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TRANSCO TEST REPORT TR-110

FIRE AND HOSE STREAM TESTS OF TCO-003 HIGH DENSITY SILICONE ELASTOMER

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A) Synopsis:

This report describes a three hour fire and subsequent hose stream floor test of Transco #TCO-003 High Density Silicone Elastomer installed 12" deep in three electrical openings. The test was performed in accordance with the ASTM E-119 time/temperature curve for three hours along with provisions set forth in the IEEE 634-78, ANI, NML, and ASTM E-814 (for a "F" rating) test standards. These penetration seals were tested along with twenty-four other penetration seals in a 17'-9" x 13'-10-1/2" x 12" thick concrete slab on March 9, 1983 at Portland Cement Association's Fire Research Laboratory (Skokie, Illinois).

The test specimens consisted of three simulated electrical openings which measured 72" x 32" (penetrated by two 30" x 4" and one 24" x 6" cable trays and two conduits) and 1-1/2" and 6" diameter embedded conduits. All trays and conduits were filled in excess of 100% loadings with PVC jacketed cables (with the exception of the 24" x 6" tray which was filled with Hypalon jacketed cables).

The symmetrical penetration seals consisted of 12" of #TCO-003 High Density Silicone Elastomer (no permanent damming material was used). The elastomer weighs 150 lbs./cubic foot (min.) and is normally used for sealing penetrations in radiation shield walls or floors.

Besides qualifying the seals to the test standards mentioned, several other objectives were established in this test. These are:

1) The material's ability to seal both narrow and wide areas without support;
2) The use of the material when installed next to either steel or concrete substrates;
3) The use of the material to seal both solid and ladder back cable trays; and,
4) The ability of the sealing material to be removed for additional cable installation.(use of temporary plugs);

B.) Test Slab:

The test slab measured 17'-9" x 13'-10-1/2" x 12" thick. Twenty-seven openings which ranged from 1-1/2" diameter to 109-1/2" x 32" in size penetrated the test slab. The penetrations were arranged in the slab so that 18" wide (min.) concrete columns separated each row of penetrations. These columns were placed in the direction which would allow for the least amount of deflection from heat during the fire test.

The slab's steel reinforcement design and slab fabrication were completed by Portland Cement Association's personnel. After the slab was cast, the concrete was allowed to dry for several days after which the slab was subjected to additional heat curing on a furnace.

The slab's superstructure, specimen fabrication and seal installations were performed by Transco employees. The slab's superstructure consisted of steel angle braces mounted to the slab which supported the pipes, cable trays, cables, etc., for the test.

C.) Specimen Configurations:

The large rectangular test penetration was 72" x 32" x 12" deep. Two sides of the penetration were lined with 1/4" thick steel plat (set at a right angle in the plan view of the penetration). The remaining two substrate surfaces were cast concrete.

This opening was penetrated by three cable trays and a 6" and 2" diameter conduit. Each cable tray was mounted so that it extended 36" above the slab's unexposed surface and 12" below its exposed surface. The conduits were 12" long and were mounted flush inside of the penetration.

One 6" and one 1-1/2" diameter (x 12" long) rigid steel conduits were also cast into the concrete slab outside of the large rectangular opening. These were used to simulate embedded conduits (or sleeves) which pass through walls or floors.

The cable trays and conduits were filled with cables based on loadings which exceeded 100% fills. The loadings were calculated so that a 100% fill was equivalent to 40% of the actual sectional area of

the cable trays or conduits. Some of the loadings were increased so that 100% visual loadings were also achieved. Cable loadings were as follows:

A.) 32" x 72" RECTANGULAR OPENING:

1.) 30" x 4" ladder back tray filled with PVC jacketed cable:

134	2/c #14	0.1372	18.3848
35	12/c #14	0.5329	18.6190
26	1/c, 500MCM	0.7013	18.2359

Total Loading = 55.2397 sq. in.
(115% fill of tray)

2.) 30" x 4" solid back tray filled PVC jacketed cable:

134	2/c #14	0.1372	18.3848
35	12/c #14	0.5329	18.6190
26	1/c, 500MCM	0.7013	18.2359

Total Loading = 55.2397 sq. in.
(115% fill of tray)

*Two 2/c #14 and one 12/C #14 cables were added to this tray as part of the repair to this seal.

3.) 24" x 6" solid back cable tray filled with Hypalon jacketed cable:

18	1 pr.	#16	0.1046	1.8828
6	2 pr	#16	0.2874	1.6964
14	8 pr.	#16	0.6792	9.5088
8	12 pr.	#16	0.9160	7.3280
3	2/C	#14	0.1839	0.5517
4	3/C	#14	0.2058	0.8232
3	4/C	#14	0.2715	0.8145
14	7/C	#14	0.3717	5.2038
9	9/C	#14	0.4938	4.4442
5	12/C	#14	0.7013	3.5065
6	3/C	4/0	2.6822	16.0932
2	3/C	1/0	1.6695	5.3644
1	3/C	500MCM	5.2563	5.2563

Total Loading = 62.4738 sq. in.
(162.6% fill of tray)

*one 12/C #14 cable was added to this tray as part of the repair to this seal.

4.) 3" diameter conduit filled with Hypalon jacketed cable:

3	2/C #14	0.1839	0.5517
2	12/C #14	0.7013	1.426
2	3/C,6/0	0.7133	1.4266

Total Loading = 3.3809 sq. in.
(119.5% fill of conduit)

5.) 6" diameter conduit filled with PVC jacketed cable:

30	2/c #14	0.1372	4.1160
8	12/c #14	0.5329	4.2632
7	1/c, 500MCM	0.7013	4.9091

Total Loading = 13.2883 sq.in.

(117.4% fill of conduit)

B.) 1-1/2" diameter embedded conduit filled with PVC jacketed cable (separate penetration):

3	2/C #14	0.1372	0.4116
1	12/C #14	0.5329	0.5329

Total Loading = 0.9445 sq. in.
(113.6% fill of conduit)

C.) 6" diameter embedded conduit filled with PVC jacketed cable (separate penetration):

30	2/C #14	0.1372	4.1160
8	12/C #14	0.5329	4.2632
7	1/C 500MCM	0.7013	4.9091

Total Loading = 13.2883 sq.in.
(117.4% fill of conduit)

All cables used in the test extended 36" above the slab's unexposed surface and 12" below its exposed surface. Cables were held to the trays with both compression clamps and metal plates located approximately 12" from the top of each tray. In addition, a threaded rod was used across the bottom of each tray to prevent the cables from being pulled forward during the seal installation. This was done to simulate field conditions where continuous cable make it impossible in some cases to move the cables apart for seal installation.

The top ends of all cables used inside of the cable trays were covered with silicone adhesive while conduit cable ends were covered with electrical tape. This was done in accordance with IEEE 634-78 requirements.

Finally, the cables used in the conduits were grouped and mounted by type (i.e., power, control and instrument cables). The grouping of power cables in each conduit sleeve created a more severe condition because of the high concentation of heat that would be produced during the fire test.

D.) Seal Installation:

The openings were first dammed by packing mineral wool between the cables to prevent leakage of the liquid high density silicone elastomer material. The rest of the opening was formed with plywood. Once the elastomer was installed and set, all forming materials were removed.

The two-component high density silicone elastomer were installed in a one to one ratio (+/- 5%) 12" deep inside of the large penetration and conduits. A portion of the seal was installed using dispensing equipment while the remainder of the seal was completed with large (30 gallon drum) hand mixed batches. Where the elastomer was used in cable bundles, the bundles were spread apart by hand. A trowel was used to push the elastomer into the cable bundles to facilitate its flow.

Once the elastomer installation was completed, the damming material was removed. It was noted at this time that a small layer of material at the elastomer/PVC jacketed cable interface did not completely cure. The inhibition of cure at the PVC surfaces was attributed to the free sulphur in the PVC material. Sulphur is a material which affects the curing mechanism of the platinum catalyst silicone product. Although the amount of inhibition varied from PVC jacketed cable to cable, none was immediately observed at the silicone elastomer/hypalon jacketed cable interfaces. No attempt was made to repair the seal where inhibition occurred in order to show both conditions.

E.) Thermocouples:

Thermocouples were mounted to the test specimens to gather temperature data throughout the test at five minute intervals for the first two hours and at ten minute intervals for the remaining hour (in accordance with the IEEE 634-78 standard). Temperatures were recorded for the seal surfaces, seal/substrate interfaces (unexposed surface only), and penetration members.

All seal surface thermocouples were embedded 1/4"-1/2" into seal surfaces to prevent the effect of contact with ambient air temperatures. Thermocouples used for monitoring cable temperatures were tied with wire to the cables so that their tips were also embedded into the seal surface.

The thermocouples used in this test along with final temperature readings are as follows (temperature data for the entire test can be found in section "H" of this report):

T/C#	Print#	Description	Final Temperature (°F)	
91	9c	Seal surface	118.0	
92	92c	Seal surface	109.0	
93	93c	Seal surface	102.0	
94	94c	Instrument cable	187.0	Solid back cable tray with Hypalon jacketed cable
95	95c	Control cable	185.0	
96	96c	Power cable	174.0	
97	97c	Cable tray	181.0	
98	98c	Seal surface	283.0	
99	99c	Instrument cable	329.0	Conduit filled with Hypalon Jacketed cable
100	100c	Control cable	316.0	
101	101c	Power cable	327.0	
102	102c	Interface	303.0	
103	103c	Instrument cable	186.0	
104	104c	Control cable	350.0	Ladder back tray filled with PVC jacketed cable
105	105c	Power cable	434.0	
106	106c	Cable tray	186.0	

T/C#	Print#	Description	Final Temperature (°F)	
107	107c	Instrument cable	166.0	
108	108c	Control cable	333.0	Solid back tray
109	109c	Power cable	385.0	filled with PVC
110	110c	Cable tray	180.0	jacketed cable
111	97b	Seal surface	323.8	Conduit filled w/
112	24b	Instrument cable	361.4	PVC jacketed cable
113	28b	Control cable	378.8	
114	25b	Power cable	486.8	
115	26b	Interface	339.8	
116	27b	Steel substrate/ steel interface	301.5	
117	117c	Concrete substrate/ Seal surface	126.0	
186	186c	Seal surface	102.0	
187	187c	Seal surface	94.0	
188	188c	Seal surface	94.0	
213	23b	Repair surface	92.1	
214	29b	Repair cable	99.7	PVC jacketed cable
215	43b	Repair surface	109.2	Hypalon jacketed
216	42b	Repair cable	110.9	cable

1-1/2" Embedded steel conduit/sleeve:

75	20a	Seal surface	188.3
76	21a	Interface	164.7
77	22a	Instrument cable	191.9

6" Embedded steel conduit/sleeve:

78	28a	Seal surface	204.9
79	29	Instrument cable	494.2
80	32a	Control cable	412.1
81	30a	Power cable	591.2
82	31a	Interface	257.8

F.) Furnace:

The furnace used for this test measures approximately 14' x 18' at its support points. It is approximately 7' tall making it possible to work on the specimen's exposed surface and view it prior to the fire test. The furnace atmosphere is controlled by six self-igniting burners which burn natural gas and operate in unison. The burners are automatically controlled by a computer located inside of the control room. As the furnace atmosphere temperatures are monitored in the control room, manual adjustments can be made to the burners to account for varying amounts of fuel contribution throughout the test.

The furnace atmosphere temperatures are monitored by 16 thermocouples located 12" below the test slab. These temperatures are individually printed on a continuous chart and also averaged on a computer printout.

The furnace draft is manually operated and averages to approximately -.08" of water pressure throughout the test. Since manual adjustments are made to the burners in order to follow the ASTM E-119 time/temperature curve, brief periods of positive pressure are introduced inside of the furnace. This is evidenced by visible puffs of smoke generated through openings in the test specimen (i.e., through a fire damper, unsealed pipe insulation, etc.).

G.) Test Record:

The fire test was conducted for three hours in accordance with the ASTM E-119 time temperature curve. Throughout the test, an even blanket of flame covered the plan area of the furnace. All combustible materials located on the exposed surface of the slab quickly ignited and continued to char throughout the test. During the first 2 hours of the tests, very little smoke was generated from the cables used in this specimen. Light smoke from the cables occurred for most of the last hour of the test.

Between 3 hours and 3 hours, 1 minute (after the fire test) the center of the seal bulged up approximately 4" above the slab and cracked. The "U"-shaped crack was studied after the test and it was determined that the crack was caused by the thermal expansion of the growing bulge and not by the fire burning through the seal. The material at the break where the thermal expansion took place was approximately 3/4"-1" thick.

The hose stream tests were conducted on the concrete slab and 3 penetration seals. Water did not penetrate the two embedded conduit seals and the two conduit seals (conduits which penetrated the large opening). Because of the crack, it was not possible to perform a meaningful hose stream test on the large seal.

The two hose stream tests were conducted for 6 minutes and 18 seconds each in accordance with the following requirements:

a.) IEEE-634-78: 75 p.s.i. hose stream delivered through an 1-1/2" hose equipped with a fog nozzle set at a discharge angle of 30° from a distance of 10'.

b.) ANI: Same as above except that the nozzle was set at a discharge angle of 15°.

H.) Temperature Data:

The following sheets identify both furnace atmosphere and unexposed surface temperatures obtained throughout the fire test.

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FURNACE ATMOSPHERE TEMPERATURE (DEG. F)

TEST TIME, Hr:Min	FURNACE TEMP. F	ASTM E119 TEMP. F	VARIATION FROM ASTM TEMP. F
0:00	196	68	128
0:05	995	1000	-5
0:10	1271	1300	-29
0:15	1503	1399	104
0:20	1527	1462	65
0:25	1547	1510	37
0:30	1557	1550	7
0:35	1608	1584	24
0:40	1626	1613	13
0:45	1638	1638	0
0:50	1655	1661	-6
0:55	1704	1681	23
1:00	1714	1700	14
1:05	1724	1718	6
1:10	1729	1735	-6
1:15	1748	1750	-2
1:20	1771	1765	6
1:25	1776	1779	-3
1:30	1779	1792	-13
1:35	1818	1804	14
1:40	1823	1815	8
1:45	1830	1826	4
1:50	1836	1835	1
1:55	1844	1843	1
2:00	1854	1850	4
2:10	1873	1862	11
2:20	1880	1875	5
2:30	1890	1888	-8
2:40	1895	1900	-5
2:50	1916	1912	4
3:00	1930	1925	5

TEST TIME HR:MIN	THERMOCOUPLES (temperatures in degrees F)					
	111	112	113	114	115	116
0:00	72.0	71.0	71.1	72.5	71.6	72.1
0:05	72.1	72.0	71.9	74.6	71.8	72.2
0:10	72.4	72.4	72.3	81.8	72.3	72.3
0:15	73.2	74.4	73.9	95.4	73.6	73.1
0:20	75.3	77.7	76.7	114.8	76.4	74.6
0:25	78.9	82.9	82.0	138.0	80.7	76.7
0:30	84.3	90.1	89.6	160.0	86.7	79.6
0:35	91.4	98.9	99.2	180.4	94.4	83.6
0:40	99.9	108.5	110.6	200.6	102.4	88.8
0:45	109.8	119.0	123.1	220.0	111.8	92.0
0:50	120.3	120.0	136.1	237.5	121.8	98.0
0:55	131.0	141.5	149.5	255.0	131.9	103.4
1:00	140.2	151.5	160.9	269.6	141.0	107.9
1:05	150.4	163.0	174.4	287.0	151.5	113.7
1:10	161.0	174.6	187.7	301.9	162.7	119.7
1:15	171.2	186.0	200.5	316.1	173.7	125.8
1:20	181.2	196.6	212.9	328.1	184.4	132.1
1:25	191.2	207.2	225.2	338.5	194.5	138.8
1:30	200.7	217.0	237.0	347.9	203.4	145.3
1:35	209.8	226.7	248.7	358.9	212.6	152.1
1:40	217.9	235.3	259.7	369.7	220.3	158.7
1:45	226.2	244.1	270.5	378.9	227.9	165.1
1:50	234.1	252.3	280.6	386.7	235.3	171.5
1:55	241.6	260.6	290.0	393.8	241.6	177.9
2:00	248.7	268.4	298.7	402.1	248.0	184.4
2:10	263.1	284.4	315.2	410.9	263.1	196.0
2:20	276.3	299.1	328.5	424.8	277.1	206.9
2:30	288.6	313.6	340.0	446.4	289.2	221.4
2:40	299.8	327.4	352.4	458.8	302.5	241.3
2:50	311.5	343.6	365.2	472.1	320.3	267.7
3:00	323.8	361.4	378.8	486.4	339.8	310.5

TEST TIME HR:MIN	THERMOCOUPLES (temperatures in degrees F)					
	117	186	187	188	213	214
0:00	76	76	76	75	71.9	71.5
0:05	72	74	73	73	72.0	71.7
0:10	73	74	73	73	72.0	72.1
0:15	73	74	73	73	72.3	72.8
0:20	73	74	73	73	72.6	73.3
0:25	73	74	73	73	72.9	73.9
0:30	73	74	74	73	73.2	74.4
0:35	74	74	74	74	73.7	75.0
0:40	74	74	74	74	74.0	75.6
0:45	74	75	74	74	74.5	76.2
0:50	74	75	74	74	74.9	76.7
0:55	74	75	75	75	75.5	77.3
1:00	75	75	76	75	75.8	77.8
1:05	75	75	76	75	76.4	78.6
1:10	76	76	76	76	77.0	7[illegible]3
1:15	78	76	77	76	77.6	80.1
1:20	83	76	77	77	78.0	80.7
1:25	80	77	78	77	78.8	81.6
1:30	82	77	78	78	79.3	82.3
1:35	83	79	79	79	80.0	83.1
1:40	86	77	79	79	80.5	83.9
1:45	88	77	80	80	80.8	84.4
1:50	90	77	81	81	81.2	85.1
1:55	93	77	81	81	82.0	86.0
2:00	95	78	82	82	82.7	87.0
2:10	100	78	84	84	83.7	88.7
2:20	105	79	85	85	85.4	91.2
2:30	110	80	87	88	86.8	92.9
2:40	115	81	89	90	88.2	94.9
2:50	120	86	91	92	90.0	97.2
3:00	126	102	94	94	92.1	99.7

TEST TIME HR:MIN	THERMOCOUPLES (temperatures in degrees F)						
	215	216	75	76	77	78	79
0:00	73.1	73.1	71.7	72.3	72.3	72.2	72.4
0:05	73.1	73.1	73.1	72.3	72.3	72.1	72.8
0:10	73.1	73.1	72.2	72.7	73.4	72.3	75.4
0:15	73.1	73.	72.9	73.6	75.6	72.8	81.2
0:20	73.3	73.4	74.5	75.2	79.2	73.9	90.8
0:25	73.4	73.6	76.4	77.3	83.3	75.5	104.3
0:30	73.5	73.8	79.1	79.7	87.5	77.7	120.3
0:35	73.7	74.1	81.7	82.2	91.7	80.5	136.8
0:40	74.0	74.5	84.7	84.8	95.2	85.1	152.9
0:45	74.4	75.0	87.6	87.5	99.2	89.1	167.5
0:50	74.8	75.6	90.7	89.9	103.0	93.8	180.1
0:55	75.4	76.3	94.1	93.0	107.0	98.7	203.2
1:00	75.9	76.9	97.4	94.6	110.8	104.7	218.1
1:05	76.6	77.7	100.5	101.2	114.6	110.5	230.9
1:10	77.5	78.7	104.4	105.9	118.6	115.7	244.5
1:15	78.4	79.6	108.2	112.0	122.4	120.5	257.7
1:20	79.4	80.7	112.1	116.1	126.6	128.6	269.7
1:25	80.6	82.0	115.5	119.6	130.4	133.5	282.6
1:30	81.9	83.3	117.1	122.5	133.6	140.8	295.5
1:35	83.1	84.6	121.9	125.4	137.8	143.5	307.9
1:40	84.1	85.6	128.8	129.6	143.3	149.1	319.2
1:45	84.8	86.2	135.3	134.0	149.5	154.3	333.4
1:50	86.0	87.4	144.6	140.2	156.4	160.9	345.6
1:55	87.5	88.9	149.7	142.6	161.6	163.1	358.1
2:00	89.1	90.5	154.6	146.8	166.3	164.21	369.4
2:10	91.5	92.8	163.4	152.7	173.9	174.5	389.4
2:20	94.8	96.2	169.2	158.5	179.2	193.0	413.0
2:30	98.4	99.8	168.5	154.8	181.5	192.2	433.0
2:40	101.8	013.1	172.1	158.3	183.4	195.0	451.6
2:50	105.3	106.9	182.7	157.3	187.9	203.8	472.4
3:00	109.2	110.9	188.3	164.7	191.9	204.9	494.2

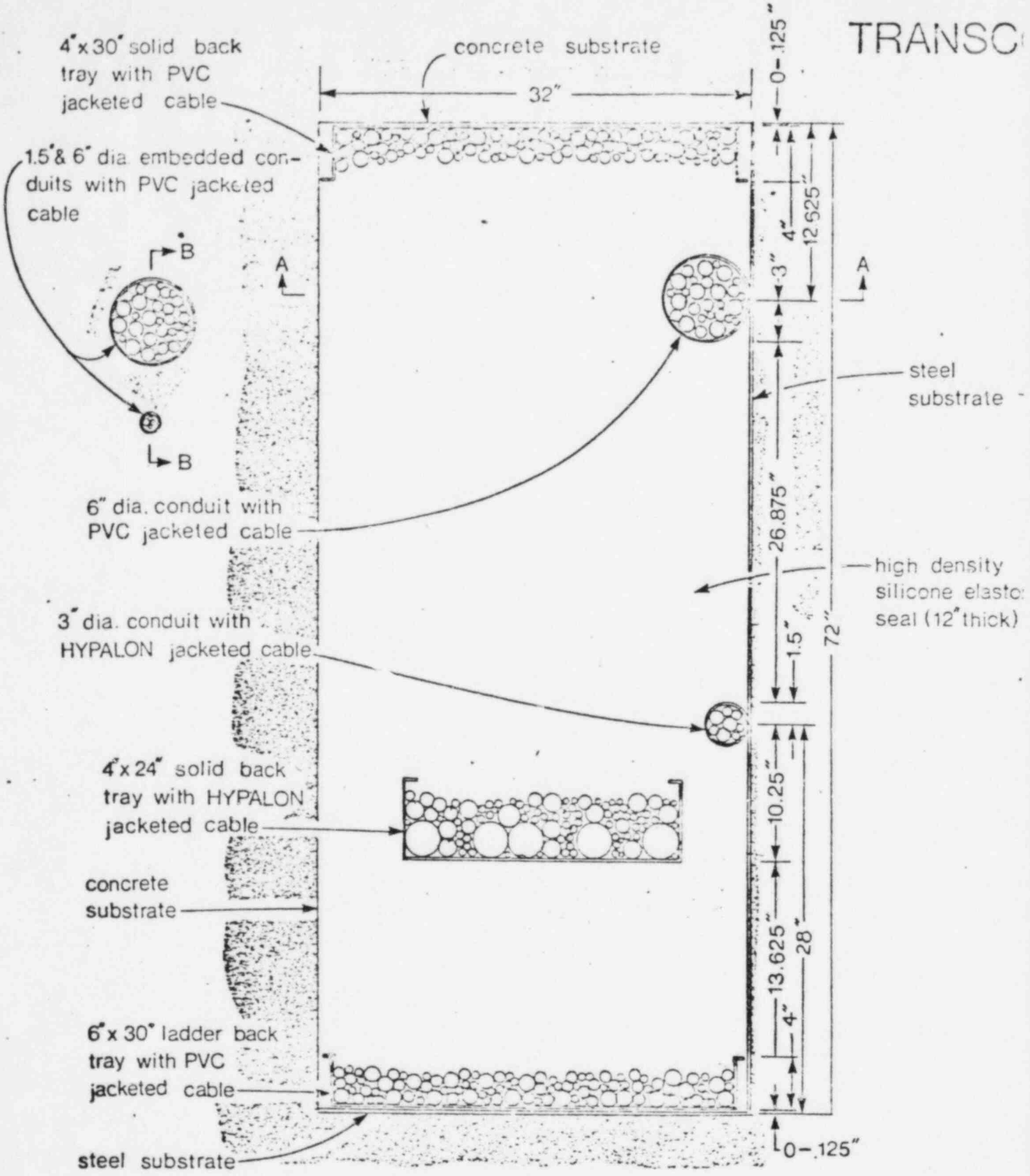
TEST TIME HR:MIN	THERMOCOUPLES (temperatures in degrees F)		
	80	81	82
0:00	72.6	72.8	72.5
0:05	72.8	73.9	72.5
0:10	74.0	80.5	72.8
0:15	77.4	92.3	72.8
0:20	83.9	110.1	74.8
0:25	93.7	132.9	77.1
0:30	106.8	157.1	80.4
0:35	121.4	180.7	84.5
0:40	137.0	204.5	90.0
0:45	152.9	225.7	96.1
0:50	165.0	243.2	102.6
0:55	178.9	262.4	109.6
1:00	193.2	282.6	117.1
1:05	205.6	298.4	124.2
1:10	218.2	312.7	132.4
1:15	229.7	325.6	140.2
1:20	240.4	337.2	148.9
1:25	250.8	349.3	157.7
1:30	262.5	363.2	165.9
1:35	274.7	377.1	172.1
1:40	287.3	391.8	178.8
1:45	299.0	409.6	184.2
1:50	309.3	430.2	191.0
1:55	319.5	446.3	195.4
2:00	326.8	460.3	199.2
2:10	336.0	486.8	209.8
2:20	347.5	516.5	224.3
2:30	361.3	536.6	232.0
2:40	377.4	555.4	240.2
2:50	393.9	572.7	250.1
3:00	412.1	591.2	257.8

TEST TIME HR:MIN	THERMOCOUPLES (temperatures in degrees F)		
	91	92	93
0:00	76	76	76
0:05	73	73	74
0:10	73	73	74
0:15	73	73	74
0:20	73	73	74
0:25	73	73	74
0:30	74	74	74
0:35	74	74	74
0:40	73	74	74
0:45	74	74	74
0:50	74	74	74
0:55	74	74	74
1:00	75	75	75
1:05	75	75	75
1:10	75	75	75
1:15	76	76	75
1:20	76	76	75
1:25	76	76	76
1:30	77	76	76
1:35	77	77	76
1:40	77	77	76
1:45	77	77	76
1:50	77	78	76
1:55	77	77	77
2:00	78	78	77
2:10	78	78	77
2:20	79	80	78
2:30	80	81	78
2:40	82	82	81
2:50	89	88	92
3:00	118	109	102

I.) Post Test Observations:

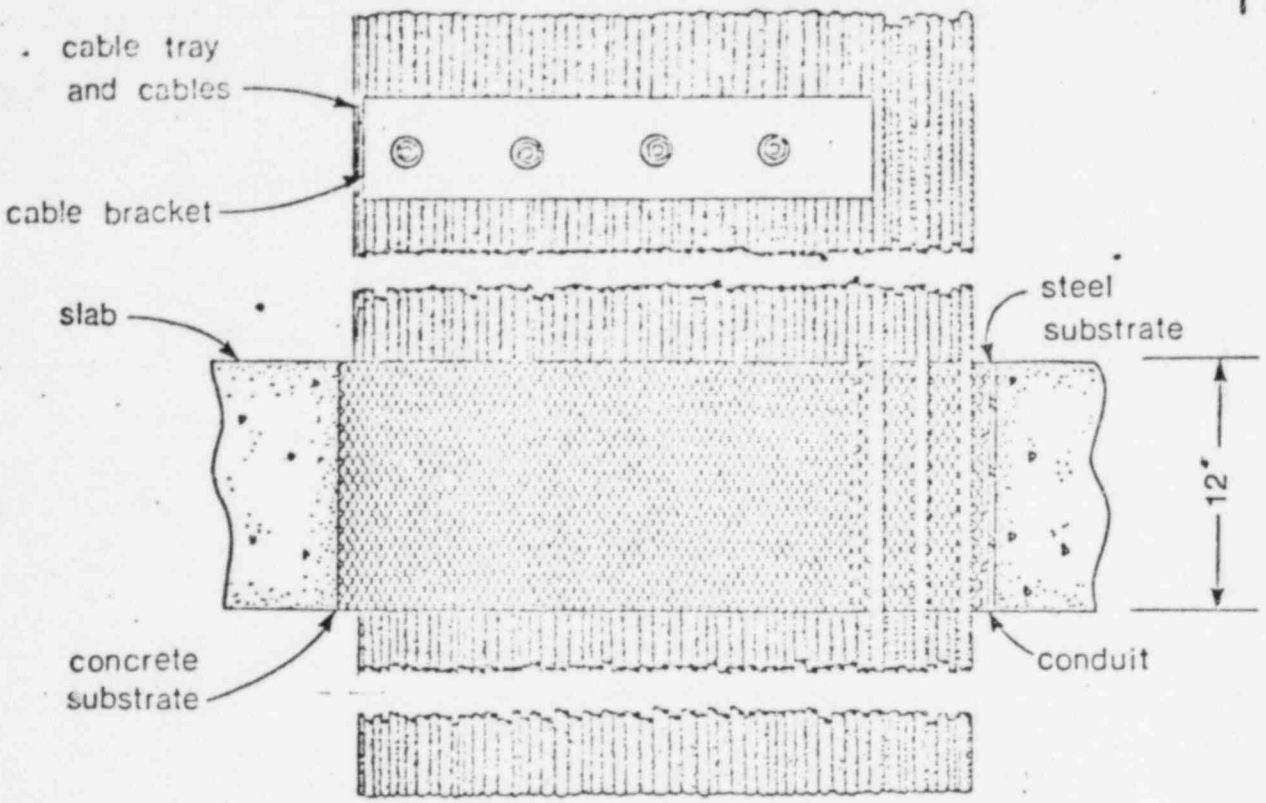
The large electrical opening and all conduit sleeves successfully completed the three hour long fire test. Because of the thermal expansion crack which occurred after the fire test in the large opening it was not possible to conduct the hose stream test for this seal.

The unexposed seal surfaces (with the exception of the crack) in all openings were not affected by either the fire or hose stream tests. Swelling of the PVC jacketed cables occurred in all cases at the seal surfaces. The attached sketches indicate the amount of material remaining in the large opening at the conclusion of the test.

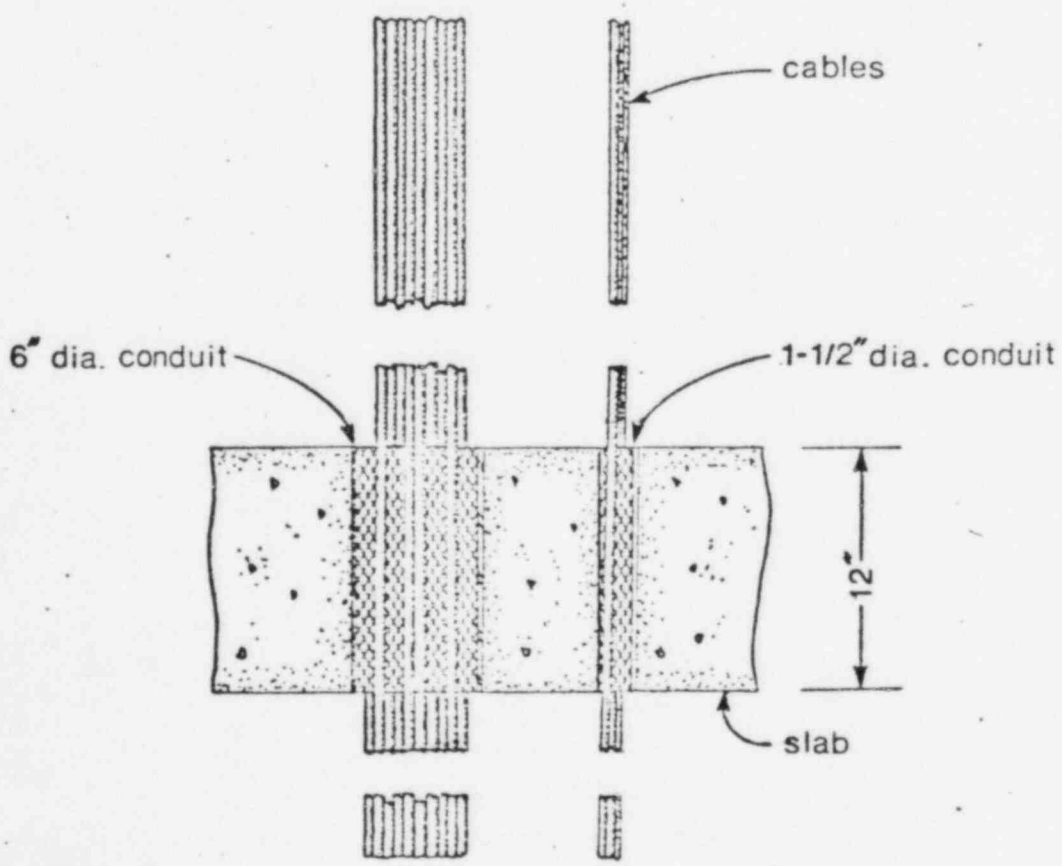


PLAN VIEW

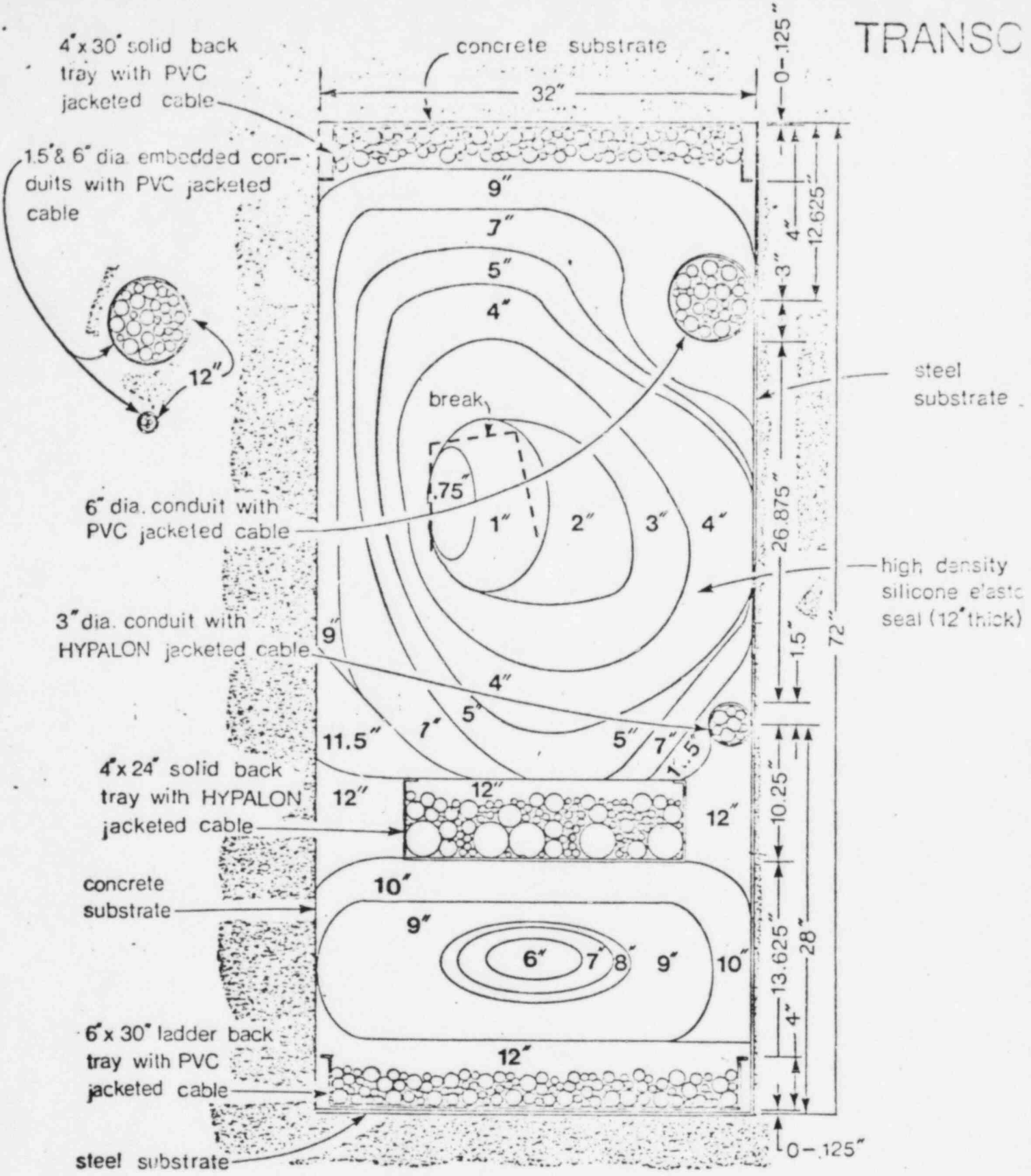
HIGH DENSITY SILICONE ELASTOMER PENETRATION SEALS



SECTION A-A



SECTION B-B



PLAN VIEW

BURN AWAY OF HIGH DENSITY ELASTOMER.

(remaining seal after three hour fire test)