*0.57*
	Running Man Exit (PL)	12.8	8.0	7.0	4.5	*0.40*
	Running Man Exit Distance (LED)	34.1	18.7	16.0	9.1	*0.73*
	Running Man Exit Distance (PL)	15.2	9.0	7.8	4.8	*0.53*
	Text EXIT (LED)	21.8	14.1	12.5	8.3	*0.61*
	Text EXIT (PL)	17.2	9.7	8.3	4.9	*0.50*
	Running Man Symbol (LED)	25.3	15.0	13.1	8.0	*0.48*
	Phone (PL)	7.6	4.8	4.2	2.7	*0.35*
	Refuge (PL)	8.5	5.3	4.7	3.0	*0.25*

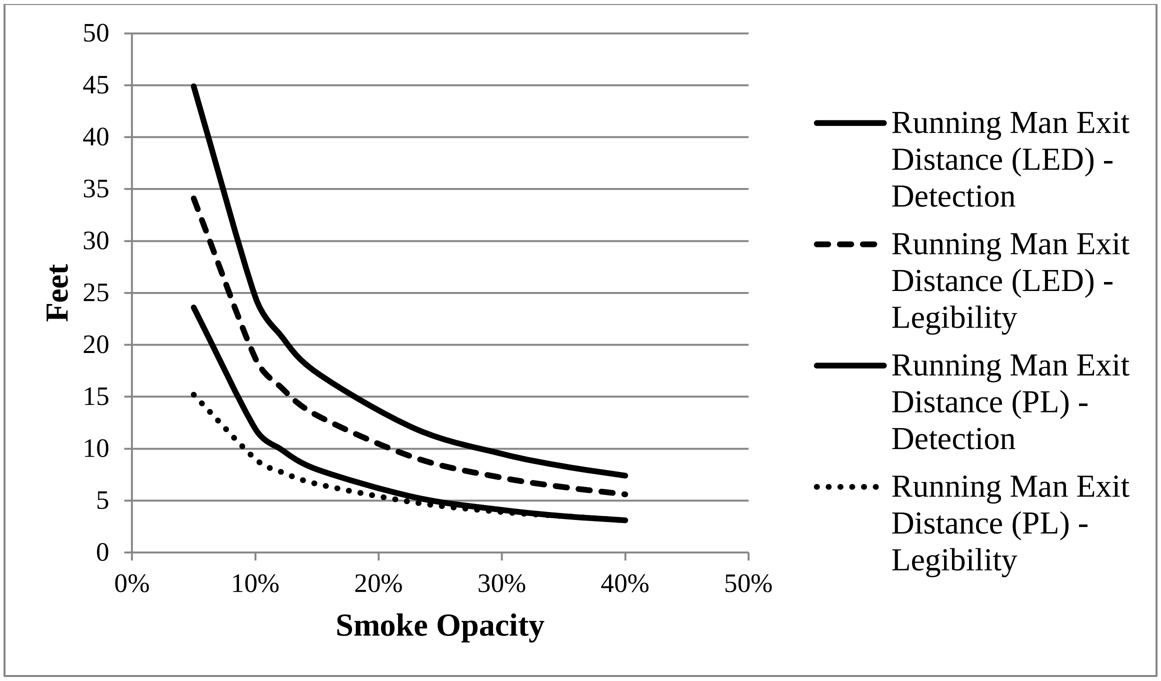


Figure 27. Estimated detection and legibility distances at varying smoke opacity percentages.

Details of the observed detection and legibility distances of tested signs are provided in the following sections.

Running Man EXIT Signs

The running man EXIT signs consisted of a running man symbol accompanied by the word "EXIT." These signs had an illuminated (LED) or glow (PL) white background, with dark green symbols and text. Figure 28 shows the scatter plots and trend lines for the detection distances of the internally illuminated and photoluminescent versions of the signs. Figure 29 shows the scatter plots and trend lines for the legibility distances of these signs.

The regression equation for detection of the LED-illuminated running man EXIT sign (R^2 = 0.84) predicted a detection distance of 22.4 feet when smoke opacity was 10 percent and 19.2 feet when smoke opacity was 12 percent. Predicted detection distance for the PL version of this sign (R^2 = 0.78) was 11.1 feet at 10 percent smoke opacity and 9.4 feet at 12 percent opacity, approximately half the respective distances for the LED version of the sign. Greater variances in the observed legibility distances for these two signs resulted in weaker trends than those for the detection distances, but predicted legibility distances for the PL sign were also about half the distances for the LED sign at 10 percent and 12 percent smoke opacity.

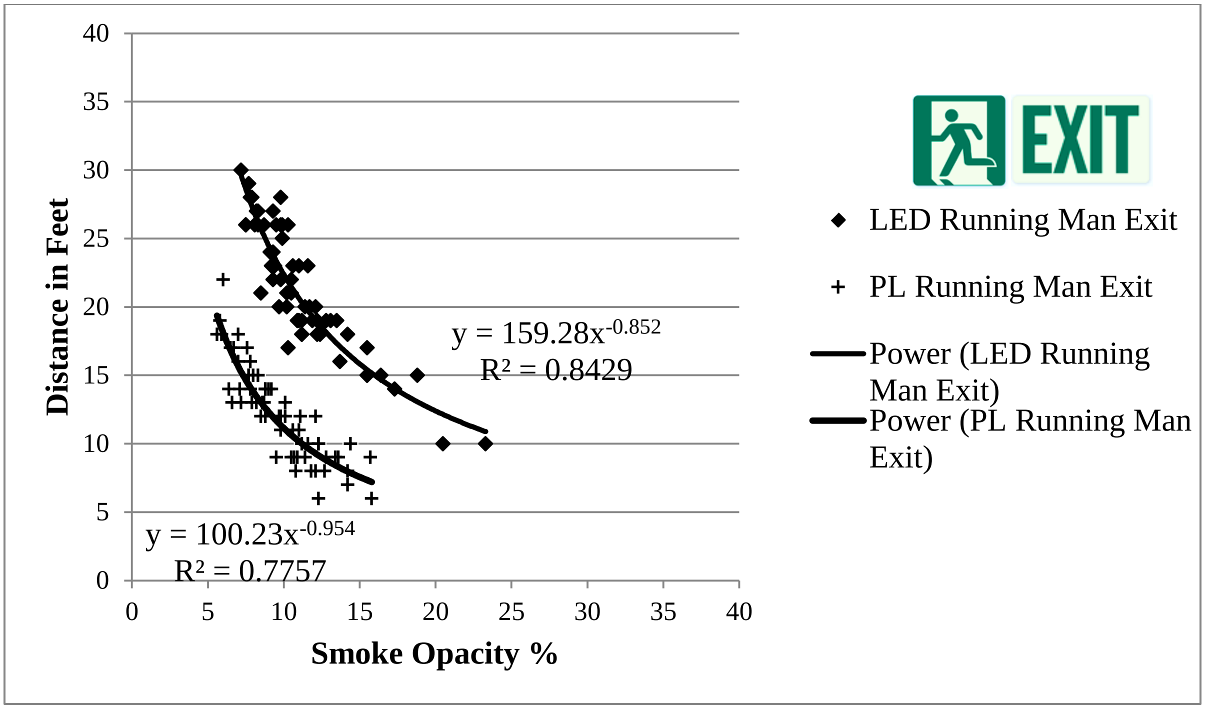


Figure 28. Detection distances for running man EXIT signs, LED and PL.

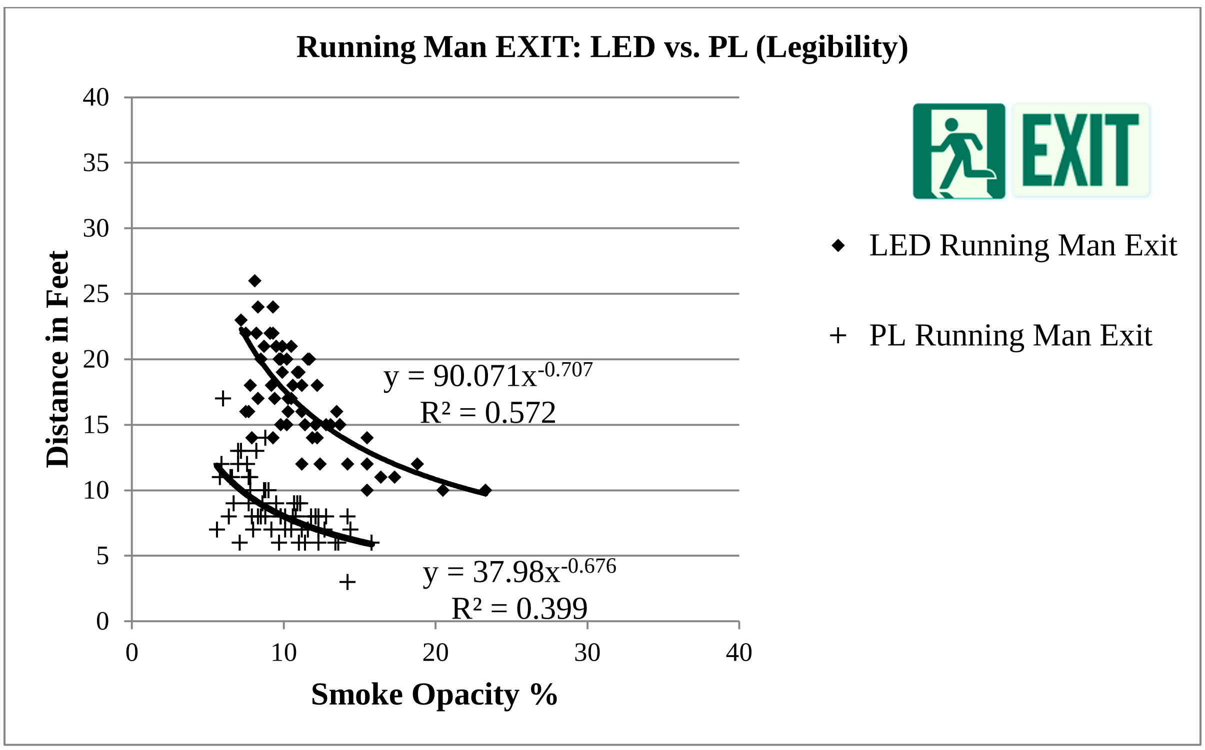


Figure 29. Legibility distances for running man EXIT Signs, LED and PL.

Running Man Directional/Distance Signs

The running man directional/distance test signs included the running man symbol and "EXIT" text, plus a distance shown in numerals and a tailed arrow pointing either left or right. Figure 30 shows the scatter plots and trend lines for the observed detection distances of the internally illuminated and photoluminescent versions of the running man directional signs. Figure 31 shows the scatter plots and trend lines for the observed legibility distances of the internally illuminated and photoluminescent versions of these signs.

The regression equation for detection of the LED-illuminated running man direction/distance sign ($R^2 = 0.85$) predicted detection distances of 24.6 feet at smoke opacity of 10.0 percent and 21 feet at 12 percent opacity. Detection distances predicted for the PL version of this sign ($R^2 = 0.77$) were 11.9 feet at 10 percent smoke opacity and 10 feet at 12 percent opacity. Legibility distances predicted for the LED version of the sign ($R^2 = 0.73$) were 18.7 feet at 10 percent smoke opacity and 16.0 feet at 12 percent opacity; the legibility distances predicted for the PL version of the sign ($R^2 = 0.53$) were 9 feet at 10 percent opacity and 7.8 feet at 12 percent opacity.

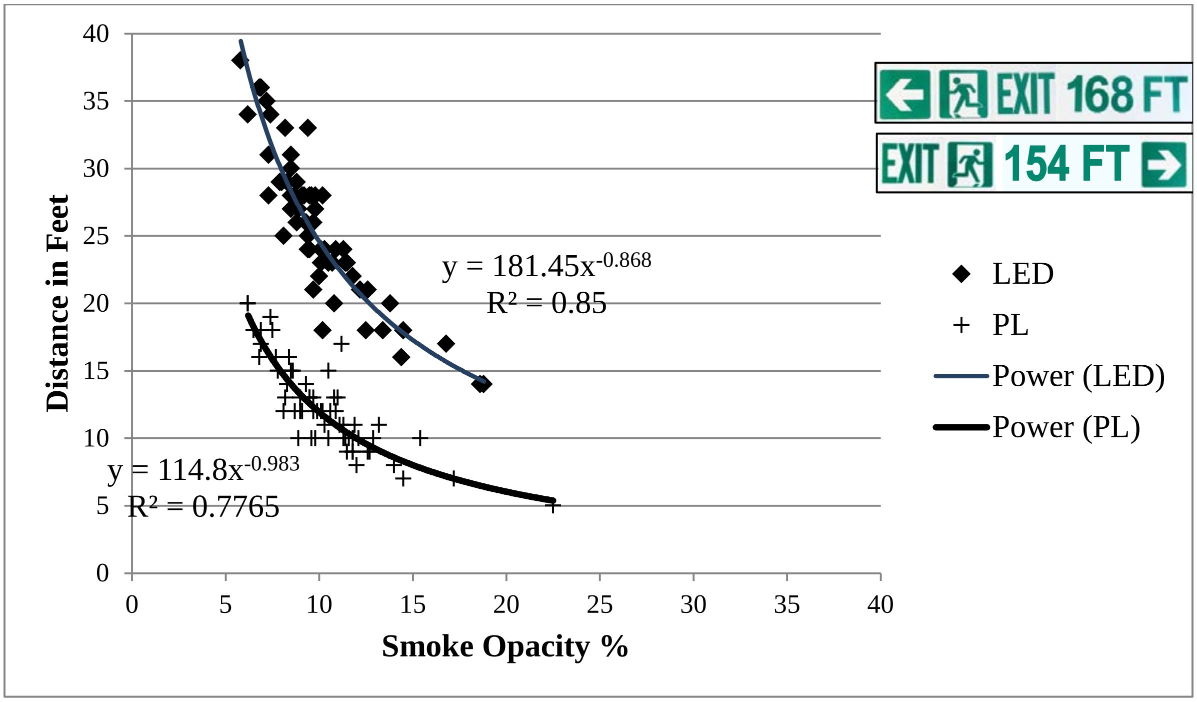


Figure 30. Detection distances for running man direction/distance signs, LED and PL.

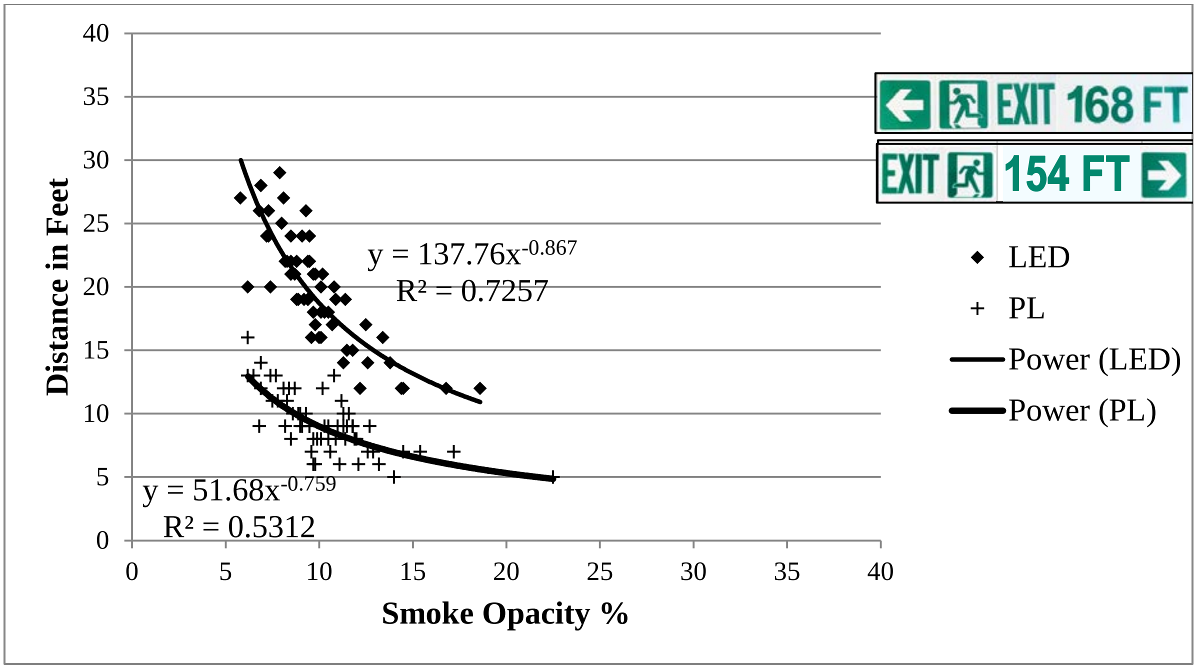


Figure 31. Legibility distances for running man direction/distance signs, LED and PL.

Text EXIT Signs

Two text-only EXIT signs with illuminated (LED) or glow (PL) letters on a non-illuminated background were tested. The LED version of the sign had red illuminated text illuminated internally by red LEDs; the PL version of the sign had photoluminescent white text. Significantly, these two signs were the only two positive contrast (i.e., illuminated text against a non-illuminated background) exit signs tested; the other exit signs were negative contrast signs, with illuminated or glow backgrounds and darker text. Figure 32 shows the scatter plots and trend lines for the detection distances of the internally illuminated and photoluminescent versions of the text EXIT signs. Figure 33 shows the scatter plots and trend lines for the legibility distances of these two signs.

The regression equation for detection distance of the LED text-only EXIT sign ($R^2 = 0.83$) predicted detection distances of 15.7 feet at smoke opacity of 10 percent and 13.3 feet at opacity of 12 percent. Detection distances predicted for the PL version of the EXIT text sign ($R^2 = 0.79$) were 10.6 feet at 10 percent smoke opacity and 8.7 feet at 12 percent opacity.

Predicted legibility distances for the LED sign ($R^2 = .60$) were 14.1 feet at 10 percent opacity and 12.6 feet at 12 percent opacity. Predicted legibility distances for the PL sign ($R^2 = .49$) were 9.7 feet at 10 percent opacity and 8.4 feet at 12 percent opacity.

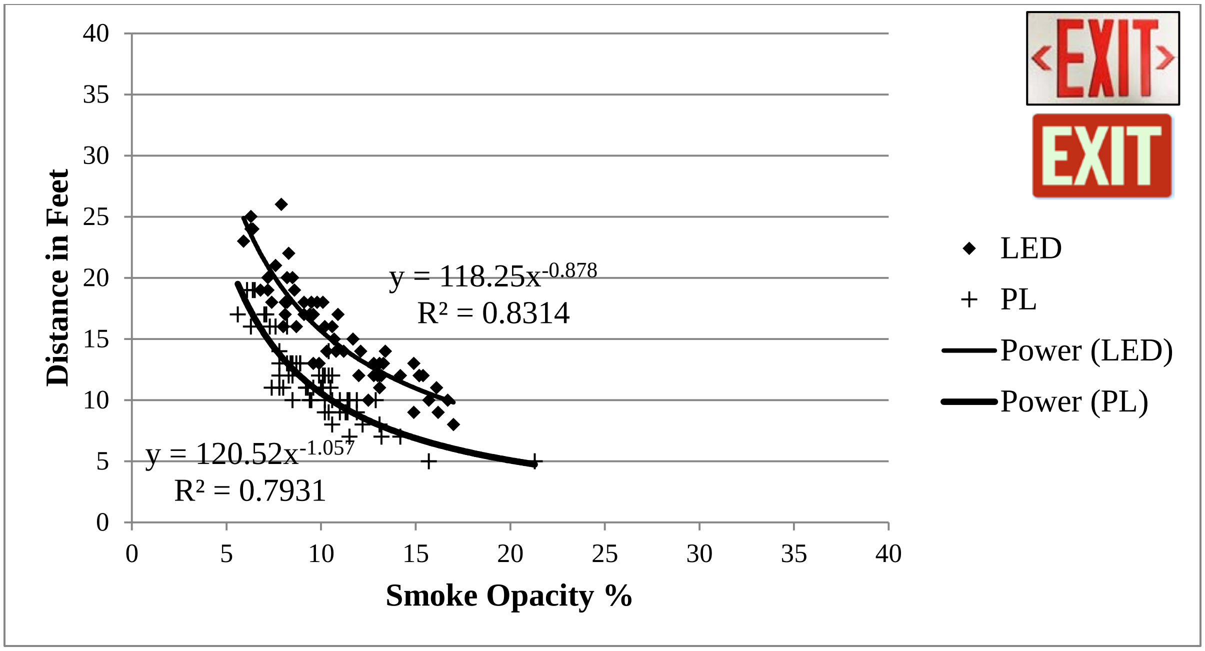


Figure 32. Detection distances for text EXIT signs, LED and PL.

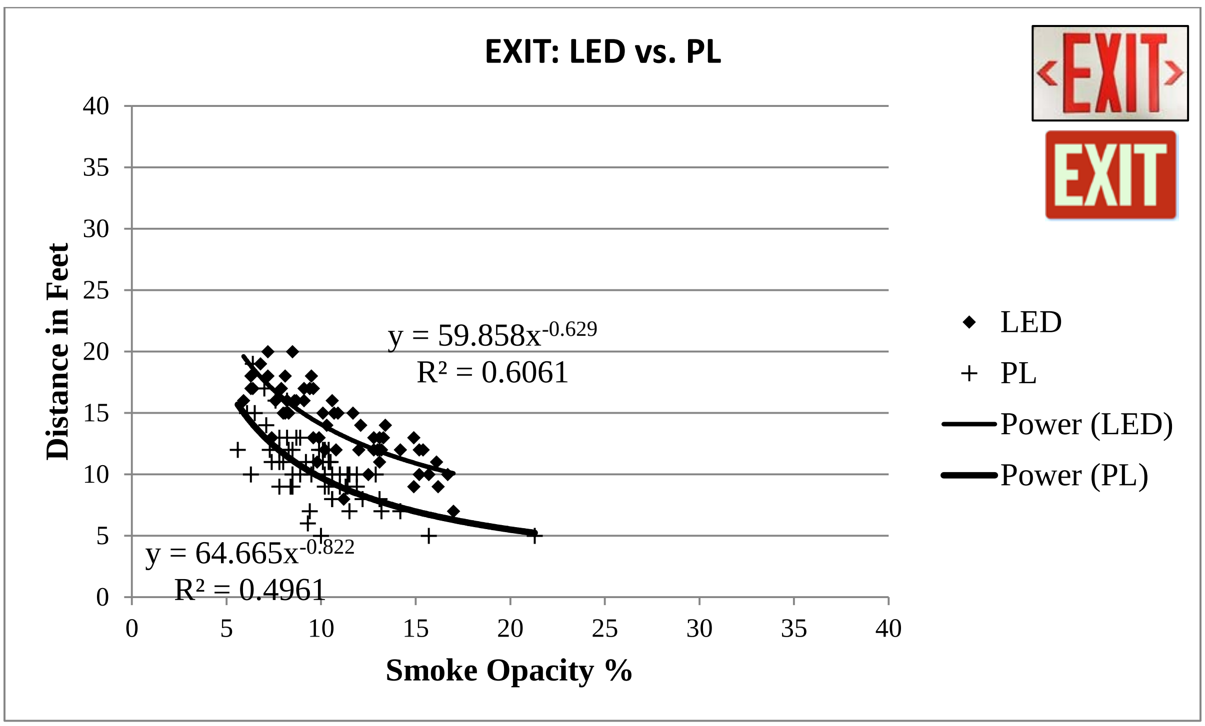


Figure 33. Legibility distances for text EXIT signs, LED and PL.

Running Man Symbol (LED)

The running man symbol-only sign was the first sign presented to participants. Because the artificial smoke in the tunnel was densest at the start of each testing session, the average opacity at which participants viewed this sign was just over 14 percent. Additionally, since this was the first sign that participants saw, it was also the practice sign: participants learned with this first sign what to look for and where (at least in terms of height above the floor). It is not surprising, therefore, that the observed detection and legibility distances varied somewhat more than those for most of the other exit signs (see Figure 34). The regression equation for the detection distance of the running man symbol-only sign ($R^2 = 0.64$) predicted detection distances of 19.2 feet at 10 percent smoke opacity and 15.9 feet at 12 percent opacity. Legibility distances at the same two opacities were predicted as 14.9 feet and 13.0 feet ($R^2 = 0.48$).

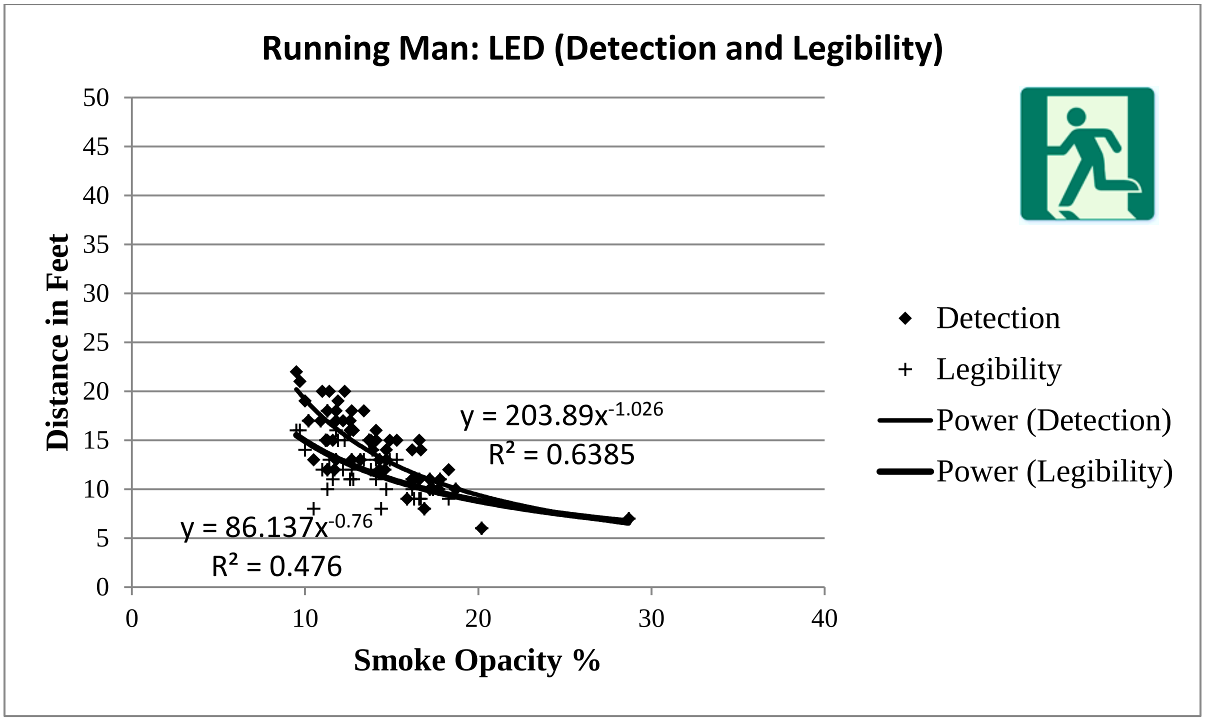


Figure 34. Detection and legibility distances for running man symbol-only sign (LED).

Emergency Phone and Refuge Point Signs

The emergency phone and refuge point signs were considerably smaller than the exit signs, and the photoluminescent material was not as powerful as other photoluminescent signs used. For these reasons, the detection and legibility distances for these signs were short, and the variability of these distances resulted in very weak regression trend lines (see Figure 35 and Figure 36).

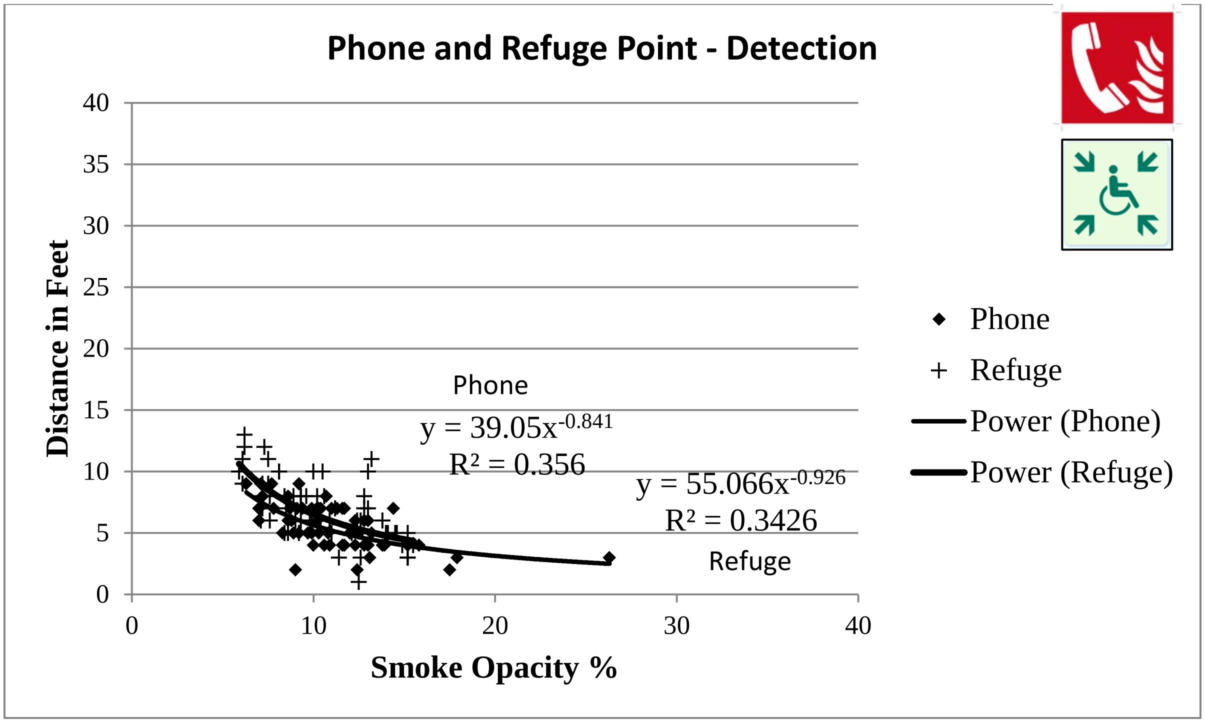


Figure 35. Detection distances for emergency phone and refuge point signs.

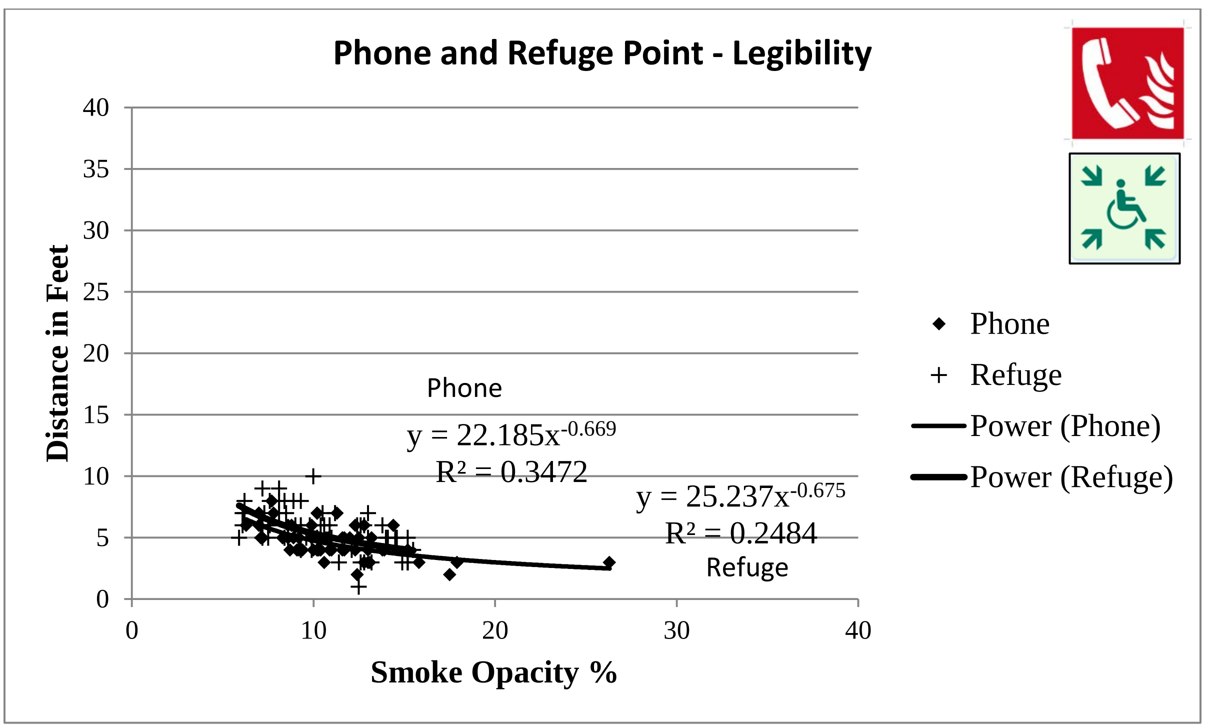


Figure 36. Legibility distances for emergency phone and refuge point signs.

PL Path Marker

Detection distances predicted for the PL path marker ($R^2 = 0.67$) were 12.1 feet at 10 percent smoke opacity and 10.3 feet at 12 percent opacity (see Figure 37).

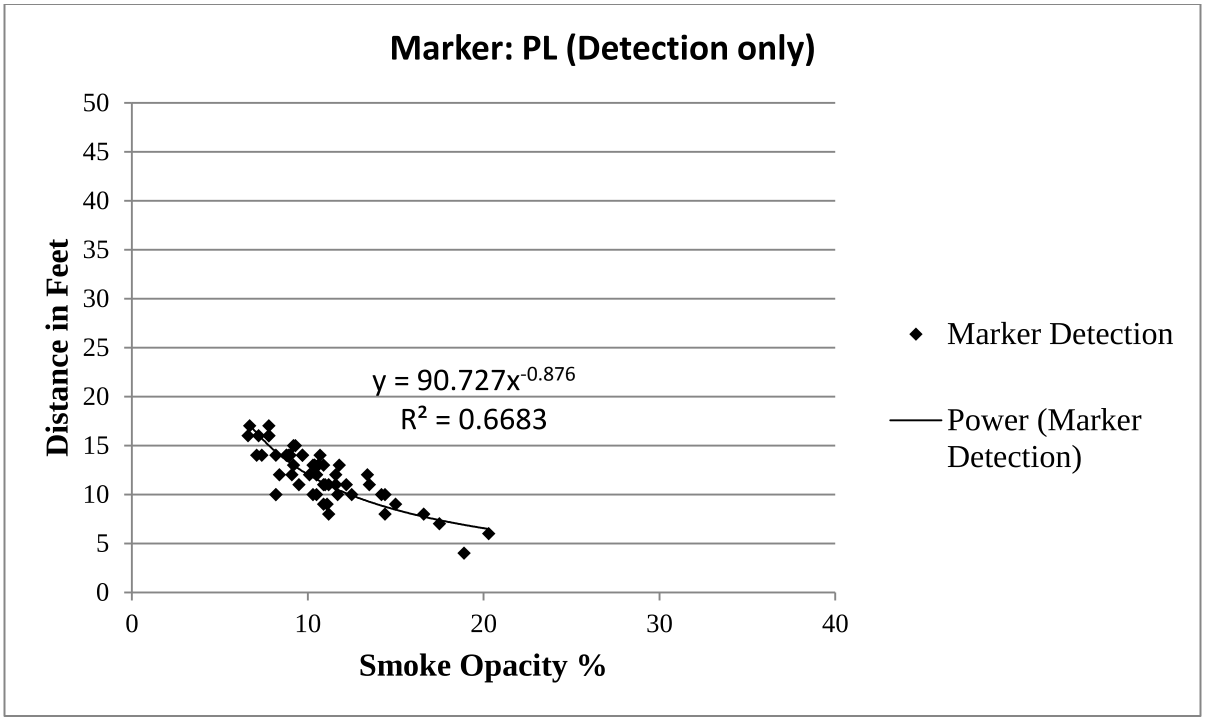


Figure 37. Detection distances for PL path marker.

PHOTOMETRIC MEASUREMENT AND VISIBILITY CONCLUSIONS

Smoke density/opacity was a significant factor in detection and visibility distances, as would be expected from the sharp drop in sign/marking luminance and contrast that was seen in the photometric measurements. The internally LED-illuminated signs could all be seen from farther away than the photoluminescent signs; the regression equations for the detection and legibility distances indicate that most of the internally LED-illuminated signs could be detected and read at approximately twice the distances of the corresponding photoluminescent signs. An exception was the positive contrast PL EXIT sign, with detection and legibility distances that were between 60 and 75 percent of the distances for the LED version of the positive contrast EXIT sign, depending on the smoke opacity levels (the LED version of this sign, however, was also less bright than the LED versions of the running man signs).

Visibility testing with participants was done at an ambient lighting level of 10 lux measured at floor level, provided by overhead LED bulbs. Photometric measurements confirmed that even this low level of ambient lighting, when smoke was present, generated veiling luminance that reduced contrast ratios between the signs and the tunnel wall, and between sign legends and backgrounds. The measurements suggest that lowering overhead/ambient light level below 10 lux while providing brightly lit signs and path markers may improve visibility of the exits and exit paths in smoky conditions.

CHAPTER 6. CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTED RESEARCH

This study focused on providing data to help accomplish the project's primary objectives:

- Determine the messages and delivery methods (visual, audible, or both) that will encourage drivers to leave their cars and exit a tunnel on foot when conditions warrant such an evacuation.
- Determine the sign graphics and colors, sign messages, marking types and colors, and auditory messages that most effectively lead people to emergency tunnel exits.
- Determine the most visible sign and marking materials and technologies for dark and smoky conditions.

Conclusions and recommendations pertaining to each of these objectives are summarized in this chapter. More detailed recommendations are presented in a proposed set of guidelines, published as a brochure, which can be found at http://www.trb.org/Main/Blurbs/173414.aspx.

RESEARCH CONCLUSIONS

Emergency Evacuation Messages

The literature, the focus groups, and the tunnel simulation all pointed to the value of notifying vehicle occupants of an emergency situation and providing clear directions about the appropriate course of action. The results of the tunnel emergency simulation, which presented visual and audio evidence of an unfolding fire-related emergency to participants, provided a strong indication that drivers are more likely to leave their vehicles and self-evacuate if they see or hear a message instructing them to do so.

The two messaging media tested during the tunnel simulation (DMS and audio) appeared to be equally effective in convincing participants that leaving the vehicle was the proper course of action.

Emergency Exit Sign and Marking Formats

Comprehension of the ISO 7010 running man symbol was tested in the focus groups and with the tunnel simulation participants. While a symbol-only version of the sign was understood or partially understood by approximately 86 percent of participants, most participants preferred a sign that combined the symbol with "EXIT" text. Directional signs that included the running man symbol, "EXIT" text, a directional arrow and a distance in feet were correctly interpreted by 98 percent of participants. These results indicate that a combination symbol and text sign is likely the best option for marking emergency exits in the United States, at least until the running man symbol is more widely recognized by U.S. residents.

During the tunnel simulation, the most common misconception among participants regarding the running man exit sign was that the running man symbol was next to an exit or indicated the direction of a nearby exit, versus being on the exit door itself (the text-only EXIT sign currently standard in most U.S. buildings was anticipated by most participants to be on or over the door itself). However, all signs in the simulation were placed in a frame on the wall for visual consistency, rather than some being placed on a door; a running man sign placed on an exit door would provide visual context for this symbol that simulation participants did not have.

Seventy-five percent of participants expressed preferences for tailed directional arrows over chevron-style arrows, and a few participants did not recognize chevron-style arrows as directional symbols. Tailed arrows pointing directly left or right were clearly understood; arrows pointing directly up or down, or pointing diagonally up or down (e.g., to indicate an exit located up or down stairs), required explanation.

Of the three LED path marking formats tested, lights illuminating/strobing in a sequence that indicated a direction were the most favored by participants. Lights that flashed/strobed in unison along the path were second in preference overall, and lights that remained on (without flashing/strobing) were third.

A simulated audio beacon with a repeated "exit here" announcement was considered helpful by a majority of participants though some could not tell which direction the sound was coming from. It should be noted that the acoustics of the simulated tunnel were not the same as they would be in an actual highway tunnel.

Sign Technologies

The tested photoluminescent signs were not as bright as internally illuminated signs under the test conditions, and visibility distances were shorter on average (with low levels of ambient light in white smoke). However, the PL signs tested had higher contrast ratios between the text and background compared to LED signs, as well as greater contrast ratios with the tunnel wall versus LED signs when both were tested with photometric equipment in dark conditions.

The reduction in contrast ratios for both types of sign was due in part to light scatter off smoke particles. Visibility testing was conducted in ambient light of approximately 10 lux (typical of a tunnel under emergency lighting levels). Higher ambient light levels, such as what would typically be present in non-emergency tunnel lighting, could result in increased light scatter when smoke is present; this might have the effect of further reducing the contrast ratios and therefore the visibility of signs. A strategy that merits further exploration is reducing overhead or other ambient lighting along pedestrian evacuation paths to increase the visibility and conspicuity of exit path lights and exit signs in smoky conditions. It may also be advisable to space signs more closely together or to use lighted or photoluminescent path markings to provide additional visual cues between signs.

RECOMMENDATIONS

The study results highlighted the importance of communicating emergency information, including evacuation instructions when necessary, to vehicle drivers and occupants, and provided support for the use of the running man symbol on emergency exit signs. The study's major recommendations are summarized below; these and additional recommendations are detailed further in the proposed guide.

Emergency Evacuation Messages

An emergency evacuation message should contain, at minimum, the following pieces of information:

- A brief statement about the nature of the emergency, e.g., "fire in tunnel" or "vehicle fire ahead."

- Direct instructions about the action to take, e.g., “walk to exits” or “leave vehicles, walk to exits” if evacuation on foot is warranted. An evacuation direction should be specified (e.g., upstream of the fire) if applicable.
- If slightly longer messages are possible, given the medium used, it may be beneficial to include a small amount of supplementary information. Useful supplementary information can include the identity of the person or agency making the announcement and additional instructions or guidance regarding exit locations and procedures.

Emergency Exit Sign and Marking Formats

The ISO 7010 running man symbol is recommended for use on emergency exit signs for highway tunnels. An additional recommendation is to include text specifying “EXIT” with the symbol, at least until the symbol achieves wider recognition in the United States.

As specified in NFPA 502, signs indicating directions to emergency exits should be placed at least every 25 meters (82 feet) along the tunnel wall. These signs should include the running symbol and “EXIT” text, with the addition of a tailed directional arrow and the distance to the nearest exit in feet. If exits are located in two directions relative to the location of the sign, two signs should be placed side by side to indicate the directions and respective distances to the two exits.

Exit path markings are recommended to supplement directional signs in guiding pedestrians to emergency exits. Markings should be placed no higher than 1 meter (3.3 feet) from the ground or trafficway surface.

Exit doors should be marked with distinctive lighting as well as exit signs. The recommended lighting scheme is the one described by CIE 193-2010, including both illumination around the door and supplemental emergency strobe lights flashing at a rate of 1 to 2 Hz.

Auditory beacons may be beneficial as a supplemental exit door marker, depending on acoustic conditions. Auditory beacons may be used to supplement (not replace) illuminated exit door lighting and, if used, should be calibrated to be audible to listeners who are in relatively close proximity to the exit door. The recommended sound is a simple, repeated voice announcement such as “exit here,” which may be in more than one language (in addition to English).

Sign Technologies and Visibility

Because of the severe degradation of sign contrast in smoke, the designed contrast ratio between sign backgrounds and legends should be as high as possible given the materials and colors used. This is one metric in which the tested PL signs scored higher than the tested LED-illuminated signs. If internally illuminated signs are used, greater contrast can be achieved by maximizing the opacity of the negative/darker elements of the sign.

Photoluminescent signs require ambient light in order to charge. If photoluminescent signs are used for emergency exits or path indicators, it is recommended that they be selected in consultation with a manufacturer that specializes in materials for tunnel environments, taking expected ambient light levels into consideration.

Depending on the available power and control infrastructure, LED lights or photoluminescent markings may be used to delineate an emergency exit path for pedestrians. LED lights that can be controlled by tunnel operators to indicate a recommended direction to an exit (e.g., by illuminating in a sequence that indicates movement in a given direction) were considered particularly useful by most study participants, but any marker that is visible under a variety of potential emergency conditions (darkness, smoke, etc.) should be helpful to evacuees.

SUGGESTED RESEARCH

Given the wide range of tunnel geometries and infrastructures, the myriad of possible emergency situations that may arise, and the evolving technologies for signs and markings, mass communications, and emergency management, the project team identified several potential issues that can be addressed in further detail and refined through further research. These issues are discussed in the following sections.

Emergency Announcements/Messages

The DMS messages used in this study to provide information about the hypothetical tunnel emergency to focus group and simulation participants were two-phase messages. Two phases are the maximum currently recommended by the MUTCD for dynamic signs, though that recommendation assumes three lines of text for each phase, while the DMS used in the study was a single line of text. While there might be some benefit to providing additional information (beyond the MUTCD two-phase standard) in stopped traffic conditions, there could also be the danger that people will delay taking action if they think that further information will continue to be provided on the DMS. A short, repeated message may convince people to start moving. The question of the maximum number of message phases for both normal and emergency conditions in a highway tunnel merit additional testing in the future.

Further research is needed to examine the effects of tunnel reverberation, ambient noise from traffic and from other emergency systems (ventilation fans, fire suppression systems), and other conditions that can interfere with the intelligibility of audio announcements from loudspeakers.

While the current study focused on fire as the emergency incident, future behavioral research should examine an all-hazards approach for providing messages and advisories to drivers about other types of incidents and emergencies.

Sign and Marking Formats and Placement

This study tested exit signs with 6-inch-tall text and graphics. Depending on the width of a highway tunnel, larger-scale emergency exit signs may be necessary or beneficial. A larger-scale visibility test, perhaps conducted in an actual highway tunnel or a test facility such as the Memorial Tunnel in West Virginia, would allow for a realistic comparison of different size signs.

In a two-bore tunnel with cross passages between the bores, should emergency exit signs (directing pedestrians to exit from one bore to the other via the cross passage) be placed only on the walls adjacent to the exit, or should supplemental signs be placed on walls that are opposite to exits? Signing for this and other complex tunnel geometries is another research topic that would be suitable for testing in an actual tunnel environment.

Successive signs along a tunnel passageway, for instance, distance signs showing progressively shorter distances to a tunnel exit, could not be tested within the limited space of the simulated tunnel. A larger-scale testing environment would provide the opportunity to test the effects of successive signs and markings on user comprehension and confidence regarding exit locations.

Similarly, signs showing the distances to emergency exits in two opposite directions were not tested in this study due to size constraints in the testing facility; while the study's results for the two-directional text EXIT sign (without distances being specified) and the single-direction exit distance signs indicate that two-directional distance signs would likely be well understood, an actual test of this configuration would provide a more definitive answer.

Recent testing by the University of Greenwich in the United Kingdom found that signs with dynamic elements—specifically, signs with flashing green arrows to indicate an exit direction and signs with red X's to indicate a route that does not lead to an exit—were well understood, were noticed by more people than static signs, and reduced evacuation time. (The Guardian, 2014) This and potentially other types of dynamic signage would be valuable to test with United States drivers.

IMPLEMENTATION OF RESEARCH FINDINGS AND PRODUCTS

As stated in the introduction to this report, there is not yet a consistent format for emergency exit signs and markings for highway tunnels across the United States. Implementing the proposed guidelines into practice and incorporating them into existing standards will require input and acceptance from NFPA, as well as from professionals and professional organizations in the tunnel and roadway operations industries and in the emergency response community. This plan proposes activities to be conducted by the research team to promote the proposed guidelines, as well as products and activities that could potentially be developed as future implementation projects.

Successful implementation of the proposed guidelines should result in widespread adoption of the running man symbol + EXIT text as the accepted format for emergency exit identification in highway tunnels in the United States. The adoption of this sign format, as well as other recommended elements such as exit door and exit path markings, is likely to be gradual as new tunnels are built and existing ones are refurbished. The guidelines may also evolve as further research is conducted (as outlined in the previous section).

Initial Implementation—Presentations and Papers on Study Recommendations

Implementation activities conducted by research team members will include development of papers and presentations on this research study and the proposed guidelines, to include the following:

- A brief PowerPoint presentation will be prepared, highlighting the study results and major recommendations from the proposed guidelines. Target audiences include AASHTO's T-20 Subcommittee on Bridges and Structures, the NCUCTD Regulatory and Warning Signs Technical Committee, and one or more of NFPA's technical committees if possible (502 Road Tunnel and Highway Fire Protection Technical Committee, 101 Safety to Life – Means of Egress, and/or 72 Signaling Systems—Public Fire Reporting Systems). The research team includes members on the AASHTO and NCUCTD technical committees, but not currently on NFPA committees, which may preclude the opportunity to present directly to that audience. This presentation can be prepared prior to the end of the current contract.
- A proposal will be submitted to present study findings and recommendations at the 2016 NFPA Conference & Expo (proposals due in September 2015).
- One or more papers will be written for submittal to the Transportation Research Board's 2016 Annual Meeting and the Transportation Research Record (submittals due July 2015). The paper will be submitted to the AFF60 Tunnels and Underground Structures Committee for review.

- If permissions can be secured, a presentation focusing on the study recommendations will also be delivered as a webinar and/or conference presentation to the National Volunteer Fire Council, International Association of Fire Chiefs and International Association of Chiefs of Police, and/or the International Bridge, Tunnel and Turnpike Association (IBTTA).

In addition to the committee and conference presentations (if submissions are accepted for presentation), the proposed guidelines will be submitted as a potential annex to NFPA 502, through the NFPA's online public input process.

Table 15 summarizes the implementation activities and expected milestone dates.

Table 15. Implementation Activities by Research Team.

Implementation Activity	Intended Audiences	Target Completion Dates
Prepare PowerPoint presentation summarizing study results and major recommendations	NCUTCD, AASHTO, NFPA subcommittees	• August 1, 2015
Submit paper(s) for submission to TRB	Transportation professionals	• July 31, 2015 – submit paper for review • January, 2016 – present paper (if accepted)
Submit proposal to present at NFPA Conference & Expo	Fire protection professionals and emergency responders	• September 30, 2015 – submit proposal • June, 2016 – present (if accepted)
Contact National Volunteer Fire Council, International Association of Fire Chiefs and International Association of Chiefs of Police, IBTTA	Emergency responders, tunnel operators	• August 1, 2015 – contact organization representatives and report results to NCHRP • TBD (based on feedback) – conduct webinars/presentations

Suggested Future Implementation Projects

The following activities are suggestions for future outreach, training, and funding programs to encourage the implementation of the proposed guidelines by tunnel operators and to expand training and education regarding emergency exit signs and markings.

- Development of a module to be used with the Federal Emergency Management Agency's (FEMA) national incident management training when the training is being delivered to responders that have tunnels in their area of responsibility.
- A web video for drivers that educates them about the importance of having a plan to self-evacuate from a highway tunnel if needed, where to look/listen for emergency announcements when inside a tunnel, and what highway tunnel emergency exit doors,

exit path markings, and exit signs look like. Examples of similar videos include a three-video series by EastLink Tunnel Safety in Australia, viewable on YouTube.

- A laminated visor card for emergency responders, illustrating the running man exit and related emergency signs and their meanings.
- A planning template for tunnel operators that includes an assessment of existing emergency exit signs and markings in a highway tunnel and an integration plan for replacement and/or additional devices.
- Establishment of a technical services contact that practitioners can use to get guidance and assistance on implementation of emergency exit signs and markings.
- A grant program to assist tunnel operators in purchasing new exit signs and conducting training for their operators and local emergency responders.

Table 16 lists the intended audiences and potential lead agencies for the suggested implementation projects.

Table 16. Suggested Future Implementation Projects.

Implementation Project	Intended Audiences	Potential Lead Organizations/Agencies
Submit recommendations to NFPA 502 via public input process.	NFPA 502 technical committee	AASHTO T-20 Committee, TRB AFF60 Committee on Tunnels and Underground Structures, or FHWA
Module for FEMA national incident management training.	Emergency responders	IBTTA
Web video on tunnel incidents and self-evacuation.	Drivers/Public	State DOTs, local transportation and/or tunnel authorities
Laminated visor card illustrating tunnel exit signs.	Emergency responders	State DOTs, local transportation and/or tunnel authorities
Sign/marking planning template.	Tunnel operators	AASHTO, FHWA
Technical services contact for guidance on implementation of emergency exit signs and markings.	Tunnel operators	FHWA, state DOTs
Grant program for new exit sign purchases and operator/responder training.	Tunnel operators	State DOTs

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Appendix C

Photographs

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Appendix C Photographs

Fire Detection

Photo 1: Remains of Ventilation Control Niche. Control System has been removed.

Photo 2: Remains of Fire Extinguisher Niche. Fire Extinguisher has been removed.

Photo 3: Remains of Telephone (Left) and Traffic Control Niche (Right) at West Portal SB Barrel. Similar arrangement at all Portals.

Photo 4: Remains of Fire Extinguisher Niche. Note deterioration in tunnel liner wall.

Egress

Photo 5: Existing NB Barrel Cross Section with 2'-6" safety curbs and gated entrance to abandoned control room. Also note inoperable tunnel lights in ceiling.

Photo 6: Gate entrance to abandoned control room.

Photo 7: Interior of abandoned control room.

Emergency Vent

Photo 8: Control room showing rectangular opening for ventilation fans and 6'0" diameter ventilation shafts leading to ventilation building at top of West Rock Ridge.

Photo 9: Control room showing rectangular opening for ventilation fans and 6'0" diameter ventilation shafts leading to ventilation building at top of West Rock Ridge.

Photo 10: Dual openings for ventilation fans that have been removed.

Photo 11: Existing 6'-0" diameter ventilation shaft. Note the evidence of leakage at joints in shaft.

Photo 12: Existing concrete tunnel liner. Note the deterioration and exposed rebar, all conditions that could affect the fire resistance of the existing concrete tunnel liner.

Electrical Systems

Photo 13: Abandoned Electrical Junction Box with exposed wiring.

Photo 14: Existing PVC Conduit with duct tape repairing damage to the conduit.

Photo 15: Abandoned conduit with exposed wiring in control room.

Photo 16: Lighting in control room no longer functioning.

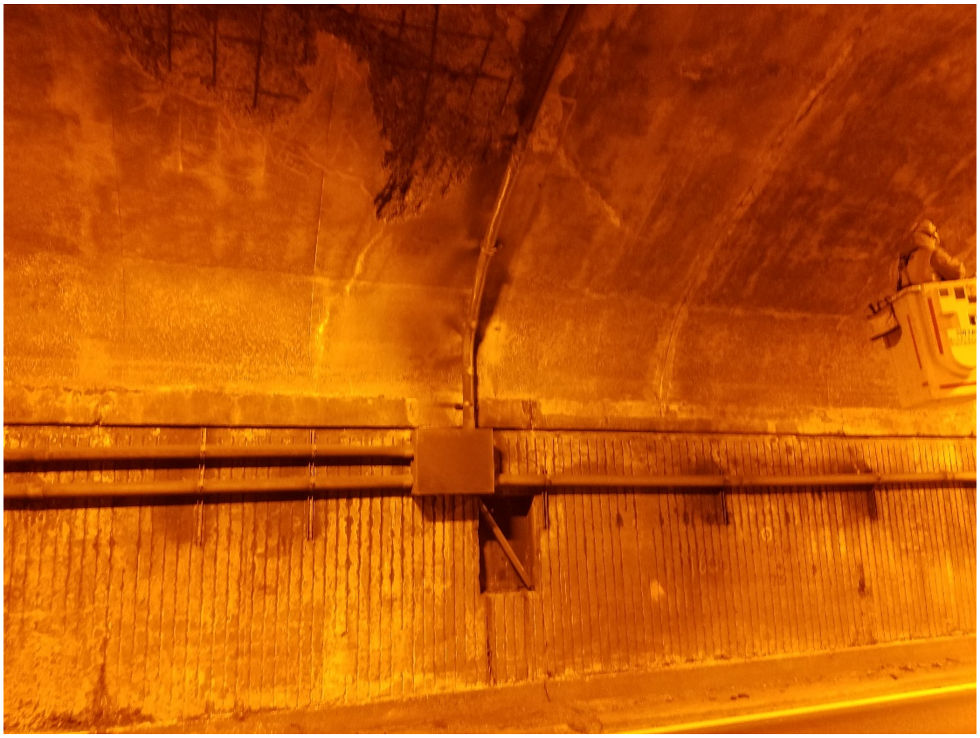

Photo 17: Conduit in SB Barrel at tunnel centerline with junction box and a run of conduit mounted to ceiling going to the lighting system.

Photo 18: Inoperable tunnel lighting. Note condition of concrete tunnel liner with extensive map cracking and efflorescence.

Photo 19: Lighting at tunnel portal.

Photo 20: Tunnel lighting with random luminaires no longer functioning.

Photo 21: Ventilation Exhaust Building at top of West Rock Ridge.

Photo 22: Ventilation Exhaust Building at top of West Rock Ridge.

Electrical Cabinet

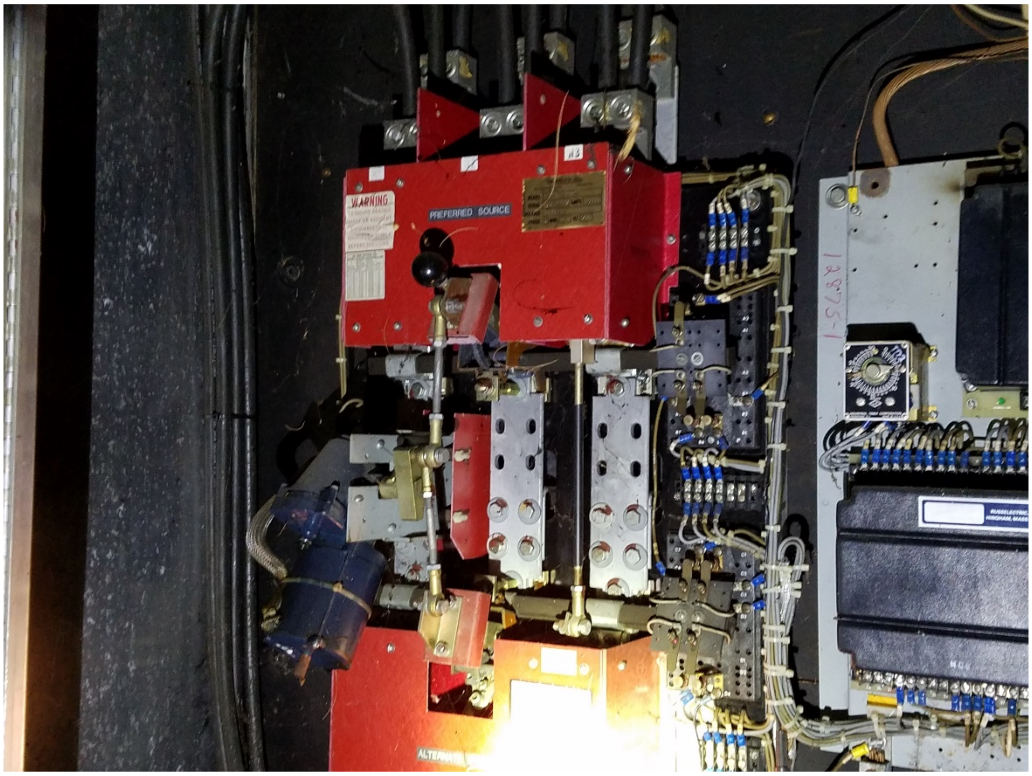

Photo 23: Automatic transfer switch

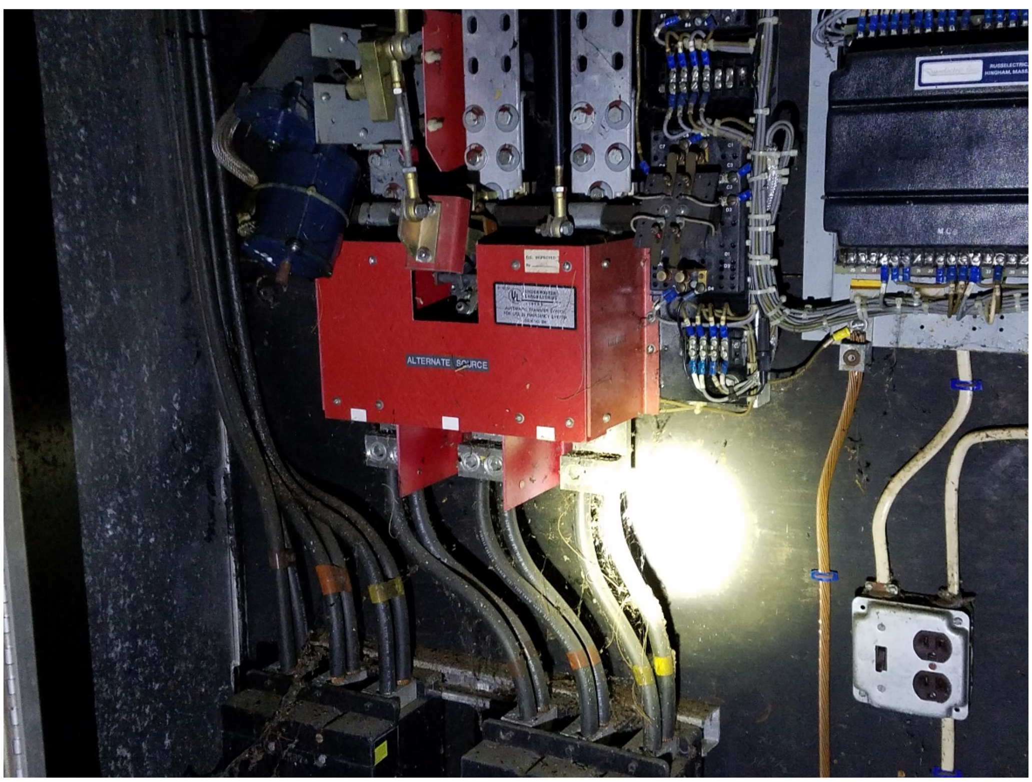

Photo 24: Automatic transfer switch

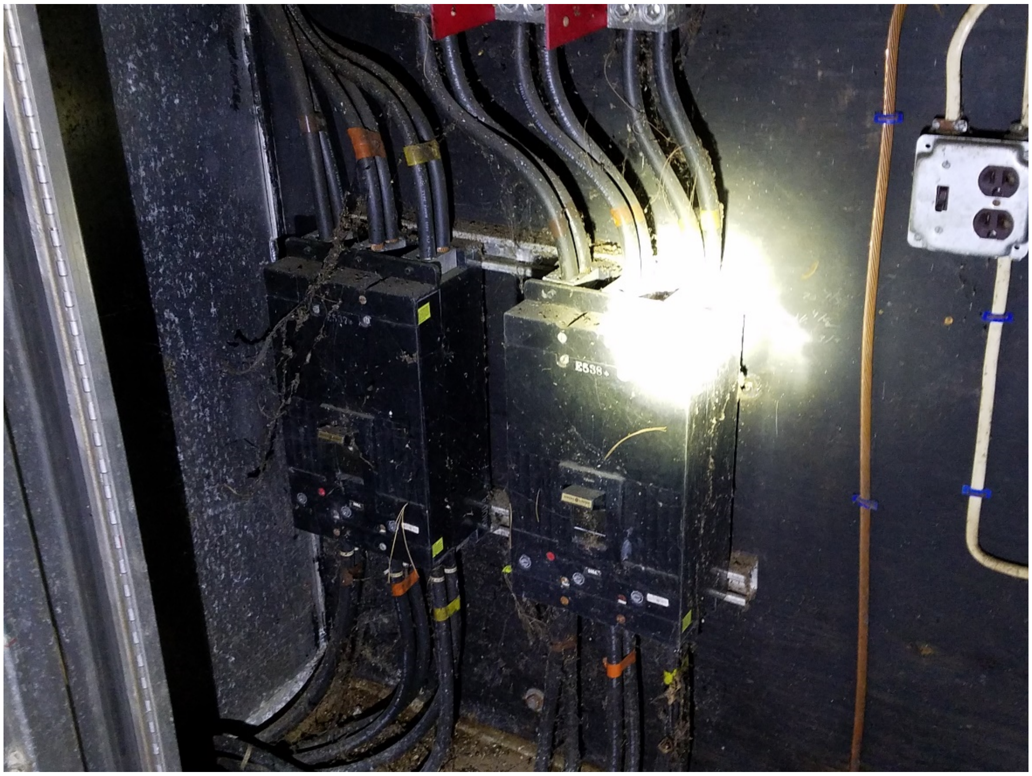

Photo 25: 500A main circuit breakers for the two utility services

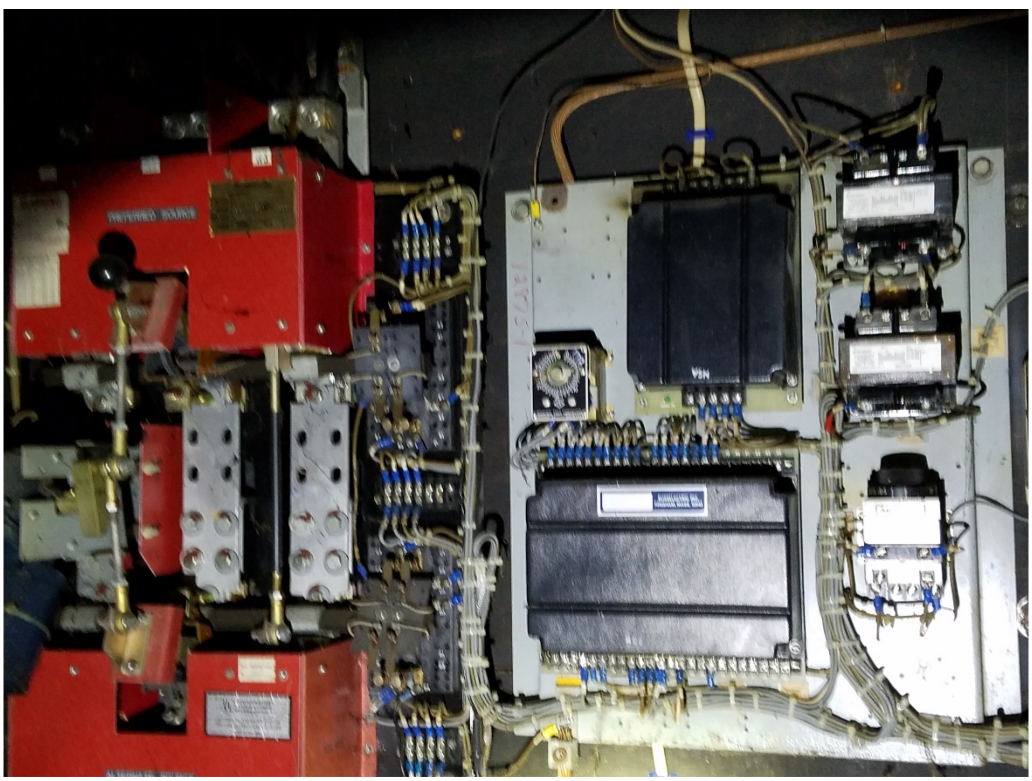

Photo 26: Automatic transfer switch and associated controls

Photo 27: 120V Panelboard (Left), 480-120/240V transformer (Right)

Photo 28: Daytime lighting panelboard

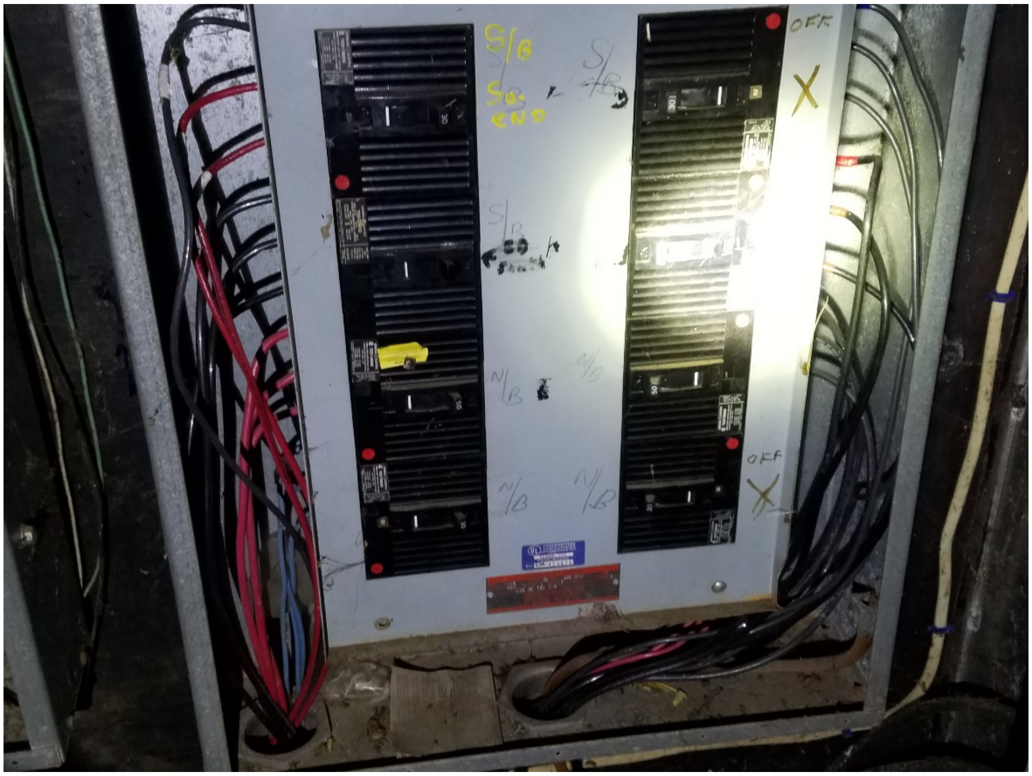

Photo 29: Daytime lighting panelboard

Photo 30: Daytime lighting panelboard

Photo 31: Electrical distribution pedestal cabinet

Photo 32: Corroded conduits containing lighting and Wintergreen Avenue electrical service wiring.

Photo 33: Additional corrosion on conduit and conduit bodies.

Appendix D

Air Quality Technical Memorandum

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Technical Memorandum Air Quality

1 Introduction

This memorandum presents the air quality analysis conducted for the proposed Project. The analysis includes a description of the existing conditions of the project site and surrounding area. Emission calculations and air quality modeling results are provided in the Appendix to this Technical Memorandum.

2 Criteria Air Pollutants

The following section provides a detailed description of these air pollutants, as adapted from the EPA[1] and Connecticut Department of Energy & Environmental Protection (CTDEEP)[2].

2.1 Carbon Monoxide

Carbon Monoxide (CO) is a colorless, odorless and poisonous gas produced by incomplete burning of carbon in fuels. Sources include motor-vehicle exhaust, industrial processes, wood-burning stoves, or forest fires. High concentrations can be found in confined spaces such as parking garages, poorly ventilated tunnels, or traffic intersections, especially during peak hours. When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues, which negatively affects those with cardiovascular or respiratory disease.

2.2 Ozone

Ozone (O_3) is a colorless gas that is not directly emitted into the air but created through chemical reactions between precursors of O_3 in the presence of sunlight. O_3 is a major constituent of smog. Ozone is found both at high altitude and ground level. High altitude ozone is beneficial because it shields the earth from the sun's ultraviolet radiation. Ground level ozone is harmful because it reacts with the mucus membranes of the respiratory system and causes inflammation.

Primary precursor compounds that lead to formation of O_3 include VOCs and NOx. Both VOCs and NOx are emitted from transportation and industrial sources. Ozone does not come directly from any source. The VOCs that form ozone come from vehicle and industrial exhaust as well as evaporation of gasoline, solvents and paints, and many other sources.

2.3 Sulfur Oxides

Sulfur Dioxide (SO_2) is a colorless gas. It is odorless at low concentrations but pungent at very high concentrations. SO_2 is generated primarily by burning of fuels that contain sulfur. The largest source of SO_2 in the atmosphere is from oil and coal fired power plants and other industrial facilities. Smaller sources of SO_2 include vehicles and heavy equipment that burn fuel with a high

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[1] Detailed description of the criteria air pollutants can be found on USEPA website.
Source: https://www.epa.gov/criteria-air-pollutants (Accessed April 18, 2018)
[2] Pollutant description of the criteria air pollutants as found on CTDEEP website.
Source: https://www.ct.gov/deep/cwp/view.asp?a=2684&Q=321804&deepNav_GID=1744 (Accessed September 26, 2018)

sulfur content. Short-term exposures to SO_2 can harm the human respiratory system and make breathing difficult. Children, the elderly, and those who suffer from asthma are particularly sensitive to effects of SO_2.

SO_2 emissions that lead to high concentrations of SO_2 in the air generally also lead to the formation of other Sulfur Oxides (SO_x). SO_x can react with other compounds in the atmosphere to form small particles. These particles contribute to particulate matter pollution which also contributes to negative health effects. It is also a main contributor to acid rain.

2.4 Nitrogen Oxides

Nitrogen Dioxide (NO_2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NO_x). Other nitrogen oxides include nitrous acid and nitric acid. NO_2 is used as the indicator for the larger group of nitrogen oxides. NO_2 is a yellowish brown, highly reactive gas that is the primary ingredient in formation of ground-level ozone. It is formed from high temperature fuel combustion such as from cars, trucks, buses, power plants, and off-road equipment. Short-term NO_2 exposures, ranging from 30 minutes to 24 hours, can produce adverse respiratory effects including increased asthma symptoms, more difficulty controlling asthma, and an increase in respiratory illnesses and symptoms. NO_2 along with other NO_x reacts with other chemicals in the air to form both particulate matter and ozone.

2.5 Particulate Matter

Particulate Matter (PM) includes PM_{10} which are inhalable particles, with diameter less than 10 microns and PM2.5 which are fine inhalable particles, with diameters less than 2.5 microns. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles. Particulates can damage human health and retard plant growth. Health concerns associated with suspended particulate matter focus on those particles small enough to reach the lungs when inhaled. Particulates also reduce visibility and corrode materials. The size of a particle is directly linked to its potential for causing health problems. Small particles, that is, those less than 10 microns in diameter (PM_{10}), pose the greatest problems because of their ability to penetrate deeply into the lungs and bloodstream affecting human immune systems. Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) can be emitted directly from sources (e.g., engines) or can form in the atmosphere from precursor compounds.

2.6 Mobile Source Air Toxics

Mobile Source Air Toxics (MSATs) are a subset of the 188 air toxics defined by the CAA. MSATs are compounds emitted from highway vehicles and non-road equipment. Some toxic compounds are present in fuel and are emitted to the air when the fuel evaporates or passes through the engine unburned. Other toxics are emitted from the incomplete combustion of fuels or as secondary combustion products. Metal air toxics also result from engine wear or from impurities in oil or gasoline. Most air toxics originate from human-made sources, including on-road mobile sources, non- road mobile sources (e.g., airplanes), area sources (e.g., dry cleaners) and stationary sources (e.g., factories or refineries).

3 Existing Condition Emissions

Following sections provide a summary of the modeling approach and results from the regional emissions inventory calculated for the existing condition (i.e. No Build Alternative).

3.1 Modeling Approach

U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES) model was used to develop an emission factor for all criteria air pollutants (CO, NOx, SO_2, PM_{10}, $PM_{2.5}$ and VOC). This analysis used the current EPA-approved version of MOVES2014a (released on November 17, 2016) to develop emission factors for different vehicle source types. A predicted peak hour volume of vehicles was used to calculate operational emissions in tons per year for the existing conditions.

A run specification (RunSpec) was created for New Haven county with "Emission Rate" as calculation type[3] using a national scale domain for the year 2018.The month of January, a weekday and hour 17:00-17:59 was selected for the modeled time span, and hourly time aggregation was used. Gasoline was assumed as worst-case fuel for emissions and the vehicle source types selected were Motorcycle, Light commercial truck, passenger car and passenger truck. The vehicle and fuel combinations were selected to match the types of vehicles that operate to simulate regional emissions. All five road types were selected in the MOVES Road Type panel, however, the Heroes Tunnel is assumed to be in an "Urban Restricted" road type. A separate RunSpec was created for New Haven County with "Inventory" as calculation type to obtain activity data for the different model years, which was then used to obtain a weighted emission factor in grams/miles/vehicle. The model output was selected to include model years and source types.

3.2 Modeling Results

Upon completion of successful execution of MOVES run, the rate per distance emissions factors were post-processed using mySQL script to obtain a "running exhaust" emission factor in grams per mile for each of the Source Types for an Urban Restricted Road Type. For this analysis operational emissions were calculated from the maximum no. of vehicles expected at a peak hour in tunnel in one direction (i.e. per barrel). Emissions of CO, NO_2, VOC, SO_2, PM_{10} and $PM_{2.5}$ represent emissions from vehicle exhaust only. Table 4 of Section 3.21 summarizes peak hourly operational emissions associated with existing conditions in the tunnel per barrel. Detailed MOVES output tables and calculations are provided in the Appendix, included at the end of this Technical Memorandum. A weighted emission factor in grams per mile was calculated using the sumproduct of activity (for different model years obtained from the separate RunSpec) and the rate per distance divide by sum of activity. Based on available traffic data, it is estimated that about 2,983 vehicles can be expected in the tunnel in peak hour conditions in one barrel.

[3] A RunSpec is an extensible markup language (XML) file that contains the input parameters for a model run.

Heroes Tunnel, New Haven, CT
MOVES Results Summary
Existing Conditions (For inventory year 2018, gasoline fuel type, for weekday at 17:00-17:59, at 57 mph speed (avg Speed Bin ID = 12))

Source Type ID	Source Type	Activity	Rate per distance X Activity					
			NOx	CO	SO2	PM10	PM2.5	VOC
11	Motorcycle	1,356.88	1,254.19	17,179.95	3.42	56.38	49.88	679.33
21	Passenger Car	324,853.82	48,745.70	630,177.12	609.13	3,478.27	3,076.95	6,274.39
31	Passenger Truck	195,524.25	63,957.44	624,880.85	486.24	2,932.27	2,593.94	8,571.78
32	Light Commercial Truck	48,475.87	14,850.84	145,297.78	118.60	597.03	528.15	1,843.99
SUM		**570,210.81**	**128,808.18**	**1,417,535.69**	**1,217.39**	**7,063.96**	**6,248.91**	**17,369.48**

	2018	
Avg Vehicles in the tunnel (per barrel)	2,983	
Length of tunnel	0.231	mi

Pollutant	Emission Factor (g/mi)	g/hr	Peak lb/hr per barrel
NOx	0.23	155.70	0.34
CO	2.49	1,713.47	3.78
SO2	0.00	1.47	0.003
PM10	0.01	8.54	0.02
PM2.5	0.01	7.55	0.02
VOC	0.03	21.00	0.05

Unit Conversion

1lb =	453.592	g
1 ton =	2000	lb
1 year =	8760	hours

APPENDIX - MOVES OUTPUT

MOVESRur	iterationID	yearID	monthID	dayID	hourID	stateID	countyID	zoneID	linkID	sourceTyp	regClassID	fuelTypeID	modelYear	roadTypeI	SCC	engTechID	sectorID	hpID	activityTyp	activity	activityMe	activitySign
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4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	1998	4	NULL	NULL	NULL	NULL	1	2598.24	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	1999	4	NULL	NULL	NULL	NULL	1	3480.08	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2000	4	NULL	NULL	NULL	NULL	1	4855.66	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2001	4	NULL	NULL	NULL	NULL	1	5505.17	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2002	4	NULL	NULL	NULL	NULL	1	6844.57	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2003	4	NULL	NULL	NULL	NULL	1	8259.99	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2004	4	NULL	NULL	NULL	NULL	1	9463.45	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2005	4	NULL	NULL	NULL	NULL	1	11798.9	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2006	4	NULL	NULL	NULL	NULL	1	13026.6	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	21	NULL	NULL	2007	4	NULL	NULL	NULL	NULL	1	14908.4	NULL	NULL
4	1	2018	1	5	18	9	9009															

LL	NULL	2008	4	NULL	NULL	NULL	NULL	1	14300.8	NULL	NULL
LL	NULL	2009	4	NULL	NULL	NULL	NULL	1	12007.3	NULL	NULL
LL	NULL	2010	4	NULL	NULL	NULL	NULL	1	13755.1	NULL	NULL
LL	NULL	2011	4	NULL	NULL	NULL	NULL	1	12566.8	NULL	NULL
LL	NULL	2012	4	NULL	NULL	NULL	NULL	1	20815.6	NULL	NULL
LL	NULL	2013	4	NULL	NULL	NULL	NULL	1	23399.6	NULL	NULL
LL	NULL	2014	4	NULL	NULL	NULL	NULL	1	25302.5	NULL	NULL
LL	NULL	2015	4	NULL	NULL	NULL	NULL	1	26486.1	NULL	NULL
LL	NULL	2016	4	NULL	NULL	NULL	NULL	1	27817.1	NULL	NULL
LL	NULL	2017	4	NULL	NULL	NULL	NULL	1	28588.4	NULL	NULL
LL	NULL	2018	4	NULL	NULL	NULL	NULL	1	28732.1	NULL	NULL

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MOVESRur	iterationID	yearID	monthID	dayID	hourID	stateID	countyID	zoneID	linkID	sourceTyp	regClassID	fuelTypeID	modelYear	roadTypeI	SCC	engTechID	sectorID	hpID	activityTyp	activity	activityMe	activitySign
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1988	4	NULL	NULL	NULL	NULL	1	262.816	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1989	4	NULL	NULL	NULL	NULL	1	314.655	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1990	4	NULL	NULL	NULL	NULL	1	313.931	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1991	4	NULL	NULL	NULL	NULL	1	365.094	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1992	4	NULL	NULL	NULL	NULL	1	439.671	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1993	4	NULL	NULL	NULL	NULL	1	560.247	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1994	4	NULL	NULL	NULL	NULL	1	844.775	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1995	4	NULL	NULL	NULL	NULL	1	984.685	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1996	4	NULL	NULL	NULL	NULL	1	1079.78	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1997	4	NULL	NULL	NULL	NULL	1	1550.08	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1998	4	NULL	NULL	NULL	NULL	1	1928.81	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	1999	4	NULL	NULL	NULL	NULL	1	2486.47	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2000	4	NULL	NULL	NULL	NULL	1	3029.26	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2001	4	NULL	NULL	NULL	NULL	1	3534.03	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2002	4	NULL	NULL	NULL	NULL	1	4356.76	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2003	4	NULL	NULL	NULL	NULL	1	5056.73	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2004	4	NULL	NULL	NULL	NULL	1	6305.08	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2005	4	NULL	NULL	NULL	NULL	1	6893.12	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2006	4	NULL	NULL	NULL	NULL	1	7370	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2007	4	NULL	NULL	NULL	NULL	1	7376.98	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2008	4	NULL	NULL	NULL	NULL	1	7848.73	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2009	4	NULL	NULL	NULL	NULL	1	4637.62	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2010	4	NULL	NULL	NULL	NULL	1	6490.59	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2011	4	NULL	NULL	NULL	NULL	1	7147.14	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2012	4	NULL	NULL	NULL	NULL	1	11541.4	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2013	4	NULL	NULL	NULL	NULL	1	13917.5	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2014	4	NULL	NULL	NULL	NULL	1	15504.4	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2015	4	NULL	NULL	NULL	NULL	1	17119.1	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2016	4	NULL	NULL	NULL	NULL	1	18348.7	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2017	4	NULL	NULL	NULL	NULL	1	18820	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	31	NULL	NULL	2018	4	NULL	NULL	NULL	NULL	1	19096.1	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1988	4	NULL	NULL	NULL	NULL	1	48.8675	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1989	4	NULL	NULL	NULL	NULL	1	56.1696	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1990	4	NULL	NULL	NULL	NULL	1	53.7889	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1991	4	NULL	NULL	NULL	NULL	1	49.1411	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1992	4	NULL	NULL	NULL	NULL	1	53.6956	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1993	4	NULL	NULL	NULL	NULL	1	105.487	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1994	4	NULL	NULL	NULL	NULL	1	111.398	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1995	4	NULL	NULL	NULL	NULL	1	180.068	NULL	NULL
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4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1997	4	NULL	NULL	NULL	NULL	1	290.173	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1998	4	NULL	NULL	NULL	NULL	1	290.679	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	1999	4	NULL	NULL	NULL	NULL	1	495.166	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2000	4	NULL	NULL	NULL	NULL	1	717.377	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2001	4	NULL	NULL	NULL	NULL	1	917.169	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2002	4	NULL	NULL	NULL	NULL	1	1169.08	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2003	4	NULL	NULL	NULL	NULL	1	1363.51	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2004	4	NULL	NULL	NULL	NULL	1	1705.95	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2005	4	NULL	NULL	NULL	NULL	1	1856.21	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2006	4	NULL	NULL	NULL	NULL	1	2006.18	NULL	NULL
4	1	2018	1	5	18	9	9009	NULL	NULL	32	NULL	NULL	2007	4	NULL	NULL	NULL	NULL	1	1969.6	NULL	NULL
4	1	2018	1	5	18	9	9009	NU														

ULL	NULL	2008	4	NULL	NULL	NULL	NULL	1	2112.12	NULL	NULL
ULL	NULL	2009	4	NULL	NULL	NULL	NULL	1	1227.5	NULL	NULL
ULL	NULL	2010	4	NULL	NULL	NULL	NULL	1	1704.05	NULL	NULL
ULL	NULL	2011	4	NULL	NULL	NULL	NULL	1	1924.15	NULL	NULL
ULL	NULL	2012	4	NULL	NULL	NULL	NULL	1	2767.26	NULL	NULL
ULL	NULL	2013	4	NULL	NULL	NULL	NULL	1	3350.23	NULL	NULL
ULL	NULL	2014	4	NULL	NULL	NULL	NULL	1	3754.54	NULL	NULL
ULL	NULL	2015	4	NULL	NULL	NULL	NULL	1	4170.72	NULL	NULL
ULL	NULL	2016	4	NULL	NULL	NULL	NULL	1	4494.79	NULL	NULL
ULL	NULL	2017	4	NULL	NULL	NULL	NULL	1	4629.92	NULL	NULL
ULL	NULL	2018	4	NULL	NULL	NULL	NULL	1	4714.32	NULL	NULL

MOVESScenarioID	MOVESRu	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceTyp	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDistanc	Activity	Rate per Distance X Activity
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1988	4	12	33.2	59.6	18.7558	0.923808	17.33
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1989	4	12	33.2	59.6	18.7558	0.94527	17.73
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1990	4	12	33.2	59.6	18.7558	1.37178	25.73
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1991	4	12	33.2	59.6	18.7558	1.78772	33.53
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1992	4	12	33.2	59.6	18.7558	2.4386	45.74
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1993	4	12	33.2	59.6	18.7558	3.1664	59.39
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1994	4	12	33.2	59.6	21.5452	4.15018	89.42
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1995	4	12	33.2	59.6	21.5471	3.83712	82.68
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1996	4	12	33.2	59.6	21.5493	5.39972	116.36
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1997	4	12	33.2	59.6	21.5518	6.33558	136.54
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1998	4	12	33.2	59.6	21.5542	6.80422	146.66
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	1999	4	12	33.2	59.6	21.5567	8.25878	178.03
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2000	4	12	33.2	59.6	21.5591	11.3034	243.69
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2001	4	12	33.2	59.6	24.0229	14.75	354.34
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2002	4	12	33.2	59.6	24.0229	18.1009	434.84
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2003	4	12	33.2	59.6	24.0229	21.3404	512.66
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2004	4	12	33.2	59.6	17.4931	26.0378	455.48
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2005	4	12	33.2	59.6	17.4931	32.215	563.54
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2006	4	12	33.2	59.6	17.4931	38.7754	678.30
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2007	4	12	33.2	59.6	17.4931	43.0254	752.65
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2008	4	12	33.2	59.6	11.0636	51.3064	567.63
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2009	4	12	33.2	59.6	11.0636	30.7848	340.59
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2010	4	12	33.2	59.6	11.0636	31.812	351.96
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2011	4	12	33.2	59.6	11.0636	38.0732	421.23
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2012	4	12	33.2	59.6	11.0636	51.675	571.71
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2013	4	12	33.2	59.6	11.0636	63.7692	705.52
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2014	4	12	33.2	59.6	11.0636	80.5606	891.29
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2015	4	12	33.2	59.6	11.0636	101.499	1,122.94
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2016	4	12	33.2	59.6	11.0636	134.96	1,493.14
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2017	4	12	33.2	59.6	11.0636	183.46	2,029.73
ScenarioID1	2	2018	1	5	18	90090412	2	1	11	0		0	2018	4	12	33.2	59.6	11.0636	338.008	3,739.59
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1988	4	12	33.2	59.6	8.52664	531	4,524.83
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1989	4	12	33.2	59.6	8.52664	404	3,444.66
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1990	4	12	33.2	59.6	6.96152	498	3,464.40
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1991	4	12	33.2	59.6	6.96152	608	4,231.07
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1992	4	12	33.2	59.6	6.96152	747	5,199.87
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1993	4	12	33.2	59.6	6.96152	937	6,525.19
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1994	4	12	33.2	59.6	5.8098	1,160	6,736.81
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1995	4	12	33.2	59.6	5.81033	1,583	9,197.11
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1996	4	12	33.2	59.6	4.93134	1,670	8,235.58
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1997	4	12	33.2	59.6	4.9319	2,205	10,872.37
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1998	4	12	33.2	59.6	4.93246	2,598	12,815.71
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	1999	4	12	33.2	59.6	4.91281	3,480	17,096.97
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2000	4	12	33.2	59.6	4.91337	4,856	23,857.65
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2001	4	12	33.2	59.6	3.11544	5,505	17,151.03
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2002	4	12	33.2	59.6	3.09213	6,845	21,164.30
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2003	4	12	33.2	59.6	3.14757	8,260	25,998.90
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2004	4	12	33.2	59.6	2.74249	9,463	25,953.42
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2005	4	12	33.2	59.6	2.64926	11,799	31,258.35
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2006	4	12	33.2	59.6	2.59469	13,027	33,799.99
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2007	4	12	33.2	59.6	2.51301	14,908	37,464.96
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2008	4	12	33.2	59.6	2.50665	14,301	35,847.10
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2009	4	12	33.2	59.6	2.03642	12,007	24,451.91
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2010	4	12	33.2	59.6	2.03258	13,755	27,958.34
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2011	4	12	33.2	59.6	1.91372	12,567	24,049.34
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2012	4	12	33.2	59.6	1.91372	20,816	39,835.23
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2013	4	12	33.2	59.6	1.67583	23,400	39,213.75
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2014	4	12	33.2	59.6	1.67583	25,303	42,402.69
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2015	4	12	33.2	59.6	0.915459	26,486	24,246.94
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2016	4	12	33.2	59.6	0.960132	27,817	26,708.09
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2017	4	12	33.2	59.6	0.650613	28,588	18,599.98
ScenarioID1	2	2018	1	5	18	90090412	2	1	21	0		0	2018	4	12	33.2	59.6	0.621972	28,732	17,870.56

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		MOVESScenarioID	MOVESRun	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceType	regClassID	SCC	fuelTypeID	modelYear	roadTypeID	avgSpeedB	temperatu	relHumidit	ratePerDistanc	Activity	Rate per Distance X Activity
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	1988	4	12	33.2	59.6	19.7153	263	5,181.50
		Scenar																				
		Scenar																				
59.6	19.5955	Scenar	315		6,197.29																	
		Scenar																				
59.6	18.3309	Scenar	314		5,754.64																	
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	1994	4	12	33.2	59.6	11.6299	845	9,824.65
59.6	18.3258	Scenar	365		6,690.64																	
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	1996	4	12	33.2	59.6	6.92291	1,080	7,475.22
59.6	18.3257	Scenar	440		8,057.28																	
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	1998	4	12	33.2	59.6	9.04558	1,929	17,447.21
59.6	18.3187	ScenarioID1	560	2	2018	10,263.00 1	5	18	90090412	2	1	31	0	0	1999	4	12	33.2	59.6	8.88455	2,486	22,091.17
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2000	4	12	33.2	59.6	8.86675	3,029	26,859.69
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2001	4	12	33.2	59.6	6.49224	3,534	22,943.77
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2002	4	12	33.2	59.6	6.40578	4,357	27,908.45
59.6	11.578	ScenarioID1	985	2	2018	11,400.68 1	5	18	90090412	2	1	31	0	0	2003	4	12	33.2	59.6	6.67492	5,057	33,753.27
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2004	4	12	33.2	59.6	4.31476	6,305	27,204.91
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2005	4	12	33.2	59.6	3.92411	6,893	27,049.36
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2006	4	12	33.2	59.6	3.90018	7,370	28,744.33
59.6	9.30296	ScenarioID1	1,550 2	2	2018	14,420.33 1	5	18	90090412	2	1	31	0	0	2007	4	12	33.2	59.6	3.77319	7,377	27,834.75
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2008	4	12	33.2	59.6	3.74995	7,849	29,432.35
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2009	4	12	33.2	59.6	2.99814	4,638	13,904.23
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2010	4	12	33.2	59.6	2.94974	6,491	19,145.55
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2011	4	12	33.2	59.6	2.88278	7,147	20,603.63
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2012	4	12	33.2	59.6	2.8846	11,541	33,292.32
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2013	4	12	33.2	59.6	2.44517	13,918	34,030.65
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2014	4	12	33.2	59.6	2.44484	15,504	37,905.78
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2015	4	12	33.2	59.6	1.37367	17,119	23,515.99
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2016	4	12	33.2	59.6	1.43236	18,349	26,281.94
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2017	4	12	33.2	59.6	1.19316	18,820	22,455.27
		ScenarioID1		2	2018	1	5	18	90090412	2	1	31	0	0	2018	4	12	33.2	59.6	0.901284	19,096	17,211.01
		ScenarioID1		2	2018	1	5	18	90090412	2	1	32	0	0	1988	4	12	33.2	59.6	18.2686	48.8675	892.74
		Scenar																				
		Scenar																				
		ScenarioID1		2																		
		Scenar																				
		Scenar																				
		Scenar 916.44																				
		Scenar																				
		Scenar 1,801.97																				
		Scenar																				
		Scenar 1,283.64																				
		Scenar																				
		Scenar 2,109.24																				
		Scenar																				
		Scenar 1,387.00																				
		Scenar																				
		Scenar 2,753.77																				
		Scenar																				
		Scenar 2,484.89																				
		Scenar																				
		Scenar 4,122.02																				
		Scenar																				
		Scenar 6,009.80																				
		Scenar																				
		Scenar 5,925.98																				
		Scenar																				
		Scenar 7,166.83																				
		Scenar																				
		Scenar 8,721.91																				
		Scenar																				
		Scenar 7,428.42																				
		7,352.11																				
59.6	18.2048	8,056.56 56.1696			1,022.56																	
59.6	17.0366	7,387.53 53.7889			916.38																	
		7,906.66																				

APPENDIX - MOVES OUTPUT

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceType	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDis	activity	Rate per Distance X Activity					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1988	4	12	33.2	59.6	1.18915	0.923808	1.10					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1989	4	12	33.2	59.6	1.18915	0.94527	1.12					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1990	4	12	33.2	59.6	1.18915	1.37178	1.63					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1991	4	12	33.2	59.6	1.18915	1.78772	2.13					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1992	4	12	33.2	59.6	1.18915	2.4386	2.90					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1993	4	12	33.2	59.6	1.18915	3.1664	3.77					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1994	4	12	33.2	59.6	1.16975	4.15018	4.85					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1995	4	12	33.2	59.6	1.16975	3.83712	4.49					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1996	4	12	33.2	59.6	1.16975	5.39972	6.32					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1997	4	12	33.2	59.6	1.16975	6.33558	7.41					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1998	4	12	33.2	59.6	1.16975	6.80422	7.96					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	1999	4	12	33.2	59.6	1.16975	8.25878	9.66					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2000	4	12	33.2	59.6	1.16975	11.3034	13.22					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2001	4	12	33.2	59.6	1.17026	14.75	17.26					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2002	4	12	33.2	59.6	1.17026	18.1009	21.18					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2003	4	12	33.2	59.6	1.17026	21.3404	24.97					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2004	4	12	33.2	59.6	0.958744	26.0378	24.96					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2005	4	12	33.2	59.6	0.958744	32.215	30.89					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2006	4	12	33.2	59.6	0.958744	38.7754	37.18					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2007	4	12	33.2	59.6	0.958744	43.0254	41.25					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2008	4	12	33.2	59.6	0.895139	51.3064	45.93					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2009	4	12	33.2	59.6	0.895139	30.7848	27.56					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2010	4	12	33.2	59.6	0.895139	31.812	28.48					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2011	4	12	33.2	59.6	0.895139	38.0732	34.08					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2012	4	12	33.2	59.6	0.895139	51.675	46.26					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2013	4	12	33.2	59.6	0.895139	63.7692	57.08					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2014	4	12	33.2	59.6	0.895139	80.5606	72.11					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2015	4	12	33.2	59.6	0.895139	101.499	90.86					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2016	4	12	33.2	59.6	0.895139	134.96	120.81					
ScenarioID	2	2018	1	5	18	90090412	3	1	11	0		0	2017	4	12	33.2	59.6	0.895139	183.46	164.22					
ScenarioID	2	2018	1	5	18																				
												90090412	3	1	11	0		0	2018	4	12	33.2	59.6	0.895139	338.008
						ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1988	4	12	33.2	59.6	1.7247	530.67
						ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1989	4	12	33.2	59.6	1.7247	403.988
						ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1990	4	12	33.2	59.6	1.69328	497.65
ScenarioID	2	2018	1	5	18	90090412 / ScenarioID	3 / 2	1 / 2018	21 / 1	0 / 5	18	0 / 90090412	1992 / 3	4 / 1	12 / 21	33.2 / 0	59.6	1.69328 / 0	746.945 / 1991	4	12	1,264.79 / 33.2	59.6	1.69328	607.779
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1993	4	12	33.2	59.6	1.69328	937.323	1,587.15					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1994	4	12	33.2	59.6	1.52667	1159.56	1,770.27					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1995	4	12	33.2	59.6	1.52667	1582.89	2,416.55					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1996	4	12	33.2	59.6	1.14479	1670.05	1,911.86					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1997	4	12	33.2	59.6	1.14479	2204.5	2,523.69					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1998	4	12	33.2	59.6	1.14479	2598.24	2,974.44					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	1999	4	12	33.2	59.6	1.14063	3480.08	3,969.48					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2000	4	12	33.2	59.6	1.14063	4855.66	5,538.51					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2001	4	12	33.2	59.6	0.294844	5505.17	1,623.17					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2002	4	12	33.2	59.6	0.277469	6844.57	1,899.16					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2003	4	12	33.2	59.6	0.260749	8259.99	2,153.78					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2004	4	12	33.2	59.6	0.144214	9463.45	1,364.76					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2005	4	12	33.2	59.6	0.11625	11798.9	1,371.62					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2006	4	12	33.2	59.6	0.111073	13026.6	1,446.90					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2007	4	12	33.2	59.6	0.093663	14908.4	1,396.37					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2008	4	12	33.2	59.6	0.088128	14300.8	1,260.31					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2009	4	12	33.2	59.6	0.071052	12007.3	853.15					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2010	4	12	33.2	59.6	0.066325	13755.1	912.31					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2011	4	12	33.2	59.6	0.052962	12566.8	665.56					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2012	4	12	33.2	59.6	0.052962	20815.6	1,102.43					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2013	4	12	33.2	59.6	0.043312	23399.6	1,013.48					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2014	4	12	33.2	59.6	0.043312	25302.5	1,095.90					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2015	4	12	33.2	59.6	0.027547	26486.1	729.62					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2016	4	12	33.2	59.6	0.028892	27817.1	803.68					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2017	4	12	33.2	59.6	0.029147	28588.4	833.27					
ScenarioID	2	2018	1	5	18	90090412	3	1	21	0		0	2018	4	12	33.2	59.6	0.027137	28732.1	779.71					

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceType	regClassID	SCC	fuelTypeID	modelYear	roadTypeID	avgSpeedB	temperatu	relHumidit	ratePerDist	activity	Rate per Distance X Activity
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1988	4	12	33.2	59.6	3.50034	262.816	919.95
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1989	4	12	33.2	59.6	3.5056	314.655	1,103.05
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1990	4	12	33.2	59.6	3.733	313.931	1,171.90
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1991	4	12	33.2	59.6	3.73049	365.094	1,361.98
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1992	4	12	33.2	59.6	3.73041	439.671	1,640.15
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1993	4	12	33.2	59.6	3.72696	560.247	2,088.02
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1994	4	12	33.2	59.6	3.3478	844.775	2,828.14
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1995	4	12	33.2	59.6	3.34933	984.685	3,298.04
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1996	4	12	33.2	59.6	1.86334	1079.78	2,012.00
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1997	4	12	33.2	59.6	1.84183	1550.08	2,854.98
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1998	4	12	33.2	59.6	1.82758	1928.81	3,525.05
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	1999	4	12	33.2	59.6	1.82773	2486.47	4,544.60
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2000	4	12	33.2	59.6	1.80952	3029.26	5,481.51
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2001	4	12	33.2	59.6	0.834291	3534.03	2,948.41
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2002	4	12	33.2	59.6	0.822815	4356.76	3,584.81
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2003	4	12	33.2	59.6	0.87458	5056.73	4,422.51
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2004	4	12	33.2	59.6	0.39755	6305.08	2,506.58
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2005	4	12	33.2	59.6	0.302075	6893.12	2,082.24
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2006	4	12	33.2	59.6	0.247404	7370	1,823.37
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2007	4	12	33.2	59.6	0.211708	7376.98	1,561.77
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2008	4	12	33.2	59.6	0.191319	7848.73	1,501.61
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2009	4	12	33.2	59.6	0.140579	4637.62	651.95
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2010	4	12	33.2	59.6	0.132538	6490.59	860.25
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2011	4	12	33.2	59.6	0.108909	7147.14	778.39
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2012	4	12	33.2	59.6	0.108983	11541.4	1,257.82
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2013	4	12	33.2	59.6	0.088145	13917.5	1,226.76
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2014	4	12	33.2	59.6	0.088115	15504.4	1,366.16
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2015	4	12	33.2	59.6	0.055286	17119.1	946.44
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2016	4	12	33.2	59.6	0.057632	18348.7	1,057.46
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2017	4	12	33.2	59.6	0.081288	18820	1,529.84
ScenarioID	2	2018	1	5	18	90090412	3	1	31	0		0	2018	4	12	33.2	59.6	0.053503	19096.1	1,021.71
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1988	4	12	33.2	59.6	3.58527	48.8675	175.20
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1989	4	12	33.2	59.6	3.60217	56.1696	202.33
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1990	4	12	33.2	59.6	3.66954	53.7889	197.38
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1991	4	12	33.2	59.6	3.67845	49.1411	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1992	4	12	33.2	59.6	3.69256	53.6956	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1993	4	12	33.2	59.6	3.70382	105.487	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1994	4	12	33.2	59.6	3.31286	111.398	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1995	4	12	33.2	59.6	3.30468	180.068	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1996	4	12	33.2	59.6	1.90298	186.558	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1997	4	12	33.2	59.6	1.8853	290.173	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1998	4	12	33.2	59.6	1.79196	290.679	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	1999	4	12	33.2	59.6	1.80684	495.166	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2000	4	12	33.2	59.6	1.84754	717.377	
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2001	4	12	33.2	59.6	0.896266	917.169	822.03
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2002	4	12	33.2	59.6	0.837166	1169.08	978.71
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2003	4	12	33.2	59.6	0.889596	1363.51	1,212.97
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2004	4	12	33.2	59.6	0.464425	1705.95	792.29
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2005	4	12	33.2	59.6	0.370263	1856.21	687.29
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2006	4	12	33.2	59.6	0.335982	2006.18	674.04
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2007	4	12	33.2	59.6	0.273234	1969.6	538.16
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2008	4	12	33.2	59.6	0.230914	2112.12	487.72
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2009	4	12	33.2	59.6	0.141013	1227.5	173.09
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2010	4	12	33.2	59.6	0.130983	1704.05	223.20
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2011	4	12	33.2	59.6	0.113393	1924.15	218.19
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2012	4	12	33.2	59.6	0.113598	2767.26	314.36
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2013	4	12	33.2	59.6	0.090377	3350.23	302.78
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2014	4	12	33.2	59.6	0.090291	3754.54	339.00
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2015	4	12	33.2	59.6	0.055616	4170.72	231.96
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2016	4	12	33.2	59.6	0.057492	4494.79	258.42
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2017	4	12	33.2	59.6	0.083795	4629.92	387.96
ScenarioID	2	2018	1	5	18	90090412	3	1	32	0		0	2018	4	12	33.2	59.6	0.054489	4714.32	256.88

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantIE	processID	sourceType	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDistance	activity	Rate per Distance X Activity
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1988	4	12	33.2	59.6	0.00200008	0.923808	0.00
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1989	4	12	33.2	59.6	0.00200008	0.94527	0.00
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1990	4	12	33.2	59.6	0.00200008	1.37178	0.00
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1991	4	12	33.2	59.6	0.00225744	1.78772	0.00
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1992	4	12	33.2	59.6	0.00228926	2.4386	0.01
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1993	4	12	33.2	59.6	0.00232108	3.1664	0.01
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1994	4	12	33.2	59.6	0.0023529	4.15018	0.01
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1995	4	12	33.2	59.6	0.00238472	3.83712	0.01
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1996	4	12	33.2	59.6	0.00241654	5.39972	0.01
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1997	4	12	33.2	59.6	0.00244837	6.33558	0.02
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1998	4	12	33.2	59.6	0.00248019	6.80422	0.02
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	1999	4	12	33.2	59.6	0.00252602	8.25878	0.02
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2000	4	12	33.2	59.6	0.00252602	11.3034	0.03
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2001	4	12	33.2	59.6	0.00252602	14.75	0.04
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2002	4	12	33.2	59.6	0.00252602	18.1009	0.05
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2003	4	12	33.2	59.6	0.00252602	21.3404	0.05
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2004	4	12	33.2	59.6	0.00252602	26.0378	0.07
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2005	4	12	33.2	59.6	0.00252602	32.215	0.08
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2006	4	12	33.2	59.6	0.00252602	38.7754	0.10
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2007	4	12	33.2	59.6	0.00252602	43.0254	0.11
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2008	4	12	33.2	59.6	0.00252602	51.3064	0.13
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2009	4	12	33.2	59.6	0.00252602	30.7848	0.08
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2010	4	12	33.2	59.6	0.00252602	31.812	0.08
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2011	4	12	33.2	59.6	0.00252602	38.0732	0.10
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2012	4	12	33.2	59.6	0.00252602	51.675	0.13
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2013	4	12	33.2	59.6	0.00252602	63.7692	0.16
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2014	4	12	33.2	59.6	0.00252602	80.5606	0.20
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2015	4	12	33.2	59.6	0.00252602	101.499	0.26
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2016	4	12	33.2	59.6	0.00252602	134.96	0.34
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2017	4	12	33.2	59.6	0.00252602	183.46	0.46
ScenarioID	2	2018	1	5	18	90090412	31	1	11	0		0	2018	4	12	33.2	59.6	0.00252602	338.008	0.85
ScenarioID	2	2018	1	5	18	90090412	31	1	21	0		0	1988	4	12	33.2	59.6	0.00206856	530.67	1.10
ScenarioID	2	2018	1	5	18	90090412	31	1	21	0		0	1989	4	12	33.2	59.6	0.00208666	403.988	0.84
ScenarioID	2	2018	1	5	18	90090412	31	1	21	0		0	1990	4	12	33.2	59.6	0.00209326	497.65	1.04
ScenarioID	2	2018	1	5																

4	12	33.2	59.6	0.00200815	607.779	1.22
4	12	33.2	59.6	0.00206137	746.945	1.54
4	12	33.2	59.6	0.00203023	937.323	1.90
4	12	33.2	59.6	0.00205735	1159.56	2.39
4	12	33.2	59.6	0.00204306	1582.89	3.23
4	12	33.2	59.6	0.00206911	1670.05	3.46
4	12	33.2	59.6	0.00203923	2204.5	4.50
4	12	33.2	59.6	0.00204819	2598.24	5.32
4	12	33.2	59.6	0.00206596	3480.08	7.19
4	12	33.2	59.6	0.00206596	4855.66	10.03

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceTyp	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDistance	activity	Rate per Distance X Activity
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1988	4	12	33.2	59.6	0.00295725	262.816	0.78
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1989	4	12	33.2	59.6	0.00286222	314.655	0.90
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1990	4	12	33.2	59.6	0.00286687	313.931	0.90
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1991	4	12	33.2	59.6	0.00261476	365.094	0.95
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1992	4	12	33.2	59.6	0.00261601	439.671	1.15
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1993	4	12	33.2	59.6	0.00264426	560.247	1.48
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1994	4	12	33.2	59.6	0.00266312	844.775	2.25
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1995	4	12	33.2	59.6	0.00274761	984.685	2.71
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1996	4	12	33.2	59.6	0.00269812	1079.78	2.91
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1997	4	12	33.2	59.6	0.00293151	1550.08	4.54
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1998	4	12	33.2	59.6	0.00293689	1928.81	5.66
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	1999	4	12	33.2	59.6	0.00293018	2486.47	7.29
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2000	4	12	33.2	59.6	0.00293264	3029.26	8.88
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2001	4	12	33.2	59.6	0.00307347	3534.03	10.86
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2002	4	12	33.2	59.6	0.00307513	4356.76	13.40
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2003	4	12	33.2	59.6	0.00307673	5056.73	15.56
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2004	4	12	33.2	59.6	0.00307379	6305.08	19.38
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2005	4	12	33.2	59.6	0.00307818	6893.12	21.22
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2006	4	12	33.2	59.6	0.00308083	7370	22.71
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2007	4	12	33.2	59.6	0.00307994	7376.98	22.72
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2008	4	12	33.2	59.6	0.00279105	7848.73	21.91
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2009	4	12	33.2	59.6	0.00276418	4637.62	12.82
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2010	4	12	33.2	59.6	0.00276886	6490.59	17.97
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2011	4	12	33.2	59.6	0.00254732	7147.14	18.21
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2012	4	12	33.2	59.6	0.00242582	11541.4	28.00
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2013	4	12	33.2	59.6	0.00236179	13917.5	32.87
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2014	4	12	33.2	59.6	0.00229511	15504.4	35.58
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2015	4	12	33.2	59.6	0.00220226	17119.1	37.70
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2016	4	12	33.2	59.6	0.00208467	18348.7	38.25
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2017	4	12	33.2	59.6	0.00204869	18820	38.56
ScenarioID	2	2018	1	5	18	90090412	31	1	31	0		0	2018	4	12	33.2	59.6	0.00199647	19096.1	38.12
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	1988	4	12	33.2	59.6	0.00288276	48.8675	0.14
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	1989	4	12	33.2	59.6	0.00278801	56.1696	0.16
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	1990	4	12	33.2	59.6	0.0027919	53.7889	0.15
ScenarioID	2	2018	1	5	18															

91	4	12	33.2	59.6	0.00253849	49.1411	0.12
92	4	12	33.2	59.6	0.00253678	53.6956	0.14
93	4	12	33.2	59.6	0.00256343	105.487	0.27
94	4	12	33.2	59.6	0.00258409	111.398	0.29
95	4	12	33.2	59.6	0.00266831	180.068	0.48
96	4	12	33.2	59.6	0.00262049	186.558	0.49
97	4	12	33.2	59.6	0.00284682	290.173	0.83
98	4	12	33.2	59.6	0.00284835	290.679	0.83
99	4	12	33.2	59.6	0.00284247	495.166	1.41
00	4	12	33.2	59.6	0.00284657	717.377	2.04
01	4	12	33.2	59.6	0.0029848	917.169	2.74
02	4	12	33.2	59.6	0.00298456	1169.08	3.49
03	4	12	33.2	59.6	0.00298632	1363.51	4.07
04	4	12	33.2	59.6	0.00298352	1705.95	5.09
05	4	12	33.2	59.6	0.00298771	1856.21	5.55
06	4	12	33.2	59.6	0.00299076	2006.18	6.00
07	4	12	33.2	59.6	0.00298914	1969.6	5.89
08	4	12	33.2	59.6	0.00272405	2112.12	5.75
09	4	12	33.2	59.6	0.0026939	[illegible]	3.31

ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2010	4	12	33.2	59.6	0.00269558	1704.05	4.59
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2011	4	12	33.2	59.6	0.00250044	1924.15	4.81
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2012	4	12	33.2	59.6	0.00238929	2767.26	6.61
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2013	4	12	33.2	59.6	0.00232734	3350.23	7.80
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2014	4	12	33.2	59.6	0.0022634	3754.54	8.50
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2015	4	12	33.2	59.6	0.00217654	4170.72	9.08
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2016	4	12	33.2	59.6	0.00206497	4494.79	9.28
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2017	4	12	33.2	59.6	0.00202884	4629.92	9.39
ScenarioID	2	2018	1	5	18	90090412	31	1	32	0		0	2018	4	12	33.2	59.6	0.00197491	4714.32	9.31

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantI	processID	sourceTyp	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDis	activity	Rate per D
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1988	4	12	33.2	59.6	0.121943	0.923808	0.11
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1989	4	12	33.2	59.6	0.121943	0.94527	0.12
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1990	4	12	33.2	59.6	0.121943	1.37178	0.17
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1991	4	12	33.2	59.6	0.121943	1.78772	0.22
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1992	4	12	33.2	59.6	0.121943	2.4386	0.30
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1993	4	12	33.2	59.6	0.121943	3.1664	0.39
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1994	4	12	33.2	59.6	0.121943	4.15018	0.51
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1995	4	12	33.2	59.6	0.121943	3.83712	0.47
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1996	4	12	33.2	59.6	0.121943	5.39972	0.66
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1997	4	12	33.2	59.6	0.121943	6.33558	0.77
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1998	4	12	33.2	59.6	0.121943	6.80422	0.83
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	1999	4	12	33.2	59.6	0.121943	8.25878	1.01
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2000	4	12	33.2	59.6	0.121943	11.3034	1.38
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2001	4	12	33.2	59.6	0.118623	14.75	1.75
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2002	4	12	33.2	59.6	0.118623	18.1009	2.15
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2003	4	12	33.2	59.6	0.118623	21.3404	2.53
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2004	4	12	33.2	59.6	0.03454	26.0378	0.90
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2005	4	12	33.2	59.6	0.03454	32.215	1.11
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2006	4	12	33.2	59.6	0.03454	38.7754	1.34
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2007	4	12	33.2	59.6	0.03454	43.0254	1.49
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2008	4	12	33.2	59.6	0.03454	51.3064	1.77
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2009	4	12	33.2	59.6	0.03454	30.7848	1.06
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2010	4	12	33.2	59.6	0.03454	31.812	1.10
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2011	4	12	33.2	59.6	0.03454	38.0732	1.32
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2012	4	12	33.2	59.6	0.03454	51.675	1.78
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2013	4	12	33.2	59.6	0.03454	63.7692	2.20
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2014	4	12	33.2	59.6	0.03454	80.5606	2.78
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2015	4	12	33.2	59.6	0.03454	101.499	3.51
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2016	4	12	33.2	59.6	0.03454	134.96	4.66
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2017	4	12	33.2	59.6	0.03454	183.46	6.34
ScenarioID	2	2018	1	5	18	90090412	100	1	11	0		0	2018	4	12	33.2	59.6	0.03454	338.008	11.67
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1988	4	12	33.2	59.6	0.152783	530.67	81.08
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1989	4	12	33.2	59.6	0.152783	403.988	61.72
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1990	4	12	33.2	59.6	0.219063	497.65	109.02
ScenarioID	2	2018	1	5								0	1991	4	12	33.2	59.6	0.134515	607.779	81.76
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1992	4	12	33.2	59.6	0.134515	746.945	100.48
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1993	4	12	33.2	59.6	0.134515	937.323	126.08
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1994	4	12	33.2	59.6	0.105936	1159.56	122.84
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1995	4	12	33.2	59.6	0.08434	1582.89	133.50
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1996	4	12	33.2	59.6	0.064009	1670.05	106.90
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1997	4	12	33.2	59.6	0.115539	2204.5	254.71
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1998	4	12	33.2	59.6	0.087429	2598.24	227.16
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	1999	4	12	33.2	59.6	0.045577	3480.08	158.61
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2000	4	12	33.2	59.6	0.064263	4855.66	312.04
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2001	4	12	33.2	59.6	0.03867	5505.17	212.89
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2002	4	12	33.2	59.6	0.035995	6844.57	246.37
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2003	4	12	33.2	59.6	0.022193	8259.99	183.31
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2004	4	12	33.2	59.6	0.005375	9463.45	50.86
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2005	4	12	33.2	59.6	0.005375	11798.9	63.41
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2006	4	12	33.2	59.6	0.005375	13026.6	70.01
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2007	4	12	33.2	59.6	0.005375	14908.4	80.13
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2008	4	12	33.2	59.6	0.005375	14300.8	76.86
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2009	4	12	33.2	59.6	0.004074	12007.3	48.92
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2010	4	12	33.2	59.6	0.004074	13755.1	56.04
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2011	4	12	33.2	59.6	0.003478	12566.8	43.70
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2012	4	12	33.2	59.6	0.003478	20815.6	72.39
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2013	4	12	33.2	59.6	0.002969	23399.6	69.46
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2014	4	12	33.2	59.6	0.002969	25302.5	75.11
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2015	4	12	33.2	59.6	0.002341	26486.1	62.01
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2016	4	12	33.2	59.6	0.002341	27817.1	65.12
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2017	4	12	33.2	59.6	0.002243	28588.4	64.12
ScenarioID	2	2018	1	5	18	90090412	100	1	21	0		0	2018	4	12	33.2	59.6	0.002147	28732.1	61.68

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceTyp	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDis	activity	Rate per D
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1988	4	12	33.2	59.6	0.142469	262.816	37.44
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1989	4	12	33.2	59.6	0.142771	314.655	44.92
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1990	4	12	33.2	59.6	0.196508	313.931	61.69
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1991	4	12	33.2	59.6	0.08202	365.094	29.94
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1992	4	12	33.2	59.6	0.082034	439.671	36.07
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1993	4	12	33.2	59.6	0.082572	560.247	46.26
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1994	4	12	33.2	59.6	0.098953	844.775	83.59
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1995	4	12	33.2	59.6	0.092656	984.685	91.24
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1996	4	12	33.2	59.6	0.102582	1079.78	110.77
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1997	4	12	33.2	59.6	0.093928	1550.08	145.60
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1998	4	12	33.2	59.6	0.083917	1928.81	161.86
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	1999	4	12	33.2	59.6	0.084879	2486.47	211.05
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2000	4	12	33.2	59.6	0.074418	3029.26	225.43
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2001	4	12	33.2	59.6	0.072188	3534.03	255.11
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2002	4	12	33.2	59.6	0.040836	4356.76	177.91
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2003	4	12	33.2	59.6	0.055158	5056.73	278.92
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2004	4	12	33.2	59.6	0.008651	6305.08	54.54
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2005	4	12	33.2	59.6	0.008636	6893.12	59.53
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2006	4	12	33.2	59.6	0.008669	7370	63.89
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2007	4	12	33.2	59.6	0.008611	7376.98	63.52
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2008	4	12	33.2	59.6	0.008634	7848.73	67.77
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2009	4	12	33.2	59.6	0.007067	4637.62	32.78
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2010	4	12	33.2	59.6	0.007048	6490.59	45.74
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2011	4	12	33.2	59.6	0.006361	7147.14	45.46
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2012	4	12	33.2	59.6	0.006362	11541.4	73.43
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2013	4	12	33.2	59.6	0.005684	13917.5	79.10
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2014	4	12	33.2	59.6	0.005683	15504.4	88.11
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2015	4	12	33.2	59.6	0.003626	17119.1	62.08
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2016	4	12	33.2	59.6	0.003626	18348.7	66.53
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2017	4	12	33.2	59.6	0.003626	18820	68.24
ScenarioID	2	2018	1	5	18	90090412	100	1	31	0		0	2018	4	12	33.2	59.6	0.003337	19096.1	63.73
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1988	4	12	33.2	59.6	0.136749	48.8675	6.68
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1989	4	12	33.2	59.6	0.137698	56.1696	7.73
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1990	4	12	33.2	59.6	0.182231	53.7889	9.80
ScenarioID	2	2018	1	5	18															
0	1991	4	12	33.2	59.6	0.076299	49.1418	3.75												
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1992	4	12	33.2	59.6	0.074605	53.6956	4.01
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1993	4	12	33.2	59.6	0.073254	105.487	7.73
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1994	4	12	33.2	59.6	0.101171	111.398	11.27
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1995	4	12	33.2	59.6	0.086247	180.068	15.53
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1996	4	12	33.2	59.6	0.089918	186.558	16.77
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1997	4	12	33.2	59.6	0.089125	290.173	25.86
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1998	4	12	33.2	59.6	0.072943	290.679	21.20
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	1999	4	12	33.2	59.6	0.070337	495.166	34.83
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2000	4	12	33.2	59.6	0.064364	717.377	46.17
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2001	4	12	33.2	59.6	0.063115	917.169	57.89
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2002	4	12	33.2	59.6	0.036573	1169.08	42.76
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2003	4	12	33.2	59.6	0.047886	1363.51	65.29
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2004	4	12	33.2	59.6	0.008017	1705.95	13.68
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2005	4	12	33.2	59.6	0.007981	1856.21	14.81
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2006	4	12	33.2	59.6	0.008063	2006.18	16.18
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2007	4	12	33.2	59.6	0.007916	1969.6	15.59
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2008	4	12	33.2	59.6	0.007976	2112.12	16.85
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2009	4	12	33.2	59.6	0.006461	1227.5	7.93
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2010	4	12	33.2	59.6	0.006409	1704.05	10.92
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2011	4	12	33.2	59.6	0.005877	1924.15	11.31
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2012	4	12	33.2	59.6	0.00588	2767.26	16.27
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2013	4	12	33.2	59.6	0.005239	3350.23	17.55
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2014	4	12	33.2	59.6	0.005237	3754.54	19.66
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2015	4	12	33.2	59.6	0.00334	4170.72	13.93
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2016	4	12	33.2	59.6	0.00334	4494.79	15.01
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2017	4	12	33.2	59.6	0.00334	4629.92	15.46
ScenarioID	2	2018	1	5	18	90090412	100	1	32	0		0	2018	4	12	33.2	59.6	0.003096	4714.32	14.59

APPENDIX - MOVES OUTPUT

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantI[	processID	sourceTyp(	regClassID	SCC	fuelTypeID	modelYear	roadTypeI[	avgSpeedB	temperatu	relHumidit	ratePerDis	activity	Rate per D
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1988	4	12	33.2	59.6	0.107873	0.923808	0.10
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1989	4	12	33.2	59.6	0.107873	0.94527	0.10
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1990	4	12	33.2	59.6	0.107873	1.37178	0.15
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1991	4	12	33.2	59.6	0.107873	1.78772	0.19
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1992	4	12	33.2	59.6	0.107873	2.4386	0.26
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1993	4	12	33.2	59.6	0.107873	3.1664	0.34
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1994	4	12	33.2	59.6	0.107873	4.15018	0.45
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1995	4	12	33.2	59.6	0.107873	3.83712	0.41
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1996	4	12	33.2	59.6	0.107873	5.39972	0.58
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1997	4	12	33.2	59.6	0.107873	6.33558	0.68
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1998	4	12	33.2	59.6	0.107873	6.80422	0.73
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	1999	4	12	33.2	59.6	0.107873	8.25878	0.89
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2000	4	12	33.2	59.6	0.107873	11.3034	1.22
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2001	4	12	33.2	59.6	0.104936	14.75	1.55
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2002	4	12	33.2	59.6	0.104936	18.1009	1.90
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2003	4	12	33.2	59.6	0.104936	21.3404	2.24
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2004	4	12	33.2	59.6	0.030555	26.0378	0.80
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2005	4	12	33.2	59.6	0.030555	32.215	0.98
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2006	4	12	33.2	59.6	0.030555	38.7754	1.18
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2007	4	12	33.2	59.6	0.030555	43.0254	1.31
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2008	4	12	33.2	59.6	0.030555	51.3064	1.57
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2009	4	12	33.2	59.6	0.030555	30.7848	0.94
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2010	4	12	33.2	59.6	0.030555	31.812	0.97
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2011	4	12	33.2	59.6	0.030555	38.0732	1.16
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2012	4	12	33.2	59.6	0.030555	51.675	1.58
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2013	4	12	33.2	59.6	0.030555	63.7692	1.95
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2014	4	12	33.2	59.6	0.030555	80.5606	2.46
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2015	4	12	33.2	59.6	0.030555	101.499	3.10
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2016	4	12	33.2	59.6	0.030555	134.96	4.12
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2017	4	12	33.2	59.6	0.030555	183.46	5.61
ScenarioID	2	2018	1	5	18	90090412	110	1	11	0		0	2018	4	12	33.2	59.6	0.030555	338.008	10.33
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1988	4	12	33.2	59.6	0.135155	530.67	71.72
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1989	4	12	33.2	59.6	0.135155	403.988	54.60
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1990	4	12	33.2	59.6	0.193788	497.65	96.44
ScenarioID	2	2018	1	5	18															
0 1991 4 12 33.2 59.6 0.118995 607.77[illegible] [illegible]																				
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1992	4	12	33.2	59.6	0.118995	746.945	88.88
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1993	4	12	33.2	59.6	0.118995	937.323	111.54
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1994	4	12	33.2	59.6	0.093713	1159.56	108.67
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1995	4	12	33.2	59.6	0.074609	1582.89	118.10
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1996	4	12	33.2	59.6	0.056623	1670.05	94.56
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1997	4	12	33.2	59.6	0.102208	2204.5	225.32
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1998	4	12	33.2	59.6	0.077342	2598.24	200.95
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	1999	4	12	33.2	59.6	0.040318	3480.08	140.31
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2000	4	12	33.2	59.6	0.056848	4855.66	276.03
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2001	4	12	33.2	59.6	0.034208	5505.17	188.32
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2002	4	12	33.2	59.6	0.031842	6844.57	217.94
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2003	4	12	33.2	59.6	0.019632	8259.99	162.16
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2004	4	12	33.2	59.6	0.004754	9463.45	44.99
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2005	4	12	33.2	59.6	0.004754	11798.9	56.10
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2006	4	12	33.2	59.6	0.004754	13026.6	61.93
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2007	4	12	33.2	59.6	0.004754	14908.4	70.88
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2008	4	12	33.2	59.6	0.004754	14300.8	67.99
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2009	4	12	33.2	59.6	0.003604	12007.3	43.27
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2010	4	12	33.2	59.6	0.003604	13755.1	49.57
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2011	4	12	33.2	59.6	0.003076	12566.8	38.66
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2012	4	12	33.2	59.6	0.003076	20815.6	64.04
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2013	4	12	33.2	59.6	0.002626	23399.6	61.45
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2014	4	12	33.2	59.6	0.002626	25302.5	66.44
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2015	4	12	33.2	59.6	0.002071	26486.1	54.85
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2016	4	12	33.2	59.6	0.002071	27817.1	57.61
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2017	4	12	33.2	59.6	0.001984	28588.4	56.72
ScenarioID	2	2018	1	5	18	90090412	110	1	21	0		0	2018	4	12	33.2	59.6	0.001899	28732.1	54.56

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceType	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDist	activity	Rate per D
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1988	4	12	33.2	59.6	0.126031	262.816	33.12
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1989	4	12	33.2	59.6	0.126298	314.655	39.74
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1990	4	12	33.2	59.6	0.173835	313.931	54.57
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1991	4	12	33.2	59.6	0.072556	365.094	26.49
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1992	4	12	33.2	59.6	0.072569	439.671	31.91
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1993	4	12	33.2	59.6	0.073045	560.247	40.92
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1994	4	12	33.2	59.6	0.087536	844.775	73.95
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1995	4	12	33.2	59.6	0.081965	984.685	80.71
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1996	4	12	33.2	59.6	0.090746	1079.78	97.99
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1997	4	12	33.2	59.6	0.083091	1550.08	128.80
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1998	4	12	33.2	59.6	0.074235	1928.81	143.18
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	1999	4	12	33.2	59.6	0.075086	2486.47	186.70
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2000	4	12	33.2	59.6	0.065831	3029.26	199.42
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2001	4	12	33.2	59.6	0.063859	3534.03	225.68
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2002	4	12	33.2	59.6	0.036124	4356.76	157.38
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2003	4	12	33.2	59.6	0.048794	5056.73	246.74
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2004	4	12	33.2	59.6	0.007653	6305.08	48.25
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2005	4	12	33.2	59.6	0.00764	6893.12	52.66
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2006	4	12	33.2	59.6	0.007669	7370	56.52
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2007	4	12	33.2	59.6	0.007618	7376.98	56.19
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2008	4	12	33.2	59.6	0.007638	7848.73	59.95
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2009	4	12	33.2	59.6	0.006252	4637.62	28.99
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2010	4	12	33.2	59.6	0.006235	6490.59	40.47
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2011	4	12	33.2	59.6	0.005627	7147.14	40.22
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2012	4	12	33.2	59.6	0.005628	11541.4	64.96
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2013	4	12	33.2	59.6	0.005028	13917.5	69.98
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2014	4	12	33.2	59.6	0.005027	15504.4	77.95
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2015	4	12	33.2	59.6	0.003208	17119.1	54.91
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2016	4	12	33.2	59.6	0.003208	18348.7	58.86
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2017	4	12	33.2	59.6	0.003208	18820	60.37
ScenarioID	2	2018	1	5	18	90090412	110	1	31	0		0	2018	4	12	33.2	59.6	0.002952	19096.1	56.38
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1988	4	12	33.2	59.6	0.120971	48.8675	5.91
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1989	4	12	33.2	59.6	0.12181	56.1696	6.84
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1990	4	12	33.2	59.6	0.161205	53.7889	8.67
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1991	4	12	33.2	59.6	0.067496	49.1418	3.42
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1992	4	12	33.2	59.6	0.065997	53.6956	3.54
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1993	4	12	33.2	59.6	0.064802	105.487	6.84
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1994	4	12	33.2	59.6	0.089498	111.398	9.97
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1995	4	12	33.2	59.6	0.076296	180.068	13.74
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1996	4	12	33.2	59.6	0.079543	186.558	14.84
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1997	4	12	33.2	59.6	0.078841	290.173	22.88
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1998	4	12	33.2	59.6	0.064527	290.679	18.76
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	1999	4	12	33.2	59.6	0.062222	495.166	30.81
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2000	4	12	33.2	59.6	0.056938	717.377	40.85
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2001	4	12	33.2	59.6	0.055833	917.169	51.21
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2002	4	12	33.2	59.6	0.032353	1169.08	37.82
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2003	4	12	33.2	59.6	0.042361	1363.51	57.76
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2004	4	12	33.2	59.6	0.007092	1705.95	12.10
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2005	4	12	33.2	59.6	0.00706	1856.21	13.10
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2006	4	12	33.2	59.6	0.007132	2006.18	14.31
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2007	4	12	33.2	59.6	0.007002	1969.6	13.79
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2008	4	12	33.2	59.6	0.007056	2112.12	14.90
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2009	4	12	33.2	59.6	0.005716	1227.5	7.02
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2010	4	12	33.2	59.6	0.00567	1704.05	9.66
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2011	4	12	33.2	59.6	0.005199	1924.15	10.00
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2012	4	12	33.2	59.6	0.005202	2767.26	14.40
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2013	4	12	33.2	59.6	0.004634	3350.23	15.53
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2014	4	12	33.2	59.6	0.004633	3754.54	17.39
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2015	4	12	33.2	59.6	0.002955	4170.72	12.32
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2016	4	12	33.2	59.6	0.002954	4494.79	13.28
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2017	4	12	33.2	59.6	0.002955	4629.92	13.68
ScenarioID	2	2018	1	5	18	90090412	110	1	32	0		0	2018	4	12	33.2	59.6	0.002739	4714.32	12.91

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceType	regClassID	SCC	fuelTypeID	modelYear	roadTypeID	avgSpeedB	temperatu	relHumidit	ratePerDist	activity	Rate per Distance X A
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1988	4	12	33.2	59.6	1.08433	0.923808	1.00
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1989	4	12	33.2	59.6	1.08433	0.94527	1.02
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1990	4	12	33.2	59.6	1.08712	1.37178	1.49
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1991	4	12	33.2	59.6	1.08712	1.78772	1.94
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1992	4	12	33.2	59.6	1.08712	2.4386	2.65
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1993	4	12	33.2	59.6	1.08712	3.1664	3.44
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1994	4	12	33.2	59.6	1.16357	4.15018	4.83
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1995	4	12	33.2	59.6	1.16357	3.83712	4.46
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1996	4	12	33.2	59.6	1.17126	5.39972	6.32
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1997	4	12	33.2	59.6	1.17126	6.33558	7.42
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1998	4	12	33.2	59.6	1.17126	6.80422	7.97
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	1999	4	12	33.2	59.6	1.17126	8.25878	9.67
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2000	4	12	33.2	59.6	1.17126	11.3034	13.24
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2001	4	12	33.2	59.6	1.05985	14.75	15.63
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2002	4	12	33.2	59.6	1.05985	18.1009	19.18
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2003	4	12	33.2	59.6	1.05985	21.3404	22.62
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2004	4	12	33.2	59.6	0.736379	26.0378	19.17
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2005	4	12	33.2	59.6	0.736379	32.215	23.72
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2006	4	12	33.2	59.6	0.736379	38.7754	28.55
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2007	4	12	33.2	59.6	0.736379	43.0254	31.68
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2008	4	12	33.2	59.6	0.409875	51.3064	21.03
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2009	4	12	33.2	59.6	0.409875	30.7848	12.62
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2010	4	12	33.2	59.6	0.409875	31.812	13.04
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2011	4	12	33.2	59.6	0.409875	38.0732	15.61
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2012	4	12	33.2	59.6	0.409875	51.675	21.18
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2013	4	12	33.2	59.6	0.409875	63.7692	26.14
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2014	4	12	33.2	59.6	0.409875	80.5606	33.02
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2015	4	12	33.2	59.6	0.409875	101.499	41.60
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2016	4	12	33.2	59.6	0.409875	134.96	55.32
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2017	4	12	33.2	59.6	0.409875	183.46	75.20
ScenarioID	2	2018	1	5	18	90090412	87	1	11	0		0	2018	4	12	33.2	59.6	0.409875	338.008	138.54
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1988	4	12	33.2	59.6	0.383926	530.67	203.74
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1989	4	12	33.2	59.6	0.383926	403.988	155.10
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1990	4	12	33.2	59.6	0.254398	497.65	126.60
ScenarioID	2	2018	1	5								0	1991	4	12	33.2	59.6	0.254406	607.779	154.62
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1992	4	12	33.2	59.6	0.254406	746.945	190.03
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1993	4	12	33.2	59.6	0.254406	937.323	238.46
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1994	4	12	33.2	59.6	0.222156	1159.56	257.60
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1995	4	12	33.2	59.6	0.225334	1582.89	356.68
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1996	4	12	33.2	59.6	0.159449	1670.05	266.29
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1997	4	12	33.2	59.6	0.15957	2204.5	351.77
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1998	4	12	33.2	59.6	0.160146	2598.24	416.10
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	1999	4	12	33.2	59.6	0.158855	3480.08	552.83
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2000	4	12	33.2	59.6	0.160377	4855.66	778.74
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2001	4	12	33.2	59.6	0.018318	5505.17	100.84
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2002	4	12	33.2	59.6	0.017519	6844.57	119.91
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2003	4	12	33.2	59.6	0.017588	8259.99	145.28
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2004	4	12	33.2	59.6	0.014441	9463.45	136.66
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2005	4	12	33.2	59.6	0.014258	11798.9	168.23
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2006	4	12	33.2	59.6	0.014139	13026.6	184.18
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2007	4	12	33.2	59.6	0.013958	14908.4	208.09
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2008	4	12	33.2	59.6	0.013947	14300.8	199.46
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2009	4	12	33.2	59.6	0.009736	12007.3	116.90
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2010	4	12	33.2	59.6	0.009736	13755.1	133.92
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2011	4	12	33.2	59.6	0.007058	12566.8	88.69
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2012	4	12	33.2	59.6	0.007058	20815.6	146.91
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2013	4	12	33.2	59.6	0.005128	23399.6	119.98
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2014	4	12	33.2	59.6	0.005128	25302.5	129.74
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2015	4	12	33.2	59.6	0.002088	26486.1	55.30
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2016	4	12	33.2	59.6	0.00219	27817.1	60.91
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2017	4	12	33.2	59.6	0.002001	28588.4	57.19
ScenarioID	2	2018	1	5	18	90090412	87	1	21	0		0	2018	4	12	33.2	59.6	0.001867	28732.1	53.63

MOVESSce	MOVESRur	yearID	monthID	dayID	hourID	linkID	pollutantID	processID	sourceTyp	regClassID	SCC	fuelTypeID	modelYear	roadTypeI	avgSpeedB	temperatu	relHumidit	ratePerDist	activity	Rate per Distance X A
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1988	4	12	33.2	59.6	0.65919	262.816	173.25
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1989	4	12	33.2	59.6	0.659836	314.655	207.62
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1990	4	12	33.2	59.6	0.577905	313.931	181.42
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1991	4	12	33.2	59.6	0.579154	365.094	211.45
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1992	4	12	33.2	59.6	0.579191	439.671	254.65
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1993	4	12	33.2	59.6	0.580649	560.247	325.31
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1994	4	12	33.2	59.6	0.533376	844.775	450.58
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1995	4	12	33.2	59.6	0.533283	984.685	525.12
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1996	4	12	33.2	59.6	0.21321	1079.78	230.22
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1997	4	12	33.2	59.6	0.323422	1550.08	501.33
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1998	4	12	33.2	59.6	0.308999	1928.81	596.00
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	1999	4	12	33.2	59.6	0.297756	2486.47	740.36
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2000	4	12	33.2	59.6	0.297399	3029.26	900.90
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2001	4	12	33.2	59.6	0.091394	3534.03	322.99
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2002	4	12	33.2	59.6	0.08749	4356.76	381.17
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2003	4	12	33.2	59.6	0.096294	5056.73	486.93
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2004	4	12	33.2	59.6	0.036639	6305.08	231.01
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2005	4	12	33.2	59.6	0.027604	6893.12	190.28
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2006	4	12	33.2	59.6	0.028444	7370	209.63
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2007	4	12	33.2	59.6	0.027271	7376.98	201.18
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2008	4	12	33.2	59.6	0.02642	7848.73	207.37
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2009	4	12	33.2	59.6	0.018141	4637.62	84.13
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2010	4	12	33.2	59.6	0.018034	6490.59	117.05
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2011	4	12	33.2	59.6	0.013384	7147.14	95.66
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2012	4	12	33.2	59.6	0.013389	11541.4	154.52
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2013	4	12	33.2	59.6	0.009499	13917.5	132.21
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2014	4	12	33.2	59.6	0.009499	15504.4	147.27
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2015	4	12	33.2	59.6	0.004047	17119.1	69.29
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2016	4	12	33.2	59.6	0.004224	18348.7	77.51
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2017	4	12	33.2	59.6	0.005267	18820	99.13
ScenarioID	2	2018	1	5	18	90090412	87	1	31	0		0	2018	4	12	33.2	59.6	0.00347	19096.1	66.26
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1988	4	12	33.2	59.6	0.68374	48.8675	33.41
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1989	4	12	33.2	59.6	0.685642	56.1696	38.51
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1990	4	12	33.2	59.6	0.593739	53.7889	31.94
ScenarioID	2	2018	1	5	18							0	1991	4	12	33.2	59.6	0.590163	49.1418	29.00
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1992	4	12	33.2	59.6	0.585195	53.6956	31.42
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1993	4	12	33.2	59.6	0.581233	105.487	61.31
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1994	4	12	33.2	59.6	0.556455	111.398	61.99
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1995	4	12	33.2	59.6	0.567376	180.068	102.17
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1996	4	12	33.2	59.6	0.256134	186.558	47.78
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1997	4	12	33.2	59.6	0.360021	290.173	104.47
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1998	4	12	33.2	59.6	0.305487	290.679	88.80
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	1999	4	12	33.2	59.6	0.29033	495.166	143.76
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2000	4	12	33.2	59.6	0.28863	717.377	207.06
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2001	4	12	33.2	59.6	0.092848	917.169	85.16
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2002	4	12	33.2	59.6	0.086288	1169.08	100.88
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2003	4	12	33.2	59.6	0.094619	1363.51	129.01
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2004	4	12	33.2	59.6	0.03981	1705.95	67.91
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2005	4	12	33.2	59.6	0.031099	1856.21	57.73
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2006	4	12	33.2	59.6	0.032912	2006.18	66.03
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2007	4	12	33.2	59.6	0.029757	1969.6	58.61
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2008	4	12	33.2	59.6	0.02706	2112.12	57.15
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2009	4	12	33.2	59.6	0.016684	1227.5	20.48
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2010	4	12	33.2	59.6	0.016479	1704.05	28.08
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2011	4	12	33.2	59.6	0.012651	1924.15	24.34
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2012	4	12	33.2	59.6	0.012662	2767.26	35.04
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2013	4	12	33.2	59.6	0.008604	3350.23	28.83
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2014	4	12	33.2	59.6	0.008603	3754.54	32.30
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2015	4	12	33.2	59.6	0.003712	4170.72	15.48
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2016	4	12	33.2	59.6	0.003849	4494.79	17.30
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2017	4	12	33.2	59.6	0.004905	4629.92	22.71
ScenarioID	2	2018	1	5	18	90090412	87	1	32	0		0	2018	4	12	33.2	59.6	0.003252	4714.32	15.33

Appendix E

Carbon Monoxide (CO) Technical Memorandum

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Technical Memorandum

Carbon Monoxide Exposure Limit

1 Introduction

This memorandum presents the justification for the determined carbon monoxide exposure limit for the proposed project. The state of Connecticut has a single tunnel within their highway system, therefore there are no standards to aid in determining exposure limits of carbon monoxide (CO) during normal traffic operations, traffic incidents and maintenance operations. Several sources including the Occupational Safety and Health Standards (OSHA), the National Fire Protection Agency (NFPA) and other state's requirements were reviewed to determine the most appropriate guidelines to use as a design basis for the Heroes Tunnel ventilation system. Excerpts from the referenced sources are provided in attachments to this Technical Memorandum.

2 Standards, Codes and Evaluation Criteria

2.1 Evaluation Criteria

To provide the safest possible environment in the tunnel, the exposure limits were chosen based on the longest anticipated time period an individual would be exposed to CO. In this case, that time would be during maintenance operations which typically last eight hours. Therefore, the acceptable exposure limits will be specified for an eight-hour duration.

2.2 Occupational Safety and Health Administration (OHSA) Standards

The Occupational Safety and Health Administration (OSHA) provides standards to ensure workers a safe and healthful working environment. Within OSHA standard 1910.1000 – Air Contaminants, permissible exposure limits for many contaminants are listed in Table Z-1 – Limits for Air Contaminants as an 8-hour time weighted average (see Appendix attachment). The time weighted average for CO is listed as 50 parts per million (ppm).

2.3 National Fire Protection Association (NFPA) Standards

The National Fire Protection Association (NFPA) offers guidance on how to eliminate fire, electrical and other related hazards. NFPA 502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways includes similar information on CO exposure limits to the OSHA standards. In Section B.2.2 (see Appendix attachment), the concentration of CO in air must average 50 ppm or less for any exposure duration over 30 minutes.

2.4 National Cooperative Highway Research Program (NCHRP)

In 2009, the National Cooperative Highway Research Program (NCHRP) conducted a conference to address the need for national tunnel standards. The participants included several state departments of transportation as well as other representatives. The resulting document, NCHRP Project 20-68A, titled "Best Practices for Roadway Tunnel Design, Construction, maintenance, Inspection, and Operations" (see Appendix attachment), outlines the participants' air quality requirements in Section 2.3.1.2. Here, a few of the departments of transportation involved, California, Colorado and Massachusetts, list their CO concentration limits. California states that at concentrations of 60 ppm or greater, exhaust fans activate to lower the concentration of CO. Colorado's and Massachusetts' maximum CO limit is 100 ppm for any exposure time and 70 ppm for a duration of one hour, respectively.

2.5 LRFD Road Tunnel Design and Construction Guide Specifications (AASHTO) 2107

Table 2.8.3.2-1 Minimum Limits for Carbon Monoxide, Oxides of Nitrogen, and Particulate Matter provides a limiting Value of 35 ppm up to 60 minutes of exposure for Carbon Monoxide. As indicated in the commentary of this section the CO limiting values are based on FHWA/EPA guidelines.

3 Recommendations

Comparing the various exposure limits, the values shown in OSHA and NFPA 502 coincide with one another at a level of 50 ppm but the exposure limit for OSHA is 8 hours while NFPA 502 is any exposure over 30 minutes a much more stringent limit. The LRFD Guide Specifications level of 35 ppm for a similar exposure limit of one hour. The values from the NCHRP program are consistently higher, reaching a maximum allowable level of 100 ppm. Since the NCHRP proceedings are based on various departments' standards and are not restricted by national code, OSHA and NFPA will be the primary resource for the exposure limits in Heroes Tunnel. The criteria for this study was to determine required upgrades that meet the NFPA 502 Standards for fire protection and life safety systems. Though the LRFD Guide Specifications will be the controlling code for this facility and moving forward in design, the NFPA 502 Standard of 50 ppm for exposures over 30 minutes will be the controlling exposure level for this report. It is CDM Smith's recommendation to implement a 50 ppm limit for exposures over 30 minutes, at which the tunnel ventilation system will activate to maintain air quality at an acceptable level.

TABLE Z–1—LIMITS FOR AIR CONTAMINANTS—Continued

Substance	CAS No. (c)	ppm (a) [1]	mg/m³ (b) [1]	Skin designation
Butanethiol; see Butyl mercaptan.				
2-Butanone (Methyl ethyl ketone)	78–93–3	200	590	
2-Butoxyethanol	111–76–2	50	240	X
n-Butyl-acetate	123–86–4	150	710	
sec-Butyl acetate	105–46–4	200	950	
tert-Butyl acetate	540–88–5	200	950	
n-Butyl alcohol	71–36–3	100	300	
sec-Butyl alcohol	78–92–2	150	450	
tert-Butyl alcohol	75–65–0	100	300	
Butylamine	109–73–9	(C)5	(C)15	X
tert-Butyl chromate (as CrO_3); see 1910.1026 [6]	1189–85–1			
n-Butyl glycidyl ether (BGE)	2426–08–6	50	270	
Butyl mercaptan	109–79–5	10	35	
p-tert-Butyltoluene	98–51–1	10	60	
Cadmium (as Cd); see 1910.1027	7440–43–9			
Calcium carbonate	1317–65–3			
Total dust			15	
Respirable fraction			5	
Calcium hydroxide	1305–62–0			
Total dust			15	
Respirable fraction			5	
Calcium oxide	1305–78–8		5	
Calcium silicate	1344–95–2			
Total dust			15	
Respirable fraction			5	
Calcium sulfate	7778–18–9			
Total dust			15	
Respirable fraction			5	
Camphor, synthetic	76–22–2		2	
Carbaryl (Sevin)	63–25–2		5	
Carbon black	1333–86–4		3.5	
Carbon dioxide	124–38–9	5000	9000	
Carbon disulfide	75–15–0		([2])	
Carbon monoxide	630–08–0	50	55	
Carbon tetrachloride	56–23–5		([2])	
Cellulose	9004–34–6			
Total dust			15	
Respirable fraction			5	
Chlordane	57–74–9		0.5	X
Chlorinated camphene	8001–35–2		0.5	X
Chlorinated diphenyl oxide	55720–99–5		0.5	
Chlorine	7782–50–5	(C)1	(C)3	
Chlorine dioxide	10049–04–4	0.1	0.3	
Chlorine trifluoride	7790–91–2	(C)0.1	(C)0.4	
Chloroacetaldehyde	107–20–0	(C)1	(C)3	
a-Chloroacetophenone (Phenacyl chloride)	532–27–4	0.05	0.3	
Chlorobenzene	108–90–7	75	350	
o-Chlorobenzylidene malononitrile	2698–41–1	0.05	0.4	
Chlorobromomethane	74–97–5	200	1050	
2-Chloro-1,3-butadiene; see beta-Chloroprene.				
Chlorodiphenyl (42% Chlorine) (PCB)	53469–21–9		1	X
Chlorodiphenyl (54% Chlorine) (PCB)	11097–69–1		0.5	X
1-Chloro-2,3-epoxypropane; see Epichlorohydrin.				
2-Chloroethanol; see Ethylene chlorohydrin.				
Chloroethylene; see Vinyl chloride.				
Chloroform (Trichloromethane)	67–66–3	(C)50	(C)240	
bis(Chloromethyl) ether; see 1910.1008	542–88–1			
Chloromethyl methyl ether; see 1910.1006	107–30–2			
1-Chloro-1-nitropropane	600–25–9	20	100	
Chloropicrin	76–06–2	0.1	0.7	
beta-Chloroprene	126–99–8	25	90	X
2-Chloro-6-(trichloromethyl) pyridine	1929–82–4			
Total dust			15	
Respirable fraction			5	
Chromium (II) compounds.				
(as Cr)	7440–47–3		0.5	
Chromium (III) compounds.				
(as Cr)	7440–47–3		0.5	
Chromium (VI) compounds; See 1910.1026 [5]				
Chromium metal and insol. salts (as Cr)	7440–47–3		1	
Chrysene; see Coal tar pitch volatiles.				
Clopidol	2971–90–6			

As with toxic gases, an exposed occupant can be considered to accumulate a dose of convected heat over a period of time. The FED of convected heat accumulated per minute is the reciprocal of t_{Iconv} .

Convected heat accumulated per minute depends on the extent to which an exposed occupant is clothed and the nature of the clothing. For fully clothed subjects, equation B.2.1b is suggested:

[B.2.1b]

$$t_{Iconv} = \left(4.1 \times 10^{8}\right) T^{-3.61}$$

where:
t_{Iconv} = time (minutes)
T = temperature (°C)

For unclothed or lightly clothed subjects, it might be more appropriate to use equation B.2.1c:

[B.2.1c]

$$t_{Iconv} = \left(5.0 \times 10^{7}\right) T^{-3.4}$$

where:
t_{Iconv} = time (minutes)
T = temperature (°C)

Equations B.2.1b and B.2.1c are empirical fits to human data. It is estimated that the uncertainty is ±25 percent.

Thermal tolerance data for unprotected human skin suggest a limit of about 120°C (248°F) for convected heat, above which there is, within minutes, onset of considerable pain along with the production of burns. Depending on the length of exposure, convective heat below this temperature can also cause hyperthermia.

The body of an exposed occupant can be regarded as acquiring a "dose" of heat over a period of time. A short exposure to a high radiant heat flux or temperature generally is less tolerable than a longer exposure to a lower temperature or heat flux. A methodology based on additive FEDs similar to that used with toxic gases can be applied. Providing that the temperature in the fire is stable or increasing, the total fractional effective dose of heat acquired during an exposure can be calculated using equation B.2.1d:

[B.2.1d]

$$\text{FED} = \sum\left(\frac{1}{t_{Irad}} + \frac{1}{t_{Iconv}}\right)\Delta t_{t_1}^{t_2}$$

where:
FED = fraction equivalent dose
t_{Irad} = time (min)
t_{Iconv} = time (min)
$\Delta t_{t_1}^{t_2}$ = change in time (min)

Note 1: In areas within an occupancy where the radiant flux to the skin is under 2.5 kW/m^2, the first term in equation B.2.1d is to be set at zero.

Note 2: The uncertainty associated with the use of equation B.2.1d would depend on the uncertainties associated with the use of the three earlier equations.

The time at which the FED accumulated sum exceeds an incapacitating threshold value of 0.3 represents the time available for escape for the chosen radiant and convective heat exposures.

Consider an example with the following characteristics:

(1) Evacuees are lightly clothed.
(2) There is zero radiant heat flux.
(3) The time to FED is reduced by 25 percent to allow for uncertainties in equations B.2.1b and B.2.1c.
(4) The exposure temperature is constant.
(5) The FED is not to exceed 0.3.

Equations B.2.1c and B.2.1d can be manipulated to provide the following equation:

[B.2.1e]

$$t_{exp} = \left(1.125 \times 10^{7}\right) T^{-3.4}$$

where:
t_{exp} = time of exposure to reach a FED of 0.3 (minutes)
T = temperature (°C)

This gives the results in Table B.2.1.

B.2.2 Air Carbon Monoxide Content. Air carbon monoxide (CO) content is as follows:

(1) Maximum of 2000 ppm for a few seconds
(2) Averaging 1150 ppm or less for the first 6 minutes of the exposure
(3) Averaging 450 ppm or less for the first 15 minutes of the exposure
(4) Averaging 225 ppm or less for the first 30 minutes of the exposure
(5) Averaging 50 ppm or less for the remainder of the exposure

These values should be adjusted for altitudes above 984 m (3000 ft).

B.2.3 Toxicity. The toxicity of fire smoke should be determined by considering contributing gases, which can act cumulatively.

Table B.2.1 Exposure Time and Incapacitation

Exposure Temperature		Maximum Exposure Time Without Incapacitation
°C	°F	(min)
80	176	3.8
75	167	4.7
70	158	6.0
65	149	7.7
60	140	10.1
55	131	13.6
50	122	18.8
45	113	26.9
40	104	40.2

switching lighting technology, although it has had not found this technology to be beneficial in the past.

2.3.1.2 Air Quality and Opacity Air Quality Requirements

Ventilation systems, CO/nitrogen oxides (NOx)/particulate matter (PM) monitoring systems, and fire and life-safety provisions are utilized in tunnels as needed based on design calculations of anticipated air quality exposure levels and EPA/OSHA requirements. The extent of ventilation capacity is based on tunnel length as defined by NFPA 502. Regulation varies from internal handling to reporting to local or state environmental agencies. Video is used to monitor opacity; ventilation stacks do not typically have air scrubbers.

AKDOT&PF: The Anton Anderson Memorial (Whittier) Tunnel is one of the first tunnels in the U.S. to use jet fans for ventilation. The AKDOT&PF monitors its CO levels due to the mix of trains and vehicles, but has no specific regulator.

Caltrans: Caltrans does not specify specialized air quality equipment (e.g., video imaging, laser based imaging, or newer technologies). Instead, it specifies local CO and NOx monitors located in the tunnel and dedicated to a zone. The monitors are manually calibrated, and sensors are replaced by a maintenance schedule.

Design calculations for all tunnels, including short tunnels that normally would not be expected to require ventilation, must show that CO exposure levels will not exceed the EPA maximum exposure levels during normal ADT volumes and the predicted maximum vehicle per hour traffic rate. If design calculations (i.e., computer modeling) of CO exposure levels show they could reach 50 ppm for the expected exposure time of vehicles in the tunnel, then real-time CO monitoring equipment must be installed and monitored and the contract drawings must provide for future addition of ventilation equipment. This means that sections in the structure must be blocked out for ducting and mounting of ventilation equipment, and empty power conduits to the future equipment locations must be provided. If design calculations of CO exposure levels show they could reach 120 ppm for the expected exposure time of vehicles in the tunnel, then the contract drawings must provide for the installation and operation of ventilation equipment, electrical power and controls, CO monitoring equipment, and fire/life-safety provisions.

The extent of ventilation capacity is based on the tunnel length as defined in the latest edition of NFPA 502 and as follows:

- For tunnels less than 300 feet in length, specific ventilation and fire/life-safety provisions are evaluated on a case-by-case basis, with engineering analysis required for evaluation.
- For tunnels 300 feet and greater in length, if engineering analysis indicates CO accumulations are probable, at a minimum ventilation capacity is required to dilute CO concentrations. Two-speed fans will operate at low speed when concentrations reach 60 ppm CO and high speed when concentrations reach 100 ppm CO. All other provisions of NFPA 502 apply.
- For tunnels lengths greater than 800 feet, all provisions of NFPA 502 apply, and ventilation

capacity must produce the critical velocity required to prevent back layering of the smoke of a design fire.

Documentation of air quality sampling is expected to be recorded and stored for historical and tort liability. Ventilation stacks (usually exhaust) do not have air scrubbers.

Colorado DOT: The EJMT effectively employs the original full transverse ventilation system. The HLT has not needed to run fans routinely, as the normal CO levels remain below 15 ppm.

Historically, the requirement has been a maximum 100 ppm for CO. CO ppm measurements are taken in the exhaust plenum immediately prior to being exhausted into open air. Much lower levels (i.e., 5 to 20 ppm) are typical.

The Colorado Department of Health and Environment is the regulating agency, but there is limited scrutiny due to decades without violations. CDOT does not have air scrubbers on its ventilation stacks.

MassDOT: MassDOT is under Massachusetts DEP air quality requirements. It follows the DEP regulated Continuous Emissions Monitoring (CEM) Program, which is unique to Boston. The CEM is a hybrid of ambient air quality monitoring and continuous emissions monitoring systems. Emissions are regulated as a direct source, similar to power plants, although vehicular exhaust is an indirect source, and monitored over time for air quality concentration with respect to time. CO and PM-10[30] are measured continuously, while NOx is calculated using a CO:NOx correlation. Emission limits are as follows:

- Maximum CO is 70 ppm in one hour
- Maximum NOx is 8.88 ppm in one hour
- Maximum PM-10 is 500 mg/m^3 in 24 hours

New state regulations on PM go from PM-10 to PM-3. The hourly average is reported at 16 locations in ventilation buildings, exhaust plenums, and entrance and exit ramps. Typical equipment components at each location are continuous CO gas analyzer, multi gas calibration unit, zero air generator, data logger, CO calibration gas, and a PM-10 sampler at four locations. CEM design and capital cost were $2 million, with annual non labor operating costs of $200,000, including a five year permit renewal. The CEM labor requirements to operate, maintain, and report are two environmental technicians and one senior environmental engineer. The CEM is independent of in tunnel CO monitoring.

PennDOT: PennDOT has done CO monitoring inside tunnels only. Air sampling is continuous, but there are no reporting requirements. PennDOT does not have air scrubbers on its ventilation stacks.

PANY&NJ: The PANY&NJ follows OSHA and EPA regulations and monitors CO levels

[30] PM standard that includes particles with a diameter of 10 micrometers or less

accordingly. The PANY&NJ is self regulated and does not report to external agencies. Its tunnels are equipped with CO monitors, and CO levels are monitored 24/7 via manned control rooms from which fans are adjusted accordingly. PANY&NJ also monitors NOx. It does not have air scrubbers on its ventilation stacks.

VA CBBT: The CBBT District effectively employs the original full transverse ventilation system in its tunnels.

VDOT: VDOT uses video monitoring for opacity and CO monitoring for air quality. In accordance with OSHA requirements, the maximum CO level cannot exceed 35 ppm for an 8-hour time weighted average. Air sampling is performed to determine CO levels, and regulation is performed internally by VDOT. VDOT is exempt from discharge regulations based on the Code of Virginia.

WSDOT: In normal operation, air is moved through the tunnel portals with a series of jet fans, so specialized technologies cannot be applied. The vertical fans will only operate during extreme congestion or during an emergency. The Puget Sound Air Quality Agency regulates air quality, and the tunnel project must meet local air quality standards, as must all transportation projects. There are regional air quality monitors. WSDOT does not have air scrubbers on its ventilation stacks and will resist installing them since they will only be used occasionally.

2.3.1.3 Waterproofing Systems

Various waterproofing systems have been used in tunnels, as described below. Tunnels that do not have waterproofing membranes have drainage systems to collect seep water.

Caltrans: At the Devil's Slide Tunnel and new Caldecott Tunnel, between the initial lining and the final lining, a geotextile material will be placed against a smoothed shotcrete layer and a waterproofing membrane will be placed against the final lining. This system will drain into an under drain system that will carry the water outside the tunnel and past the portals into a drainage system.

At the Doyle Drive Southbound Battery Tunnel, a geo composite drainage material will be placed at the retaining walls. A waterproofing system will be applied on the inside face of the retaining wall or tunnel walls and will drain into a sub drain system underneath the tunnel and flow out underneath the tunnel.

The Posey/Webster Tubes' precast segments were wrapped in a waterproofing material and timber lagging.

Colorado DOT: The Eisenhower bore of the EJMT does not have a waterproofing membrane. The Johnson bore was effectively treated with a membrane. Maintenance forces have drilled past the tunnel liner in the Eisenhower bore in the wet locations of the air ducts and have built a drainage system to collect the seep water in these locations. An extensive drainage system is in place above and below the roadway in both bores.

The HLT includes an elastomeric waterproofing membrane at spot locations with a formation drainage system.

Appendix F

Electrical Supporting Documents

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Form No. Tra. 25 Ed. 7/82

F.H.W.A. REGION NO.	STATE	TOWN	FED. AID PROJ. NO.	PROJ. NO.	YEAR	ROUTE NO.	SHEET NO.	TOTAL SHEETS
1	CONN.	NEW HAVEN - WOODBRIDGE		167-80	1983	15	5A	13

CONDUCTORS FOR CIR. # 1-10 TO BE IDENTIFIED AT EACH JB BY COLOR CODING OR MARKING. ALL PHASES TO BE BALANCED. ALTERNATE FIXTURES ON CIR. # 1 & 2, CIR. # 3 & 4, CIR. # 6 & 7, CIR. # 8 & 9.

NOTE:

1. RUN GROUNDS AS REQUIRED
2. SERVICE TRANSFORMER TAPS TO BE FIELD SET TO COMPENSATE FOR VOLTAGE DROP.
3. ALL TERMINATORS, LUGS, CONNECTORS, SPLICES TO BE APPROPRIATE FOR WIRE SIZE & USAGE.
4. LIGHTING & OUTLETS IN CONTROL ROOM & TOWER ROOM TO BE DETERMINED IN THE FIELD.

DESIGN BY	DRAWN BY	CHECKED BY
	S.H.N. 9/83	

REVISIONS

NO.	DATE	DESCRIPTION
5A	7/84	

CONNECTICUT
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
DIVISION OF TRAFFIC

TOWNS OF NEW HAVEN & WOODBRIDGE

WEST ROCK TUNNEL

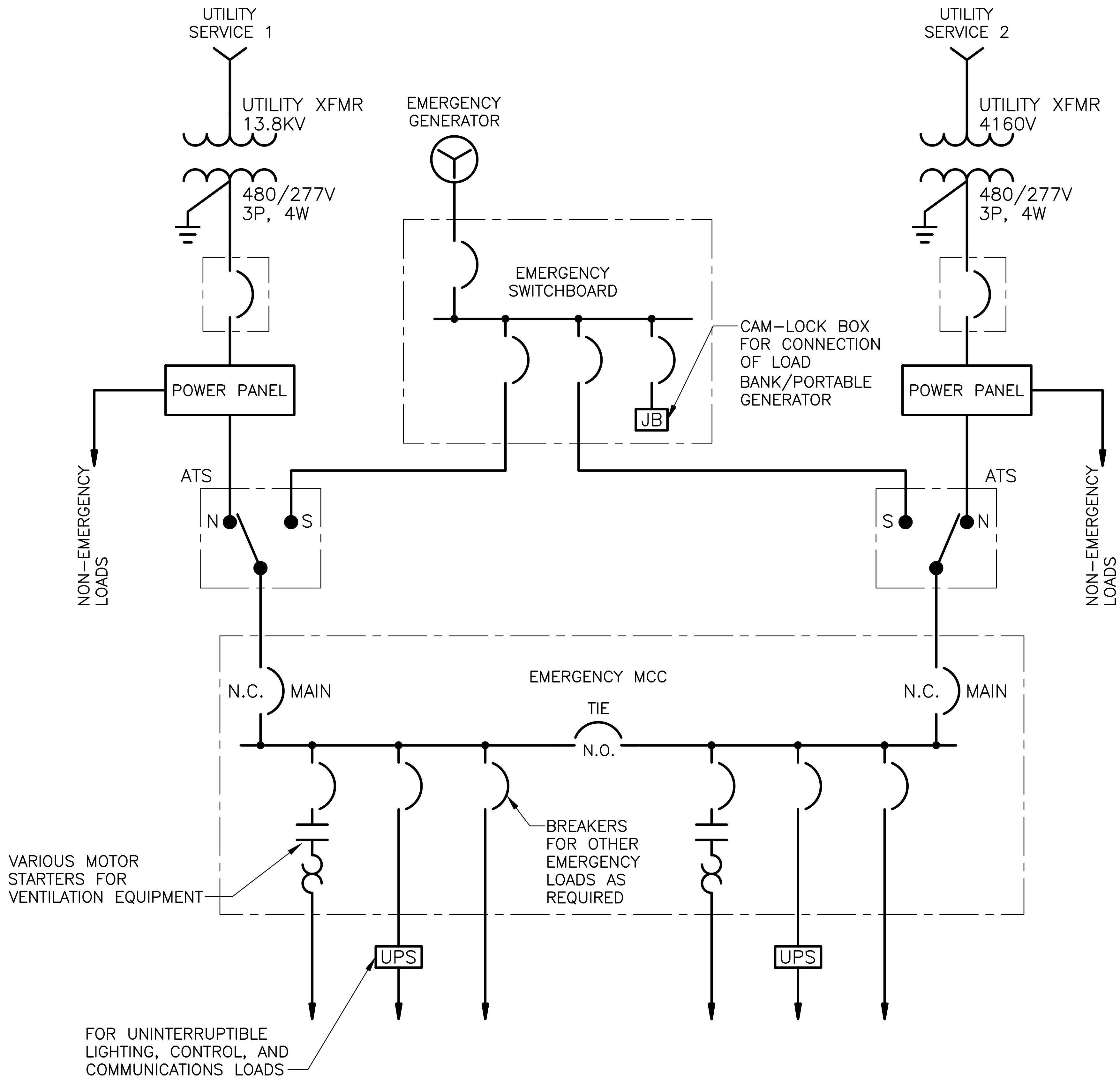
WIRING DIAGRAM

SUBMITTED BY [signature] TRANS. ASSOC. ENG.-TRAFFIC DATE 9-83

APPROVED BY [signature] ENG. OF TRAFFIC DATE 10/83

SCALE

344-08



RECOMMENDED

ONE LINE DIAGRAM

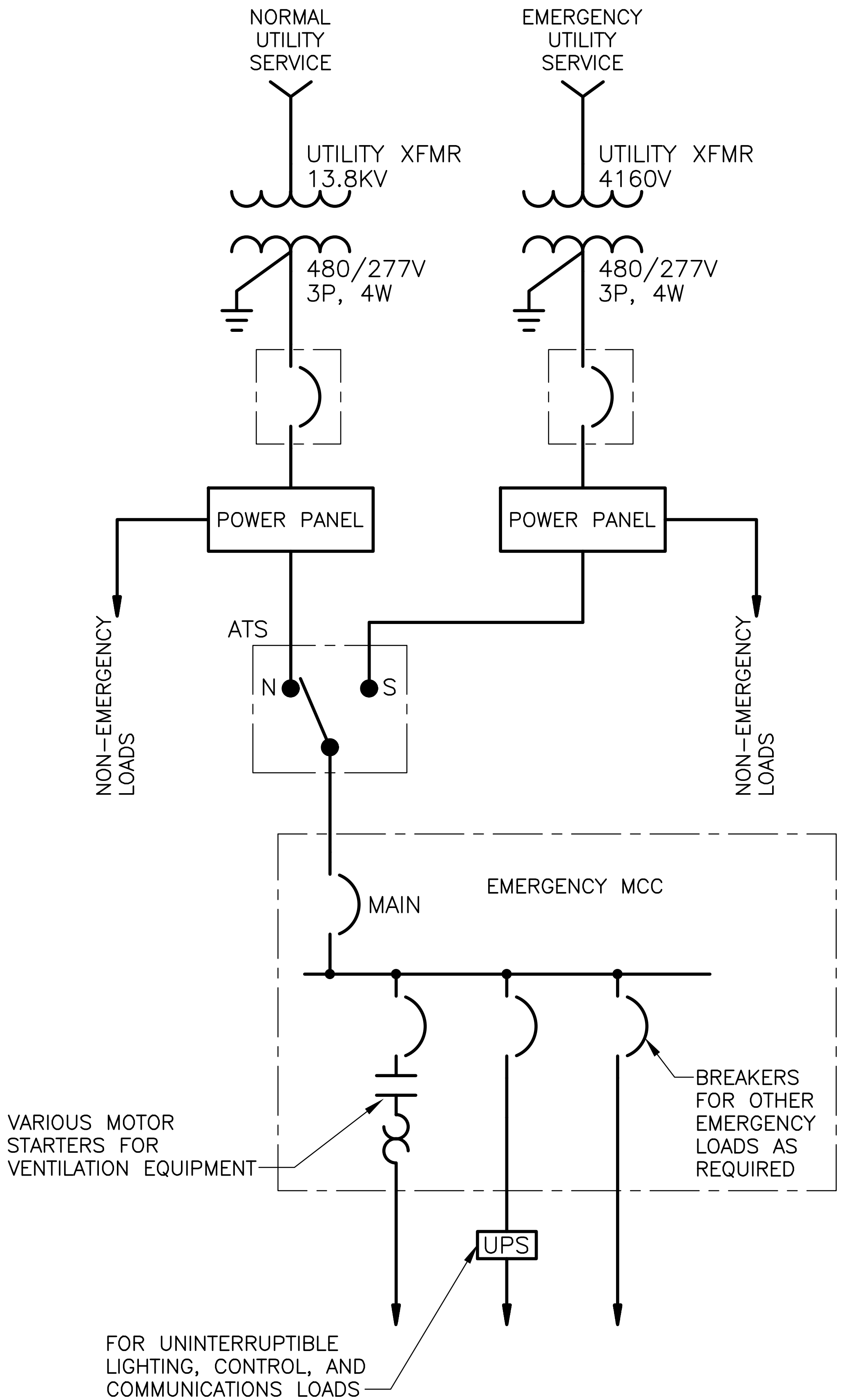
N.T.S.

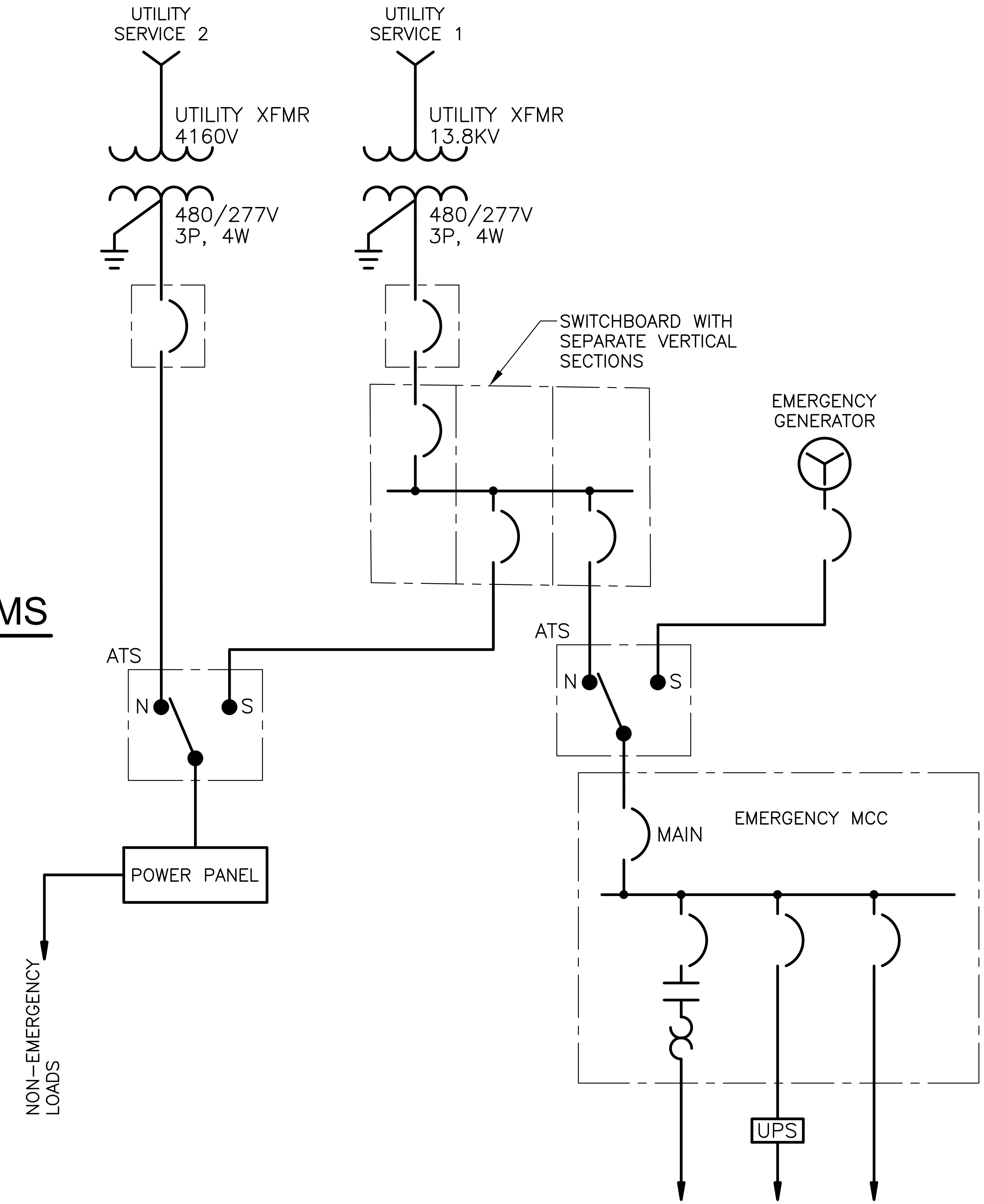
CDM Smith

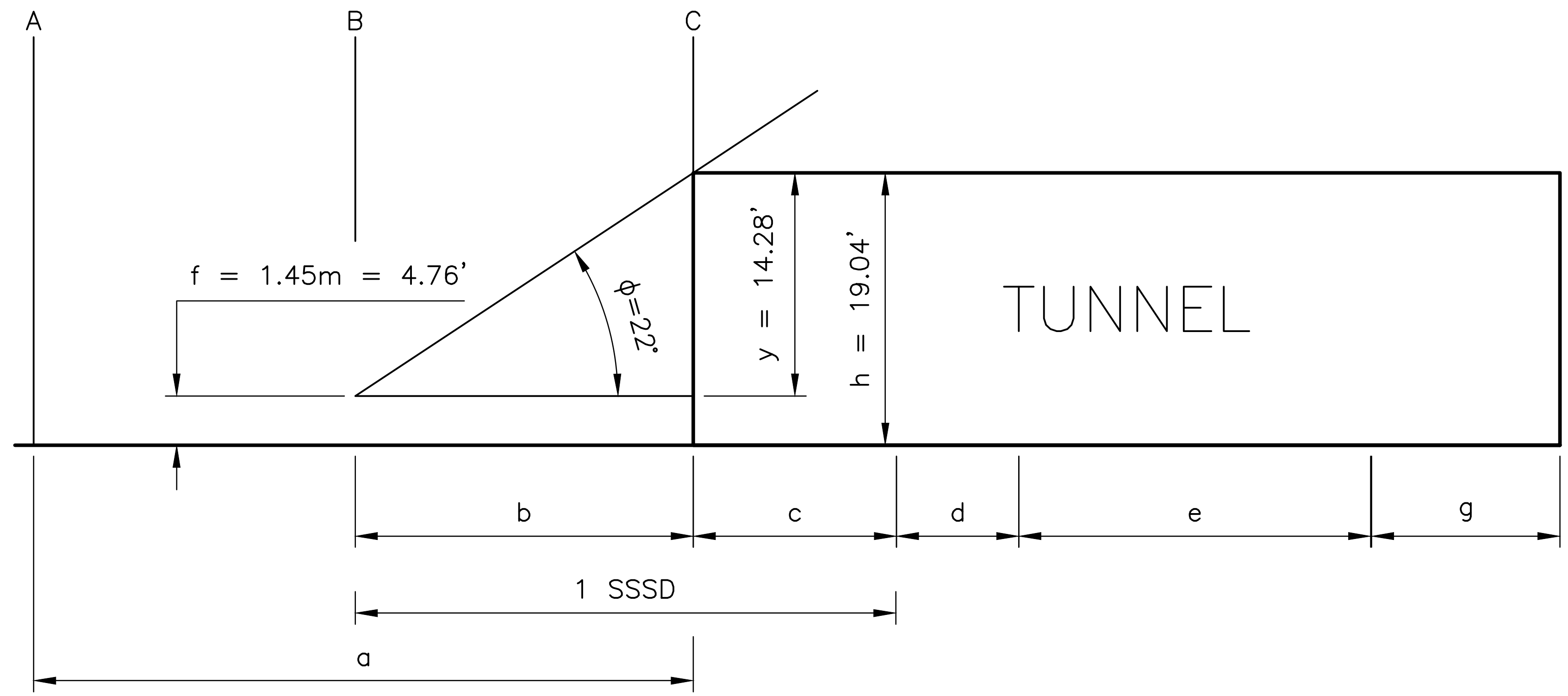
ALTERNATIVE

ONE LINE DIAGRAMS

N.T.S.







A = Fixation Point = 520'
B = Adaptation Point = 35.34'
C = Portal
ϕ = 22°

a = Approach = 520'
b = Adaptation Distance = 35.34'
c = Threshold Zone = 484.66'
d = Transition Zone* = 806.67'

c + d = 1291.33'

f = driver eye height = 4.76'

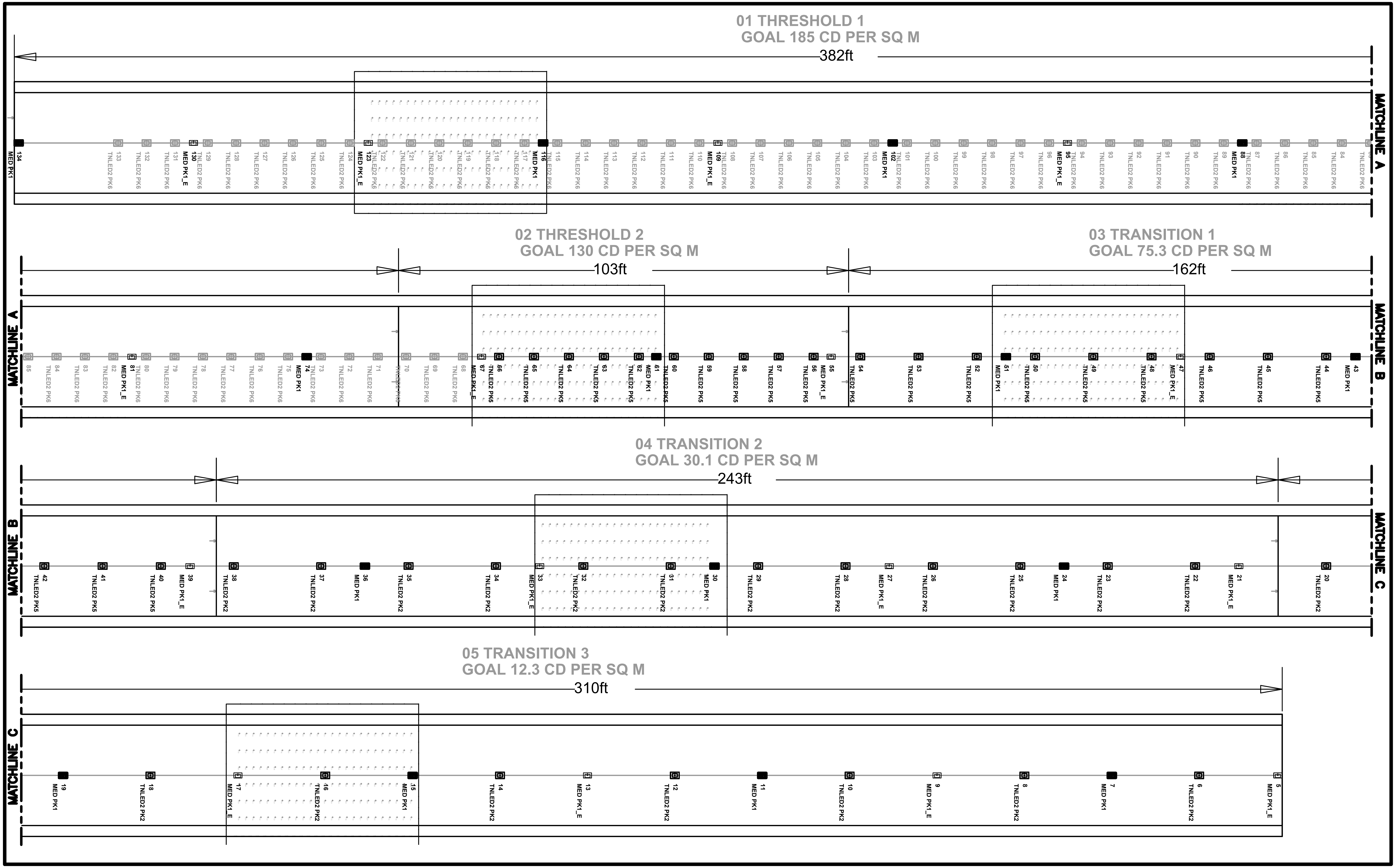
*Transition zone extends beyond the length of the tunnel.

The following sections do not exist for this tunnel.

e = interior
g = exit zone

CDM Smith

Heroes Tunnel Rehabilitation
Tunnel Lighting Topology

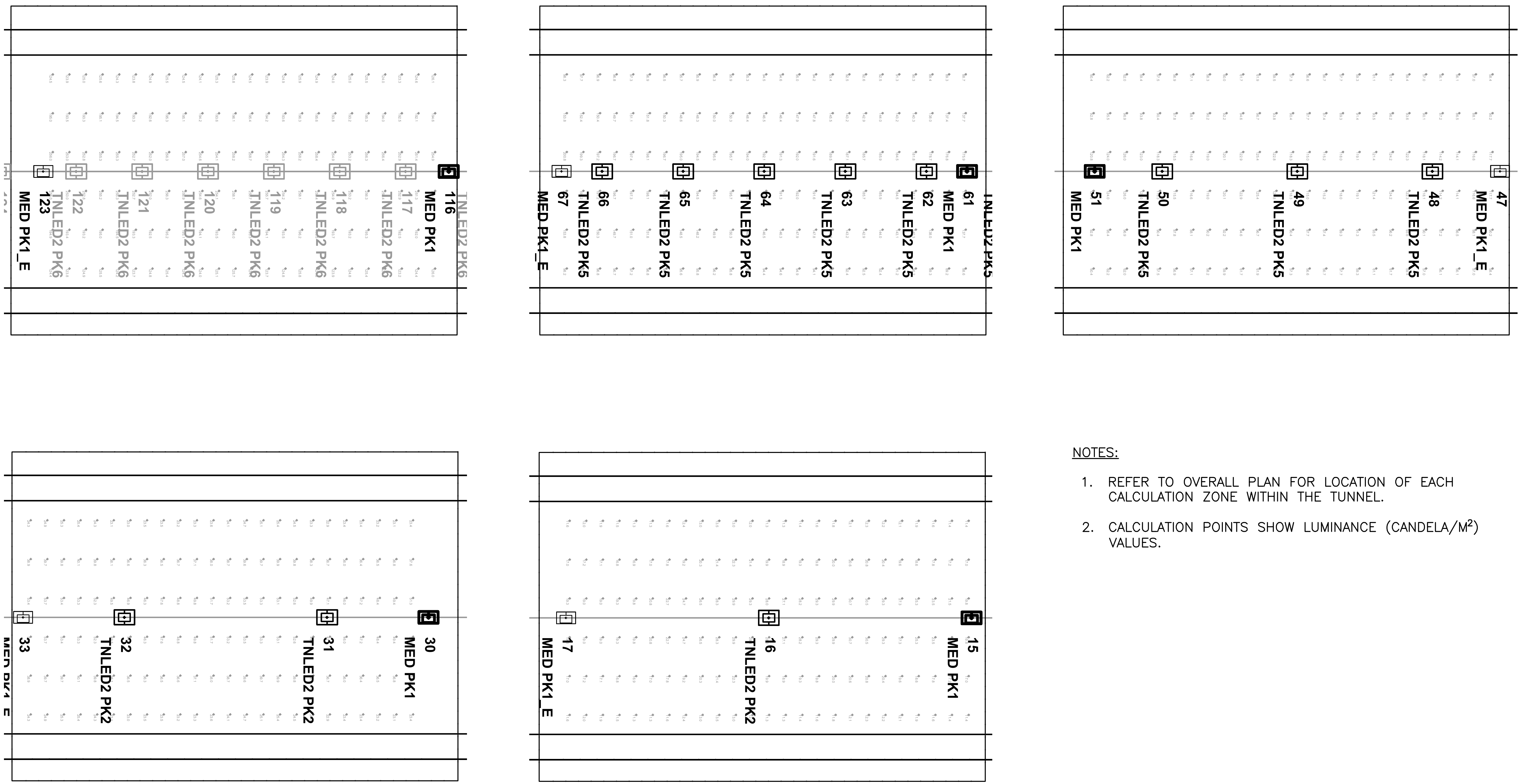


CDM Smith

1" = 20'

10 0 20

Heroes Tunnel Rehabilitation
Interior Lighting Layout and Daytime Calculations



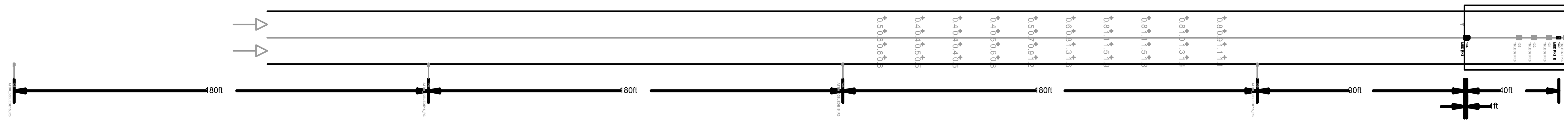
NOTES:

1. REFER TO OVERALL PLAN FOR LOCATION OF EACH CALCULATION ZONE WITHIN THE TUNNEL.
2. CALCULATION POINTS SHOW LUMINANCE (CANDELA/M^2) VALUES.

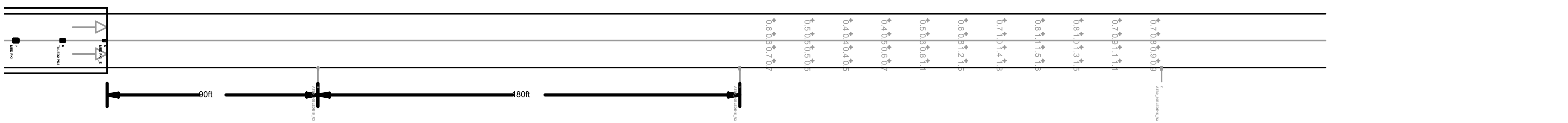
1" = 10'

5 0 10

Heroes Tunnel Rehabilitation
Interior Lighting Layout - Daytime Calculation
Enlarged Calculation Zones



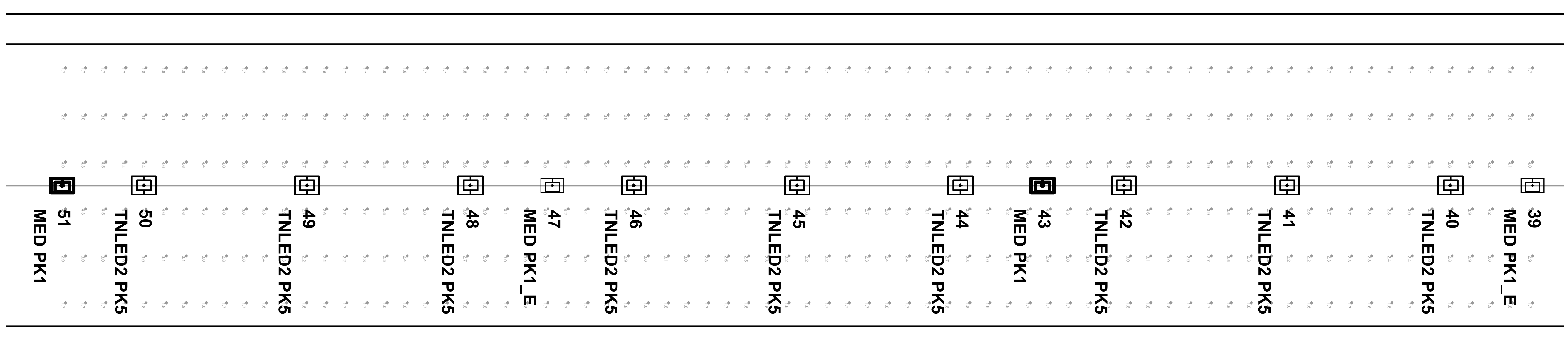
APPROACH



EXIT

1" = 50'

25 0 50



INTERIOR

1" = 10'

5 0 10

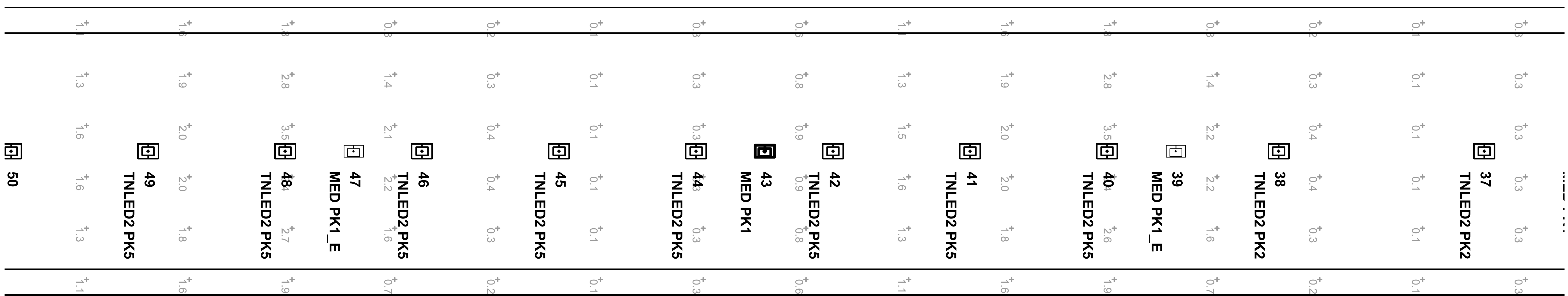
NOTES:

1. REFER TO OVERALL PLAN FOR LOCATION OF EACH CALCULATION ZONE WITHIN THE TUNNEL. ONLY RELEVANT NIGHTTIME CALCULATIONS ARE SHOWN.

2. CALCULATION POINTS SHOW LUMINANCE (CANDELA/M^2) VALUES.

CDM Smith

Heroes Tunnel Rehabilitation
Interior & Exterior Lighting Layout - Nighttime Calculation
Enlarged Calculation Zones



NOTES:

1. REFER TO OVERALL PLAN FOR LOCATION OF THE CALCULATION ZONE WITHIN THE TUNNEL. ONLY A SAMPLE SECTION IS SHOWN

2. CALCULATION POINTS SHOW LUMINANCE (CANDELA/M^2) VALUES.

CDM Smith

1” = 10’

5 0 10

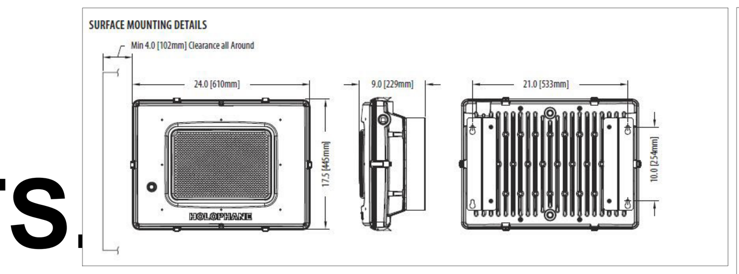
Heroes Tunnel Rehabilitation
Interior Lighting Layout - Emergency Calculation
Enlarged Calculation Zone

Summary of Scene Calculations with Product Numbers and Dimming Values

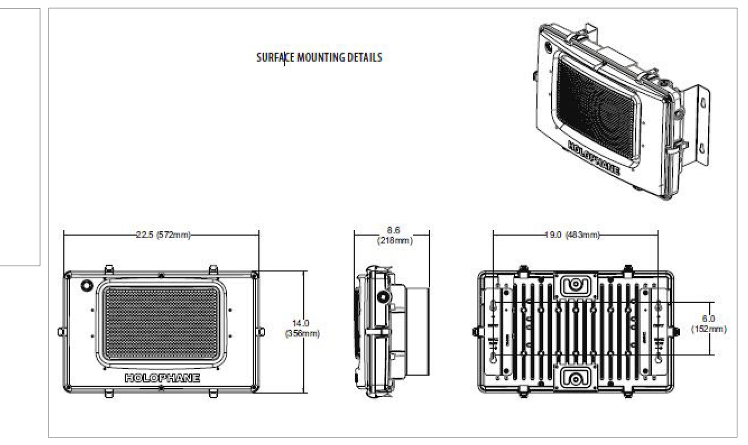
IMPORTANT
THIS LAYOUT IS FOR ONE DIRECTION OF TRAVEL.
MULTIPLY THE FIXTURE COUNT BY TWO FOR FINAL COUNTS.

Luminaire Location Summary								
Scene: DAY								
LumNo	Label	X	Y	Z	Tilt	Channel	Switched	Dimming
1	ATB0_30BLEDE15_R3	17.5	1830	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
2	ATB0_30BLEDE15_R3	17.5	1650	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
3	ATB0_30BLEDE15_R3	17.5	1470	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
4	ATB0_30BLEDE15_R3	17.5	1290	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
5	MED PK1_E	0	1199	18.25	0	NIGHT AND EMERGENCY	Off	0.69
6	TNLED2 PK2	0	1181	18.25	0	DAY	On	1.00
7	MED PK1	0	1161	18.25	0	NIGHT	Off	0.69
8	TNLED2 PK2	0	1141	18.25	0	DAY	On	1.00
9	MED PK1_E	0	1121	18.25	0	NIGHT AND EMERGENCY	Off	0.69
10	TNLED2 PK2	0	1101	18.25	0	DAY	On	1.00
11	MED PK1	0	1081	18.25	0	NIGHT	Off	0.69
12	TNLED2 PK2	0	1061	18.25	0	DAY	On	1.00
13	MED PK1_E	0	1041	18.25	0	NIGHT AND EMERGENCY	Off	0.69
14	TNLED2 PK2	0	1021	18.25	0	DAY	On	1.00
15	MED PK1	0	1001	18.25	0	NIGHT	Off	0.69
16	TNLED2 PK2	0	981	18.25	0	DAY	On	1.00
17	MED PK1_E	0	961	18.25	0	NIGHT AND EMERGENCY	Off	0.69
18	TNLED2 PK2	0	941	18.25	0	DAY	On	1.00
19	MED PK1	0	921	18.25	0	NIGHT	Off	0.69
20	TNLED2 PK2	0	901	18.25	0	DAY	On	1.00
21	MED PK1_E	0	881	18.25	0	NIGHT AND EMERGENCY	Off	0.69
22	TNLED2 PK2	0	871	18.25	0	DAY	On	1.00
23	TNLED2 PK2	0	851	18.25	0	DAY	On	1.00
24	MED PK1	0	841	18.25	0	NIGHT	Off	0.69
25	TNLED2 PK2	0	831	18.25	0	DAY	On	1.00
26	TNLED2 PK2	0	811	18.25	0	DAY	On	1.00
27	MED PK1_E	0	801	18.25	0	NIGHT AND EMERGENCY	Off	0.69
28	TNLED2 PK2	0	791	18.25	0	DAY	On	1.00
29	TNLED2 PK2	0	771	18.25	0	DAY	On	1.00
30	MED PK1	0	761	18.25	0	NIGHT	Off	0.69
31	TNLED2 PK2	0	751	18.25	0	DAY	On	1.00
32	TNLED2 PK2	0	731	18.25	0	DAY	On	1.00
33	MED PK1_E	0	721	18.25	0	NIGHT AND EMERGENCY	Off	0.69
34	TNLED2 PK2	0	711	18.25	0	DAY	On	1.00
35	TNLED2 PK2	0	691	18.25	0	DAY	On	1.00
36	MED PK1	0	681	18.25	0	NIGHT	Off	0.69
37	TNLED2 PK2	0	671	18.25	0	DAY	On	1.00
38	TNLED2 PK2	0	651	18.25	0	DAY	On	1.00
39	MED PK1_E	0	641	18.25	0	NIGHT AND EMERGENCY	Off	0.69
40	TNLED2 PK5	0	634.3	18.25	0	DAY	On	1.00
41	TNLED2 PK5	0	620.97	18.25	0	DAY	On	1.00
42	TNLED2 PK5	0	607.64	18.25	0	DAY	On	1.00
43	MED PK1	0	601	18.25	0	NIGHT	Off	0.69
44	TNLED2 PK5	0	594.31	18.25	0	DAY	On	1.00
45	TNLED2 PK5	0	580.98	18.25	0	DAY	On	1.00
46	TNLED2 PK5	0	567.65	18.25	0	DAY	On	1.00
47	MED PK1_E	0	561	18.25	0	NIGHT AND EMERGENCY	Off	0.69
48	TNLED2 PK5	0	554.32	18.25	0	DAY	On	1.00
49	TNLED2 PK5	0	540.99	18.25	0	DAY	On	1.00
50	TNLED2 PK5	0	527.66	18.25	0	DAY	On	1.00
51	MED PK1	0	521	18.25	0	NIGHT	Off	0.69
52	TNLED2 PK5	0	514.33	18.25	0	DAY	On	1.00
53	TNLED2 PK5	0	501	18.25	0	DAY	On	1.00
54	TNLED2 PK5	0	487.67	18.25	0	DAY	On	1.00
55	MED PK1_E	0	481	18.25	0	NIGHT AND EMERGENCY	Off	0.69
56	TNLED2 PK5	0	477	18.25	0	DAY	On	1.00
57	TNLED2 PK5	0	469	18.25	0	DAY	On	1.00
58	TNLED2 PK5	0	461	18.25	0	DAY	On	1.00
59	TNLED2 PK5	0	453	18.25	0	DAY	On	1.00
60	TNLED2 PK5	0	445	18.25	0	DAY	On	1.00
61	MED PK1	0	441	18.25	0	NIGHT	Off	0.69
62	TNLED2 PK5	0	437	18.25	0	DAY	On	1.00
63	TNLED2 PK5	0	429	18.25	0	DAY	On	1.00
64	TNLED2 PK5	0	421	18.25	0	DAY	On	1.00
65	TNLED2 PK5	0	413	18.25	0	DAY	On	1.00
66	TNLED2 PK5	0	405	18.25	0	DAY	On	1.00
67	MED PK1_E	0	401	18.25	0	NIGHT AND EMERGENCY	Off	0.69
68	TNLED2 PK6	0	396.75	18.25	0	DAY	On	1.00
69	TNLED2 PK6	0	390.25	18.25	0	DAY	On	1.00
70	TNLED2 PK6	0	383.75	18.25	0	DAY	On	1.00
71	TNLED2 PK6	0	377.25	18.25	0	DAY	On	1.00
72	TNLED2 PK6	0	370.75	18.25	0	DAY	On	1.00
73	TNLED2 PK6	0	364.25	18.25	0	DAY	On	1.00
74	MED PK1	0	361	18.25	0	NIGHT	Off	0.69
75	TNLED2 PK6	0	356.75	18.25	0	DAY	On	1.00
76	TNLED2 PK6	0	350.25	18.25	0	DAY	On	1.00
77	TNLED2 PK6	0	343.75	18.25	0	DAY	On	1.00
78	TNLED2 PK6	0	337.25	18.25	0	DAY	On	1.00
79	TNLED2 PK6	0	330.75	18.25	0	DAY	On	1.00
80	TNLED2 PK6	0	324.25	18.25	0	DAY	On	1.00
81	MED PK1_E	0	321	18.25	0	NIGHT AND EMERGENCY	Off	0.69
82	TNLED2 PK6	0	316.75	18.25	0	DAY	On	1.00
83	TNLED2 PK6	0	310.25	18.25	0	DAY	On	1.00
84	TNLED2 PK6	0	303.75	18.25	0	DAY	On	1.00
85	TNLED2 PK6	0	297.25	18.25	0	DAY	On	1.00
86	TNLED2 PK6	0	290.75	18.25	0	DAY	On	1.00
87	TNLED2 PK6	0	284.25	18.25	0	DAY	On	1.00
88	MED PK1	0	281	18.25	0	NIGHT	Off	0.69
89	TNLED2 PK6	0	276.75	18.25	0	DAY	On	1.00
90	TNLED2 PK6	0	270.25	18.25	0	DAY	On	1.00
91	TNLED2 PK6	0	263.75	18.25	0	DAY	On	1.00
92	TNLED2 PK6	0	257.25	18.25	0	DAY	On	1.00
93	TNLED2 PK6	0	250.75	18.25	0	DAY	On	1.00
94	TNLED2 PK6	0	244.25	18.25	0	DAY	On	1.00
95	MED PK1_E	0	241	18.25	0	NIGHT AND EMERGENCY	Off	0.69
96	TNLED2 PK6	0	236.75	18.25	0	DAY	On	1.00
97	TNLED2 PK6	0	230.25	18.25	0	DAY	On	1.00
98	TNLED2 PK6	0	223.75	18.25	0	DAY	On	1.00
99	TNLED2 PK6	0	217.25	18.25	0	DAY	On	1.00
100	TNLED2 PK6	0	210.75	18.25	0	DAY	On	1.00
101	TNLED2 PK6	0	204.25	18.25	0	DAY	On	1.00
102	MED PK1	0	201	18.25	0	NIGHT	Off	0.69
103	TNLED2 PK6	0	196.75	18.25	0	DAY	On	1.00
104	TNLED2 PK6	0	190.25	18.25	0	DAY	On	1.00
105	TNLED2 PK6	0	183.75	18.25	0	DAY	On	1.00
106	TNLED2 PK6	0	177.25	18.25	0	DAY	On	1.00
107	TNLED2 PK6	0	170.75	18.25	0	DAY	On	1.00
108	TNLED2 PK6	0	164.25	18.25	0	DAY	On	1.00
109	MED PK1_E	0	161	18.25	0	NIGHT AND EMERGENCY	Off	0.69
110	TNLED2 PK6	0	156.75	18.25	0	DAY	On	1.00
111	TNLED2 PK6	0	150.25	18.25	0	DAY	On	1.00
112	TNLED2 PK6	0	143.75	18.25	0	DAY	On	1.00
113	TNLED2 PK6	0	137.25	18.25	0	DAY	On	1.00
114	TNLED2 PK6	0	130.75	18.25	0	DAY	On	1.00
115	TNLED2 PK6	0	124.25	18.25	0	DAY	On	1.00
116	MED PK1	0	121	18.25	0	NIGHT	Off	0.69
117	TNLED2 PK6	0	116.75	18.25	0	DAY	On	1.00
118	TNLED2 PK6	0	110.25	18.25	0	DAY	On	1.00
119	TNLED2 PK6	0	103.75	18.25	0	DAY	On	1.00
120	TNLED2 PK6	0	97.25	18.25	0	DAY	On	1.00
121	TNLED2 PK6	0	90.75	18.25	0	DAY	On	1.00
122	TNLED2 PK6	0	84.25	18.25	0	DAY	On	1.00
123	MED PK1_E	0	81	18.25	0	NIGHT AND EMERGENCY	Off	0.69
124	TNLED2 PK6	0	76.75	18.25	0	DAY	On	1.00
125	TNLED2 PK6	0	70.25	18.25	0	DAY	On	1.00
126	TNLED2 PK6	0	63.75	18.25	0	DAY	On	1.00
127	TNLED2 PK6	0	57.25	18.25	0	DAY	On	1.00
128	TNLED2 PK6	0	50.75	18.25	0	DAY	On	1.00
129	TNLED2 PK6	0	44.25	18.25	0	DAY	On	1.00
130	MED PK1_E	0	41	18.25	0	NIGHT AND EMERGENCY	Off	0.69
131	TNLED2 PK6	0	36.75	18.25	0	DAY	On	1.00
132	TNLED2 PK6	0	30.25	18.25	0	DAY	On	1.00
133	TNLED2 PK6	0	23.75	18.25	0	DAY	On	1.00
134	MED PK1	0	1	18.25	0	NIGHT	Off	0.69
135	ATB0_30BLEDE15_R3	17.5	-90	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
136	ATB0_30BLEDE15_R3	17.5	-270	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
137	ATB0_30BLEDE15_R3	17.5	-450	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
138	ATB0_30BLEDE15_R3	17.5	-630	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00

TUNNEL PASS LARGE AND MEDIUM SURFACE MOUNT SHOWN.
SEE SEPCIFICATION SHEET FOR OTHER MOUNTING OPTIONS



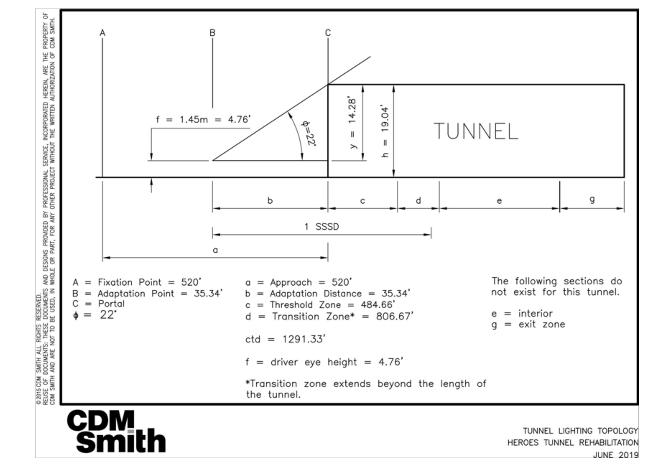
TNLED2



TNLEDMED

GIVEN INFORMATION

1. Approach scene number as seen from 1 SSSD (see illustration below) Probably 8. Sky dominates neither side. Portal is mostly the prominent feature. You could justify 7, though.
2. Posted speed - 55
3. Tunnel Length – 1200'
4. Asphalt or Concrete road surface? - Asphalt
5. Height of entrance portal above road surface – 19'
6. Traffic volume (Average annual Daily Traffic) – 71,000
7. Are there cyclists in the tunnel? - No
8. Is the tunnel exit visible from 1 SSSD before entrance portal? - yes
9. Is daylight penetration good or poor? - ? not great, classified as a long tunnel
10. Wall reflectance in percent. –40, as rehab/reconstruction of walls is not guaranteed and it's a dirty environment. If that's way out of line, use your discretion. It's reinforced concrete.
11. Direction of travel and type of tunnel – See e-mail, please.
a. Divided tunnel (Travel in one direction only)
i. Driving Direction North, East/West, South)
ii. Number of lanes and lane width - 2 in each tunnel
iii. Distance from edge of travel lanes to walls – 2'-6" sidewalk on each side of road (e.g. 2 in each tunnel)
12. Preference for wall or ceiling mounted luminaires – Ceiling - CCB.



CRITERIA, DAY
TH1: 185 CD PER SQ M, 382 FT LENGTH
TH2: 130 CD PER SQ M, 103 FT LENGTH
TR1: 75.3 CD PER SQ M, 162 FT LENGTH
TR2: 30.1 CD PER SQ M, 243 FT LENGTH
TR3: 12 CD PER SQ M. BALANCE OF TUNNEL (310 FT)

CRITERIA NIGHT
2.5 CD PER SQ M
ROAD LUMINANCE BEFORE AND AFTER TUNNEL PORTAL
TO BE AT LEAST 1/3RD NIGHT TUNNEL ORAD LUMINANCE
FOR ONE SSSD

LOWER 6.6 FT OF WALLS AT LEAST 40% OF ROAD LUMINACE

SURFACE UNIFORMITY
2.0 AVG TO MIN, 3.5 MAX TO MIN.

CRITERIA: EMERGENCY
1 FC AVG, 0.1 MIN, 40:1 MAX TO MIN ALONG PATH OF EGRESS

Below is the data for TNLED 9 4K 1 AH WCR.
At 480V, 100% Input power = 377W

Dimming Voltage	% Input Power	Power Factor	% Lumens Delivered
10	100%	0.96	100%
9	100%	0.96	100%
8	100%	0.96	100%
7	82%	0.94	89%
6	70%	0.92	80%
5	59%	0.90	69%
4	48%	0.86	57%
3	36%	0.79	44%
2	24%	0.65	28%
1	16%	0.44	14%
0	16%	0.44	14%

GENERAL RELATION OF INPUT POWER, POWER FACTOR AND DELIVERED LUMENS FOR VARIOUS DIMMING LEVELS. CONTACT THE TECHNICAL SERVICES GROUP AT "ProductSupportINF@AcuityBrands.com" FOR THE ACTUAL PRODUCT BEIING APPLIED.

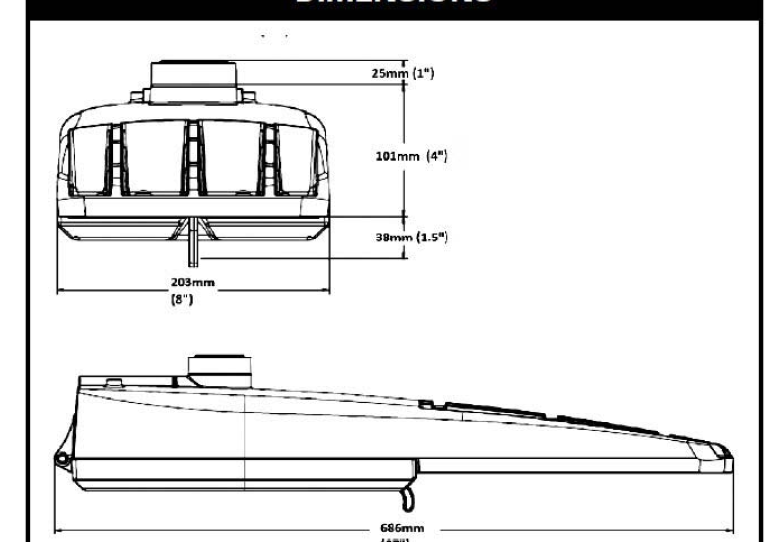
Luminaire Schedule									
Scene: DAY									
Symbol	Qty	Label	LLF	Description	Arm	Filename	Lum. Watts	Lum. Lumens	Total Watts
	15	MED PK1	0.678	TNLEDMED PK1 40K CCB 100k HRS LDD= 0.8 DIM TO 69%	0	TNLEDMED PK1 40K XXXXX CCB.ies	34	7344	510
	16	MED PK1_E	0.678	TNLEDMED PK1 40K CCB 100k HRS LDD= 0.8 DIM TO 69%	0	TNLEDMED PK1 40K XXXXX CCB.ies	34	7344	544
	57	TNLED2 PK6	0.707	TNLED2 PK6 XX 40K CCB	0	TNLED2 PK6 XX 40K CCB.ies	494.5	57624	28186.5
	22	TNLED2 PK5	0.752	TNLED2 PK5 XX 40K CCB	0	TNLED2 PK5 XX 40K CCB.ies	434.9	51612	9567.8
	20	TNLED2 PK2	0.769	TNLED2 PK2 XX 40K CCB	0	TNLED2 PK2 XX 40K CCB.ies	261.6	31414	5232
	8	ATB0_30BLEDE15_R3	0.792	ATB0 30BLEDE15 XXXXX R3 4K_5K	6	ATB0_30BLEDE15_XXXXX_R3_4K_5K.ies	145	16192	1160

TYPES "MED PK1" AND "MED PK1_E" INPUT WATTS ADJUSTED FOR 5-VOLT INPUT DIMMING.
THE LUMEN OUTPUT IS ADJUSTED TO 69% OF FULL OUTPUT FOR THIS SETTING.

Calculation Summary								
Scene: DAY								
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min	LVRatio
01 TH1_Illum	Illuminance	Fc	186.03	211.0	148.2	1.26	1.42	N.A.
01 TH1_Luminance	Luminance	Cd/Sq.m	191.33	258.7	123.2	1.55	2.10	N.A.
01 TH1_Veil_Lum	Veiling Luminance	Cd/Sq.m	30.64	36.7	23.3	1.32	1.58	0.19
02 TH2_Illum	Illuminance	Fc	147.24	171.2	116.6	1.26	1.47	N.A.
02 TH2_Luminance	Luminance	Cd/Sq.m	143.94	200.8	88.6	1.62	2.27	N.A.
03 TR1_Illum	Illuminance	Fc	89.73	112.5	67.0	1.34	1.68	N.A.
03 TR1_Luminance	Luminance	Cd/Sq.m	89.92	126.0	56.1	1.60	2.25	N.A.
04 TR2_Illum	Illuminance	Fc	37.68	52.2	27.7	1.36	1.88	N.A.
04 TR2_Luminance	Luminance	Cd/Sq.m	37.49	53.7	22.9	1.64	2.34	N.A.
05 TR3_Illum	Illuminance	Fc	18.49	38.5	11.2	1.65	3.44	N.A.
05 TR3_Luminance	Luminance	Cd/Sq.m	18.68	30.7	11.3	1.65	2.72	N.A.
05 TR3_Veil_Lum	Veiling Luminance	Cd/Sq.m	3.04	4.7	1.9	1.60	2.47	0.25
01 TH1 TYPICAL WALL	L_Diffuse	Cd/Sq.m	120.93	125.1	115.2	1.05	1.09	
02 TH2 TYPICAL WALL	L_Diffuse	Cd/Sq.m	95.65	100.5	90.1	1.06	1.12	
03 TR1 TYPICAL WALL	L_Diffuse	Cd/Sq.m	61.71	64.7	59.2	1.04	1.09	
04 TR2 TYPICAL WALL	L_Diffuse	Cd/Sq.m	25.26	27.7	22.6	1.12	1.23	
05 TR3 TYPICAL WALL	L_Diffuse	Cd/Sq.m	11.78	17.8	7.0	1.68	2.54	

ATB0

DIMENSIONS



Effective Projected Area (EPA): The EPA for the ATB0 is 0.76 sq. ft.
Approx. Wt. = 14 lbs.

HOLOPHANE® LEADER IN LIGHTING SOLUTIONS
An Acuity Brands Company

DESIGN BY: RWY
Checked By:
Date:6/19/2019
Scale:

HEROES TUNNEL
WILBUR CROSS PARKWAY
NEW HAVEN, CT

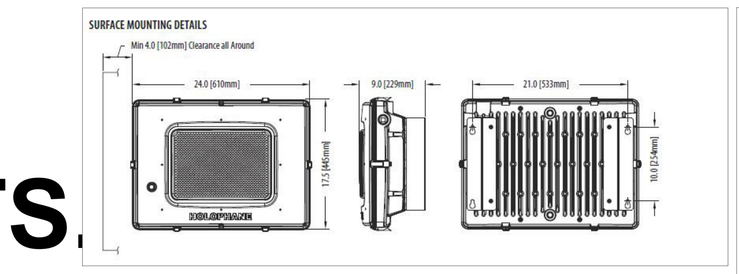
PROJECT NUMBER 2019 JUNE 004

IMPORTANT
THIS LAYOUT IS FOR ONE DIRECTION OF TRAVEL.
MULTIPLY THE FIXTURE COUNT BY TWO FOR FINAL COUNTS.

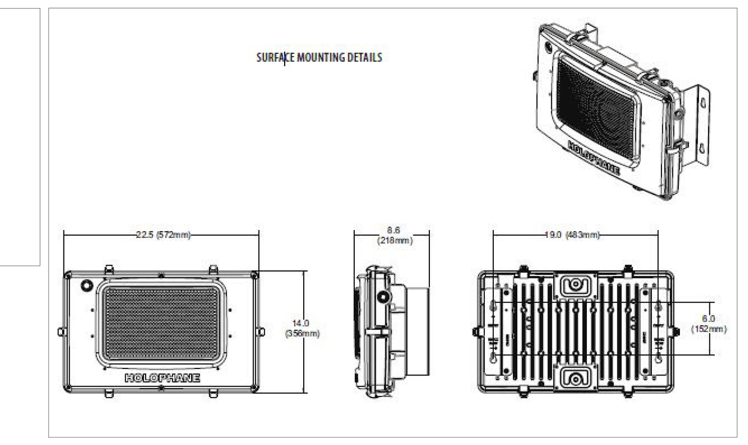
Luminaire Location Summary
Scene: EMERGENCY

LumNo	Label	X	Y	Z	Tilt	Channel	Switched	Dimming
1	ATB0_30BLEDE15_R3	17.5	1830	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
2	ATB0_30BLEDE15_R3	17.5	1650	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
3	ATB0_30BLEDE15_R3	17.5	1470	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
4	ATB0_30BLEDE15_R3	17.5	1290	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
5	MED PK1_E	0	1199	18.25	0	NIGHT AND EMERGENCY	On	0.69
6	TNLED2 PK2	0	1181	18.25	0	DAY	Off	1.00
7	MED PK1	0	1161	18.25	0	NIGHT	Off	0.69
8	TNLED2 PK2	0	1141	18.25	0	DAY	Off	1.00
9	MED PK1_E	0	1121	18.25	0	NIGHT AND EMERGENCY	On	0.69
10	TNLED2 PK2	0	1101	18.25	0	DAY	Off	1.00
11	MED PK1	0	1081	18.25	0	NIGHT	Off	0.69
12	TNLED2 PK2	0	1061	18.25	0	DAY	Off	1.00
13	MED PK1_E	0	1041	18.25	0	NIGHT AND EMERGENCY	On	0.69
14	TNLED2 PK2	0	1021	18.25	0	DAY	Off	1.00
15	MED PK1	0	1001	18.25	0	NIGHT	Off	0.69
16	TNLED2 PK2	0	981	18.25	0	DAY	Off	1.00
17	MED PK1_E	0	961	18.25	0	NIGHT AND EMERGENCY	On	0.69
18	TNLED2 PK2	0	941	18.25	0	DAY	Off	1.00
19	MED PK1	0	921	18.25	0	NIGHT	Off	0.69
20	TNLED2 PK2	0	901	18.25	0	DAY	Off	1.00
21	MED PK1_E	0	881	18.25	0	NIGHT AND EMERGENCY	On	0.69
22	TNLED2 PK2	0	871	18.25	0	DAY	Off	1.00
23	TNLED2 PK2	0	851	18.25	0	DAY	Off	1.00
24	MED PK1	0	841	18.25	0	NIGHT	Off	0.69
25	TNLED2 PK2	0	831	18.25	0	DAY	Off	1.00
26	TNLED2 PK2	0	811	18.25	0	DAY	Off	1.00
27	MED PK1_E	0	801	18.25	0	NIGHT AND EMERGENCY	On	0.69
28	TNLED2 PK2	0	791	18.25	0	DAY	Off	1.00
29	TNLED2 PK2	0	771	18.25	0	DAY	Off	1.00
30	MED PK1	0	761	18.25	0	NIGHT	Off	0.69
31	TNLED2 PK2	0	751	18.25	0	DAY	Off	1.00
32	TNLED2 PK2	0	731	18.25	0	DAY	Off	1.00
33	MED PK1_E	0	721	18.25	0	NIGHT AND EMERGENCY	On	0.69
34	TNLED2 PK2	0	711	18.25	0	DAY	Off	1.00
35	TNLED2 PK2	0	691	18.25	0	DAY	Off	1.00
36	MED PK1	0	681	18.25	0	NIGHT	Off	0.69
37	TNLED2 PK2	0	671	18.25	0	DAY	Off	1.00
38	TNLED2 PK2	0	651	18.25	0	DAY	Off	1.00
39	MED PK1_E	0	641	18.25	0	NIGHT AND EMERGENCY	On	0.69
40	TNLED2 PK5	0	634.3	18.25	0	DAY	Off	1.00
41	TNLED2 PK5	0	620.97	18.25	0	DAY	Off	1.00
42	TNLED2 PK5	0	607.64	18.25	0	DAY	Off	1.00
43	MED PK1	0	601	18.25	0	NIGHT	Off	0.69
44	TNLED2 PK5	0	594.31	18.25	0	DAY	Off	1.00
45	TNLED2 PK5	0	580.98	18.25	0	DAY	Off	1.00
46	TNLED2 PK5	0	567.65	18.25	0	DAY	Off	1.00
47	MED PK1_E	0	561	18.25	0	NIGHT AND EMERGENCY	On	0.69
48	TNLED2 PK5	0	554.32	18.25	0	DAY	Off	1.00
49	TNLED2 PK5	0	540.99	18.25	0	DAY	Off	1.00
50	TNLED2 PK5	0	527.66	18.25	0	DAY	Off	1.00
51	MED PK1	0	521	18.25	0	NIGHT	Off	0.69
52	TNLED2 PK5	0	514.33	18.25	0	DAY	Off	1.00
53	TNLED2 PK5	0	501	18.25	0	DAY	Off	1.00
54	TNLED2 PK5	0	487.67	18.25	0	DAY	Off	1.00
55	MED PK1_E	0	481	18.25	0	NIGHT AND EMERGENCY	On	0.69
56	TNLED2 PK5	0	477	18.25	0	DAY	Off	1.00
57	TNLED2 PK5	0	469	18.25	0	DAY	Off	1.00
58	TNLED2 PK5	0	461	18.25	0	DAY	Off	1.00
59	TNLED2 PK5	0	453	18.25	0	DAY	Off	1.00
60	TNLED2 PK5	0	445	18.25	0	DAY	Off	1.00
61	MED PK1	0	441	18.25	0	NIGHT	Off	0.69
62	TNLED2 PK5	0	437	18.25	0	DAY	Off	1.00
63	TNLED2 PK5	0	429	18.25	0	DAY	Off	1.00
64	TNLED2 PK5	0	421	18.25	0	DAY	Off	1.00
65	TNLED2 PK5	0	413	18.25	0	DAY	Off	1.00
66	TNLED2 PK5	0	405	18.25	0	DAY	Off	1.00
67	MED PK1_E	0	401	18.25	0	NIGHT AND EMERGENCY	On	0.69
68	TNLED2 PK6	0	396.75	18.25	0	DAY	Off	1.00
69	TNLED2 PK6	0	390.25	18.25	0	DAY	Off	1.00
70	TNLED2 PK6	0	383.75	18.25	0	DAY	Off	1.00
71	TNLED2 PK6	0	377.25	18.25	0	DAY	Off	1.00
72	TNLED2 PK6	0	370.75	18.25	0	DAY	Off	1.00
73	TNLED2 PK6	0	364.25	18.25	0	DAY	Off	1.00
74	MED PK1	0	361	18.25	0	NIGHT	Off	0.69
75	TNLED2 PK6	0	356.75	18.25	0	DAY	Off	1.00
76	TNLED2 PK6	0	350.25	18.25	0	DAY	Off	1.00
77	TNLED2 PK6	0	343.75	18.25	0	DAY	Off	1.00
78	TNLED2 PK6	0	337.25	18.25	0	DAY	Off	1.00
79	TNLED2 PK6	0	330.75	18.25	0	DAY	Off	1.00
80	TNLED2 PK6	0	324.25	18.25	0	DAY	Off	1.00
81	MED PK1_E	0	321	18.25	0	NIGHT AND EMERGENCY	On	0.69
82	TNLED2 PK6	0	316.75	18.25	0	DAY	Off	1.00
83	TNLED2 PK6	0	310.25	18.25	0	DAY	Off	1.00
84	TNLED2 PK6	0	303.75	18.25	0	DAY	Off	1.00
85	TNLED2 PK6	0	297.25	18.25	0	DAY	Off	1.00
86	TNLED2 PK6	0	290.75	18.25	0	DAY	Off	1.00
87	TNLED2 PK6	0	284.25	18.25	0	DAY	Off	1.00
88	MED PK1	0	281	18.25	0	NIGHT	Off	0.69
89	TNLED2 PK6	0	276.75	18.25	0	DAY	Off	1.00
90	TNLED2 PK6	0	270.25	18.25	0	DAY	Off	1.00
91	TNLED2 PK6	0	263.75	18.25	0	DAY	Off	1.00
92	TNLED2 PK6	0	257.25	18.25	0	DAY	Off	1.00
93	TNLED2 PK6	0	250.75	18.25	0	DAY	Off	1.00
94	TNLED2 PK6	0	244.25	18.25	0	DAY	Off	1.00
95	MED PK1_E	0	241	18.25	0	NIGHT AND EMERGENCY	On	0.69
96	TNLED2 PK6	0	236.75	18.25	0	DAY	Off	1.00
97	TNLED2 PK6	0	230.25	18.25	0	DAY	Off	1.00
98	TNLED2 PK6	0	223.75	18.25	0	DAY	Off	1.00
99	TNLED2 PK6	0	217.25	18.25	0	DAY	Off	1.00
100	TNLED2 PK6	0	210.75	18.25	0	DAY	Off	1.00
101	TNLED2 PK6	0	204.25	18.25	0	DAY	Off	1.00
102	MED PK1	0	201	18.25	0	NIGHT	Off	0.69
103	TNLED2 PK6	0	196.75	18.25	0	DAY	Off	1.00
104	TNLED2 PK6	0	190.25	18.25	0	DAY	Off	1.00
105	TNLED2 PK6	0	183.75	18.25	0	DAY	Off	1.00
106	TNLED2 PK6	0	177.25	18.25	0	DAY	Off	1.00
107	TNLED2 PK6	0	170.75	18.25	0	DAY	Off	1.00
108	TNLED2 PK6	0	164.25	18.25	0	DAY	Off	1.00
109	MED PK1_E	0	161	18.25	0	NIGHT AND EMERGENCY	On	0.69
110	TNLED2 PK6	0	156.75	18.25	0	DAY	Off	1.00
111	TNLED2 PK6	0	150.25	18.25	0	DAY	Off	1.00
112	TNLED2 PK6	0	143.75	18.25	0	DAY	Off	1.00
113	TNLED2 PK6	0	137.25	18.25	0	DAY	Off	1.00
114	TNLED2 PK6	0	130.75	18.25	0	DAY	Off	1.00
115	TNLED2 PK6	0	124.25	18.25	0	DAY	Off	1.00
116	MED PK1	0	121	18.25	0	NIGHT	Off	0.69
117	TNLED2 PK6	0	116.75	18.25	0	DAY	Off	1.00
118	TNLED2 PK6	0	110.25	18.25	0	DAY	Off	1.00
119	TNLED2 PK6	0	103.75	18.25	0	DAY	Off	1.00
120	TNLED2 PK6	0	97.25	18.25	0	DAY	Off	1.00
121	TNLED2 PK6	0	90.75	18.25	0	DAY	Off	1.00
122	TNLED2 PK6	0	84.25	18.25	0	DAY	Off	1.00
123	MED PK1_E	0	81	18.25	0	NIGHT AND EMERGENCY	On	0.69
124	TNLED2 PK6	0	76.75	18.25	0	DAY	Off	1.00
125	TNLED2 PK6	0	70.25	18.25	0	DAY	Off	1.00
126	TNLED2 PK6	0	63.75	18.25	0	DAY	Off	1.00
127	TNLED2 PK6	0	57.25	18.25	0	DAY	Off	1.00
128	TNLED2 PK6	0	50.75	18.25	0	DAY	Off	1.00
129	TNLED2 PK6	0	44.25	18.25	0	DAY	Off	1.00
130	MED PK1_E	0	41	18.25	0	NIGHT AND EMERGENCY	On	0.69
131	TNLED2 PK6	0	36.75	18.25	0	DAY	Off	1.00
132	TNLED2 PK6	0	30.25	18.25	0	DAY	Off	1.00
133	TNLED2 PK6	0	23.75	18.25	0	DAY	Off	1.00
134	MED PK1	0	1	18.25	0	NIGHT	Off	0.69
135	ATB0_30BLEDE15_R3	17.5	-90	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
136	ATB0_30BLEDE15_R3	17.5	-270	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
137	ATB0_30BLEDE15_R3	17.5	-450	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00
138	ATB0_30BLEDE15_R3	17.5	-630	30	0	NIGHT OUTSIDE TUNNEL	Off	1.00

TUNNEL PASS LARGE AND MEDIUM SURFACE MOUNT SHOWN.
SEE SEPCIFICATION SHEET FOR OTHER MOUNTING OPTIONS



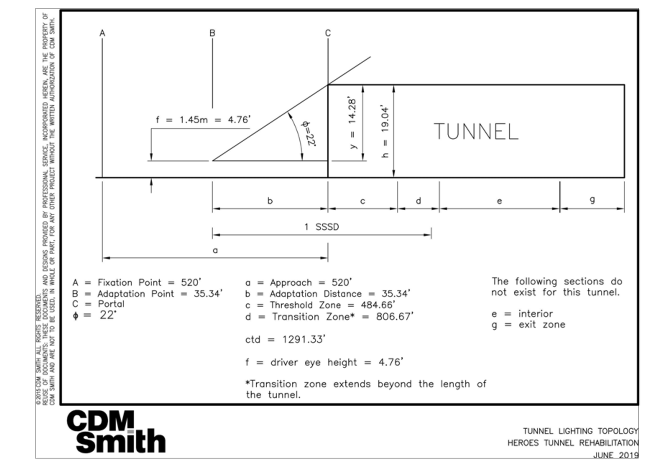
TNLED2



TNLEDMED

GIVEN INFORMATION

1. Approach scene number as seen from 1 SSSD (see illustration below) Probably B. Sky dominates neither side. Portal is mostly the prominent feature. You could justify 1, though.
2. Posted speed - 55
3. Tunnel Length - 1200'
4. Asphalt or Concrete road surface? - Asphalt
5. Height of entrance portal above road surface - 18'
6. Traffic volume (Average annual Daily Traffic) - 71,000
7. Are there curbs in the tunnel? - No
8. Is the tunnel exit visible from 1 SSSD before entrance portal? - yes
9. Is daylight penetration good or poor? - ? not great, classified as a long tunnel
10. Wall reflectance in percent - 40, as rehab/construction of walls is not guaranteed and it's a dirty environment. If that's way out of line, use your discretion. It's reinforced concrete.
11. Direction of travel and type of tunnel - See e-mail, please.
a. Divided tunnel (Travel in one direction only)
i. Driving Direction North, East(West, South)
b. Number of lanes and lane width - 2 in each tunnel
c. Distance from edge of travel lanes to walls - 2'-6" sidewalk on each side of road (e.g. 2 in each tunnel)
12. Preference for wall or ceiling mounted luminaires - Ceiling - CCB.



CRITERIA: DAY
TH1: 180 CD PER SQ M, 382 FT LENGTH
TH2: 130 CD PER SQ M, 133 FT LENGTH
TR1: 78.3 CD PER SQ M, 182 FT LENGTH
TR2: 39.1 CD PER SQ M, 243 FT LENGTH
TR3: 12 CD PER SQ M, BALANCE OF TUNNEL (210 FT)

CRITERIA NIGHT:
2.5 CD PER SQ M
ROAD LUMINANCE BEFORE AND AFTER TUNNEL PORTAL TO BE AT LEAST 1/3RD NIGHT TUNNEL ROAD LUMINANCE FOR ONE SSSD

LOWER 6.6 FT OF WALLS AT LEAST 40% OF ROAD LUMINANCE

SURFACE UNIFORMITY
2.0 AVG TO MIN, 3.5 MAX TO MIN

CRITERIA: EMERGENCY
1 FC AVG, 0.1 MIN, 40:1 MAX TO MIN ALONG PATH OF EGRESS

Below is the data for TNLED 9 4K 1 AH WCR.
At 480V, 100% Input power = 377W

Dimming Voltage	% Input Power	Power Factor	% Lumens Delivered
10	100%	0.96	100%
9	100%	0.96	100%
8	100%	0.96	100%
7	82%	0.94	89%
6	70%	0.92	80%
5	59%	0.90	69%
4	48%	0.86	57%
3	36%	0.79	44%
2	24%	0.65	28%
1	16%	0.44	14%
0	16%	0.44	14%

GENERAL RELATION OF INPUT POWER, POWER FACTOR AND DELIVERED LUMENS FOR VARIOUS DIMMING LEVELS. CONTACT THE TECHNICAL SERVICES GROUP AT "ProductSupportINF@AcuityBrands.com" FOR THE ACTUAL PRODUCT BEIING APPLIED.

Luminaire Schedule
Scene: EMERGENCY

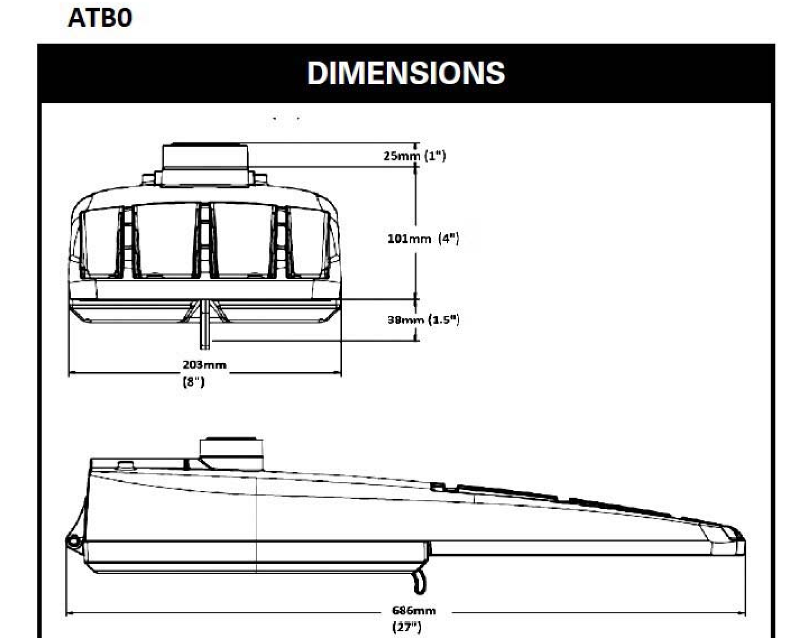
Symbol	Qty	Label	LLF	Description	Arrangement	Filename	Lum. Watts	Lum. Lumens	Total Watts
	15	MED PK1	0.679	TNLEDMED PK1 40K CCB 100k HRS LOD= 0.9 DIM TO 69%	S	TNLEDMED PK1 40K XXXXX CCB.ies	38	7344	570
	16	MED PK1_E	0.679	TNLEDMED PK1 40K CCB 100k HRS LOD= 0.9 DIM TO 69%	S	TNLEDMED PK1 40K XXXXX CCB.ies	34	7344	544
	57	TNLED2 PK6	0.787	TNLED2 PK6 XX 40K CCB	S	TNLED2 PK6 XX 40K CCB.ies	494.5	57624	28186.5
	22	TNLED2 PK5	0.792	TNLED2 PK5 XX 40K CCB	S	TNLED2 PK5 XX 40K CCB.ies	424.5	51612	9339
	20	TNLED2 PK2	0.769	TNLED2 PK2 XX 40K CCB	S	TNLED2 PK2 XX 40K CCB.ies	251.8	31414	5036
	8	ATB0_30BLEDE15_R3	0.792	ATB0 30BLEDE15 XXXXX R3 4K_9K	S	ATB0_30BLEDE15_XXXXX_R3_4K_9K.ies	145	16192	1160

TYPES "MED PK1" AND "MED PK1_E" INPUT WATTS ADJUSTED FOR 5-VOLT INPUT DIMMING.
THE LUMEN OUTPUT IS ADJUSTED TO 69% OF FULL OUTPUT FOR THIS SETTING.

Calculation Summary
Scene: EMERGENCY

Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Tunnel_1_Floor	Illuminance	Fc	1.15	3.6	0.1	11.50	36.00

ATB0



Effective Projected Area (EPA): The EPA for the ATB0 is 0.76 sq. ft.
Approx. Wt. = 14 lbs.

HOLOPHANE®
LEADER IN LIGHTING SOLUTIONS
An Acuity Brands Company

DESIGN BY: RWY
Checked By:
Date:6/19/2019
Scale:

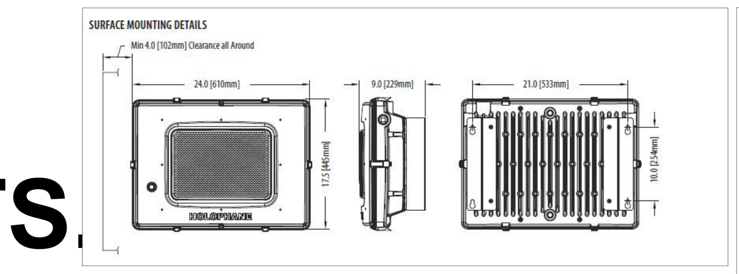
HEROES TUNNEL
WILBUR CROSS PARKWAY
NEW HAVEN, CT

PROJECT NUMBER 2019 JUNE 004

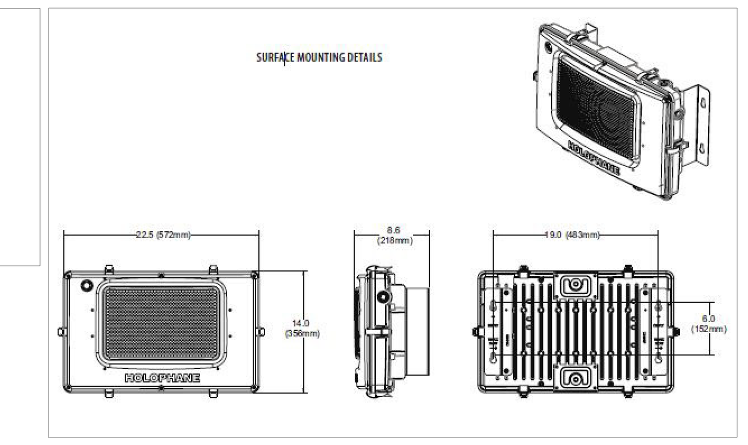
IMPORTANT
THIS LAYOUT IS FOR ONE DIRECTION OF TRAVEL.
MULTIPLY THE FIXTURE COUNT BY TWO FOR FINAL COUNTS.

Luminaire Location Summary								
Scene: NIGHT								
LumNo	Label	X	Y	Z	Tilt	Channel	Switched	Dimming
1	ATB0_30BLEDE15_R3	17.5	1830	30	0	NIGHT OUTSIDE TUNNEL	On	1.00
2	ATB0_30BLEDE15_R3	17.5	1650	30	0	NIGHT OUTSIDE TUNNEL	On	1.00
3	ATB0_30BLEDE15_R3	17.5	1470	30	0	NIGHT OUTSIDE TUNNEL	On	1.00
4	ATB0_30BLEDE15_R3	17.5	1290	30	0	NIGHT OUTSIDE TUNNEL	On	1.00
5	MED PK1_E	0	1199	18.25	0	NIGHT AND EMERGENCY	On	0.69
6	TNLED2 PK2	0	1181	18.25	0	DAY	Off	1.00
7	MED PK1	0	1161	18.25	0	NIGHT	On	0.69
8	TNLED2 PK2	0	1141	18.25	0	DAY	Off	1.00
9	MED PK1_E	0	1121	18.25	0	NIGHT AND EMERGENCY	On	0.69
10	TNLED2 PK2	0	1101	18.25	0	DAY	Off	1.00
11	MED PK1	0	1081	18.25	0	NIGHT	On	0.69
12	TNLED2 PK2	0	1061	18.25	0	DAY	Off	1.00
13	MED PK1_E	0	1041	18.25	0	NIGHT AND EMERGENCY	On	0.69
14	TNLED2 PK2	0	1021	18.25	0	DAY	Off	1.00
15	MED PK1	0	1001	18.25	0	NIGHT	On	0.69
16	TNLED2 PK2	0	981	18.25	0	DAY	Off	1.00
17	MED PK1_E	0	961	18.25	0	NIGHT AND EMERGENCY	On	0.69
18	TNLED2 PK2	0	941	18.25	0	DAY	Off	1.00
19	MED PK1	0	921	18.25	0	NIGHT	On	0.69
20	TNLED2 PK2	0	901	18.25	0	DAY	Off	1.00
21	MED PK1_E	0	881	18.25	0	NIGHT AND EMERGENCY	On	0.69
22	TNLED2 PK2	0	871	18.25	0	DAY	Off	1.00
23	TNLED2 PK2	0	851	18.25	0	DAY	Off	1.00
24	MED PK1	0	841	18.25	0	NIGHT	On	0.69
25	TNLED2 PK2	0	831	18.25	0	DAY	Off	1.00
26	TNLED2 PK2	0	811	18.25	0	DAY	Off	1.00
27	MED PK1_E	0	801	18.25	0	NIGHT AND EMERGENCY	On	0.69
28	TNLED2 PK2	0	791	18.25	0	DAY	Off	1.00
29	TNLED2 PK2	0	771	18.25	0	DAY	Off	1.00
30	MED PK1	0	761	18.25	0	NIGHT	On	0.69
31	TNLED2 PK2	0	751	18.25	0	DAY	Off	1.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TUNNEL PASS LARGE AND MEDIUM SURFACE MOUNT SHOWN.
SEE SEPCIFICATION SHEET FOR OTHER MOUNTING OPTIONS



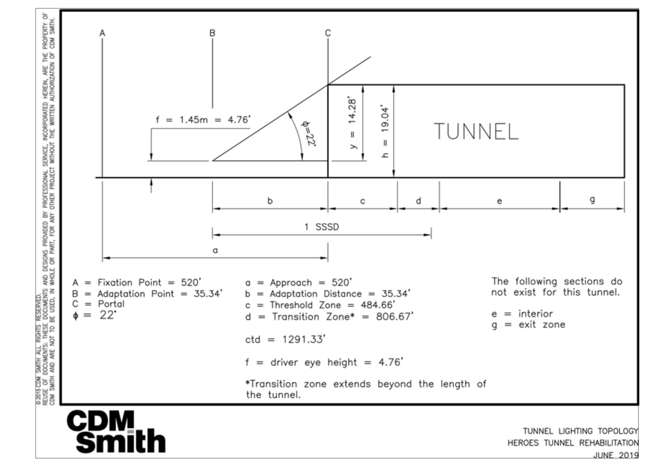
TNLED2



TNLEDMED

GIVEN INFORMATION

1. Approach scene number as seen from 1 SSSD (see illustration below) Probably 8. Sky dominates neither side. Portal is mostly the prominent feature. You could justify 7, though.
2. Posted speed - 55
3. Tunnel Length – 1200’
4. Asphalt or Concrete road surface? - Asphalt
5. Height of entrance portal above road surface – 19’
6. Traffic volume (Average annual Daily Traffic) – 71,000
7. Are there cyclists in the tunnel? - No
8. Is the tunnel exit visible from 1 SSSD before entrance portal? - yes
9. Is daylight penetration good or poor? - ? not great, classified as a long tunnel
10. Wall reflectance in percent. –40, as rehab/reconstruction of walls is not guaranteed and it’s a dirty environment. If that’s way out of line, use your discretion. It’s reinforced concrete.
11. Direction of travel and type of tunnel – See e-mail, please.
a. Divided tunnel (Travel in one direction only)
i. Driving Direction North, East/West, South)
ii. Number of lanes and lane width - 2 in each tunnel
iii. Distance from edge of travel lanes to walls – 2’-6” sidewalk on each side of road (e.g. 2 in each tunnel)
12. Preference for wall or ceiling mounted luminaires – Ceiling - CCB.



CRITERIA, DAY
TH1: 185 CD PER SQ M, 382 FT LENGTH
TH2: 130 CD PER SQ M, 103 FT LENGTH
TR1: 75.3 CD PER SQ M, 162 FT LENGTH
TR2: 30.1 CD PER SQ M, 243 FT LENGTH
TR3: 12 CD PER SQ M. BALANCE OF TUNNEL (310 FT)

CRITERIA NIGHT
2.5 CD PER SQ M
ROAD LUMINANCE BEFORE AND AFTER TUNNEL PORTAL
TO BE AT LEAST 1/3RD NIGHT TUNNEL ORAD LUMINANCE
FOR ONE SSSD

LOWER 6.6 FT OF WALLS AT LEAST 40% OF ROAD LUMINACE

SURFACE UNIFORMITY
2.0 AVG TO MIN, 3.5 MAX TO MIN.

CRITERIA: EMERGENCY
1 FC AVG, 0.1 MIN, 40:1 MAX TO MIN ALONG PATH OF EGRESS

Below is the data for TNLED 9 4K 1 AH WCR.
At 480V, 100% Input power = 377W

Dimming Voltage	% Input Power	Power Factor	% Lumens Delivered
10	100%	0.96	100%
9	100%	0.96	100%
8	100%	0.96	100%
7	82%	0.94	89%
6	70%	0.92	80%
5	59%	0.90	69%
4	48%	0.86	57%
3	36%	0.79	44%
2	24%	0.65	28%
1	16%	0.44	14%
0	16%	0.44	14%

GENERAL RELATION OF INPUT POWER, POWER FACTOR AND DELIVERED LUMENS FOR VARIOUS DIMMING LEVELS. CONTACT THE TECHNICAL SERVICES GROUP AT "ProductSupportINF@AcuityBrands.com" FOR THE ACTUAL PRODUCT BEIING APPLIED.

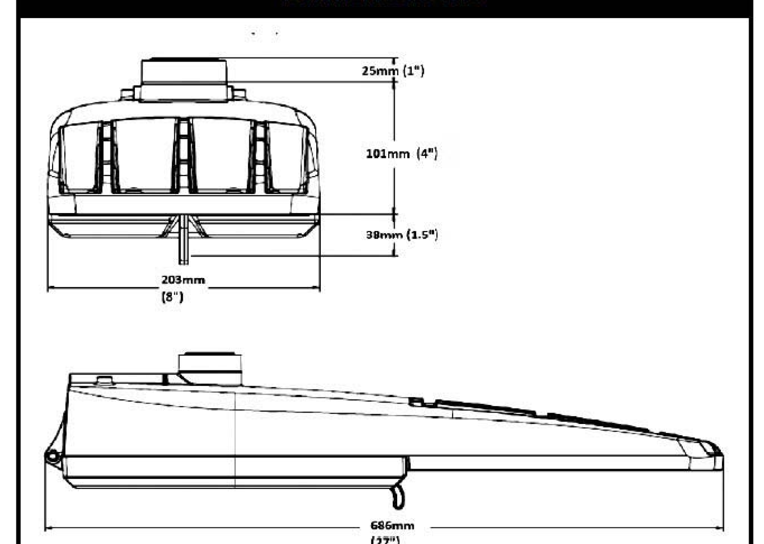
Luminaire Schedule									
Scene: NIGHT									
Symbol	Qty	Label	LLF	Description	Arm	Filename	Lum. Watts	Lum. Lumens	Total Watts
	15	MED PK1	0.678	TNLEDMED PK1 40K CCB 100k HRS LDD= 0.8 DIM TO 69%	0	TNLEDMED PK1 40K XXXXX CCB.ies	34	7344	510
	16	MED PK1_E	0.678	TNLEDMED PK1 40K CCB 100k HRS LDD= 0.8 DIM TO 69%	0	TNLEDMED PK1 40K XXXXX CCB.ies	34	7344	544
	57	TNLED2 PK6	0.707	TNLED2 PK6 XX 40K CCB	0	TNLED2 PK6 XX 40K CCB.ies	494.5	57624	28186.5
	22	TNLED2 PK5	0.752	TNLED2 PK5 XX 40K CCB	0	TNLED2 PK5 XX 40K CCB.ies	434.9	51612	9567.8
	20	TNLED2 PK2	0.769	TNLED2 PK2 XX 40K CCB	0	TNLED2 PK2 XX 40K CCB.ies	261.6	31414	5232
	8	ATB0_30BLEDE15_R3	0.792	ATB0 30BLEDE15 XXXXX R3 4K_5K	6	ATB0_30BLEDE15_XXXXX_R3_4K_5K.ies	145	16192	1160

TYPES "MED PK1" AND "MED PK1_E" INPUT WATTS ADJUSTED FOR 5-VOLT INPUT DIMMING.
THE LUMEN OUTPUT IS ADJUSTED TO 69% OF FULL OUTPUT FOR THIS SETTING.

Calculation Summary								
Scene: NIGHT								
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min	LVRatio
AFTER EXIT PORTAL_Illum	Illuminance	Fc	1.09	2.8	0.3	3.63	9.33	N.A.
AFTER EXIT PORTAL_Luminance	Luminance	Cd/Sq.m	0.85	1.8	0.4	2.13	4.50	N.A.
AFTER EXIT PORTAL_Veil_Lum	Veiling Luminance	Cd/Sq.m	0.09	0.2	0.0	N.A.	N.A.	0.24
BEFORE ENTRANCE PORTAL_Illum	Illuminance	Fc	0.94	2.2	0.3	3.13	7.33	N.A.
BEFORE ENTRANCE PORTAL_Luminance	Luminance	Cd/Sq.m	0.87	1.9	0.4	2.18	4.75	N.A.
BEFORE ENTRANCE PORTAL_Veil_Lum	Veiling Luminance	Cd/Sq.m	0.10	0.3	0.0	N.A.	N.A.	0.34
TUNNEL ROAD NIGHT_Illum	Illuminance	Fc	2.69	5.5	1.6	1.68	3.44	N.A.
TUNNEL ROAD NIGHT_Luminance	Luminance	Cd/Sq.m	2.68	4.6	1.6	1.68	2.88	N.A.
TUNNEL ROAD NIGHT_Veil_Lum	Veiling Luminance	Cd/Sq.m	0.38	0.7	0.2	1.90	3.50	0.26
Tunnel_1_TYPICAL WALL SECTION	Diffuse Luminance	Cd/Sq.m	1.66	2.4	1.0	1.66	2.40	N.A.

ATB0

DIMENSIONS



Effective Projected Area (EPA): The EPA for the ATB0 is 0.76 sq. ft.
Approx. Wt. = 14 lbs.

HOLOPHANE®
LEADER IN LIGHTING SOLUTIONS
An AcuityBrands Company

DESIGN BY: RWY
Checked By:
Date:6/19/2019
Scale:

HEROES TUNNEL
WILBER CROSS PARKWAY
NEW HAVEN, CT

PROJECT NUMBER 2019 JUNE 004

Sample Lighting Fixture Cutsheets

Sample Lighting Fixture Cutsheets

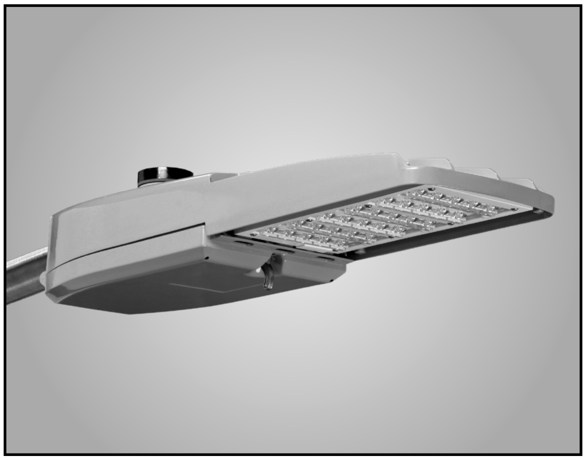
NIGHTTIME FRIENDLY

Consistent with LEED® goals
& Green Globes™ criteria
for light pollution reduction

Autobahn Series ATB0

Roadway Lighting

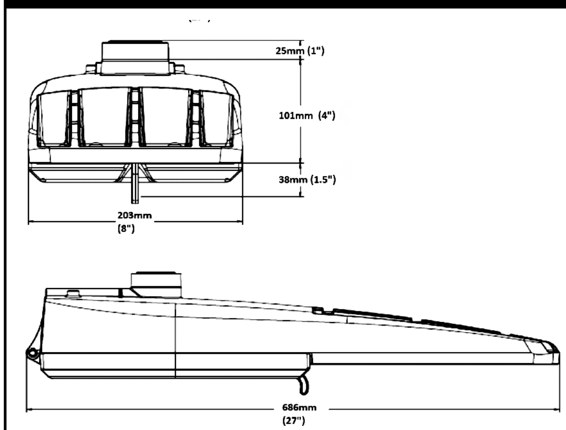
PRODUCT OVERVIEW



Applications:

Roadways
Off ramps
Residential streets
Parking lots

DIMENSIONS



Effective Projected Area (EPA): The EPA for the ATB0 is 0.76 sq. ft.
Approx. Wt. = 14 lbs.

STANDARDS

DesignLights Consortium® (DLC) qualified product. Not all versions of this product may be DLC qualified. Please check the DLC Qualified Products List at www.designlights.org/QPL to confirm which versions are qualified.

Color temperatures of ≤ 3000K must be specified for International Dark-Sky Association certification.

Rated for -40°C to 40°C ambient
CSA Certified to U.S. and Canadian standards
Complies with ANSI: C136.2, C136.10, C136.14, C136.31, C136.15, C136.37

Features:

OPTICAL

Same Light: Performance is comparable to 70-250W HPS roadway luminaires.

White Light: Correlated color temperature - 4000K, 70 CRI minimum, 3000K, 70 CRI minimum or optional 5000K, 70 CRI minimum.

Unique IP66 rated LED light engines provided 0% uplight and restrict backlight to within sidewalk depth, providing optimal application coverage and optimal pole spacing. Available in Type II, III, IV, and V roadway distributions.

ELECTRICAL

Expected Life: LED light engines are rated >100,000 hours at 25°C, L70. Electronic driver has an expected life of 100,000 hours at a 25°C ambient.

Lower Energy: Saves an expected of 40-60% over comparable HID luminaires.

Robust Surge Protection: Three different surge protection options provide a minimum of ANSI C136.2 10kV/5kA protection. 20kV/10kA protection is also available.

MECHANICAL

Includes standard AEL lineman-friendly features such as tool-less entry, 3 station terminal block and quick disconnects. Bubble level located inside the electrical compartment for easily leveling at installation.

Rugged die-cast aluminum housing and door are polyester powder-coated for durability and corrosion resistance. Rigorous five-stage pre-treating and painting process yields a finish that achieves a scribe creepage rating of 7 (per ASTM D1654) after over 5000 hours exposure to salt fog chamber (operated per ASTM B117).

Mast arm mount is adjustable for arms from 1-1/4" to 2" (1-5/8" to 2-3/8" O.D.) diameter. Provides a 3G vibration rating per ANSI C136.31

Wildlife shield is cast into the housing (not a separate piece).

CONTROLS

NEMA 3 pin photocontrol receptacle is standard, with the Acuity designed ANSI standard 7 pin receptacle optionally available.

Premium solid state locking style photocontrol - PCSS (10 year rated life) Extreme long life solid state locking style photocontrol - PCLL (20 year rated life).

Multi-level dimming available to provide scheduled dimming as specified by the customer.

Optional onboard Adjustable Output module allows the light output and input wattage to be modified to meet site specific requirements, and also can allow a single fixture to be flexibly applied in many different applications.

Note: Specifications subject to change without notice. Actual performance may differ as a result of end-user environment and application.

American Electric Lighting®

ORDERING INFORMATION

Example: ATB0 30LEDE10 MVOLT R2

Series

ATB0 Autobahn LED Roadway

Performance Packages

10BLEDE70	10B Chips, 700mA Driver
10BLEDE10	10B Chips, 1050mA Driver
10BLEDE15	10B Chips, 1500mA Driver
20BLEDE53	20B Chips, 525mA Driver
20BLEDE70	20B Chips, 700mA Driver
20BLEDE10	20B Chips, 1050mA Driver
20BLEDE13	20B Chips, 1300mA Driver
20BLEDE15	20B Chips, 1500mA Driver
30BLEDE70	30B Chips, 700mA Driver
30BLEDE85	30B Chips, 850mA Driver
30BLEDE10	30B Chips, 1050mA Driver
30BLEDE13	30B Chips, 1300mA Driver
30BLEDE15	30B Chips, 1500mA Driver

Voltage

MVOLT	Multi-volt, 120-277V
347	347V
480	480V

Optics

R2	Roadway Type II
R3	Roadway Type III
R4	Roadway Type IV
R5	Roadway Type V

Options

Color Temperature (CCT)

(Blank)	4000K CCT, 70 CRI Min.
3K	3000K CCT, 70 CRI Min.
5K	5000K CCT, 70 CRI Min.

Paint

(Blank)	Gray (Standard)
BK	Black
BZ	Bronze
DDB	Dark Bronze
GI	Graphite
WH	White

Surge Protection

(Blank)	Standard 10kV/5kA SPD
20	20kV/10KA SPD
MP[1]	MOV Pack
IL[1]	SPD with Indicator Light

Terminal Block

(Blank)	Terminal Block (Standard)
T2	Wired to L1 & L2 Positions

Misc.

BL	External Bubble Level
HS	House-Side Shield
NL	Nema Label
XL	Not CSA Certified
UMR-XX	8" Horizontal Arm for Round Pole, Painted to match Fixture
UMS-XX	8" Horizontal Arm for Square Pole, Painted to match Fixture
UMR-GALV	8" Horizontal Arm for Round Pole, Galvanized
UMS-GALV	8" Horizontal Arm for Square Pole, Galvanized

Controls

(Blank)	3 Pin NEMA Photocontrol Receptacle (Standard)
P7[2]	7 Pin Photocontrol Receptacle (Dimmable Driver Included)
NR	No Photocontrol Receptacle
AO[3]	Field Adjustable Output
DM	0V-10V Dimmable Driver (Controls by others)
ML[4,5]	Multi-Level Dimming
PCSS[1]	Solid State Lighting Photocontrol (120-277V)
PCLL	Solid State Long Life Photocontrol
SH	Shorting Cap

Packaging

(Blank)	Single Unit (Standard)
JP	Job Pack (42/Pallet)

Accessories (field installed):

ATB0 LTS20	Light Trespass Shield for ATB0 LEM 20
ATB0 LTS30	Light Trespass Shield for ATB0 LEM 30

Notes

1 Not available in 347 or 480V.

2 Not available with DM, ML or NR.

3 Not available with DM or ML options. Not available with 10BLED packages.

4 Not available with AO, DM or P7 options.

5 Dimming Schedule and light level information required from the customer in order to configure product. Contact Infrastructure Technical Support to proceed.

Warranty Five-year limited warranty. Complete warranty terms located at:
www.acuitybrands.com/resources/terms-and-conditions
Actual performance may differ as a result of end-user environment and application.
All values are design or typical values, measured under laboratory conditions at 25 °C.
Specifications subject to change without notice.

Please contact your sales representative for the latest product information.

PERFORMANCE PACKAGE

Performance Package	Drive Current (mA)	Input Watts	Optic	3K (3000K CCT, 70 CRI Min.)					4K/5K (4000K/5000K CCT, 70 CRI Min.)					LLD @ 25°C		
				Lumens	LPW	B	U	G	Lumens	LPW	B	U	G	25k Hours	75k Hours	100k Hours
10B	700	25	R2	2,670	107	1	0	1	2,994	120	1	0	1	0.98	0.97	0.96
	1050	37		4,006	108	1	0	2	4,293	116	1	0	2	0.97	0.95	0.92
	1500	54		5,364	99	1	0	2	5,688	105	1	0	2	0.93	0.90	0.88
	700	25	R3	2,702	108	1	0	1	3,009	120	1	0	1	0.98	0.97	0.96
	1050	37		4,069	110	1	0	1	4,313	117	1	0	1	0.97	0.95	0.92
	1500	54		5,409	100	1	0	1	5,742	106	1	0	1	0.93	0.90	0.88
	700	25	R4	2,686	107	1	0	1	2,992	120	1	0	1	0.98	0.97	0.96
	1050	37		3,934	106	1	0	1	4,232	114	1	0	1	0.97	0.95	0.92
	1500	54		5,383	100	1	0	2	5,653	105	1	0	2	0.93	0.90	0.88
	700	25	R5	2,806	112	2	0	1	3,065	123	2	0	1	0.98	0.97	0.96
	1050	37		4,125	111	3	0	1	4,422	120	3	0	1	0.97	0.95	0.92
	1500	54		5,551	103	3	0	1	5,844	108	3	0	1	0.93	0.90	0.88
20B	525	36	R2	4,328	120	1	0	2	4,638	129	1	0	2	0.98	0.97	0.96
	700	48		5,652	118	1	0	2	5,956	124	1	0	2	0.98	0.96	0.95
	1050	71		7,948	112	2	0	2	8,506	120	2	0	2	0.97	0.95	0.92
	1300	87		9,157	105	2	0	3	9,922	114	2	0	3	0.93	0.90	0.88
	1500	99		10,288	104	2	0	3	11,038	111	2	0	3	0.93	0.90	0.88
	525	36	R3	4,436	123	1	0	1	4,704	131	1	0	1	0.98	0.97	0.96
	700	48		5,705	119	1	0	1	6,114	127	1	0	2	0.98	0.96	0.95
	1050	71		8,080	114	2	0	2	8,606	121	2	0	2	0.97	0.95	0.92
	1300	87		9,442	109	2	0	2	10,065	116	2	0	2	0.93	0.90	0.88
	1500	99		10,503	106	2	0	2	11,181	113	2	0	2	0.93	0.90	0.88
	525	36	R4	4,459	124	1	0	2	4,676	130	1	0	2	0.98	0.97	0.96
	700	48		5,766	120	1	0	2	6,022	125	1	0	2	0.98	0.96	0.95
	1050	71		8,101	114	2	0	2	8,569	121	2	0	2	0.97	0.95	0.92
	1300	87		9,321	107	2	0	2	10,053	116	2	0	2	0.93	0.90	0.88
	1500	99		10,426	105	2	0	2	11,160	113	2	0	3	0.93	0.90	0.88
	525	36	R5	4,540	126	3	0	1	4,869	135	3	0	1	0.98	0.97	0.96
	700	48		5,832	122	3	0	1	6,287	131	3	0	1	0.98	0.96	0.95
	1050	71		8,241	116	3	0	2	8,880	125	3	0	2	0.97	0.95	0.92
	1300	87		9,597	110	3	0	2	10,397	120	4	0	2	0.93	0.90	0.88
	1500	99		10,647	108	4	0	2	11,593	117	4	0	2	0.93	0.90	0.88
30B	700	70	R2	8,406	120	2	0	2	9,174	131	2	0	3	0.98	0.97	0.96
	850	83		9,897	119	2	0	3	10,457	126	2	0	3	0.97	0.95	0.92
	1050	105		11,806	112	2	0	3	12,414	118	2	0	3	0.97	0.95	0.92
	1300	126		13,675	109	3	0	3	14,964	119	3	0	3	0.93	0.90	0.88
	1500	145		15,090	104	3	0	3	16,251	112	3	0	3	0.93	0.90	0.88
	700	70	R3	8,539	122	2	0	2	8,893	127	2	0	2	0.98	0.97	0.96
	850	83		10,056	121	2	0	2	10,825	130	2	0	2	0.97	0.95	0.92
	1050	105		11,936	114	2	0	2	12,748	121	2	0	2	0.97	0.95	0.92
	1300	126		13,893	110	3	0	3	14,850	118	3	0	3	0.93	0.90	0.88
	1500	145		15,381	106	3	0	3	16,193	112	3	0	3	0.93	0.90	0.88
	700	70	R4	8,335	119	2	0	2	8,971	128	2	0	2	0.98	0.97	0.96
	850	83		9,877	119	2	0	2	10,589	128	2	0	2	0.97	0.95	0.92
	1050	105		11,943	114	2	0	3	12,782	122	2	0	3	0.97	0.95	0.92
	1300	126		13,681	109	2	0	3	14,889	118	3	0	3	0.93	0.90	0.88
	1500	145		14,952	103	3	0	3	16,463	114	3	0	3	0.93	0.90	0.88
	700	70	R5	8,893	127	3	0	2	9,329	133	3	0	2	0.98	0.97	0.96
	850	83		10,469	126	4	0	2	11,209	135	4	0	2	0.97	0.95	0.92
	1050	105		12,382	118	4	0	2	13,296	127	4	0	2	0.97	0.95	0.92
	1300	126		14,453	115	4	0	2	15,254	121	4	0	2	0.93	0.90	0.88
	1500	145		15,853	109	4	0	2	16,871	116	4	0	2	0.93	0.90	0.88

Note: Individual fixture performance may vary.

ATB0 LLD Multiplier	15°C	20°C	25°C	30°C	35°C	40°C
	1.02	1.01	1	0.98	0.97	0.95

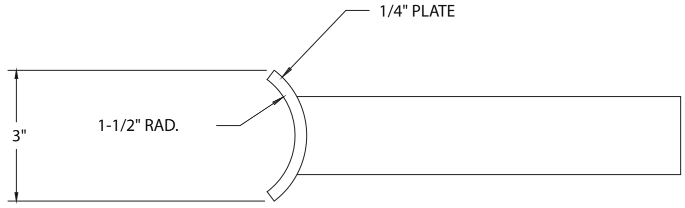
To calculate the LLD for a temperature other than 25°C, multiply the LLD @ 25°C (shown in the performance package table) by the LLD multiplier for the selected temperature.

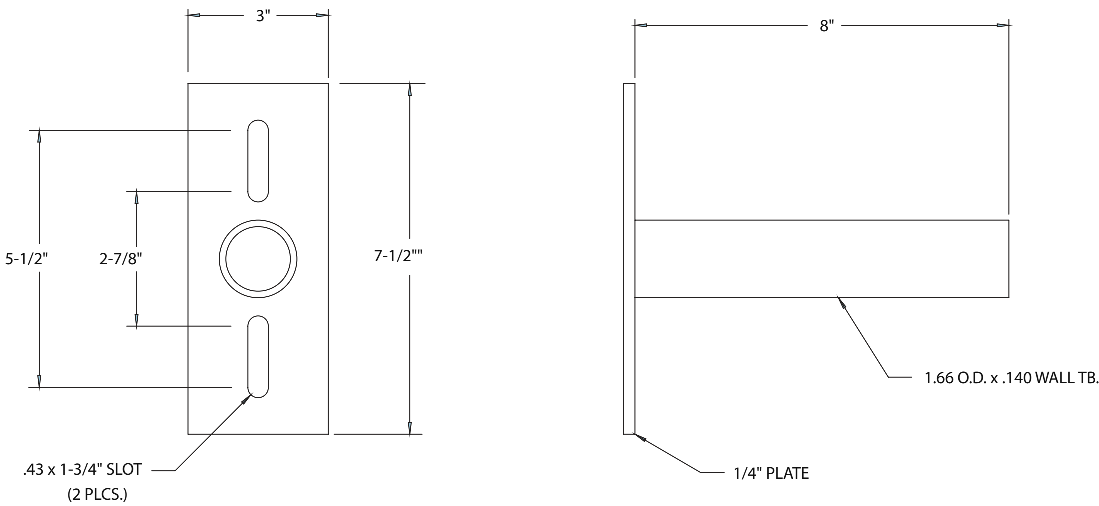
Warranty Five-year limited warranty. Complete warranty terms located at:
www.acuitybrands.com/resources/terms-and-conditions
Actual performance may differ as a result of end-user environment and application.
All values are design or typical values, measured under laboratory conditions at 25 °C.
Specifications subject to change without notice.

Please contact your sales representative for the latest product information.

UMR POLE ADAPTOR

RECOMMENDED FOR USE WITH POLES OF 4" DIAMETER OR SMALLER





UMS POLE ADAPTOR

Catalog Number

Tunnel Interior Lighting

Notes

Type

TNLED2

TunnelPass LED™ Large

Mechanical

- Low copper content diecast aluminum A360 alloy electrical and optical housing. Diecast aluminum housing has integral heat sink fins to optimize thermal management through conductive and convection cooling.
- Stainless steel bolted or latched door closure disengages top electrical cover for easy access to LED drivers, surge protection, luminaire disconnect, and terminal block.
- Super durable TGIC thermoset powder coat finish over anodized aluminum pre-finish. Rigorous pre-treating and paint process yields over 5,000 hours salt fog rating per ASTM B117.
- Luminaire mounting brackets are of 316 grade stainless steel.
- Luminaire is IP66 rated.
- Luminaire is 3G vibration rated per ANCI C136.31.
- Luminaire is suitable for continuous row mounting as standard, with through wire raceway available as an option.
- Luminaire and through wire raceway box each have three removable brass ¾-14NPT entries to facilitate wiring.

Electrical

- Quick disconnect connectors for ease of installation and maintenance.
- Extreme surge protection meets 20KV/10KA per ANSI/IEEEC62.41 and is fail off.
- Three pole terminal block is standard for ease of installation.
- LED drivers meets maximum total harmonic distortion (THD) of 20% and are ROHS compliant. Minimum operating temperature is -40C. Electronic driver has an estimated minimum life of 100,000 hours at 25C.

Optical

- PCB mounted LED technology comprised of multi-cluster LED's on a single metal core board.
- Color temperature options of 3000K, 4000K, and 5000K with CRI of 70 minimum.
- Segmented Miro 4 internal reflectors are designed for superior optical control in Counterbeam, Crossbeam, Long and Narrow.
- Borosilicate glass retractor ensures longevity and minimizes dirt depreciation and minimizes direct view of LED's, reducing glare.

Controls

- Field Adjustable Output (AO) module - Onboard device that adjusts the light output and input wattage to meet site specific requirements. The AO module is preset at the factory to position number 8 (see chart).
- ICMNYX - Nyx Hemera internally mounted control module communicates with Nyx Hemera powerline control systems (consult factory).

Testing/Compliance

Luminaire conforms to the following standards:

- ANSI/IEEE C62.41:2002 - Surge protection
- ANSI C82.77:2002 - Harmonic distortion limits
- ANSI C136.31 - Luminaire vibration
- ASTM B117 - Salt Spray
- FCC Title 47 CFR Part 15 - FCC EMC/EMI
- IEC 60068 - Environmental testing
- ANSI C136.27-17 - Environmental Testing (including Parsons test)
- IEC 60529 - Ingress Protection (IP)
- IEC 61000 - Electromagnetic Compatibility testing (EMC)
- IEEE 519 - Harmonic Control in Electrical Power systems
- UL 1598 - Wet Location Safety Listing
- UL 1598A - Marine Outside
- PK1-PK4 Suitable for ambient temeratures -40C to 50C
- PK5 Suitable -40C to 45C ambient
- PK6 Suitable -40C to 40C ambient
- TW Option suitable -40C to 40C ambient

Manufacturing

- Manufactured in Crawfordsville, Indiana, ARRA compliant
- 100% electrical testing on all luminaires before shipment
- No less than five (5) years experience in manufacturing LED based products

Warranty

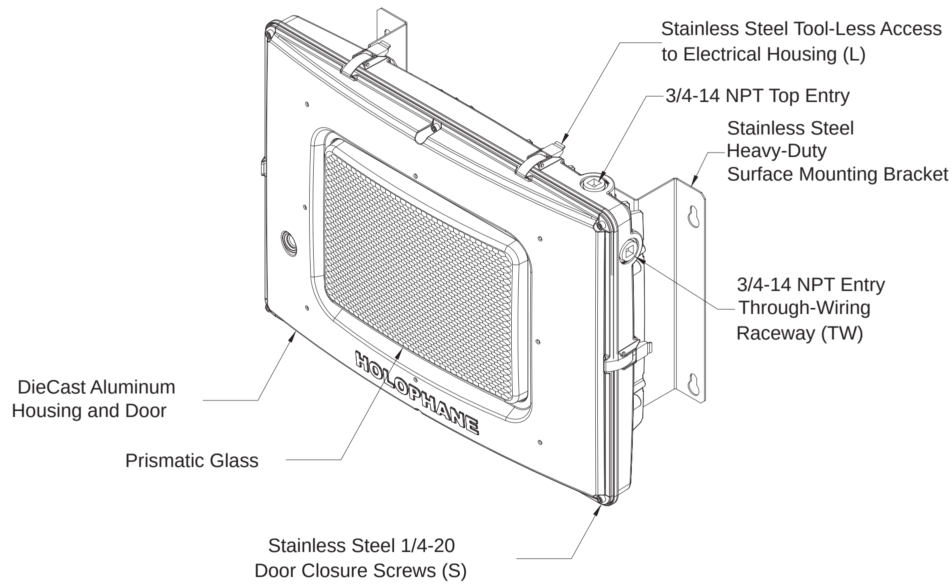
5-year limited warranty. Complete warranty terms located at: www.acuitybrands.com/resources/terms-and-conditions

Note: Actual performance may differ as a result of end-user environment and application.

All values are design or typical values, measured under laboratory conditions at 25 °C.

Specifications subject to change without notice.

Weight = 58 lbs.
IAH Voltage Option = 65 lbs.



ORDERING INFORMATION

Example: TNLED2 PK4 AS 40K CCB DGRA L TW AWB35 ICMNYX

Series	Lumen Package	Voltage	Color Temperature	Optics	Color	Door Closure
TNLED2 TunnelPass LED™ Large	PK1 25,700 PK2 31,200 PK3 37,700 PK4 41,200 PK5 51,300 PK6 57,300	AS Auto-Sensing Voltage (120V-277V) AH Auto-Sensing Voltage (347V-480V) IAH Voltage 120V-277V (provides protection when connected to circuits supplied by 277V derived from 480V-WYE)	30K 3,000 K CCT +/- 175 40K 4,000 K CCT +/- 275 50K 5,000 K CCT +/- 283	CCB Ceiling Mount Counterbeam CLN Ceiling Mount Long and Narrow WCR Wall Mount Crossbeam	A As Specified DBKA Black DBZA Bronze DGRA Gray DWHA White DGHA Graphite	L Latched S Bolted Assembly

Options:

BM	Box Mount	AWB00	Adjustable Wall Bracket Factory Set to 0 Degree Tilt	AO	Field adjustable output
F1	Single Fusing	AWB05	Adjustable Wall Bracket Factory Set to 5 Degree Tilt	ICMNYX	Nyx Hemera Internal Control Module, Consult Factory
F2	Double Fusing	AWB10	Adjustable Wall Bracket Factory Set to 10 Degree Tilt	DALI	DALI Driver Option, Consult Factory
TW	Through Wire	AWB15	Adjustable Wall Bracket Factory Set to 15 Degree Tilt		
		AWB20	Adjustable Wall Bracket Factory Set to 20 Degree Tilt		
		AWB25	Adjustable Wall Bracket Factory Set to 25 Degree Tilt		
		AWB30	Adjustable Wall Bracket Factory Set to 30 Degree Tilt		
		AWB35	Adjustable Wall Bracket Factory Set to 35 Degree Tilt		
		AWB40	Adjustable Wall Bracket Factory Set to 40 Degree Tilt		
		AWB45	Adjustable Wall Bracket Factory Set to 45 Degree Tilt		

OPTIONS MATRIX (continued next page)

Parameters		Perf Package	Optics			Color						Door Closure		Options			
		PK1-PK6	CCB	CLN	WCR	A	DBKA	DBZA	DGRA	DWHA	DGHA	L	S	BM	TW	F1	F2
LED Performance Package	PK1-PK6		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Voltage	AS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	AH	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	IAH	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Color Temperature	30K	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	40K	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	50K	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Optics	CCB	Y		N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	CLN	Y	N		N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	WCR	Y	N	N		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Color	A	Y	Y	Y	Y		N	N	N	N	N	Y	Y	Y	Y	Y	Y
	DBKA	Y	Y	Y	Y	N		N	N	N	N	Y	Y	Y	Y	Y	Y
	DBZA	Y	Y	Y	Y	N	N		N	N	N	Y	Y	Y	Y	Y	Y
	DGRA	Y	Y	Y	Y	N	N	N		N	N	Y	Y	Y	Y	Y	Y
	DWHA	Y	Y	Y	Y	N	N	N	N		N	Y	Y	Y	Y	Y	Y
	DGHA	Y	Y	Y	Y	N	N	N	N	N		Y	Y	Y	Y	Y	Y
Door Closure	L	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		N	Y	Y	Y	Y
	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N		Y	Y	Y	Y
Options	BM	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		N	Y	Y
	TW	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N		Y	Y
	F1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
	F2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Angle Wall Bracket	AWB00	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB05	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB15	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB20	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB25	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB30	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB35	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB40	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	AWB45	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Other Options	AO	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	ICMNYX	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	DALI	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes
IAH is not available in combination with ICMNYX on PK6.
ICMNYX is available (without IAH) for all performance packages.

Y= Valid Option Combination
N = Combination Not available

OPTIONS MATRIX (continued from previous page)

Parameters		Angle Wall Bracket										Other Options		
		AWB00	AWB05	AWB10	AWB15	AWB20	AWB25	AWB30	AWB35	AWB40	AWB45	AO	ICMNYX	DALI
LED Performance Package	PK1-PK6	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Voltage	AS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	AH	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	IAH	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Color Temperature	30K	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	40K	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	50K	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Optics	CCB	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	CLN	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	WCR	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Color	A	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	DBKA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	DBZA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	DGRA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	DWHA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	DGHA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Door Closure	L	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Options	BM	N	N	N	N	N	N	N	N	N	N	Y	Y	Y
	TW	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	F1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	F2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Angle Wall Bracket	AWB00		N	N	N	N	N	N	N	N	N	Y	Y	Y
	AWB05	N		N	N	N	N	N	N	N	N	Y	Y	Y
	AWB10	N	N		N	N	N	N	N	N	N	Y	Y	Y
	AWB15	N	N	N		N	N	N	N	N	N	Y	Y	Y
	AWB20	N	N	N	N		N	N	N	N	N	Y	Y	Y
	AWB25	N	N	N	N	N		N	N	N	N	Y	Y	Y
	AWB30	N	N	N	N	N	N		N	N	N	Y	Y	Y
	AWB35	N	N	N	N	N	N	N		N	N	Y	Y	Y
	AWB40	N	N	N	N	N	N	N	N		N	Y	Y	Y
	AWB45	N	N	N	N	N	N	N	N	N		Y	Y	Y
Other Options	AO	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		N	N
	ICMNYX	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N		N
	DALI	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	

Notes
IAH is not available in combination with ICMNYX on PK6.
ICMNYX is available (without IAH) for all performance packages.

Y= Valid Option Combination
N = Combination Not available

PERFORMANCE DATA

TNLEDMED	Input Watts	Distribution	3000K		4000K		5000K	
			Lumens	LPW	Lumens	LPW	Lumens	LPW
PK1	212	CCB	25,116	119	25,836	122	26,156	124
		CLN	25,479	120	26,209	124	26,534	125
		WCR	24,378	115	25,077	119	25,387	120
PK2	262	CCB	30,532	117	31,407	120	31,796	122
		CLN	30,973	118	31,860	122	32,255	123
		WCR	29,634	113	30,484	117	30,861	118
PK3	321	CCB	36,907	115	37,965	118	38,435	120
		CLN	37,440	117	38,513	120	38,990	122
		WCR	35,823	112	36,849	115	37,306	116
PK4	345	CCB	40,625	118	41,789	121	42,307	123
		CLN	41,211	120	42,392	123	42,917	125
		WCR	39,432	114	40,562	118	41,064	119
PK5	435	CCB	50,165	115	51,603	119	52,242	120
		CLN	50,889	117	52,348	120	52,996	122
		WCR	48,692	112	50,087	115	50,708	117
PK6	495	CCB	56,009	113	57,614	117	58,327	118
		CLN	56,817	115	58,445	118	59,169	120
		WCR	54,363	110	55,922	113	56,614	114

	Driver Output mA	Luminaire Input Operating Amps					
Package	mA	120V	208V	240V	277V	347V	480V
PK1	500	1.8	1.0	0.9	0.8	0.6	0.5
PK2	625	2.2	1.3	1.1	1.0	0.8	0.6
PK3	770	2.7	1.5	1.4	1.2	1.0	0.7
PK4	550	2.9	1.7	1.4	1.3	1.0	0.7
PK5	700	3.7	2.1	1.8	1.6	1.3	0.9
PK6	800	4.2	2.4	2.1	1.8	1.5	1.1

LAT TABLE

	LAT										
Package	0C	5C	10C	15C	20C	25C	30C	35C	40C	45C	50C
PK1	1.022	1.018	1.014	1.010	1.005	1.000	0.995	0.989	0.983	0.976	0.970
PK2	1.024	1.020	1.015	1.011	1.005	1.000	0.994	0.988	0.982	0.975	0.968
PK3	1.026	1.021	1.017	1.011	1.006	1.000	0.994	0.987	0.980	0.973	0.966
PK4	1.026	1.022	1.017	1.012	1.006	1.000	0.994	0.987	0.980	0.973	0.965
PK5	1.030	1.024	1.019	1.013	1.007	1.000	0.993	0.986	0.978	0.970	
PK6	1.032	1.026	1.020	1.014	1.007	1.000	0.993	0.985	0.977		

PK1-PK4 suitable for use -40C to 50C.
PK5 suitable for use -40C to 45C ambient.
PK6 suitable for use -40C to 40C ambient.
TW option suitable for use -40C to 40C ambient.

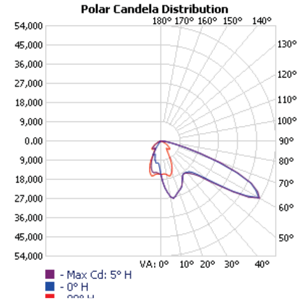
LLD TABLE

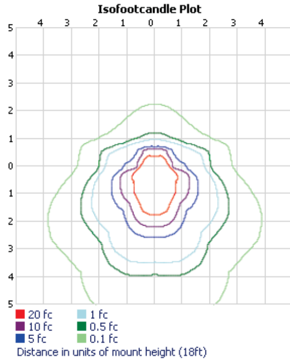
	PK1	PK2	PK3	PK4	PK5	PK6
25,000 hours	97.5%	97.5%	96.5%	97.4%	97.0%	95.6%
50,000 hours	97.1%	97.1%	94.6%	96.7%	96.0%	93.1%
75,000 hours	96.7%	96.6%	92.8%	96.0%	95.0%	90.8%
100,000 hours	96.2%	96.1%	91.0%	95.3%	94.0%	88.4%

AO OPTION SETTINGS

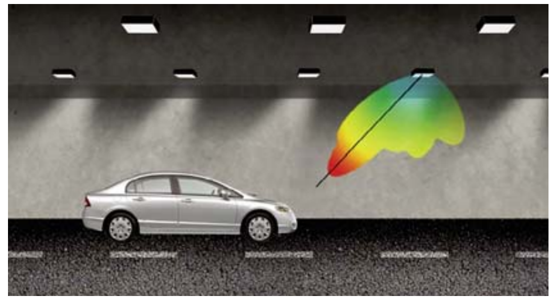
AS / IAH / AH : PK1-thru-PK6		
AO setting	Lumens %	Wattage %
8	100%	100%
7	94%	94%
6	83%	81%
5	71%	68%
4	59%	55%
3	46%	43%
2	34%	31%
1	21%	18%

CCB: Ceiling mount counterbeam

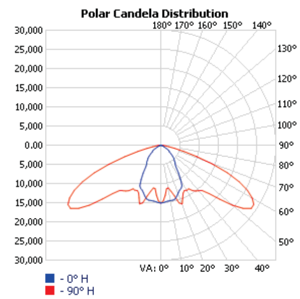


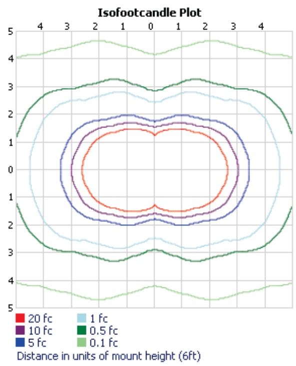


Recommended for divided tunnels where majority of lumens are directed towards oncoming drivers to maximize roadway luminance while controlling disability glare.

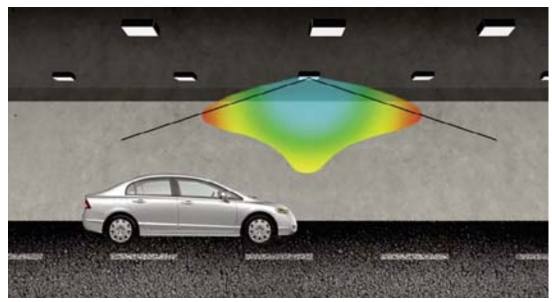


CLN: Ceiling mount counterbeam

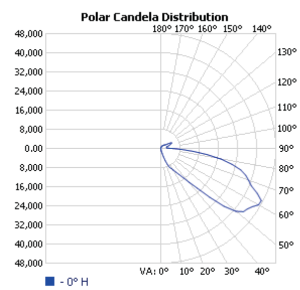


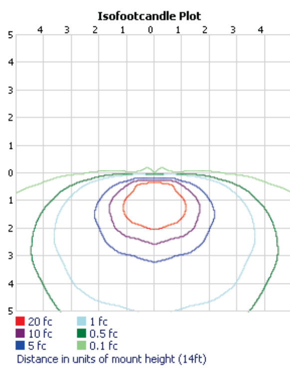


Recommended for undivided tunnels where equal lumens are with and against traffic flow.



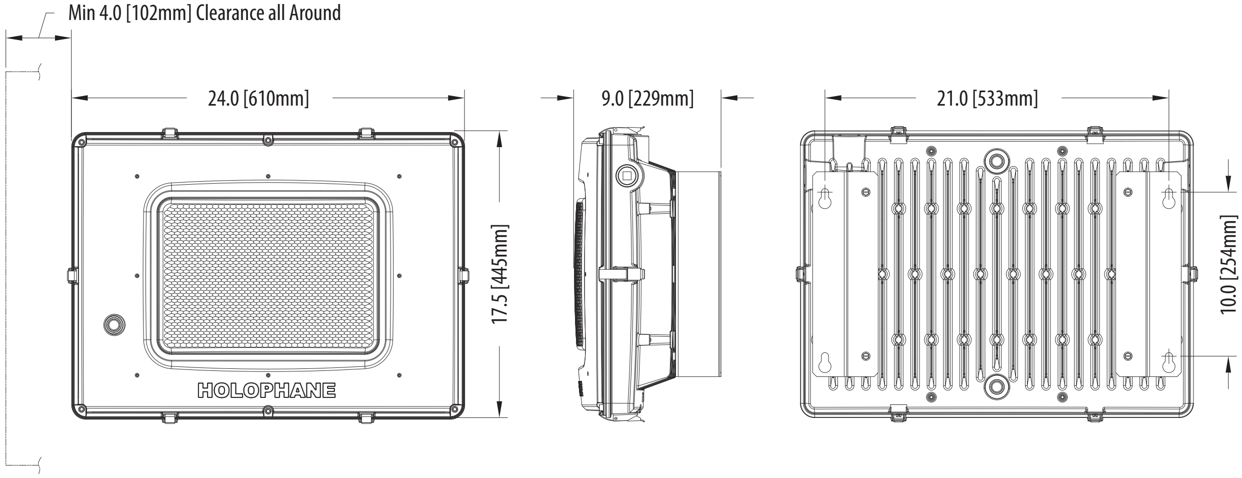
WCR: Wall mount crossbeam



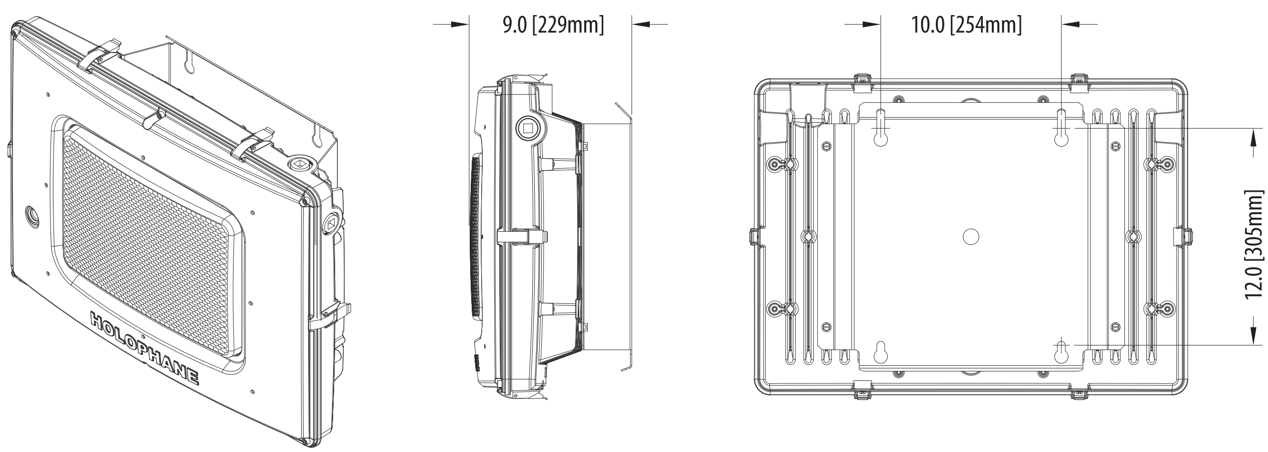


Recommended for undivided tunnels where equal lumens are with and against traffic flow.

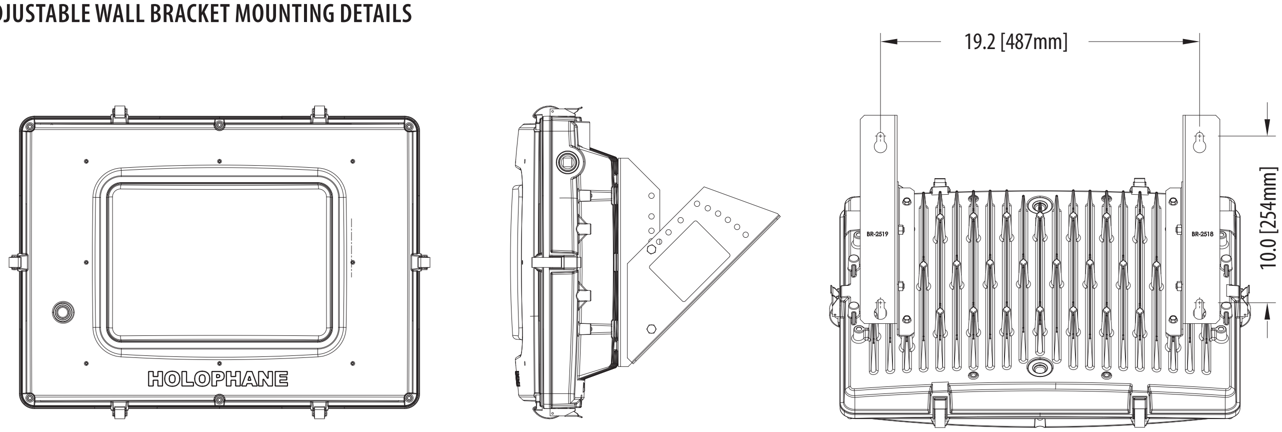
SURFACE MOUNTING DETAILS



BOX MOUNTING DETAILS



ADJUSTABLE WALL BRACKET MOUNTING DETAILS



HOLOPHANE®
LEADER IN LIGHTING SOLUTIONS

Catalog Number	Tunnel Interior Lighting
Notes	Type

TNLEDMED

TunnelPass LED™ Medium

Mechanical

- Low copper content diecast aluminum A360 alloy electrical and optical housing. Diecast aluminum housing has integral heat sink fins to optimize thermal management through conductive and convection cooling.
- Stainless steel bolted or latched door closure disengages top electrical cover for easy access to LED drivers, surge protection, luminaire disconnect, and terminal block.
- Super durable TGIC thermoset powder coat finish over anodized aluminum pre-finish. Rigorous pre-treating and paint process yields over 5,000 hours salt fog rating per ASTM B117.
- Luminaire mounting brackets are of 316 grade stainless steel.
- Luminaire is IP66 rated.
- Luminaire is 3G vibration rated per ANCI C136.31.
- Luminaire is suitable for continuous row mounting as standard, with through wire raceway available as an option.
- Luminaire and through wire raceway box each have three removable brass ¾-14NPT entries to facilitate wiring.

Electrical

- Quick disconnect connectors for ease of installation and maintenance.
- Extreme surge protection meets 20KV/10KA per ANSI/IEEEC62.41 and is fail off.
- Three pole terminal block is standard for ease of installation.
- LED drivers meets maximum total harmonic distortion (THD) of 20% and are ROHS compliant. Minimum operating temperature is -40C. Electronic driver has an estimated minimum life of 100,000 hours at 25C.

Optical

- PCB mounted LED technology comprised of multi-cluster LED's on a single metal core board.
- Color temperature options of 3000K, 4000K, and 5000K with CRI of 70 minimum.
- Segmented Miro 4 internal reflectors are designed for superior optical control in Counterbeam, Crossbeam, Long and Narrow, and Underpass optics.
- Borosilicate glass retractor ensures longevity and minimizes dirt depreciation and minimizes direct view of LED's, reducing glare.

Controls

- Field Adjustable Output (AO) module - Onboard device that adjusts the light output and input wattage to meet site specific requirements. The AO module is preset at the factory to position number 8 (see chart).
- ICMNYX - Nyx Hemera internally mounted control module communicates with Nyx Hemera powerline control systems, MVOLT only (consult factory).
- ICMECH - Echelon internally mounted control module that communicates with Echelon powerline control systems, MVOLT only (consult factory).

Testing/Compliance

Luminaire conforms to the following standards:

- ANSI/IEEE C62.41:2002 - Surge protection
- ANSI C82.77:2002 - Harmonic distortion limits
- ANSI C136.31 - Luminaire vibration
- ASTM B117 - Salt Spray
- FCC Title 47 CFR Part 15 - FCC EMC/EMI
- IEC 60068 - Environmental testing
- ANSI C136.27-17 - Environmental Testing (including Parsons test)
- IEC 60529 - Ingress Protection (IP)
- IEC 61000 - Electromagnetic Compatibility testing (EMC)
- IEEE 519 - Harmonic Control in Electrical Power systems
- UL 1598 - Wet Location Safety Listing
- UL 1598A - Marine Outside
- Suitable for ambient temperatures -40C to 40C

Manufacturing

- Manufactured in Crawfordsville, Indiana, ARRA compliant
- 100% electrical testing on all luminaires before shipment
- No less than five (5) years experience in manufacturing LED based products

Warranty

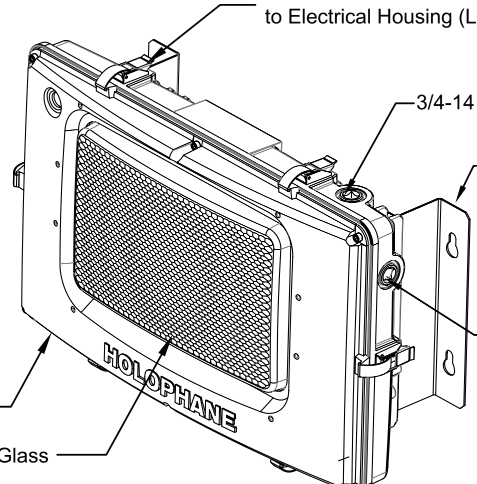
5-year limited warranty. Complete warranty terms located at: www.acuitybrands.com/CustomerResources/Terms_and_Conditions.aspx.

Note: Actual performance may differ as a result of end-user environment and application.

All values are design or typical values, measured under laboratory conditions at 25 °C.

Specifications subject to change without notice.

Max Weight = 43 lbs (19.5 kg)
Max EPA = 3.2 ft² (.30 m²)



ORDERING INFORMATION

Example: TNLEDMEDPK840KMVOLTCCBDGRAL

Series	Lumen Package	Color Temperature	Voltage	Optics	Color	Door Closure
TNLEDMED TunnelPass LED™ Medium	PK1 6,000	30K 3,000 K CCT +/- 250K	MVOLT Auto-Sensing Voltage (120V-277V)	CCB Ceiling Mount Counterbeam	A As Specified	L Latched
	PK2 9,500	40K 4,000 K CCT +/- 250K	HVOLT Auto-Sensing Voltage (347V-480V)	CLN Ceiling Mount Long and Narrow	DBKA Black	S Bolted Assembly
	PK3 12,000	50K 5,000 K CCT +/- 250K		WCR Wall Mount Crossbeam	DBZA Bronze	
	PK4 15,000			UDP Wall Mount Underpass	DGRA Gray	
	PK5 18,000				DWHA White	
	PK6 21,000				DGHA Graphite	
	PK7 24,000					
	PK8 30,000					
	PK9 36,000					

Options:		
BM Box Mount	AWB0 Adjustable Wall Bracket Factory Set to 0 Degree Tilt	ICMNYX Nyx Hemera Internal Control Module, Consult Factory
F1 Single Fusing	AWB5 Adjustable Wall Bracket Factory Set to 5 Degree Tilt	ICMECH Echelon Internal Control Module, Consult Factory
F2 Double Fusing	AWB10 Adjustable Wall Bracket Factory Set to 10 Degree Tilt	DALI DALI Driver Option, Consult Factory
TW Through Wire Box Top Mount	AWB15 Adjustable Wall Bracket Factory Set to 15 Degree Tilt	
AO Field Adjustable Module	AWB20 Adjustable Wall Bracket Factory Set to 20 Degree Tilt	
	AWB25 Adjustable Wall Bracket Factory Set to 25 Degree Tilt	

OPTIONS MATRIX

Parameters		Optic				Door Closure		Options					Wall Brackets						Controls		
		CCB	CLN	WCR	UDP	L	S	BM	F1	F2	TW	AO	AWB0	AWB5	AWB10	AWB15	AWB20	AWB25	ICMNYX	ICMECH	DALI
Lumen Package	PK1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	PK2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	PK3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	PK4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	PK5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	PK6	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	PK7	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N
	PK8	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N
	PK9 (*1)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N
Voltage	MVOLT	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	HVOLT	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y
Optic	CCB		N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	CLN	N		N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	WCR	N	N		N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	UDP	N	N	N		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Door Closure	L	Y	Y	Y	Y		N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	S	Y	Y	Y	Y	N		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Options	BM	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	F1	Y	Y	Y	Y	Y	Y	Y		N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	F2	Y	Y	Y	Y	Y	Y	Y	N		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	TW	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	AO	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	N	N	N
Wall Brackets	AWB0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		N	N	N	N	N	Y	Y	Y
	AWB5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N		N	N	N	N	Y	Y	Y
	AWB10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N		N	N	N	Y	Y	Y
	AWB15	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N		N	N	Y	Y	Y
	AWB20	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N		N	Y	Y	Y
	AWB25	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N		Y	Y	Y
Controls (Consult Factory)	ICMNYX	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y		N	Y
	ICMECH	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N		Y
	DALI	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	

Notes

*1 PK9 has non-illuminated fail-off 20kV/10kA surge (fail off mode). PK1-thru-PK8 have 20kV/10kA fail off mode surge with indicator light.

Y = Valid Option Combination

N = Combination Not available

PERFORMANCE DATA

TNLEDMED	Input Watts	Distribution	3000K		4000K		5000K	
			Lumens	LPW	Lumens	LPW	Lumens	LPW
PK1	57	CCB	6,782	119	7,343	129	7,343	129
		CLN	6,333	111	6,858	120	6,858	120
		WCR	6,485	114	7,022	123	7,022	123
		UDP	6,277	110	6,797	119	6,797	119
PK2	70	CCB	9,168	131	9,928	142	9,928	142
		CLN	8,562	122	9,271	132	9,271	132
		WCR	8,767	125	9,493	136	9,493	136
		UDP	8,486	121	9,189	131	9,189	131
PK3	102	CCB	12,592	123	13,634	134	13,634	134
		CLN	11,759	115	12,733	125	12,733	125
		WCR	12,040	118	13,037	128	13,037	128
		UDP	11,655	114	12,620	124	12,620	124
PK4	125	CCB	14,897	119	16,130	129	16,130	129
		CLN	13,911	111	15,063	121	15,063	121
		WCR	14,244	114	15,424	123	15,424	123
		UDP	13,788	110	14,930	119	14,930	119
PK5	151	CCB	17,601	117	19,059	126	19,059	126
		CLN	16,437	109	17,799	118	17,799	118
		WCR	16,831	111	18,224	121	18,224	121
		UDP	16,292	108	17,641	117	17,641	117
PK6	182	CCB	19,551	107	21,170	116	21,170	116
		CLN	18,258	100	19,770	109	19,770	109
		WCR	18,695	103	20,243	111	20,243	111
		UDP	18,097	99	19,595	108	19,595	108
PK7	203	CCB	25,497	126	27,608	136	27,608	136
		CLN	23,866	118	25,842	127	25,842	127
		WCR	24,176	119	26,178	129	26,178	129
		UDP	22,935	113	24,834	122	24,834	122
PK8	246	CCB	29,801	121	32,268	131	32,268	131
		CLN	27,895	113	30,204	123	30,204	123
		WCR	28,257	115	30,597	124	30,597	124
		UDP	26,806	109	29,026	118	29,026	118
PK9	323	CCB	34,026	105	36,843	114	36,843	114
		CLN	31,849	99	34,486	107	34,486	107
		WCR	32,263	100	34,935	108	34,935	108
		UDP	30,607	95	33,141	103	33,141	103

Package	Driver Output mA	Luminaire Input Operating Amps					
	mA	120V	208V	240V	277V	347V	480V
PK1	330	0.295	0.289	0.253	0.226	0.174	0.138
PK2	420	0.586	0.349	0.302	0.267	0.207	0.159
PK3	600	0.849	0.494	0.429	0.367	0.299	0.216
PK4	730	1.042	0.617	0.534	0.465	0.388	0.299
PK5	880	1.255	0.739	0.64	0.548	0.452	0.345
PK6	1050	1.513	0.881	0.764	0.647	0.534	0.402
PK7	600	1.693	1.007	0.872	0.763	0.623	0.486
PK8	730	2.049	1.213	1.051	0.914	0.763	0.589
PK9	960	2.76	1.64	1.43	1.2	0.75	0.73

LAT TABLE

LAT										
0C	5C	10C	15C	20C	25C	30C	35C	40C	45C	50C
1.04	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95

LLD TABLE

L70	PK1	PK2	PK3	PK4	PK5	PK6	PK7	PK8	PK9
25,000 hours		0.958			0.947		0.947	0.933	0.938
50,000 hours		0.919			0.898		0.899	0.892	0.881
75,000 hours		0.882			0.852		0.853	0.843	0.828
100,000 hours		0.847			0.809		0.810	0.797	0.777

AO OPTION SETTINGS

PK1		
Setting	Lumens	Wattage
8	100%	100%
7	100%	100%
6	100%	100%
5	100%	88%
4	88%	76%
3	65%	65%
2	53%	54%
1	40%	43%

PK2		
Setting	Lumens	Wattage
8	100%	100%
7	100%	100%
6	98%	97%
5	87%	85%
4	75%	72%
3	64%	60%
2	53%	47%
1	42%	35%

PK3-PK7		
Setting	Lumens	Wattage
8	100%	100%
7	100%	100%
6	99%	99%
5	86%	86%
4	73%	73%
3	61%	61%
2	47%	47%
1	36%	36%

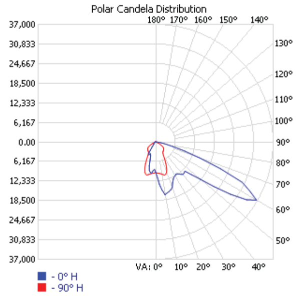
PK8		
Setting	Lumens	Wattage
8	100%	100%
7	100%	100%
6	100%	100%
5	94%	90%
4	82%	77%
3	70%	65%
2	58%	52%
1	45%	40%

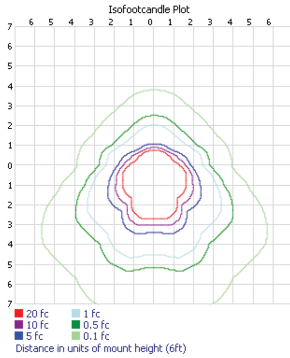
PK9		
Setting	Lumens	Wattage
8	100%	100%
7	100%	99%
6	100%	99%
5	91%	87%
4	80%	74%
3	66%	60%
2	53%	46%
1	39%	34%

Notes

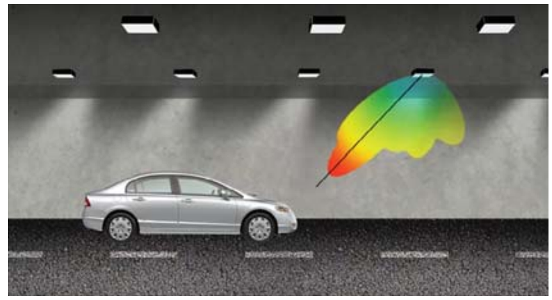
1 MVOLT Values shown - Consult Factory for HVOLT Values.

CCB: Ceiling mount counterbeam

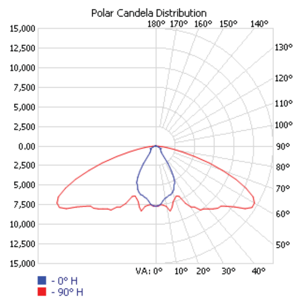


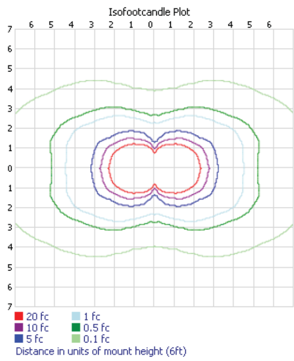


Recommended for divided tunnels where majority of lumens are directed towards oncoming drivers to maximize roadway luminance while controlling disability glare.



CLN: Ceiling mount counterbeam





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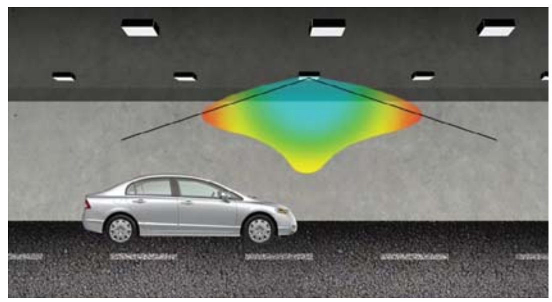
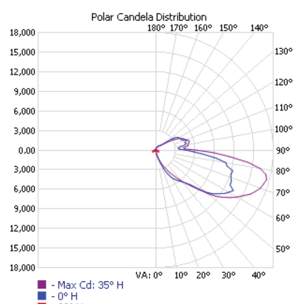
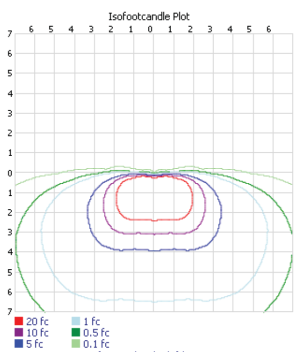
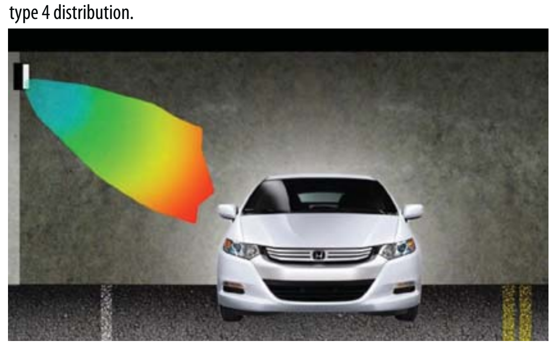


UDP: Wall mount underpass

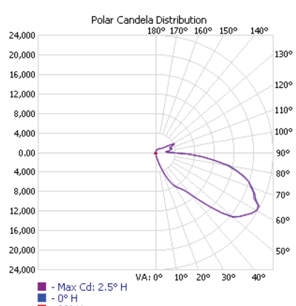


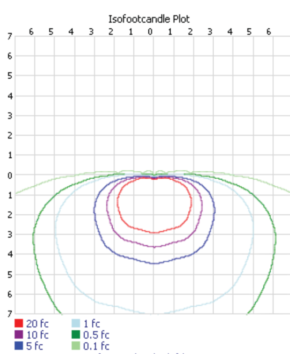


Recommended for underpass applications where illuminance is required IES type 4 distribution.



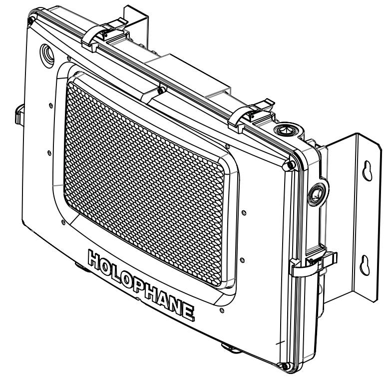
WCR: Wall mount crossbeam

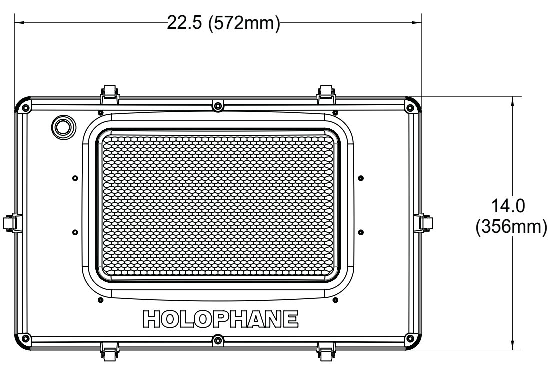


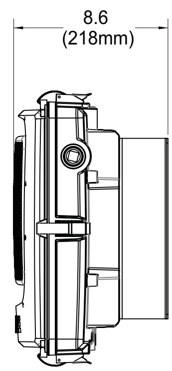


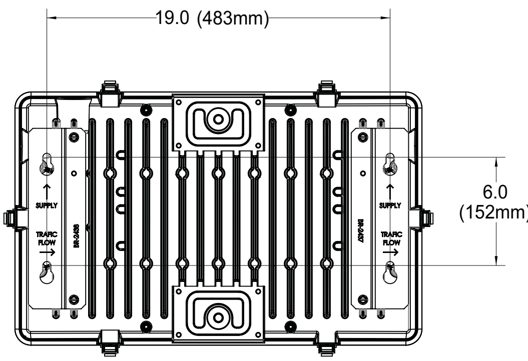
Recommended for undivided tunnels where equal lumens are with and against traffic flow.

SURFACE MOUNTING DETAILS

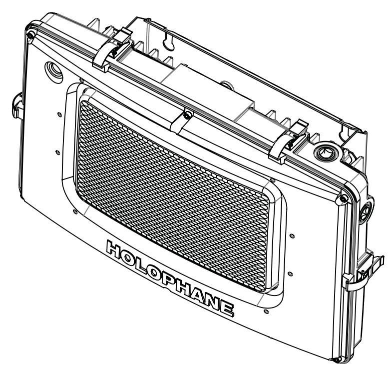


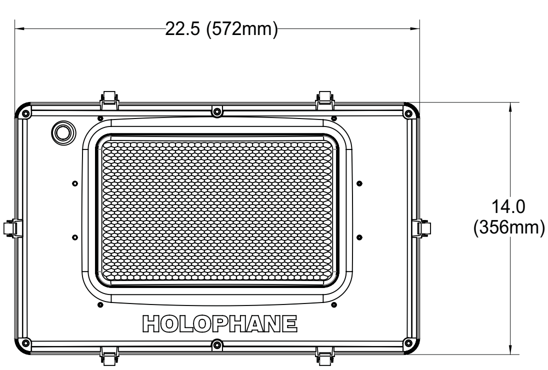


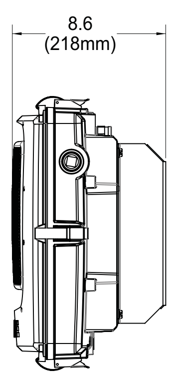


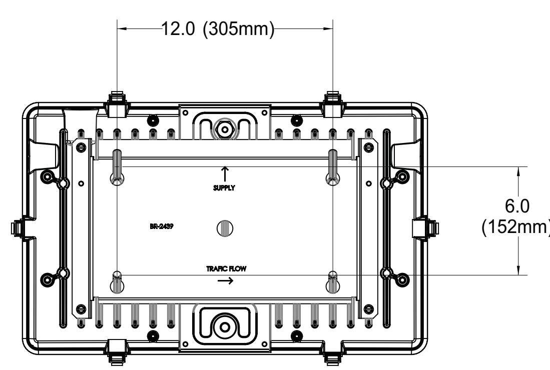


BOX MOUNTING DETAILS

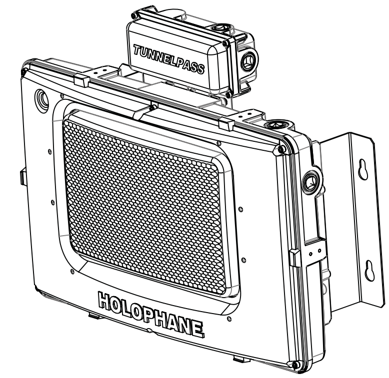


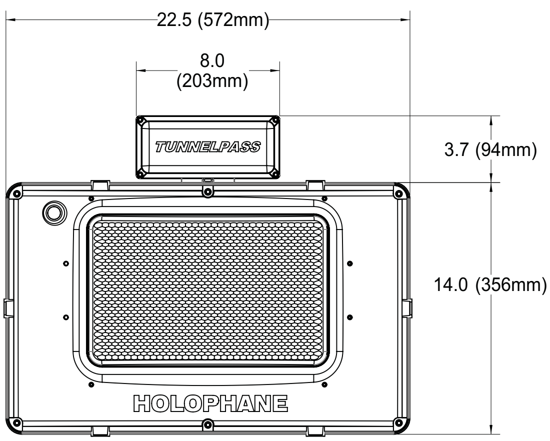


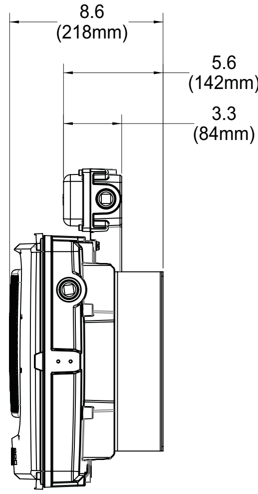


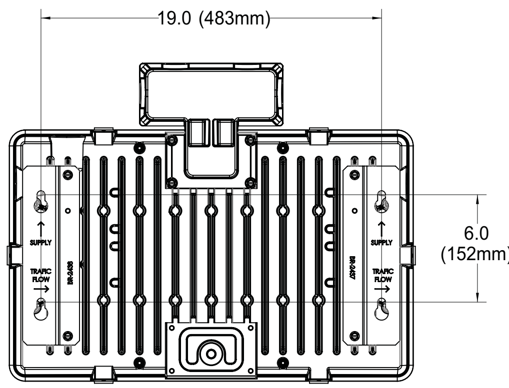


THROUGH WIRE BOX TOP MOUNTING DETAILS

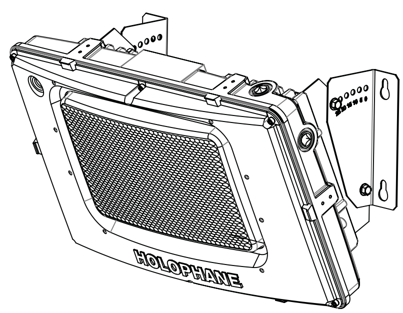


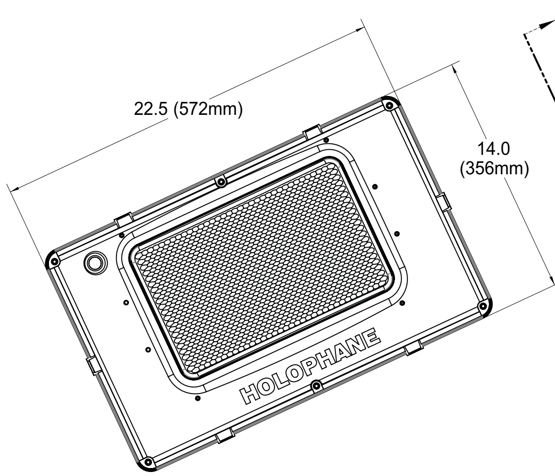


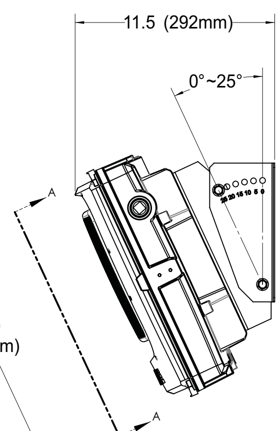


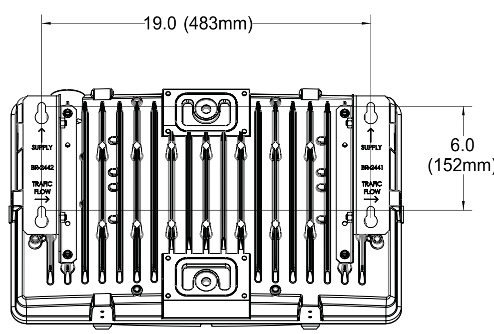


ADJUSTABLE WALL BRACKET MOUNTING DETAILS









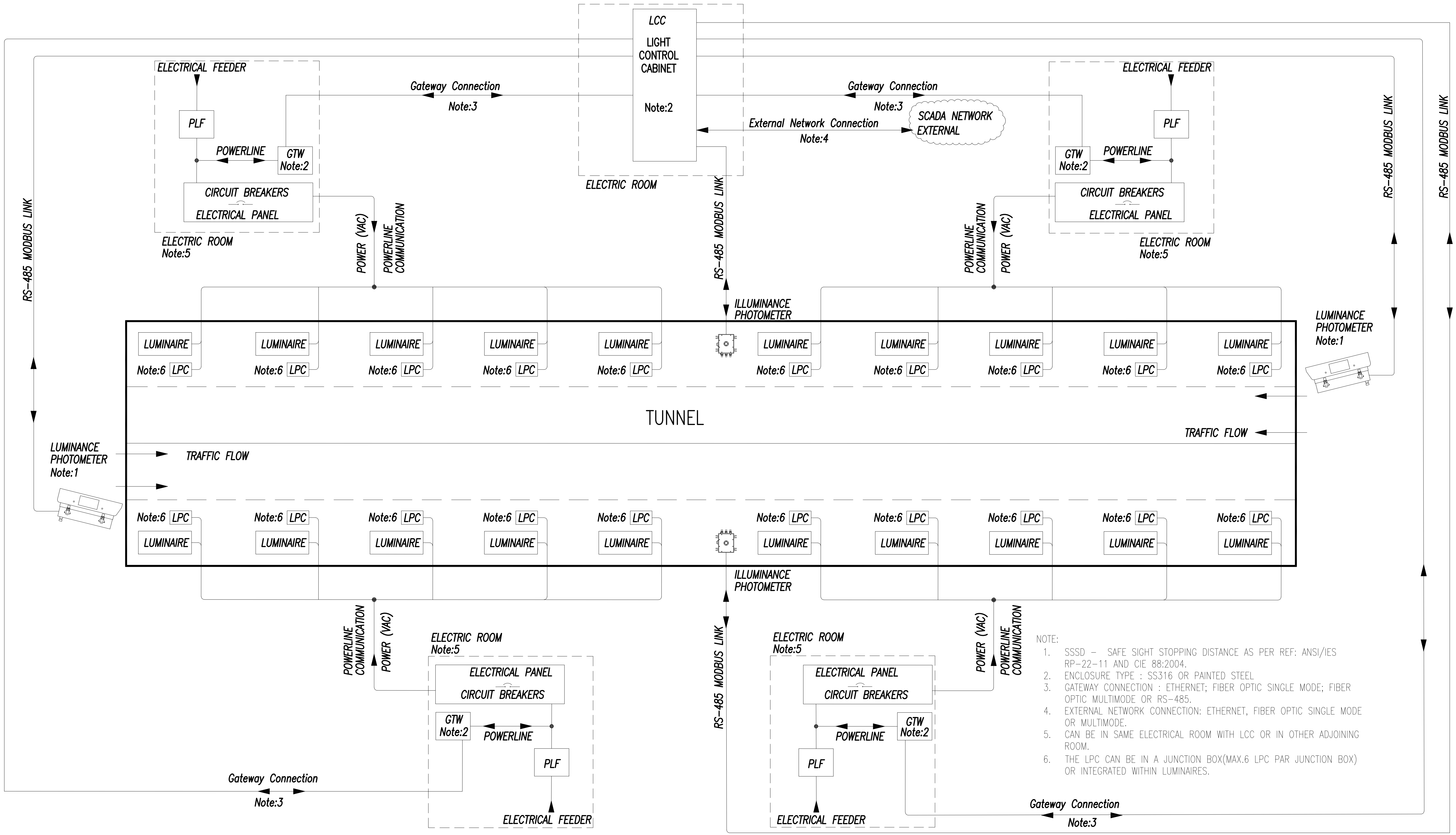
Sample Lighting Control System Cutsheets

NYX HEMERA Technologies Inc.
109, St-Vallier Est, suite 100, Québec, Qc, Canada, G1K 3N9
tel.: 418 977 7788 www.nyx-hemera.com

Project: GENERAL SYSTEM ARCHITECTURE TLACS-EM

Client: NYX HEMERA TECHNOLOGIES

Drawing: 0018-D05-20000



NOTE:

1. SSSD – SAFE SIGHT STOPPING DISTANCE AS PER REF: ANSI/IES RP-22-11 AND CIE 88:2004.
2. ENCLOSURE TYPE : SS316 OR PAINTED STEEL
3. GATEWAY CONNECTION : ETHERNET; FIBER OPTIC SINGLE MODE; FIBER OPTIC MULTIMODE OR RS-485.
4. EXTERNAL NETWORK CONNECTION: ETHERNET, FIBER OPTIC SINGLE MODE OR MULTIMODE.
5. CAN BE IN SAME ELECTRICAL ROOM WITH LCC OR IN OTHER ADJOINING ROOM.
6. THE LPC CAN BE IN A JUNCTION BOX(MAX.6 LPC PAR JUNCTION BOX) OR INTEGRATED WITHIN LUMINAIRES.

REV	DESCRIPTION	DATE	BY	CHK	APP
A	FOR INFORMATION	17/12/03	C.E.	G.D.	P.S.

GENERAL SYSTEM ARCHITECTURE
TLACS – EM
INDIVIDUAL CONTROL

DRAWN BY:	C. ENACHE	17/12/03
CHECKED BY:	G. DOGGER	17/12/03
APPROVED BY:	P. SAMSON	17/12/03
CLIENT: NYX HEMERA TECHNOLOGIES		

PROJECT No: 0018
SCALE N/A
DRAWING No: 0018-D05-20500

NYX HEMERA Technologies Inc.
109, St-Vallier Est, suite 100, Québec, Qc, Canada, G1K 3N9
tel.: 418 977 7788
www.nyx-hemera.com

TLACS' Gateway (GTW)

General Description

The TLACS Gateway (GTW) provides a link between the LCC (Lighting Control Cabinet) and the LPC (Local Product Controller) inside the luminaires.

The GTW receives commands indented to the LPC 480 from the Lighting Control Cabinet (LCC) over either a RS-485, an Ethernet or a Fiber Optic link. It translates and transfer the command to the LPC 480 through the powerline grid.

For long distance communication, multiple GTWs can be installed in different electrical panels and connected to the LCC to reach all luminaires in the lighting circuitry. A maximum of 1000 luminaires can be connected to a Gateway.

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LCAM Tunnel Entrance Photometer

General Description

The LCAM measures and communicates to the Lighting Control Cabinet (LCC) the level of luminance or brightness created by natural light at the tunnel entrance / exit. The tunnel light control system in turn adjust the tunnel luminaire light levels to ensure that the visual perception of drivers will be maintained, both day and night, by avoiding sudden variations in lighting levels and potential “black hole effect” when entering and exiting a tunnel.

The LCAM uses a specially designed, highly light-sensitive photocell, filtered to provide a spectral response close to the average human eye for optimal performance.

The light receptor measures the average luminance over a scalable range of 0 - 10,000 cd/m^2 within an acceptance angle subtending 20º as recommended by CIE 088:2044 and RP-22-11.

To ensure proper alignment of the photometer, an operator can request an image, and have it compared with a valid one taken at the installation time. An alarm can then be set up if the unit has moved and does not provide an effective reading.

Features

- CIE and IES approved measurement technology
- Accurate measurement of tunnel entrance luminance
- Photometer alignment monitoring
- Variable viewing angle to compensate if cannot be installed at a Safe Stopping Sight Distance (SSSD) from the tunnel portal.
- Specifically designed for tunnels control system
- Rugged 316 Stainless Steel construction
- Simple installation/operation
- RS-485 communication for remote diagnostic and configuration

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NYX HEMERA Technologies Inc.

Technical Specifications

Measurement Performance

Parameter	Units	Min	Max	Comment
Detector				Silicon photo diode, Vλ filtered
Viewing Angle (FWHM)	Deg	10	40	20º as standard; from 10 to 40º under request
Measurement Range	cd/m^2	0	10,000	Range [1, 10.000] cd/m^2 scalable
Resolution	cd/m^2		1	Display resolution
Accuracy	%			Under 3%
Damping	seconds	1	100	Default setting is 10s

Power

Input Voltage	Vac	100	240	50/60Hz / 277/480 VAC under request
Power Consumption	W	6	10	Excluding washer
	W	48	52	With wiper/washer system (optional)

Interface Options

Serial Outputs				ModBus RTU via RS485 (isolated) Ethernet (RJ-45) or Fiber Optic under request
Analog Outputs (one)	mA	0 / 2 / 4	20	Isolated and scalable (user selected)
Digital Relay Contacts (four)	A	0	1	@240Vac (signal levels and data valid)
Network Controller Integration				Internal diagnostic available when integrated with Nyx Hemera Network Controller. (Using RS485 Link)

Physical

Ingress Protection			IP66	
Operating Temperature	°C	-40	+50	
Storage Temperature	°C	-40	+50	
Operating Humidity	%		100	Up to
Regulatory Compliance				2004/108/EC (Electromagnetic Radiation)/ 2006/95/EC (Low Voltage)
Materials				Stainless steel 316 (powder coated)
Dimensions	mm	463 x 162 x 122 463 x 162 x 184		Without optional wiper/washer option With optional wiper/washer option
Weight	kg		5.5 6.3	Without optional wiper/washer option With optional wiper/washer option
Warranty	Months	24		Return to base warranty. Extensions available

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Lighting Control Cabinet – (LCC)

General Description

The LCC is an integrated control cabinet specifically designed for tunnel lighting control. It supports multiple configurations allowing optimal solutions targeting a wide range of tunnels layouts.

The LCC can either be used in a TLACS-RDE configuration to control a group of luminaires, in a TLACS -EM configuration to individually control every luminaire or in hybrid configuration mainly supporting very long tunnels. It interfaces with Luminescence Photometer (LCAM) and the Illuminance Photometer (ILCAM).

As optional features, the LCC can include redundant Network Controller (NWC) components, a SCADA connection, a data logger to keep and historic of the operations and a 15 inches Industrial touch screen display for an easy control and operation of the lighting system through an intuitive Human Machine Interface.

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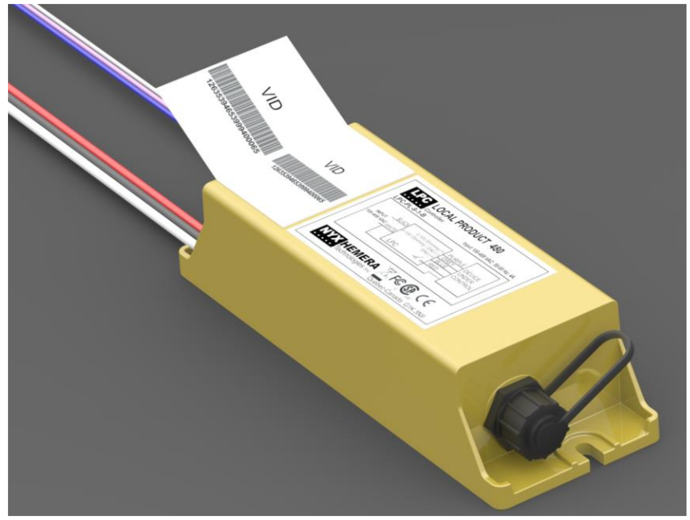
Local Product Controller 480 (LPC 480)

The LPC 480 provides a two-way communication between luminaires and Lighting Control Cabinet (LCC) and is used to individually control and monitor luminaires. Specifically designed for 100-480 VAC tunnel installation, it can be embedded in a tunnel luminaire or installed in a junction box.



The LPC 480 is a component of Nyx Hemera's Tunnel Lighting Addressable Control System (TLACS). It communicates over power line (PL) using a proven and reliable protocol thus greatly reducing installation, deployment, and operating costs.

Features

- Two-way powerline communication (without new wiring).
- Individually monitors and controls the luminaire with alarm reporting
- Voltage, Current, Power Factor, Power Consumption, Diagnostic and Luminaire Status reporting
- Luminaire burn hours monitoring
- LPC Internal Temperature monitoring
- Dynamic repeater function providing the optimum level of communication robustness
- Configurable fail-safe switching mode (On/Off)
- Dimming lighting stages optimisation
- Luminaire alternations support to average luminaire usage
- Control type DALI, 0-10V dimming and ON-OFF relay

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NYX HEMERA Technologies Inc.

Specifications

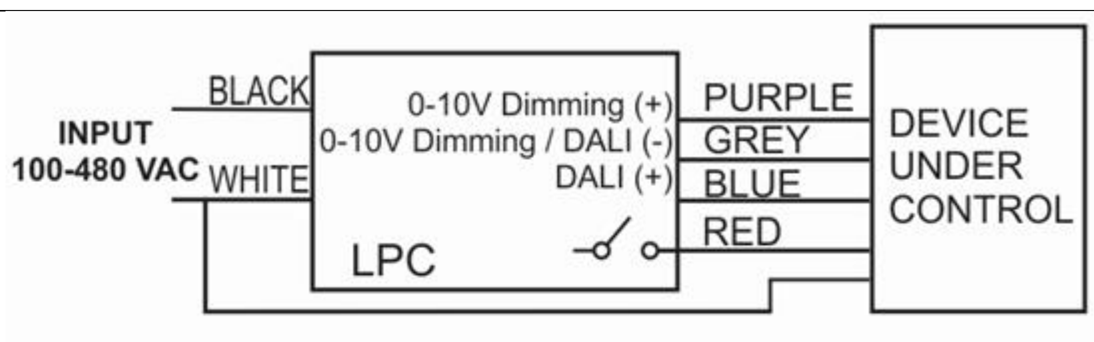
Electrical

Item	Description
Nominal input voltage	100 to 480 VAC
Frequency	50/60 Hz
Consumption	Under 3W

Luminaire Interface

Item	Description
Relay contact rated voltage	100 to 480 VAC
Relay contact rated current	Max 4 Amp at 100-347 VAC Max 2 Amp at 480 VAC
Relay contact form	SPST-NO
Analog interface	0-10V Dimming, maximum current: 10 mA
Digital interface	DALI

Wiring Diagram



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Environmental Conditions

Item	Description
Operating temperature	-40ºC to 75ºC
Storage temperature	-40ºC to 85ºC
IP Rating	IP 66
Enclosure	Fully potted electronics

Standards

Item	Description
Safety standards	CSA 60950-1-07 Second Edition UL 60950-1, Second Edition – Certified to U.S. Standards CAN/CSA C22.2 No. 0-M91 (R2001) CAN/CSA C22.2 No. 60950-1-07, 2nd Ed. Am 2:2014 (MOD) ANSI/UL Std No. 60950-1-2014, 2nd Ed. IEC 60950-1:2005 IEC 60950-1:2005/AMD1:2009 IEC 60950-1:2005/AMD2/2013 UL 916
EMC standard	EN 55032 :2012/AC :2013 EN 61000-32 :2014 (Harmonics) EN 61000-3 No. -M-3 :2013 (Flicker and voltage fluctuation) FCC 47 CFR Part 15, Subpart B ICES-003 Issue 6 January 2016
EMC immunity	EN 55024:2010 EN 61000-4-2 (Electrostatic discharge) EN 61000-4-3 (Radiated, radio-frequency, electromagnetic field) EN 61000-4-4 (Electrical fast transient/burst) EN 61000-4-5 (Surge) EN 61000-4-6 (Conducted disturbances) EN 61000-4-11 (Voltage dips, short interruptions and voltage variations)

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Appendix G

Opinion of Probable Cost

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Item Description	Opinion of Probable Cost
Fire Detection	**$400,000**
Fire Alarm System	$400,000
Fire Protection	**$720,000**
Dry Standpipe System 3000 lf @ $100.00/LF	$300,000
Fire Extinguishers and Cabinets 16 @ $5000.00 each	$80,000
Fire Department Connections (FDC)	$250,930
Mounting Standpipes	$84,000
Ventilation - Central Shaft for CO	**$3,330,000**
New Center Shaft Louvres and Ducts	$350,000
Center Shaft Fans (Axial)	$300,000
Structural Rehabilitation to Ventilation Building	$100,000
Mounting New Ventilation fans to top of shafts	$50,000
Sealing cracks in existing tunnel ventilation shafts	$2,500,000
Electrical and Lighting to Ventilation Building	$30,000
Ventilation - Jet Fans for Fire Protection	**$1,260,000**
Longitudinal Jet Fans	$1,140,000
Mounting Longitudinal Jet Fans	$120,000
Structural Improvements	**$500,000**
New Egress Pathway	$500,000
Protection of Existing Structural Liner	Not Included
Traffic Control	**$540,000**
Sign Support Foundation (assumes 4 @ $50,000)	$200,000
Sign Support Structure (assumes 2 @ $120,000)	$240,000
Lane Use Control Sign (assumes 8 @ $1,000)	$8,000
Trenching & Backfilling - 2000 LF @ $45.00/LF	$90,000
Local Incident Management System	Not Included
Variable Message Signs Inside Tunnel	Not Included
Two-Way Emergency Radio System	Not Included
Egress Signage	**$220,000**
Electrical Systems - Distribution and Lighting	**$4,430,000**
2" RMC - 15,600 LF @ $35.00/ LF	$546,000
Wires within Conduit (assume 4 required)	$300,000
Removal of Existing Luminaires @ $625 each	$195,000
Removal of Existing Conduit	$30,000
Lighting System (Surface Mounted LED Luminaries, Emergency Egress and Pathway Lighting)	$1,291,800
Mounting 2" RMC to Tunnel Walls	$150,000
Mounting Tunnel Luminaires	$130,000
Lighting Control System	$235,200
New Power Distribution Electrical Building (all inclusive)	$350,000
Emergency Generator - 750kW, Diesel	$700,000
Electrical Control Communication System	$500,000
Identified Work SUBTOTAL	**$11,400,000**
Minor Items (20%)	$2,280,000
Identified Work + Minor Items Subtotal	**$13,680,000**
Estimated as a % of Contract Work:	
Clearing and Grubbing (0.5%)	$79,075
Construction Staking (0.5%)	$79,075
MP&T (6%)	$948,902
Mobilization (6.5%)	$1,027,977
CONTRACT WORK	**$15,815,029**
Contingency (20%)	$3,163,006
ESTIMATED CONSTRUCTION COST BASE YEAR (2019)	**$18,978,035**
Inflation (3.5% for 1.75 years)	$1,162,405
ESTIMATED CONSTRUCTION COSTS WITH INFLATION	**$20,150,000**

TOTAL PROJECT COSTS	
Preliminary Design	$450,000
Final Design	$1,250,000
ESTIMATED CONSTRUCTION COSTS WITH INFLATION	$20,150,000
INCIDENTALS (20% of Contract Items)	$3,163,006
TOTAL PROJECT COSTS	**$25,020,000**

Appendix H

FHWA Specifications for the National Tunnel Inventory

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Specifications for the National Tunnel Inventory

U.S.Department of Transportation
Federal Highway Administration

July 2015
Publication No. FHWA-HIF-15-006

3.4—Mechanical Systems Section

This section defines tunnel mechanical system elements and the methodology for determining total element quantities and condition state quantities. The following elements are included.

Element Type	Element #	Element Name	Unit of Measure
Ventilation System	10200	Ventilation System	each
	10201	Fans	each
Drainage and Pumping System	10300	Drainage and Pumping System	each
	10301	Pumps	each
Emergency Generator System	10400	Emergency Generator System	each
Flood Gate	10475	Flood Gate	each

Ventilation System	
<u>Unit of Measure</u> Each	<u>Element Number</u> 10200
<u>Specification</u>	<u>Commentary</u>
Record this element for all ventilation systems. This element describes the components that provide the supply of fresh air to the tunnel while removing stale air and contaminants. The total quantity for ventilation system is the sum of all the ventilation systems.	The ventilation system may include the following subcomponents: Fans - Fan Motors, Fan Controller, Airways, Sound Attenuators, Dampers, Damper Motor, Damper Controller, Air Quality Monitoring Equipment (CO), Control Panels and Conduit. Damper inspection should also include a review of the maintenance records for each piece of equipment and note any special or frequent maintenance problems. For this element, a separate ventilation system is considered to be one system. Tunnels with twin bores may have separate ventilation systems and would be considered as two. Some tunnels may have a ventilation system at each portal that work independently and would also be considered as two.

Condition State Definitions

Defect	Condition State 1	Condition State 2	Condition State 3	Condition State 4
System Condition	The system is in good condition – no notable distress.	The system is in fair condition – isolated breakdowns or deterioration.	The system is in poor condition – widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants evaluation to determine the effect on serviceability of the element or tunnel or the evaluation has determined there is an impact on the serviceability of the element or tunnel.

Electrical Distribution System	
Unit of Measure Each	Element Number 10500
Specification	Commentary
Record this element for all electrical distribution systems. The electrical distribution system consists of the electrical equipment, wiring, conduit, and cable used for distributing electrical energy from the utility supply (service entrance) to the line terminals of utilization equipment. The total quantity for electrical distribution system is the sum of all the electrical distribution systems.	The electrical distribution system may include the following subcomponents: Switchgear, Unit Substations, Switchboard, Motor Control Centers, Starters, Transformers, Transfer Switches, Panelboards, Conduits and Raceways, and Electrical Outlets/Receptacles. For this element, a separate electrical distribution system is considered to be one system. Tunnels with twin bores may have separate electrical distribution systems and would be considered as two.

Condition State Definitions

Defect	Condition State 1	Condition State 2	Condition State 3	Condition State 4
System Condition	The system is in good condition – no notable distress.	The system is in fair condition – isolated breakdowns or deterioration.	The system is in poor condition – widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants evaluation to determine the effect on serviceability of the element or tunnel or the evaluation has determined there is an impact on the serviceability of the element or tunnel.

Fire Detection System	
Unit of Measure Each	Element Number 10650
Specification	Commentary
Record this element for all fire detection systems. These systems consist of control panels, initiating devices (heat and smoke detectors, pull-stations, etc.), notification appliances (strobes, horns, etc.), wiring, conduit, and cable used to detect a fire in the tunnel. The total quantity for fire detection system is the sum of all the fire detection systems.	The fire detection system may also include the following subcomponents: sensors, controls, and alarms. For this element, a separate fire detection system is considered to be one system. Tunnels with twin bores may have separate fire detection systems and would be considered as two.

Condition State Definitions

Defect	Condition State 1	Condition State 2	Condition State 3	Condition State 4
System Condition	The system is in good condition – no notable distress.	The system is in fair condition – isolated breakdowns or deterioration.	The system is in poor condition – widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants evaluation to determine the effect on serviceability of the element or tunnel or the evaluation has determined there is an impact on the serviceability of the element or tunnel.
Detection Sensor Operations (heat and smoke detectors)	All detection sensors are operational.		Detection sensors are not operational in one zone.	Detection sensors are not operational in multiple zones.

Fire Protection System	
Unit of Measure Each	Element Number 10700
Specification	Commentary
Record this element for all fire protection systems. These systems consist of fire extinguishers, hose connections, storage tanks, fire hydrants, building sprinklers, pumping systems, piping, circulating pumps, and hose reels used as fire protection in the tunnel. The total quantity for fire protection system is the sum of all the fire protection systems.	The fire protection system may include the following subcomponents: main fire pump, pressure maintenance/jockey pump, dry pipe valve, valves and tamper switches, storage tanks, tunnel stand pipe, pressure relief and air release valves, backflow prevention, hose stations, hose reels, building sprinklers, fire department connections and fire hydrants. For this element, a separate fire protection system is considered to be one system. Tunnels with twin bores may have separate fire protection systems and would be considered as two.

Condition State Definitions

Defect	Condition State 1	Condition State 2	Condition State 3	Condition State 4
System Condition	The system is in good condition – no notable distress.	The system is in fair condition – isolated breakdowns or deterioration.	The system is in poor condition – widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants evaluation to determine the effect on serviceability of the element or tunnel or the evaluation has determined there is an impact on the serviceability of the element or tunnel.

Emergency Communication System	
Unit of Measure Each	Element Number 10750
Specification	Commentary
Record this element for all emergency communication systems. The components of the emergency communication system include the communication device itself (i.e. intercom, radios, cell-phone), receivers, wiring, exchange devices, etc. The total quantity for emergency communication system is the sum of all the emergency communication systems.	The emergency communications system may also include the following subcomponents: signs, controllers, speakers and audio input equipment. For this element, a separate emergency communication system is considered to be one system. Tunnels with twin bores may have separate emergency communication systems and would be considered as two.

Condition State Definitions

Defect	Condition State 1	Condition State 2	Condition State 3	Condition State 4
System Condition	The system is in good condition – no notable distress.	The system is in fair condition – isolated breakdowns or deterioration.	The system is in poor condition – widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants evaluation to determine the effect on serviceability of the element or tunnel or the evaluation has determined there is an impact on the serviceability of the element or tunnel.

Traffic Sign	
Unit of Measure Each	Element Number 10850
Specification	Commentary
Record this element for all traffic signs. These elements consist of the traffic sign and supports. Signs for pedestrians, variable message signs and lane signals are not covered under this element. The total quantity for traffic signs is the sum of all the traffic signs.	The MUTCD Chapter 2 contains the requirements for the shape and wording of regulatory, warning and guide signs on a highway or road. It also contains requirements for maintaining minimum retroreflectivity of signs.

Condition State Definitions

Defect	Condition State 1	Condition State 2	Condition State 3	Condition State 4
Component Supports	No deficient support conditions.	Loose anchorage or component housing connection hardware.	Missing anchorage or component housing connection hardware which does not result in an unstable situation.	Failed anchorage or component connection hardware which results in an unstable situation.

Appendix I

2017 In-Depth Inspection for Tunnel No. 00773

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CONNECTICUT
DEPARTMENT OF TRANSPORTATION

STATE PROJECT NO. 170-3413 (NHS)
BRIDGE SAFETY INSPECTION

TUNNEL NO. 00773
WEST ROCK RIDGE

OVER

ROUTE 15

WOODBRIDGE, CONNECTICUT

IN-DEPTH INSPECTION
JANUARY 30, 2017
LAST DAY OF INSPECTION: MAY 26, 2017

Prepared By:

Michael Baker International, Inc.
500 Enterprise Drive, Suite 2B
Rocky Hill, CT 06067

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

INSPECTION REPORT TRANSMITTAL FORM
FORM BRI-27, REV. 9/97

Structure No. 00773 Town Woodbridge

Inspectors Michael Baker International, Inc. (TK, KT) Date 1/30/2017

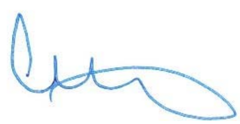
TABLE OF CONTENTS

Tunnel No. 00773, West Rock Ridge over Route 15, Woodbridge

Inspected By: Michael Baker International, Inc.   Date: 01/30/2017

William
Kristoff
2017.07.26
10:55:30
-04'00'

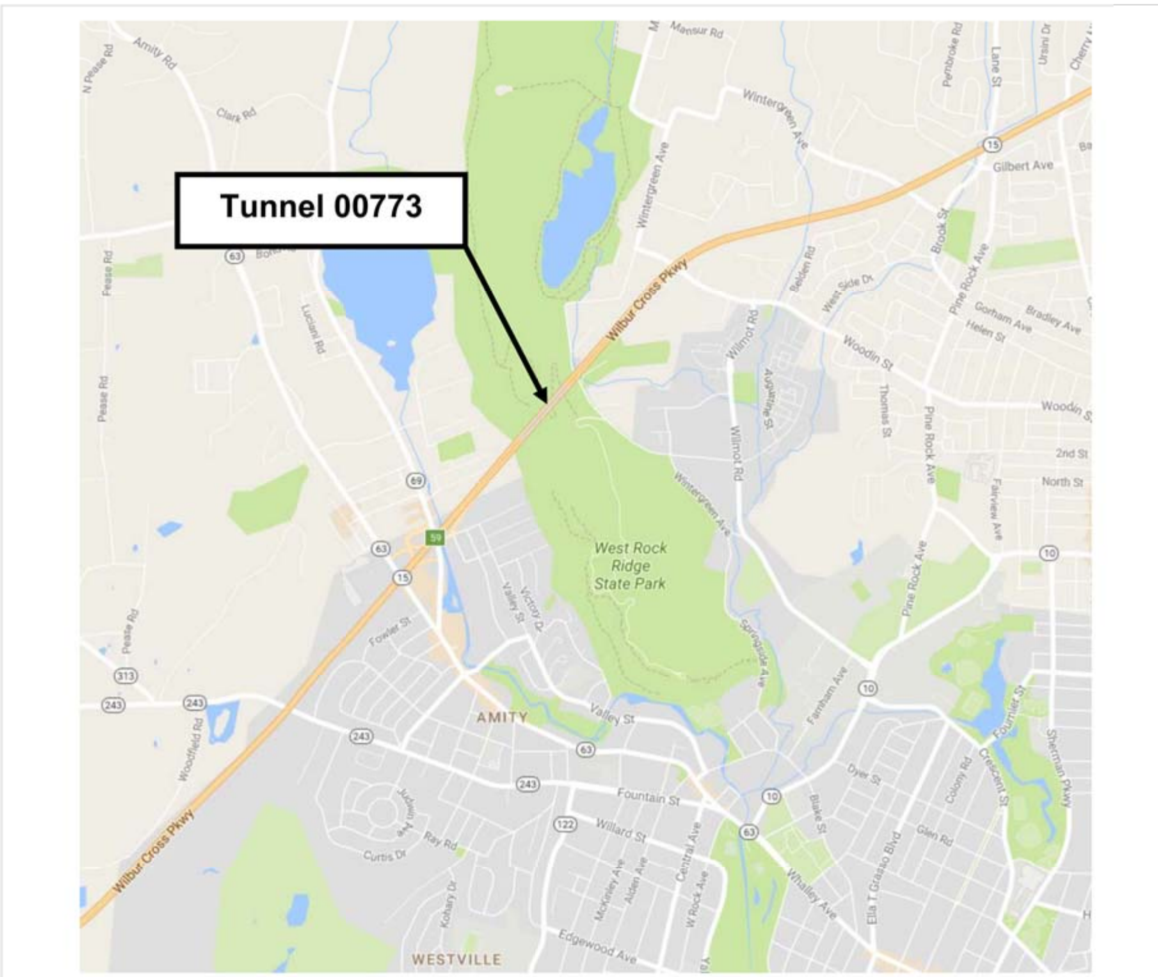
Professional Certification: I hereby certify that this report, including all of its contents, has been approved by me, and that I am a duly licensed professional engineer under the laws of the State of Connecticut.

Signature: 

License No.: CT PE 20004   *Date: 06/28/2017*

Baker

LOCATION MAP
Tunnel 00773: West Rock Ridge over Route 15



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LOCATION DATA

Tunnel Number (I.1):	00773
Tunnel Name (I.2):	Heroes Tunnel
Place Code (I.5):	Woodbridge
County Code (I.4):	
State Code (I.3):	09 Connecticut
Hwy Agency District (I.6):	New Haven
Latitude (I.13):	41.34
Longitude (I.14):	72.97
Owner (C.1):	State Highway Agency
Operator (C.2):	State Highway Agency
Urban Code (C.8):	New Haven

BORDER TUNNEL

State / Country Code (I.15):	Not Applicable (P)
Fin Responsibility (I.16):	
Border Number (I.17):	
Urban Code (C.8):	Not Applicable (P)

TUNNEL AGE

Year Built (A.1):	1949
Year Rehabilitated (A.2):	

ROUTE DATA

Route Number (I.7):	00015
Facility Carried (I.10):	Route 15 - Heroes Tunnel
LRS Route ID (I.11):	A015
LRS Milepost (I.12):	47.13
Route Direction (I.8):	Two route directions
Direction of Traffic (C.3):	2-way traffic
Total # of Lanes (A.3):	4
AADT (A.4):	77,300
ADTT (A.5):	0
Year of AADT (A.6):	2015
Detour Length (A.7):	5

GENERAL INSPECTION DATA

Load Posting Status (L.4):	A - No Restriction
Haz Mat Restriction (L.11):	1 - Yes
Other Restriction (L.12):	1 - Yes
Portal Island Protection (N.3):	0 - Nav prot not req.

GEOMETRY & RESTRICTION DATA

Number of Bores (S.1):	2
Tunnel Shape (S.2):	Horseshoe
Portal Shape (S.3):	Horseshoe
Ground Conditions (S.4):	Rock
Complex (S.5):	Not Complex
Tunnel Length (G.1):	1,200
Min Vert Clearance (G.2):	14.00
Roadway Width (G.3):	23.50
Left Sidewalk Width (G.4):	2.50
Right Sidewalk Width (G.5):	2.50
Height Restriction (L.10):	Yes
Under Nav Waterway (N.1):	No navigable waterway
Nav Waterway Clear (N.2):	0.00

LOAD RATING DATA

Load Rating Method (L.1):	Not required
Inventory Rating (L.2):	
Operating Rating (L.3):	
Posting - Gross (L.5):	
Posting - Axel (L.6):	
Posting - Type 3 (L.7):	
Posting - Type 3S2 (L.8):	
Posting - Type 3-3 (L.9):	

ROUTE CLASSIFICATION

Route Type (I.9):	State highway
Service in Tunnel (A.8):	Highway
Toll (C.4):	No tolls
NHS Route (C.5):	Route is on the NHS
STRAHNET Route (C.6):	Not a STRAHNET route
Functional Class (C.7):	Principal - Other

INSPECTION SCHEDULE

Routine Insp Target (D.1):	
Current Inspection Date:	2017-01-30
Routine Insp Date (D.2):	
Routine Insp Freq (D.3):	24
In-Depth Scheduled (D.4):	0
Damage Inspection (D.5):	
Special Scheduled (D.6):	0

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Element Number		Str Unit	Total	CS1	CS2	CS3	CS4
Structure Unit:							
10001	Cast-in-Place Conc Tunn		124,425.00	99,732.00 (80%)	7,468.00 (6%)	17,029.00 (14%)	196.00 (0%)

The overall condition of the tunnel is poor (NBI rating = 4). The concrete tunnel liner has hollow areas up to 71 square feet (Southbound tunnel ceiling at between STA's 710+00 and 710+25) and spalls with and without exposed rebar up to 120 SF x 3" deep (Northbound tunnel ceiling at STA 719+00). There are other smaller but deeper spalls, up to 63 square feet x 7" deep (Southbound tunnel ceiling between STA 719+50 – 719+75). Numerous spalls have adjacent hollow areas and/or the concrete inside the spall is hollow at some locations. Also, spalls have de-bonded rebar at isolated locations and/or isolated rebar with up to 50% section loss (estimated). There are random areas with efflorescence, punky concrete and light to severe scale. There are isolated drilled core holes in the ceiling and isolated locations with embedded remnants of the wood forms. There are random linear cracks and areas of map cracking. The linear cracks are open up to 0.125", have random efflorescence, water leakage and/or adjacent minor spalling. Both tunnels have longitudinal hairline cracking with random efflorescence along the crown throughout (only shown on field sketches if crack has efflorescence, rust or is 0.012" wide or more). There are numerous previously patched transverse cracks in the ceiling. Some of these cracks extend all the way through the walls to sidewalks. These cracks have typically re-opened, have up to heavy efflorescence and/or water leakage. There are other concrete patches throughout. These patches have areas of punky concrete, cracking, efflorescence, leakage, hollow areas, varying degrees of scale and spalls. There are transverse construction joints spaced at +/-40 feet and longitudinal construction joints between the ceiling and wall portions of the liner. Along joints, there are cracks, up to heavy scale, spalls with and without exposed rebar, hollow areas and areas of up to heavy efflorescence. All hollow areas are marked. All loose concrete has been removed. See field sheets 7-295 and photos 4-16 & 39.

80000	Leakage		163.00	0.00 (0%)	23.00 (14%)	56.00 (34%)	84.00 (52%)
82100	Delamination / Spall / Pa		19,212.00	0.00 (0%)	4,926.00 (26%)	14,174.00 (74%)	112.00 (1%)
82101	Exposed Rebar		66.00	0.00 (0%)	28.00 (42%)	38.00 (58%)	0.00 (0%)
82102	Efflorescence / Staining		1,427.00	0.00 (0%)	1,292.00 (91%)	135.00 (10%)	0.00 (0%)
82103	Cracking (Concrete Liner)		3,825.00	0.00 (0%)	1,199.00 (31%)	2,626.00 (69%)	0.00 (0%)
10031	Concrete Cross Passage		48.00	33.00 (69%)	15.00 (31%)	0.00 (0%)	0.00 (0%)

This item is being used to describe the machinery control room. The control room has efflorescence, spalling up to 2" deep and hollow areas covering up to 50% of the exterior walls/liner surface. The interior tile walls have damaged tiles and up to 2' diameter holes (possibly from removal of the ventilation system). All internal doors are missing. All fans, duct work and components of electrical/fire detection systems are removed. Water drains down the concrete lined vertical vent shafts in the ceiling and ponds on the room floor. There is random construction debris on the floor (from ventilation system removal) and minor spalling. The iron bar picket fence at the entrance to the control room in the tunnel has up to heavy laminated rust with up to 50% section loss to components. The concrete fence bases have spalls up to 8 square feet x full depth with exposed rebar. See field sheet 5 and photos 25-28.

82100	Delamination / Spall / Pa		15.00	0.00 (0%)	15.00 (100%)	0.00 (0%)	0.00 (0%)
10055	Masonry Portal		8,500.00	6,483.00 (76%)	1,965.00 (23%)	52.00 (1%)	0.00 (0%)

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The reinforced concrete portal walls with stone masonry fascia have random areas with cracked joint mortar, isolated vertical hairline cracks and minor chips in the stones. Approximately 20% (average) of mortar in the portal walls has separations, is deteriorated and/or is missing up to 8" deep (worst along the top of the wall/below the cap stones, no loose stones). There are random areas of vegetation growth in the joints typically near the top of the walls, random areas of efflorescence from the mortar joints and surface staining at the stones. Three cap stones at the south portal over the southbound tunnel are horizontally misaligned/pushed toward the roadway up to 1.5" due to a tree/vegetation growth behind and against these stones, pushing them outward. Isolated arch ring stones have horizontal hairline cracks (non-structural) with isolated rust staining. The south portal ring for the northbound tunnel has an 18" long x 1" wide x 6" deep spall/void. There is heavy efflorescence build up along the longitudinal joints between the three arch rings and random missing mortar along these joints up to 1' deep, typically worst at the arch bases. Random areas along the joints have deteriorated/punky joint material. The vertical joints between the portal walls and joints with wingwalls have random loose/missing joint filler up to full height. There are isolated locations with vegetation/vine growth in these vertical joints that spreads onto the portal walls. The concrete backside of the portal walls visible at the upper portions have random hairline cracking with and without efflorescence. Wingwalls are in similar condition as portal walls. There are chain-link fences behind the portal walls on top. The north fence is missing sections at the west end. Also, the concrete post bases are partially exposed due to apparent past erosion. Fence appears secure. Area adjacent to the fence is paved. See field sheets 3-4 and photos 2-3 and 17-20.

82102	Efflorescence / Staining	300.00	0.00 (0%)	250.00 (83%)	50.00 (17%)	0.00 (0%)
84000	Mortar Breakdown	1,700.00	0.00 (0%)	1,700.00 (100%)	0.00 (0%)	0.00 (0%)
84001	Split/Spall	2.00	0.00 (0%)	0.00 (0%)	2.00 (100%)	0.00 (0%)
84002	Masonry Displacement	15.00	0.00 (0%)	15.00 (100%)	0.00 (0%)	0.00 (0%)
10111	Concrete Slab-on-Grade	56,400.00	54,830.00 (97%)	1,570.00 (3%)	0.00 (0%)	0.00 (0%)

Not visible; paved over. Condition states are based on condition of the bituminous wearing surface. See “Asphalt Wearing Surface” item. See field sheet 7.

82109	Cracking (RC)	1,570.00	0.00 (0%)	1,570.00 (100%)	0.00 (0%)	0.00 (0%)
10158	Asphalt Wearing Surface	56,400.00	54,830.00 (97%)	1,570.00 (3%)	0.00 (0%)	0.00 (0%)

The asphalt wearing surface has random transverse cracks, typically corresponding to locations of the construction joints at the liner. Random cracks have adjacent areas with breaking up bituminous and/or potholes up to 18" x 4" x 2" deep. See field sheet 7 and photo 21.

85003	General Condition (WS)	1,551.00	0.00 (0%)	1,551.00 (100%)	0.00 (0%)	0.00 (0%)
86004	Effectiveness (WS)	19.00	0.00 (0%)	19.00 (100%)	0.00 (0%)	0.00 (0%)
10161	Concrete Traffic Barrier	4,740.00	4,388.00 (93%)	46.00 (1%)	306.00 (7%)	0.00 (0%)

Concrete safety walks are rated under this item. The concrete safety walks have light scale, minor chipping, sand/debris accumulation and hairline cracks. There are random transverse cracks up to 1” wide, and spalls up to 5” deep (Northbound tunnel, east wall at STA 712+37). At random locations PVC wall weeps drain on the safety walk causing deterioration. There are random bituminous patches at the locations where the utility access covers used to be. The safety walks typically have spalling along these patches, as well as along plates/utility covers along the safety walks and curbs. See field sheets 7, 56-151 & 200-295 and photos 22-24.

82100	Delamination / Spall / Pa	140.00	0.00 (0%)	2.00 (1%)	138.00 (99%)	0.00 (0%)
82109	Cracking (RC)	212.00	0.00 (0%)	44.00 (21%)	168.00 (79%)	0.00 (0%)
10200	Ventilation System	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)

The tunnel had a forced air ventilation system. The system was/is located in the control room at mid-length of the tunnels and consisted of four, 72" diameter fans, four electric motors (to control the fans), four, six foot diameter steel ducts (from fans to concrete shafts), four, 6 foot diameter x 180' high vertical concrete lined shafts (one per each fan), and an octagonal shaped exhaust house on top of the tunnel. The ventilation system was originally activated by removing any of the fire extinguishers from the tunnel walls and/or by elevated levels of the carbon monoxide inside the tunnel detected by carbon monoxide detectors located along tunnel walls. The fans, ducts, fire extinguishers and carbon monoxide detection devices are missing/have been removed in the past. Water is draining down the vent shafts and ponding on the control room floor. Ventilation house: There is a reinforced concrete with stone masonry fascia ventilation house on top of West Rock. The copper roof material is missing (daylight is visible from inside). Water seeps between wood roof planks and ponds on floor. The steel roof overhang has up to heavy rust and up to ½" impacted rust at the sheet metal splices. The aluminum louvers are mostly missing at the back side of the house, and the exposed steel chain-link fences/screens behind the louvers have up to 2 square foot openings. The steel entry door has up to heavy rust and was open at the time of inspection. There is steel grating on top of the vent shafts covered with tarp. The tarp is secured with timber planks. There is random timber and other debris inside the vent house. The access ladder and fall protection barrier along the entrance opening in the floor have up to heavy rust. Additionally, the steel fall protection barrier is missing/rusted out at one side. The roof-supporting beams have up to moderate rust. The concrete perimeter wall inside vent house has random graffiti and honeycombing w/exposed rebar. There is isolated bird debris inside. See field sheets 5-6 and photos 25-32.

86007	System Condition	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)
10201	Fans	4.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	4.00 (100%)

Originally, there were four 72" diameter fans (two per each tunnel) controlled by electric motors. These fans were located in the control room located at mid-length of the tunnel. The fans were activated by removal of any fire extinguisher from the tunnel wall and/or by elevated levels of the carbon monoxide gas in the tunnels. All fans are missing/have been removed in the past. See field sheets 5-6 and photos 25-27.

86017	Fan Operation	4.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	4.00 (100%)
10300	Drainage and Pumping Sy	2.00	0.00 (0%)	2.00 (100%)	0.00 (0%)	0.00 (0%)

The drainage systems consist of an 8" diameter precast concrete pipe embedded in the inboard sidewalks and a 15" diameter precast concrete pipe embedded along the outboard sidewalks. There are 2.5" diameter steel weeps that extend from wall bases and drain into these pipes. These pipes and weeps are not visible. There are catch basins along the outboard sidewalks that feed into the 15" diameter pipe. There are random locations with PVC weeps along the wall bases that drain on top of the sidewalks (some are filled with dirt). These appear to be a retrofit. Random locations with active leakage and evidence of past leakage along the walls and weeps filled with dirt suggest that the drainage system is partially dysfunctional. There is a total of 2 fully clogged and 2 partially clogged (30%) catch basins in the northbound tunnel only. All catch basins in the southbound tunnel are clear. The previously reported catch basins along the access road (Baldwin Drive) were not seen. See field sheets 56-151 & 200-295 and photos 33-34.

86007	System Condition	2.00	0.00 (0%)	2.00 (100%)	0.00 (0%)	0.00 (0%)
10500	Electrical Distribution Sys	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)

Originally, there were electrical distribution systems embedded below the sidewalks. These systems supplied power to the fire detection and fire protection systems, tunnel emergency lightning and wall phones. The electrical distribution systems are missing have been removed in the past. There are random bituminous filled utility access openings in the sidewalks (previously having steel plate cover). There are junction boxes with conduits ached to both portal walls. These junction boxes have missing covers and exposed wires. The steel conduits have up to laminated rust and rusted through holes exposing wires. PVC conduits have isolated broken areas with exposed wires. It is not clear if these conduits and junction boxes are functional and if they are part of the tunnel lightning system. There are disconnected junction boxes with opened access doors and exposed wires inside the control room. These boxes appear to be a part of the previous ventilation and fire detection system. See field sheets 5-6 & 8-295 and photos 35-39.

10600	Tunnel Lighting System	2.00	0.00 (0%)	2.00 (100%)	0.00 (0%)	0.00 (0%)

The tunnel lighting system consists of electrical conduits with junction boxes supplying power to the tunnel lights and light bulbs. The conduits along the southbound tunnel west wall have random locations with rusted out/missing supports and/or are disconnected at the couplers (no exposed wires). There are approximately of 30 locations with rusted out utility supports and/or disconnected utilities at the couplers. There is a total of 58 light fixtures with nonfunctioning light bulbs in both tunnels. Also, approximately 62 lights have broken lenses. See field sheets 8-295 and photos 4, 5, 8, 10 & 40.

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86007	System Condition	1.00	0.00 (0%)	1.00 (100%)	0.00 (0%)	0.00 (0%)
10601	Tunnel Lighting Fixture	306.00	306.00 (100%)	0.00 (0%)	0.00 (0%)	0.00 (0%)

There are light fixtures along the ceiling crown in both tunnels. These lights have random missing junction box covers exposing wires. See field sheets 8-55 & 152-199 and photos 4, 5, 8, 10 & 40.

86008	Component Supports	1.00	1.00 (100%)	0.00 (0%)	0.00 (0%)	0.00 (0%)
86009	Component Housing or E	1.00	1.00 (100%)	0.00 (0%)	0.00 (0%)	0.00 (0%)
10650	Fire Detection System	2.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	2.00 (100%)

The fire detection system originally consisted of carbon monoxide sensors located in designated wall niches in both tunnels (four total), carbon monoxide recorder and analyzer controls located in the control room (two total), and emergency caution and stop lights along tunnel walls. The carbon monoxide detectors activated control room vent fans for the concerned tunnel and turned on the traffic lights to caution if the carbon monoxide levels in that tunnel were elevated. In the case the carbon monoxide levels would continue to rise and be at very high levels, these detectors would activate vent fans in both tunnels and change the traffic lights to stop. All carbon monoxide detectors and recorder control and analyzers are missing/have been removed in the past. See field sheets 5, 6, 56-151 & 200-295 and photos 37-38 & 42.

86007	System Condition	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)
86014	Detection Sensor (Operat	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)
10700	Fire Protection System	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)

The fire protection system originally consisted of fire extinguishers located in designated wall niches at equal intervals in each tunnel (four extinguishers total). Removal of any fire extinguisher would have automatically changed the traffic light in the tunnel concerned to caution and started the ventilating fans in the control room for that tunnel. Also, there were additional fire extinguishers attached to the walls in the control room (six total). All fire extinguishers are missing/have been removed in the past. See field sheets 5, 6, 56-151 & 200-295 and photo 14.

10750	Emergency Communicati	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)

The emergency communication system originally consisted of telephone units located in designated wall niches in each tunnel (two phones in each tunnel). The telephones are missing/have been removed in the past. See field sheets 5, 6, 56-151 & 200-295 and photos 25 & 41.

86007	System Condition	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)
10850	Traffic Sign	12.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	12.00 (100%

Caution and stop emergency lights are rated under this element. The caution and stop emergency lights were initially installed for emergency use along the tunnel walls. Removal of any fire extinguisher and/or elevated levels of carbon monoxide in the tunnel (detected by the Fire Detection System) would have automatically changed the traffic lights in the tunnel concerned to caution. High levels of the carbon monoxide would change the light to stop. All traffic lights are missing/have been removed in the past. See field sheets 5, 6, 56-151 & 200-295 and photo 41.

86008	Component Supports	1.00	0.00 (0%)	0.00 (0%)	0.00 (0%)	1.00 (100%)