SEVENTH/FLOWER INTEGRATED STATION AND ADJACENT TUNNEL SECTIONS

ENVIRONMENTAL CONTROL SYSTEM (ECS) SUMMARY REPORT

OCTOBER 29, 1986

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Prepared for:

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SEVENTH/FLOWER INTEGRATED STATION AND ADJACENT TUNNEL SECTIONS ENVIRONMENTAL CONTROL SYSTEM SUMMARY REPORT

1.0 PURPOSE

The purpose of this report is to summarize the basis of the final design for the Environmental Control System (ECS) for the Flower Street subway segment, including the Integrated 7th/Flower Station, and to respond to questions raised by the District staff and members of the Fire/Life Safety Committee.

2.0 CRITERIA

SCRTD Design Criteria, Volume 1, Sections 2.2.3, 2.3.5; and Volume 4, Sections 1.3.1 and 1.4.4 and LACTC Design Criteria Section 16.2.3.1, 16.3.3, 16.3.4, 16.3.5, and 18.1.1 defines criteria for emergency ventilation during a train fire in LRT segment or in the Metro Rail tunnel adjacent to the 7th/Flower Street Station. Several scenarios were considered for the ECS analysis and the results were evaluated against the design. Changes, where required, have been made to the design to conform to criteria.

3.0 STUDY APPROACH

The Subway Environment Simulation (SES) computer program has been used to predict the subway air flows during fire conditions. This computer model accounts for the "throttling" effects of a fire (i.e., increased pressure losses), the buoyancy effects of the hot smoke which tends to flow "uphill", heat transfer to the tunnel walls by convection and radiation, and changes in the exhaust fans' performance while handling hot (i.e., less dense) gases.

The computer simulations focused on predicting the magnitude of the air velocity approaching a burning three-car train stalled in a subway section. The magnitude of the approach velocity indicates whether the spread of smoke can be confined downstream of the fire site, thus protecting the upstream evacuation route, or whether the potential for smoke spreading contrary to the forced ventilation exists (a phenomenon called "back-layering"). To prevent back-layering, the approach air velocity must be greater than a "critical" value whose magnitude depends on the fire heat release rate, the tunnel grade, and the tunnel area.

For the subway line section south of the LRT station, the critical velocity is 515 feet per minute based on the open tunnel cross section. This value has been calculated based on a 1.5 percent grade, a fire heat release rate of 85.3 million Btu/hr, and the dimensions of the two-cell box structure with a perforated dividing wall. The above heat release rate corresponds to the heat output from two fully-involved cars with a combustible loading of 60 million Btu per car (Reference 5). At the crossover and tail track tunnels north of the LRT station, required air velocities of 425 and 510 feet per minute, respectively, have been calculated based on the annulus area alongside the train. In line sections with a perforated dividing wall, the control point is the upstream end of the incident train since some of the air flow approaching the train will be diverted into the unoccupied trackway via the wall openings.

The area modelled encompassed the entire Flower Street Subway and the portion of the Metro Rail system between Wilshire/Alvarado and Fifth/Hill stations. The results of the SES simulation modelling fire incidents at four locations in LRT section are summarized in Table 1.

The SES program has been applied iteratively to determine the required fan capacity for a given station entrance configuration. When the results of a simulation predicted an approach air velocity below the required value with the proposed fan capacities (i.e., two 150,000 cfm fans at the tail track and an equal capacity at the south end of the LRT station), then the fan capacities were increased and the simulation repeated until the required air velocity was reached or exceeded.

3.1 Emergency Scenarios Examined

Simulations have been performed for a fire incident occurring in the subway line section south of the LRT station, in the tail tracks north of the LRT station, and within the station itself.

During a fire incident south of the LRT station, the conditions modelled were as shown in Figure 2. The incident train is assumed to be located at Sta. 17+90 and direction of ventilation is toward the portal. Therefore, all the fans (LRT and Metro Rail) are operated in the supply mode. This is considered a worst case because the ventilation is directed downgrade against the buoyant effect of the hot smoke.

North of the LRT station, two cases were considered. The first case examined the resulting conditions when the burning cars were located in one of the tail track tunnels where the trackways are separated by a solid dividing wall. This study recommended the use of a perforated dividing wall and provision for common intake plenum to the fans, to satisfy both the smoke control velocity and the fan temperature rating of 300°F. Current design reflects this recommendation. In the second case, the burning cars were located at the crossover tunnel where there is no dividing wall. In both instances, the fans at the tail track were operated in the exhaust mode, while the fans at the south end of the LRT station and Metro Rail fans were operated in the supply mode.

If a train fire occurs in the LRT station, the ventilation concept is to draw in outside air through the entrances, sweep it through the public area, and exhaust it through the ventilation shafts at both ends of the station. Hence, in the station ventilation simulations both fans at the tail track and both fans south of the station were operated in the exhaust mode. The OTE system was not operated. Also, the Metro Rail fans were operated in supply mode. Note that the station ventilation simulations do not consider the thermal effects of a fire, since modelling fires in large enclosures such as a station, is beyond the capability of the SES computer program. However, the simulations performed do give a good estimate of the station ventilation rates which can be achieved.

TABLE 1
SUMMARY OF SES RESULTS
FOR A FIRE INCIDENT IN LRT SECTION

Location	Fan Capacity (cfm)	Predicted Air Velocity With Fire (fpm)	Required Velocity (fpm)	Remarks
South of Station	210,000 (per fan)	546	515	Worst case
LRT Station	190,000	300 (at platform)	---	See Note 1
North of Station at Crossover	190,000	665	515	---
LRT Tail Track	190,000	670	515	See Note 2

Note 1: Ventilation rate of 130 air changes per hour in the station, which is satisfactory.

Note 2: To reduce the smoke temperature, a common intake plenum to the fans, and perforated dividing wall between the tracks have been provided.

General Note: Based on the worst case, fan capacity of 210,000 cfm per fan, four fan operation is required. Fan capacities of 150,000 cfm were increased to 210,000 cfm to overcome the deficiency indicated in the initial report and incorporate the recommendation of the Werner W. Metsch memorandum dated May 6, 1986. The results are based on an 85.3 million Btu/hr fire.

4.0 EMERGENCY VENTILATION STUDY FOR FOR FIRE INCIDENT IN A METRO RAIL TUNNEL

The March 20, 1986 study completed the verification process by examining the performance of the emergency ventilation system for the combined LRT and Metro Rail systems during a fire incident in a Metro Rail tunnel.

The emergency ventilation system for the Metro Rail was analyzed during final design for that project and the results are reported in the Final ECS Report, dated August 23, 1985. That study assumed that the LRT system had not been built.

The November 1, 1985 study considered the integrated station at 7th/Flower (both levels) including a section of the Metro Rail system extending from Fifth/Hill Station to Wilshire/Alvarado station. However, only fire incidents occurring at the LRT level were examined.

5.0 ANALYSIS FOR COMBINED LRT AND MRT SYSTEMS

The Subway Environment Simulation (SES) computer program has been used to examine the performance of the emergency ventilation system during a train fire in a Metro Rail tunnel. The incident train was assumed to be located approximately midway between the 7th/Flower and Wilshire/Alvarado stations on the AR track (i.e., outbound route). One tunnel section adjacent to 7th/Flower station was selected for analysis because any adverse effect on emergency ventilation caused by the LRT system would be more evident in the vicinity of that station. Four simulations were performed to determine whether sufficient air flow could be maintained past the incident train to control the spread of smoke. These simulations examined the following conditions:

A. <u>Evacuation Toward 7th/Flower</u>

- Operating Metro Rail fans only.
- Operating LRT fans to supplement Metro Rail fans.

B. <u>Evacuation Towards Wilshire/Alvarado</u>

- Operating Metro Rail fans only.
- Operating LRT fans to supplement Metro Rail fans.

5.1 Extent of Area Simulated

The area modelled with the SES program includes the entire LRT system from the portal near 11th Street to the tail tracks north of the LRT station and along the Metro Rail system from a point approximately 500 feet west of Union Station up to and including Wilshire/Alvarado station, as shown on Figure 1.

Wilshire/Alvarado was modelled as a terminal station (i.e., the limit of MOS-1).

5.2 Entranceways at 7th/Flower

The November 1, 1985 ventilation studies performed for the LRT system indicated that doors at two of the four entranceways serving 7th/Flower station would be required to satisfy emergency ventilation criteria in the tunnels between the LRT station and the portal. All four entranceways were assumed open for that study. In the final design configuration, there are only three entrances. The results of the study are still valid, which demonstrate the ventilation equipment capacity is more than adequate. The study recommended to close the entrances at LRT in case of fire incident in LRT section. We have closed one entrance; the other entrance has been omitted.

5.3 Location of Incident Train

The incident train was assumed to be located approximately midway between the 7th/Flower and Wilshire/Alvarado stations on the AR tracks (i.e., outbound route). The results would have been identical if the incident train had been located on the AL track in the parallel bore.

A tunnel location between the 7th/Flower and Wilshire/Alvarado Stations was selected rather than a location in the tunnel between 5th/Hill and 7th/Flower, because the former tunnel is approximately twice the length of the latter (i.e., 5,450 ft. vs. 2,425 ft.). Therefore, if the emergency ventilation system can satisfy criteria in the longer tunnel, then by extrapolation the criteria in a tunnel half the length can also be satisfied.

5.4 Conditions Simulated

In each simulation performed, a six-car train was assumed stalled in the affected tunnel between the 7th/Flower and Wilshire/Alvarado Stations and burning with a design heat release rate of 85.3 million Btu per hour.

The number of emergency fans operated and their operating mode are shown on Table 3. Also, the UPE systems (128,000 cfm) were activated at the Metro Rail station(s) whose emergency fans were operating in the exhaust mode. The LRT fans were not activated in two simulations. In those cases, the bypass dampers for the LRT shafts were assumed to remain open.

A nominal capacity of 210,000 cfm (in exhaust mode) per fan was used for each of the four LRT fans. For the supply mode, nominal fan capacities of 189,000 cfm (90% of exhaust flow rate) and 136,500 cfm (65% of exhaust flow rate) were used for the two emergency ventilation fans and the two subway ventilation fans, respectively.

The results of the four simulations performed are shown on Table 2. The location of emergency fans operated and their operating mode are shown in Table 3. The number of emergency fans at each location is shown on Table 4.

The results clearly indicate that air velocities exceeding the 590 fpm required in the annulus of the incident train to control the spread of smoke can still be achieved with the presence of the LRT system.

The presence of the LRT system will not adversely affect the performance of the emergency ventilation system for the Metro Rail tunnels. This conclusion is supported by the results of four SES Computer Program simulations performed.

TABLE 2
RESULTS OF SES SIMULATION
FOR THE COMBINED LRT/MRT SYSTEM

FAN OPERATING MODE	Predicted Air Velocity in Annulus (fpm) Combined LRT and MRT: LRT & MRT FANS	MRT FANS ONLY	MRT SYSTEM ONLY	REQUIRED AIR VELOCITY (fpm)
1. Exhaust at 7th/Flower	730	620	690	590
2. Supply at 7th/Flower	810	760	790	590

Notes:

1. Results are based an 85.3 million Btu/hr. fire.
2. See Figure 1 for location of incident of train analysis.

TABLE 3
EMERGENCY FAN OPERATING MODE

Evacuation Toward	Operating Mode: Supply	Exhaust
7th/Flower	EM-5, EM-6, EM-7 EM-8 & LRT Fans	EM-9 & EM-10
Wilshire/Alvarado	EM-9 & EM-10	EM-5, EM-6, EM-7 EM-8 & LRT Fans

Notes:

1. See Figure 1 for location of designated fans.
2. All four (4) LRT fans were operated simultaneously.

TABLE 4
MRT FAN SHAFT EQUIPMENT FOR FIGURE 1.
AND TABLE 3

FAN SHAFT NO.	NUMBER OF FANS	FAN CAPACITY CFM PER FAN
EM-5	2	150,000
EM-6	2	150,000
EM-7	2	150,000
EM-8	2	150,000
EM-9	3	150,000
EM-10	2	150,000

6.0 ECS EQUIPMENT

Based on the ECS studies, it was determined that the following equipment appropriately installed, maintained, and operated according to the procedures set forth will meet the ECS criteria for the 7th/Flower Station and the LRT segment. One emergency ventilation fan (EVF) at each end of the station is provided to meet Design Criteria IV, Section 1.4.4.

EQUIPMENT Emergency Ventilation	CAPACITY CFM	LOCATION LRT Fan Room Number	FIG. 3.4 FAN DESIGNATION -----
EVF/1L	210,000	72	EM-I
EVF/2L	210,000	73	EM-I
SVF/1L	210,000	73	TE-I
EVF/3L	210,000	95	EM-O
SVF/2L	210,000	96	TE-O
EVF/4L	210,000	96	EM-O

Note EVF/IL & EVF/4L are provided to meet criteria for the "one fan out" scenario.
EVF: Emergency Ventilation Fan
SVF: Subway Ventilation Fan
IL: Designation Number

7.0 FAN OPERATION AND CONTROL

For normal and emergency fan operation, see Attachment 5, M-209 - ECS Control Diagram.

The suggested method of fan operation is presented in Figure 3.4 revised for MOS-1 and includes LRT station at 7th/Flower in terms of a response matrix which defines the mode of fan operation (i.e., supply or exhaust) as a function of incident train location and direction of evacuation. The train location is defined by the civil station number and the track (i.e., the AR [outbound track]).

A description of damper operation shown alongside the matrix defines fan/damper interlock and "fail safe" position in case of power or control signal failure.

8.0 ECS EMERGENCY DOOR PRESSURE AND EXITING STUDY

This study demonstrates that the ECS emergency doors meet the pressure and exiting requirements.

The ECS emergency doors located at the bridge level of the Roosevelt Building LRT entrance provide 7 lanes of exiting width (2 x 82"/22" = 7.45 lanes). The escalator/stair pair at this entrance provides 5 lanes of exiting width. The doors therefore exceed the exiting lane width requirement for the entrance.

The doors are held in the open position by a positive mechanical latch during normal station operation. During emergency operation the latch is electromagnetically released and the doors close by means of industry standard balanced-door hardware and conventional, spring loaded, non-power-assisted closers.

NFPA 101-10, Section 5-2.1.4.3, requires that the forces to set the door in motion shall not exceed 30 lbf. As indicated in Attachment 7, the force required to set the Roosevelt Building entrance doors in motion is 15.63 lbf., thus meeting the NFPA requirement.

CAC Title 24 requires 8.5 lbf. maximum pressure to set a door in motion. CAC Title 24 does not apply in the case of the Roosevelt Building entrance doors, however, since these doors are not along the handicapped accessible route.

This confirms that the design of the ECS emergency doors for the Roosevelt Building entrance meets the exiting and pressure requirements called for by the Fire/Life Safety Committee.

9.0 CONCLUSION

As a result of the ECS study and based upon the above usage of the equipment, it is our conclusion that all the criteria requirements have been met.

APPENDIX

RESPONSES TO THE QUESTIONS RAISED DURING DESIGN DEVELOPMENT

ACTION #1 — At the LRT platform level, determine the extent of smoke mitigation toward the entrance during a worst case scenario.

RESPONSE #1 — The SES computer program is not capable of simulating the concentration of smoke in the exhaust air stream. This was addressed in letter of March 28, 1986 to Mr. R. J. Murray from Mr. H. J. Chaliff. Further discussions satisfied this concurrence. We recommend that operating procedures be drafted to include verification of smoke concentration of the MRT platform and subsequent evacuation of patrons from that level as a standard procedure.

ACTION #2 — As part of the existing special study authorization for the two LRT entrances, analyze the location of fire closure doors at both platform and headhouse to determine the most feasible configuration(s). This analysis must confirm that the recommended solutions satisfy exiting requirements.

RESPONSE #2 — Please see ECS Emergency Door Pressure and Exiting Study on Page 8 of this report.

ACTION #3 — Provide a solution to the Fire/Life Safety Criteria requirement that mandates operation of ECS emergency ventilation with at least one inoperable fan. If a spare fan(s) is to be used, consider a vertical location occupying no additional footprint.

RESPONSE #3 — Standby fans at each end of the LRT station have been provided.

ACTION #4 — Complete SES simulations specified by MRTC in August to confirm that ECS design still satisfies emergency ventilation requirements for a Metro Rail fire in tunnels adjacent to the 7th/Flower Station.

RESPONSE #4 — The Emergency Ventilation Study for a fire incident in a Metro Rail tunnel dated March 20, 1986, forward to SCRTD on March 21, 1986 demonstrates that the design meets the criteria requirements.

ACTION #5 — Verify the use of horizontal dampers elsewhere in the transit system for trackway ventilation.

RESPONSE #5 — Verification of horizontal dampers completed on April 25, 1986. Horizontal dampers shown in A-130, A-135, A-136 and A-187 Contracts. These ventilation dampers are not fire/smoke dampers. All fire/smoke dampers are vertical dampers. Failure mode of dampers will provide for adequate ventilation.

ACTION #6 Verify air flow adequacy past train in the LRT tail track section.

RESPONSE #6 Air flow verification completed on May 1, 1986 and found to be deficient. Alternate design underway which will require close coordination with, and special consideration approval by, the Fire/Life Safety Committee. Special Consideration was approved on May 9, 1985, and design changed accordingly.

ACTION #7 Calculate air flows in tail track ventilation system. New configuration to be sent to PBQD in New York.

RESPONSE #7 This action was completed on April 23, 1986.

ACTION #8 Reconfigure ventilation drawings to show emergency fans on each side of trainway with normal ventilation fan in center.

RESPONSE #8 This action was completed on April 30, 1986. It was shown on 60% review submittal drawings.

ACTION #9 Change fan nomenclature to show emergency or subway ventilation only. Drop "stand-by" terminology.

RESPONSE #9 This action was completed on April 30, 1986. It was shown on 60% review submittal drawings.

ACTION #10 Show overrides for limit switches for electrical drawings dealing with fan dampers.

RESPONSE #10 Standard and directive drawings have been reviewed. The review shows redundant motors and fail safe design. Please refer to Drawing MS-020B. This action was completed on April 30, 1986.

ACTION #11 Detail Roosevelt Building and Bank of America Bank Building door hardware and doors to allow opening by patrons given PSF ventilation loadings.

RESPONSE #11 Resolution erroneously reported to be 60% design level. Correct level should be 85% review level.

ACTION #12 Investigate the possibility of operating all six fans in a fire emergency.

RESPONSE #12 To accomplish the above redesign of the northwest structure would have pushed the design up by three months. Further action has been deferred by SCRTD direction dated August 7, 1986.

ACTION #13 Furnish P.S.F. door loadings, forces opposing door opening and adequate design for single LRT entrance at Roosevelt Building.

RESPONSE #13 See Attachment No. 5.

ACTION #14 Verify adequacy of emergency ventilation for train on fire at LRT platform using two emergency fans at each end of station. (Do not use combination of emergency and subway ventilation fans.)

RESPONSE #14 See Figure 5, LRT Station Emergency Ventilation (with nominal 190,000 cfm per fan), and Table 1, Summary of SES Results. This simulation modelling the fire incident in the LRT station demonstrated that if fan capacity of 190,000 cfm per fan is provided then 130 air changes per hour can be achieved. However, emergency and subway ventilation fans of 210,000 cfm capacity haivng 100% efficiency in the exhaust mode are provided in the design. In this scenario, two fans at each fan room will be operated in the exhaust mode, resulting in more than 130 air changes per hour which is considered more than adequate.

ACTION #15 Verify adequacy of emergency ventilation for train on fire on LRT line between station and portal using emergency fans. (Do not use combination of emergency and subway ventilation fans.)

RESPONSE #15 See Figure 2, November 1, 1985 ECS Study, the input data is based on one EVF and one SVF at each side of the station. EVF is 90% efficient in the supply mode and SVF is 65% efficient. Since we have three fans at each side, any combination of fans have to satisfy the requirement. The initial simulation is considered worst case as it uses the less efficient combination of fans.

ACTION #16 Verify adequacy of emergency ventilation for two car train on fire at LRT tail track having perforated wall and using emergency fans. (Do not use combination of emergency and subway ventilation fans.)

RESPONSE #16 See letter of September 15, 1986 from Murthy to Crawley, subject, Description of SES Output.

ACTION #17 Verify adequacy of emergency ventilation for train on fire at Metro Rail platform.

RESPONSE #17 See letter of March 21, 1986 from Chaliff to Murray, subject: Emergency Ventilation.

ACTION #18 Verify adequacy of emergency ventilation for Metro Rail train on fire between 5th/Hill and 7th/Flower Stations.

RESPONSE #18 See letter of August 21, 1986 from Chaliff to Murray, subject: Emergency Ventilation.

ACTION #19 Verify adequacy of emergency ventilation for Metro Rail train on fire between 7th/Flower and Wilshire/Alvarado.

RESPONSE #19 See letter of August 21, 1986 from Chaliff to Murray, subject: Emergency Ventilation.

END OF DOCUMENT.

KVS/cla

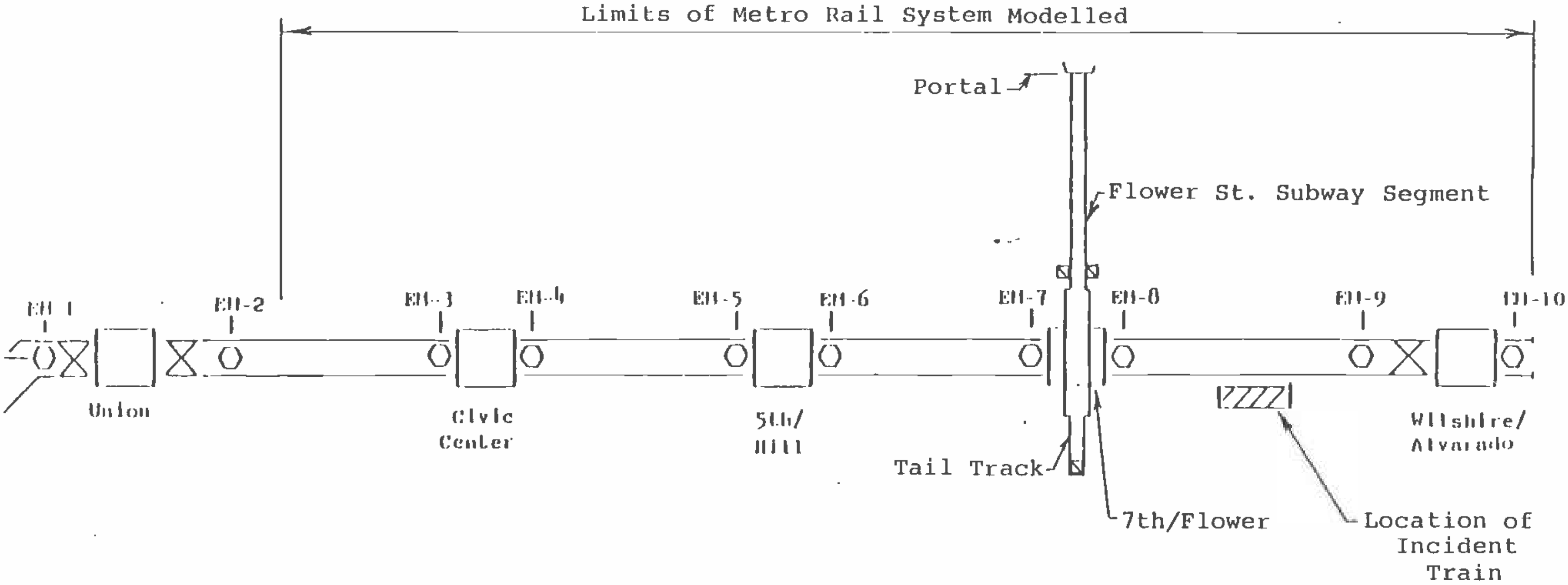


Figure 1 Limits of Study Area

Note: See Table 4 for number of fans and fan capacities at each fan shaft.

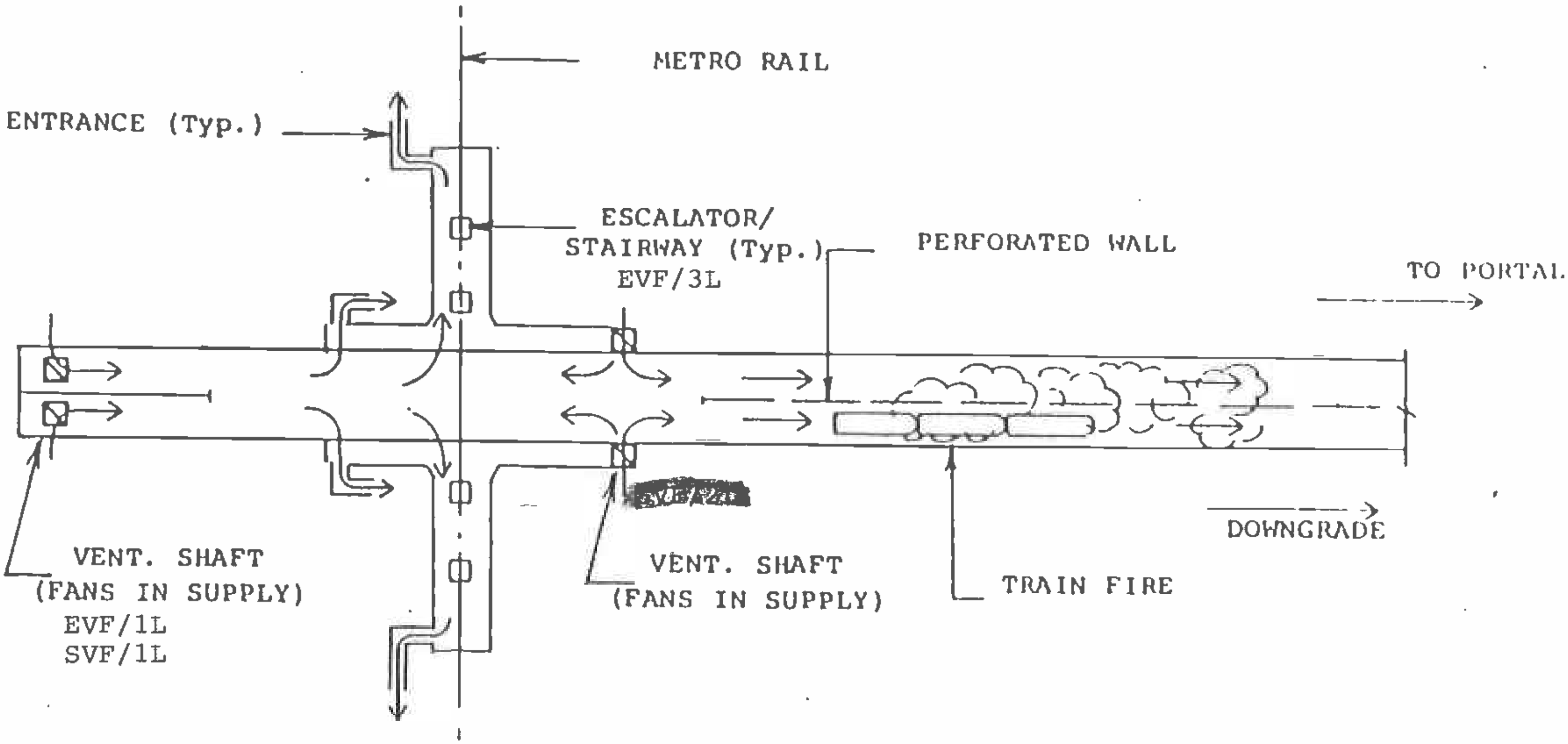


Figure 2. Emergency Condition Simulated ("worst case")

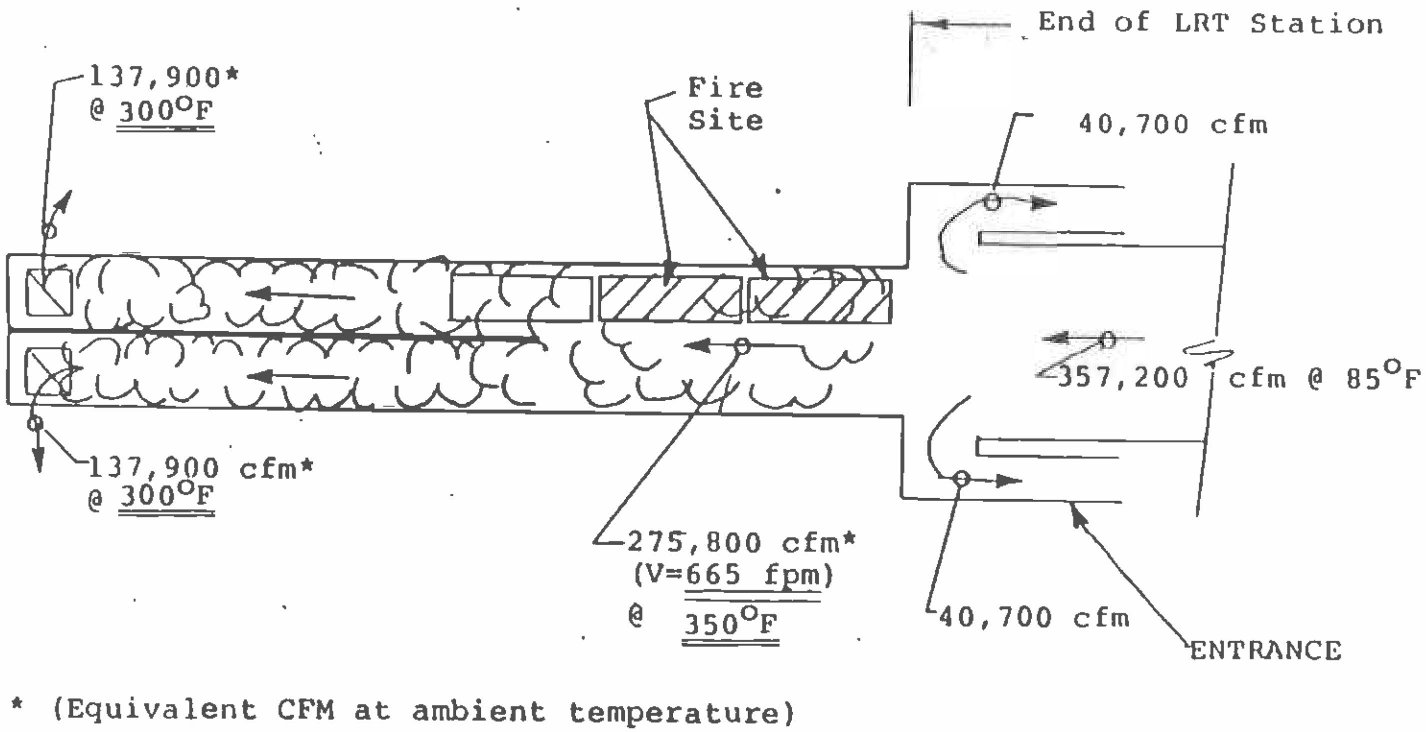
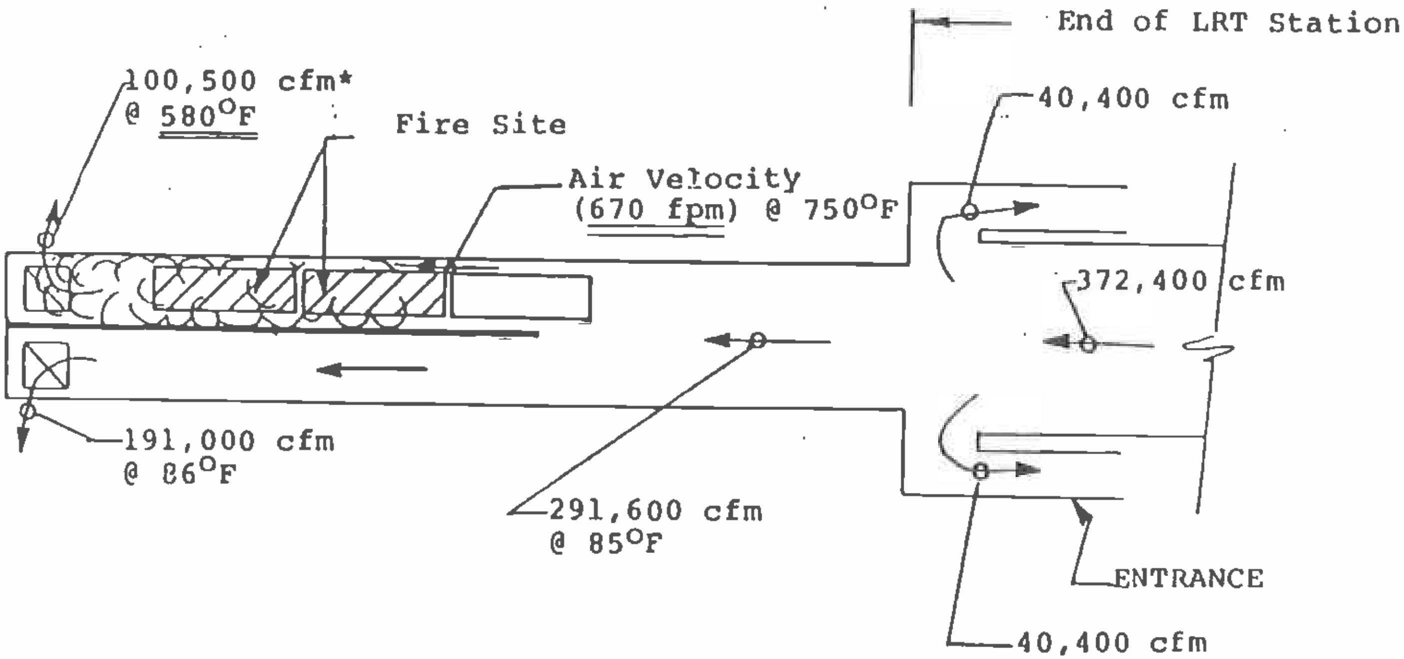


Figure 3. Results for Fire Incident at Crossover
(w/nominal 190,000 cfm per fan)



* (Equivalent CFM at ambient temperature)

Figure 4. Results for Fire Incident at Tail Track (w/nominal 190,000 cfm per fan)

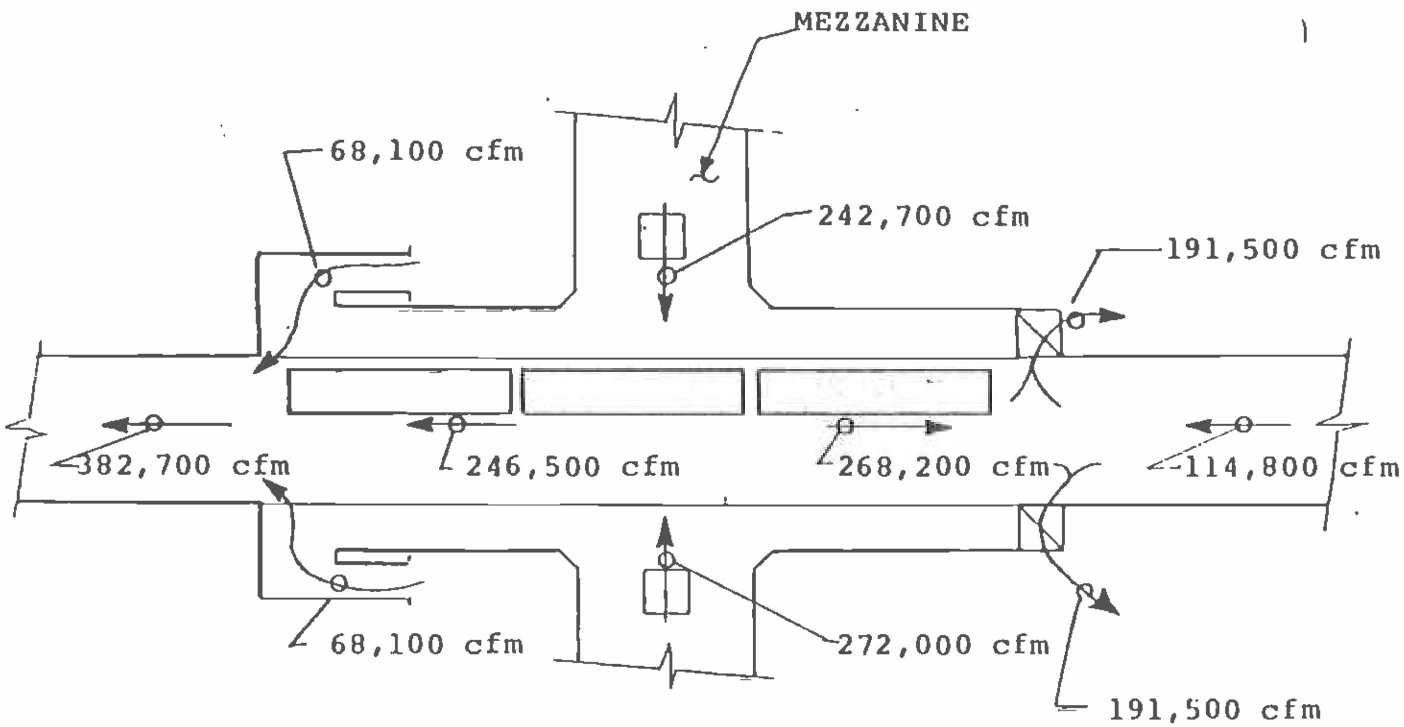


Figure 5. LRT Station Emergency Ventilation
(w/ nominal 190,000 cfm per fan)

MOS-I

DISABLED TRAIN LOCATION BETWEEN STA.	STA.	TRACK	EVACUATION DIRECTION TOWARDS:	UNION EM-I	UNION UPE	UNION SA	UNION EM-O	CIVIC CENTER EM-I	CIVIC CENTER UPE	CIVIC CENTER SA	CIVIC CENTER EM-O	5TH./HILL EM-I	5TH./HILL UPE	5TH./HILL SA	5TH./HILL EM-O	7TH./FLOWER METRO RAIL EM-I	METRO RAIL UPE	METRO RAIL SA	METRO RAIL EM-O	7TH./FLOWER LB-LA LRT EM-I	LB-LA LRT TE-I	LB-LA LRT OTE	LB-LA LRT TE-O	LB-LA LRT EM-O
84+50	99+00	YL	PORTAL	E	E		E	E	E		E	E			E	E	E		E					
		YL	UNION	S			S	S			S	S			S	S			S					
		YR	PORTAL	E	E		E	E	E		E	E	E		E	E	E		E					
		YR	UNION	S			S	S			S	S			S	S			S					
92+00	99+00	AL	EXIT AT EL MONTE STUB	E	E		E	E	E		E	E	E		E	E	E		E					
		AL	UNION	S			S	S			S	S			S	S			S					
		AR	EXIT AT ELMONTE STUB	E	E		E	E	E		E	E	E		E	E	E		E					
		AR	UNION	S			S	S			S	S			S	S			S					
99+00	103+00	AR/AL	UNION	E			S	S			S	S			S	S			S					
UNION		AR/AL	STATION EXITS	E	E		E																	
107+50	112+50	AR/AL	UNION	S			E	E	E		E	E	E		E	E	E		E					
112+50	146+50	AL	UNION	S			S	E	E		E	E	E		E	E	E		E					
		AL	CIVIC CENTER	E	E		E	S			S	S			S	S			S					
		AR	UNION	S			S	E	E		E	E	E		E	E	E		E					
		AR	CIVIC CENTER	E	E		E	S			S	S			S	S			S					
CIVIC CENTER		AR/AL	STATION EXITS					E	E		E													
152+00	170+00	AL	CIVIC CENTER	S			S	S			S	E	E		E	E	E		E					
		AL	5TH./HILL	E	E		E	E	E		E	S			S	S			S					
		AR	CIVIC CENTER	S			S	S			S	E	E		E	E	E		E					
		AR	5TH./HILL	E	E		E	E	E		E	S			S	S			S					
5TH./HILL		AR/AL	STATION EXITS									E	E		E									
178+00	199+50	AL	5TH./HILL					S			S	S			S	E	E		E	E				E
		AL	7TH./FLOWER					E	E		E	E	E		E	S			S	S	S		S	S
		AR	5TH./HILL					S			S	S			S	E	E		E	E				E
		AR	7TH./FLOWER					E	E		E	E	E		E	S			S	S	S		S	S
7TH/FLOWER		AR/AL	STATION EXITS													E	E		E	S	S		S	S
* 4+61	8+38	—	STATION EXITS													S			S	E	E		S	S
* LRT STATION		—	STATION EXITS													S			S	E	E		E	E
* 11+18	37+80	—	PORTAL													E	E		E	E	E		E	E
* 11+18	37+80	—	STATION EXITS													S			S	S	S		S	S
206+00	254+00	AL	7TH./FLOWER									S			S	S			S	S	S		S	S
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254+00	259+00	AR/AL	WILSHIRE/ALVARADO									E	E		E	E	E		E					
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264+00	313+50	AL	WILSHIRE/ALVARADO													S			S					
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396+50	400+00	AR/AL	WILSHIRE/CRENSHAW																					
WILSHIRE/CRENSHAW		AR/AL	STATION EXITS																					
405+00	435+00	AL	WILSHIRE/CRENSHAW																					
		AL	WILSHIRE/LA BREA																					
		AR	WILSHIRE/CRENSHAW																					
		AR	WILSHIRE/LA BREA																					

DISABLED TRAIN LOCATION BETWEEN STA.	STA.	TRACK	EVACUATION DIRECTION TOWARDS:	WILSHIRE/ALVARADO EM-I	WILSHIRE/ALVARADO UPE	WILSHIRE/ALVARADO SA	WILSHIRE/ALVARADO EM-O	WILSHIRE/VERMONT EM-I	WILSHIRE/VERMONT UPE	WILSHIRE/VERMONT SA	WILSHIRE/VERMONT EM-O	WILSHIRE/NORMANDIE EM-I	WILSHIRE/NORMANDIE UPE	WILSHIRE/NORMANDIE SA	WILSHIRE/NORMANDIE EM-O	WILSHIRE/WESTERN EM-I	WILSHIRE/WESTERN UPE	WILSHIRE/WESTERN SA	WILSHIRE/WESTERN EM-O	WILSHIRE/CRENSHAW EM-I	WILSHIRE/CRENSHAW UPE	WILSHIRE/CRENSHAW SA	WILSHIRE/CRENSHAW EM-O	MID TUN'L MTI-L	MID TUN'L MTI-R	WILSHIRE/LA BREA EM-I	WILSHIRE/LA BREA UPE	WILSHIRE/LA BREA SA	WILSHIRE/LA BREA EM-O
84+50	99+00	YL	PORTAL																										
		YL	UNION																										
		YR	PORTAL																										
		YR	UNION																										
92+00	99+00	AL	EXIT AT EL MONTE STUB																										
		AL	UNION																										
		AR	EXIT AT ELMONTE STUB																										
		AR	UNION																										
99+00	103+00	AR/AL	UNION																										
UNION		AR/AL	STATION EXITS																										
107+50	112+50	AR/AL	UNION																										
112+50	146+50	AL	UNION																										
		AL	CIVIC CENTER																										
		AR	UNION																										
		AR	CIVIC CENTER																										
CIVIC CENTER		AR/AL	STATION EXITS																										
152+00	170+00	AL	CIVIC CENTER																										
		AL	5TH./HILL																										
		AR	CIVIC CENTER																										
		AR	5TH./HILL																										
5TH./HILL		AR/AL	STATION EXITS																										
178+00	199+50	AL	5TH./HILL	E	E		E																						
		AL	7TH./FLOWER	S			S																						
		AR	5TH./HILL	E	E		E																						
		AR	7TH./FLOWER	S			S																						
7TH/FLOWER		AR/AL	STATION EXITS																										
* 4+61	8+38	—	STATION EXITS																										
* LRT STATION		—	STATION EXITS																										
* 11+18	37+80	—	PORTAL																										
* 11+18	37+80	—	STATION EXITS																										
206+00	254+00	AL	7TH./FLOWER	E	E		E	E	E		E																		
		AL	WILSHIRE/ALVARADO	S			S	S			S																		
		AR	7TH./FLOWER	E	E		E	E	E		E																		
		AR	WILSHIRE/ALVARADO	S			S	S			S																		
254+00	259+00	AR/AL	WILSHIRE/ALVARADO	E			S	S			S																		
WILSHIRE/ALVARADO		AR/AL	STATION EXITS	E	E		E																						
264+00	313+50	AL	WILSHIRE/ALVARADO	S			S	E	E		E	E	E		E														
		AL	WILSHIRE/VERMONT	E	E		E	S			S	S			S														
		AR	WILSHIRE/ALVARADO	S			S	E	E		E	E	E		E														
		AR	WILSHIRE/VERMONT	E	E		E	S			S	S			S														
WILSHIRE/VERMONT		AR/AL	STATION EXITS					E	E		E																		
319+00	345+50	AL	WILSHIRE/VERMONT	S			S	S			S	E	E		E	E	E		E										
		AL	WILSHIRE/NORMANDIE	E	E		E	E	E		E	S			S	S			S										
		AR	WILSHIRE/VERMONT	S			S	S			S	E	E		E	E	E		E										
		AR	WILSHIRE/NORMANDIE	E	E		E	E	E		E	S			S	S			S										
WILSHIRE/NORMANDIE		AR/AL	STATION EXITS									E	E		E														
350+50	367+50	AL	WILSHIRE/NORMANDIE					S			S	S			S	E	E		E	E	E		E						
		AL	WILSHIRE/WESTERN					E	E		E	E	E		E	S			S	S			S						
		AR	WILSHIRE/NORMANDIE					S			S	S			S	E	E		E	E	E		E						
		AR	WILSHIRE/WESTERN					E	E		E	E	E		E	S			S	S			S						
WILSHIRE/WESTERN		AR/AL	STATION EXITS													E	E		E										
373+00	396+50	AL	WILSHIRE/WESTERN									S			S	S			S	E	E		E	E	E				
		AL	WILSHIRE/CRENSHAW									E	E		E	E	E		E	S			S	S	S				
		AR	WILSHIRE/WESTERN									S			S	S			S	E	E		E	E	E				
		AR	WILSHIRE/CRENSHAW									E	E		E	E	E		E	S			S	S	S				
396+50	400+00	AR/AL	WILSHIRE/CRENSHAW									E	E		E	E	E		E	E			S	S	S				
WILSHIRE/CRENSHAW		AR/AL	STATION EXITS																	E	E		E						
405+00	435+00	AL	WILSHIRE/CRENSHAW													S			S	S			S	E	S	E	E		E
		AL	WILSHIRE/LA BREA													E	E		E	E	E		E	S	S	S			S
		AR	WILSHIRE/CRENSHAW													S			S	S			S	S	E	E	E		E
		AR	WILSHIRE/LA BREA													E	E		E	E	E		E	S	S	S			S

* DENOTES FLOWER STREET SUBWAY.

DAMPER OPERATION

DESIGNATION	LOCATION/FUNCTION/OPERATION
BYPASS DAMPERS	- LOCATED IN CLOSE PROXIMITY TO EMERGENCY OR MID-TUNNEL FANS.
	- NORMALLY OPEN TO AFFECT EXCHANGE OF TUNNEL AND OUTSIDE AIR. ALLOWS SUCH AIR TO "BYPASS" ADJACENT FANS OR FAN ROOMS.
	- IN AN EMERGENCY, WHEN MID-TUNNEL OR EMERGENCY FANS ARE ACTIVATED, BYPASS DAMPERS SHALL CLOSE AUTOMATICALLY.
	- IN CASE OF POWER OR CONTROL SIGNAL FAILURE, BYPASS DAMPERS SHALL "FAIL SAFE" IN THE CLOSED POSITION.
FAN DAMPERS	- ATTACHED TO FAN OR ITS INTERCONNECTING DUCTWORK OR SILENCER.
	- NORMALLY CLOSED SO AS TO ISOLATE THE FANS FROM THE FLOW OF TUNNEL OR OUTSIDE AIR. ALWAYS CLOSED WHEN THE FAN TO WHICH IT IS CONNECTED IS INOPERATIVE.
	- IN AN EMERGENCY, WHEN FAN IS ACTIVATED, FAN DAMPER OPENS AUTOMATICALLY.
	- IN CASE OF POWER OR CONTROL SIGNAL FAILURE, FAN DAMPERS SHALL "FAIL SAFE" IN THE OPEN POSITION, PROVIDED ITS RESPECTIVE FAN IS OPERATIVE.
TRACK DAMPERS	- LOCATED AT THE INTERFACE BETWEEN TRACKWAY AND FAN ROOM.
	- NORMALLY OPEN TO RELIEF TRAIN-PISTON-ACTION-GENERATED AIR PRESSURE FROM ONE TRAINWAY TO ADJACENT TRAINWAY.
	- WHEN EMERGENCY FANS ARE ACTIVATED, TRACK DAMPER NEAREST AFFECTED TRAINWAY OPENS AND OTHER TRACK DAMPER CLOSES.
	- WHEN THIRD MID-TUNNEL FAN IN ANY FAN ROOM IS ACTIVATED IN AN EMERGENCY, TRACK DAMPER CONNECTING TO AFFECTED TRAINWAY OPENS, OTHER TRACK DAMPER CLOSES.
	- IN CASE OF POWER OR CONTROL SIGNAL FAILURE, TRACK DAMPERS SHALL "FAIL SAFE" IN THE OPEN POSITION.

LEGEND

E	EXHAUST MODE
S	SUPPLY MODE
EM-I	EMERGENCY VENTILATION SHAFT ON THE INBOUND SIDE OF A STATION.
EM-O	EMERGENCY VENTILATION SHAFT ON THE OUTBOUND SIDE OF A STATION.
TE-I	TUNNEL EXHAUST SHAFT ON THE INBOUND SIDE OF LRT STATION.
TE-O	TUNNEL EXHAUST SHAFT ON THE OUTBOUND SIDE OF LRT STATION.
MT1-L	INTAKE OF MID-TUNNEL VENTILATION SHAFT NO. 1 CLOSE TO AL TRACK.
MT3-R	INTAKE OF MID-TUNNEL VENTILATION SHAFT NO. 1 CLOSE TO AR TRACK.
SA	SUPPLY AIR FAN.
UPE	UNDER PLATFORM EXHAUST FAN.
OTE	OVERHEAD TRACK EXHAUST FAN.

FIGURE 3.4

THE PREPARATION OF THIS DRAWING HAS BEEN FINANCED IN PART THROUGH A GRANT FROM THE U. S. DEPARTMENT OF TRANSPORTATION, URBAN MASS TRANSPORTATION ADMINISTRATION, UNDER THE URBAN MASS TRANSPORTATION ACT OF 1964, AS AMENDED, AND IN PART BY THE TAXES OF THE CITIZENS OF LOS ANGELES COUNTY AND OF THE STATE OF CALIFORNIA

REV.	DATE	BY	SUB.	APP.	DESCRIPTION

DESIGNED BY J. A. GONZALEZ
DRAWN BY N. KORKIDIS
CHECKED BY W. W. METSCH
IN CHARGE K. V. SAIN
DATE 1-10-86

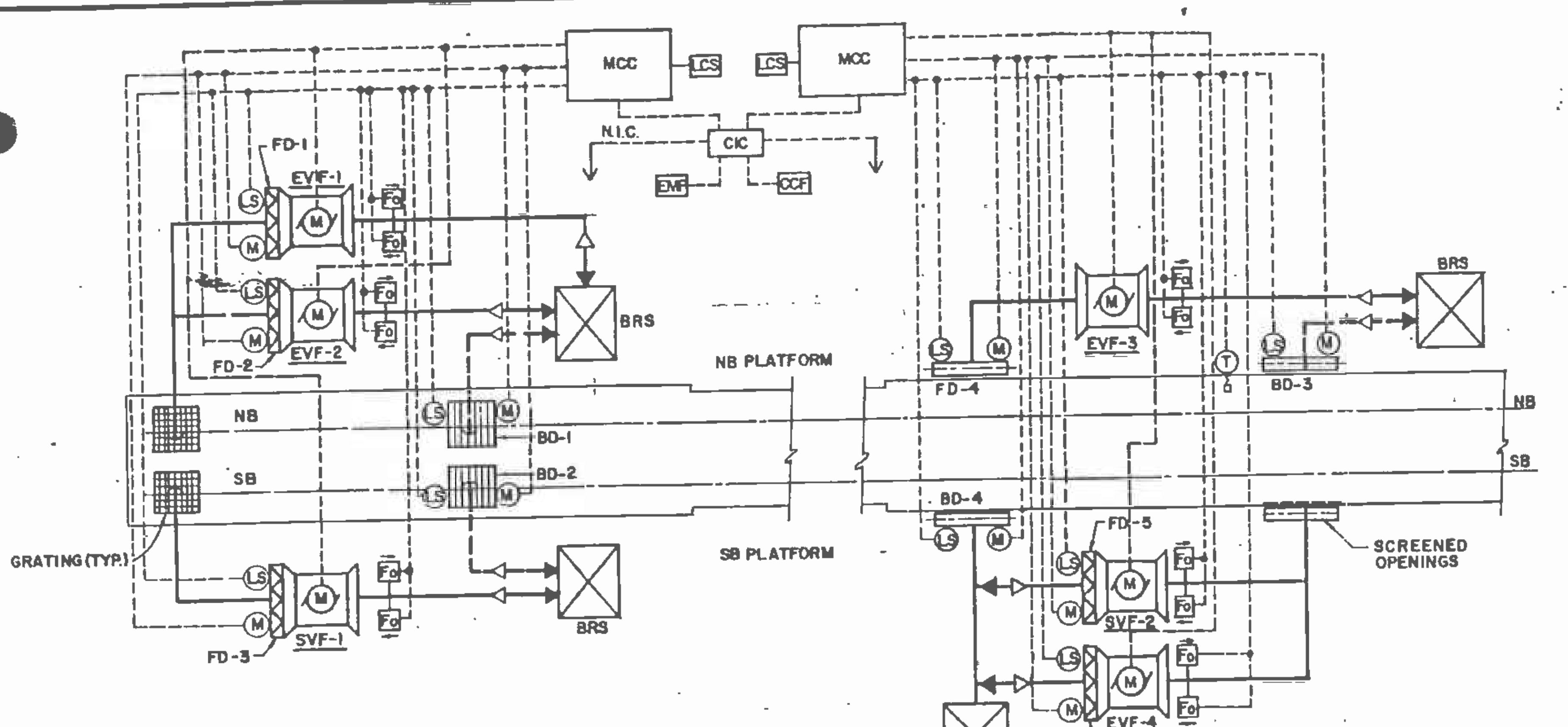
SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT
METRO RAIL PROJECT
RTD

DMJM/PBQD/KE/HWA
A JOINT VENTURE
GENERAL CONSULTANTS

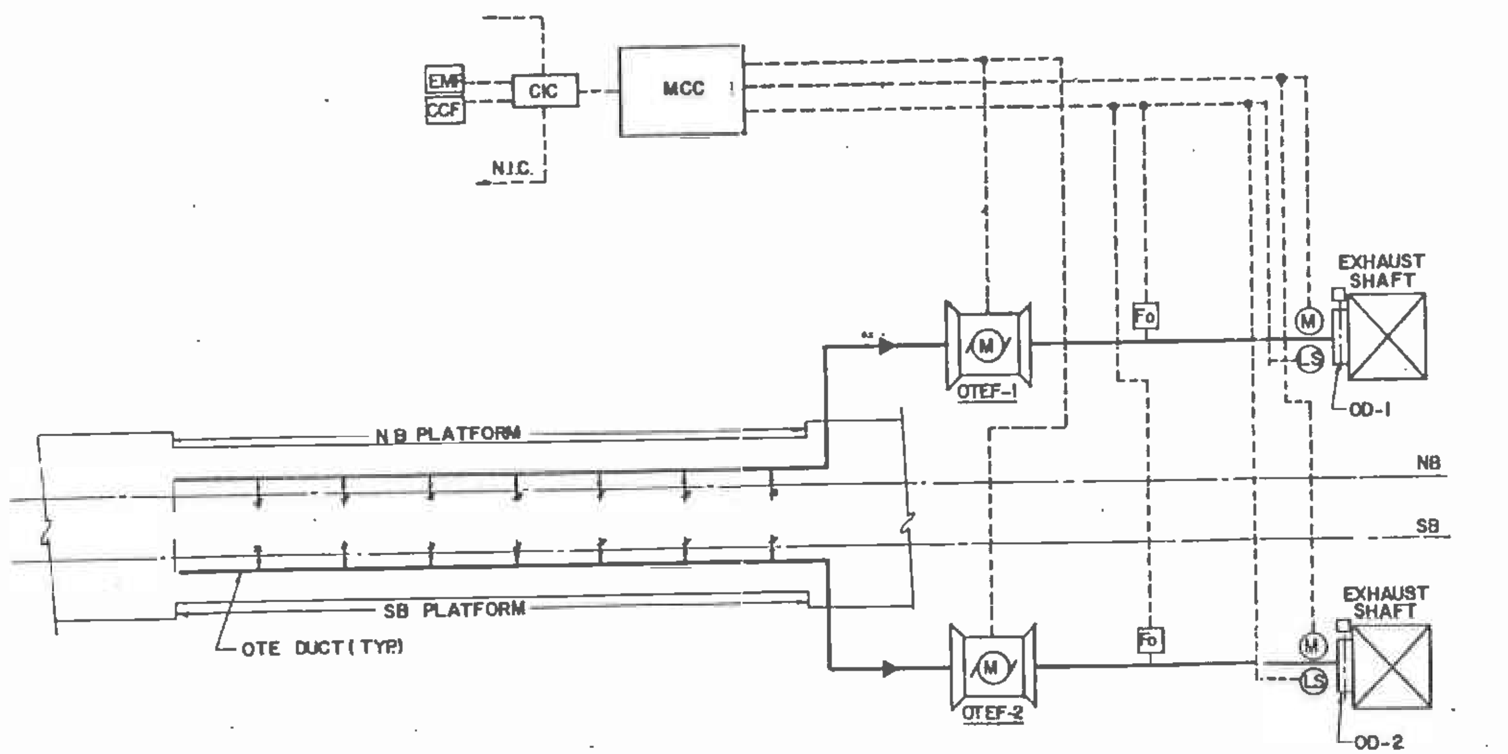
SUBMITTED ______ APPROVED ______

EMERGENCY VENTILATION OPERATING PROCEDURES

CONTRACT NO.
DRAWING NO. REV.
SCALE: NONE
SHEET NO. 1 OF 2



EVF & SVF CONTROL DIAGRAM



OTEF CONTROL DIAGRAM

SEQUENCE OF OPERATION

FAN CONTROL

MANUAL: SUBWAY VENT FANS (SVF), EMERGENCY FANS (EVF) AND OTE FANS SHALL BE STARTED AND STOPPED INDIVIDUALLY FROM CCF, MCC OR EMP.
SVF AND EVF OPERATIONAL MODE (SUPPLY OR EXHAUST) SHALL ALSO BE CONTROLLED FROM CCF, MCC OR EMP. FOR LOCAL CONTROL AND TEST PURPOSES, FANS CAN BE CONTROLLED FROM LOCAL CONTROL STATION (LCS).

PREPROGRAMMED: FANS AND DAMPERS SHALL BE CONTROLLED FROM CCF BY PREPROGRAMMED EMERGENCY SCENARIO.

DAMPER CONTROL

MANUAL: DAMPERS CAN BE MANUALLY OPENED AND CLOSED FROM MCC AND LCS.

AUTOMATIC: DAMPERS SHALL BE ELECTRICALLY INTERLOCKED WITH THEIR RESPECTIVE FAN, SEE TABLE BELOW.

FAN	OPERATION	DAMPER	POSITION
SVF OR EVF	ON	TD OR FD	OPEN
		BD	CLOSED
SVF OR EVF	OFF	TD OR FD	CLOSED
		BD	OPEN
OTE	ON	OD	OPEN
OTE	OFF	OD	CLOSED

FAIL SAFE POSITION OF DAMPERS:
DAMPERS WILL BE SPRING LOADED. IN CASE OF POWER FAILURE, FAN AND TRACK DAMPERS SHALL OPEN AND BY-PASS DAMPERS SHALL CLOSE.

OPERATION

NORMAL: EMERGENCY FANS ARE OFF.
SUBWAY VENT FANS SHALL BE CONTROLLED MANUALLY FROM CCF TO PROVIDE VENTILATION FOR SUBWAY TEMPERATURE CONTROL.
OTE FANS SHALL RUN CONTINUOUSLY.

EMERGENCY: EMERGENCY FANS & SUBWAY VENT FANS SHALL BE OPERATED BY PREPROGRAMMED EMERGENCY SCENARIO FROM CCF OR BY MANUAL CONTROL FROM CCF OR EMP.

MONITORING

FAN / DAMPER	OPERATION / POSITION	INDICATION IN CCF	MCC	LCS	EMP
SVF, EVF	RUN-EXHAUST	YES	YES	YES	YES
SVF, EVF	RUN-SUPPLY	YES	YES	YES	YES
OTEF	RUN-EXHAUST	YES	YES	YES	YES
TD, BD	OPEN/CLOSE	YES	NO	YES	NO
OD	OPEN/CLOSE	NO	NO	YES	NO
SUBWAY TEMPERATURE		YES	NO	NO	NO
FAN MOTOR HIGH TEMPERATURE		YES	YES	NO	NO
EXCESS FAN VIBRATION		NO	YES	NO	NO
EXCESSIVE CURRENT DEMAND		NO	YES	NO	NO
LOSS OF CURRENT IN ANY PHASE		NO	YES	NO	NO
TROUBLE STATUS SIGNAL		YES	NO	YES	YES
FLOW SWITCH POSITION		YES	NO	NO	YES

NOTES

1. PROVIDE NUMBER OF DAMPER MOTORS AS REQUIRED FOR PROPER DAMPER ACTION AND CONNECT DAMPER MOTORS IN PARALLEL, FOR EACH DAMPER ASSEMBLY.
2. FOR WIRING DIAGRAMS SEE ELECTRICAL DRAWINGS.
3. ELECTRICAL CONTROLS SHALL INCLUDE TIMERS TO PREVENT REVERSING OF ROTATION OF FAN FOR PERIOD OF 10 SECONDS. (APPLY TO SVF & EVF ONLY.)
4. PROVIDE DAMPER ACTUATED LIMIT SWITCHES (2) ON EACH SECTION OF EACH DAMPER FOR POSITIVE INDICATION OF FULL OPEN OR FULL CLOSED POSITION. SWITCHES SHALL BE CONNECTED IN SERIES TO PROVIDE SINGLE INDICATION FOR THE DAMPER ASSEMBLY.

LEGEND

BD	BY-PASS DAMPER
CCF	CENTRAL CONTROL FACILITY
CIC	SUPERVISORY CONTROL INTERFACE CABINET
EVF	EMERGENCY VENT FAN
EMP	EMERGENCY MANAGEMENT PANEL
LCS	LOCAL CONTROL STATION
NB	NORTHBOUND
MCC	MOTOR CONTROL CENTER
OD	OVERHEAD TRAINWAY EXHAUST FAN DAMPER
OTEF	OVERHEAD TRAINWAY EXHAUST FAN
SB	SOUTHBOUND
TD	TRACK DAMPER
SVF	SUBWAY VENT FAN
Fo	FLOW SWITCH
LS	LIMIT SWITCH ACTUATED BY DAMPER
M	MOTOR
M	DAMPER OPERATOR
T	REMOTE BULB TYPE THERMOSTAT
FD	FAN DAMPER

THE PREPARATION OF THIS DRAWING HAS BEEN FINANCED IN PART THROUGH A GRANT FROM THE U. S. DEPARTMENT OF TRANSPORTATION, URBAN MASS TRANSPORTATION ADMINISTRATION, UNDER THE URBAN MASS TRANSPORTATION ACT OF 1964, AS AMENDED, AND IN PART BY THE TAXES OF THE CITIZENS OF LOS ANGELES COUNTY AND OF THE STATE OF CALIFORNIA

DESIGNED BY
DRAWN BY R.J. [signature]
CHECKED BY
IN CHARGE
DATE

SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT
METRO RAIL PROJECT
RTD

DMJM/PBQD/KE/HWA
A JOINT VENTURE
GENERAL CONSULTANTS

LA CBD TO NORTH HOLLYWOOD
7TH/FLOWER STATION

ECS CONTROL DIAGRAMS
HVAC

CONTRACT NO.
DRAWING NO. M-209
REV.
SCALE
SHEET NO. 93

ECS SUMMARY REPORT	JOB NO. A165/167	SHEET NO. 1 OF 1	7TH/FLOWER INTEGRATED STATION:
OCTOBER 1986	DESIGNED BY MRTC	DATE 10-21-86	ECS EMERGENCY DOOR PRESSURE ANALYSIS
ATTACHMENT	APPROVED RK	NTS	

ASSUMPTIONS:

1. DOORS ARE 46" WIDE x 84" HIGH.
2. DOORS OPEN OUTWARD AND USE INDUSTRY STANDARD HARDWARE AND CLOSERS.
3. FAN SUPPLY MODE PRESSURE IS 1.0 PSF. FAN EXHAUST MODE SUCTION IS 1.45 PSF.
4. SUM OF MOMENT (TORQUE) ABOUT ROLLER IS ZERO. ($\Sigma M_R = 0$)

ANALYSIS:

BALANCED DOORS REQUIRE LESS CLOSER FORCE TO CLOSE WHEN ECS IN "SUPPLY" MODE; AND LESS PUSH FORCE TO OPEN WHEN ECS IN "EXHAUST" MODE (SEE FIG. 1).

a. AT PRESSURE OF 1.0 PSF IN SUPPLY MODE, THE CLOSER FORCE TO KEEP THE DOOR CLOSED IS:

$$\Sigma M = 0 = \left[1.0 \times \frac{29\tfrac{3}{4} \times 84}{144''} \times 14\tfrac{7}{8}''\right] - \left[1.0 \times \frac{16\tfrac{1}{4} \times 84}{144} \times 8\tfrac{1}{8}''\right] - \left[C_F \times 8\tfrac{11}{16}''\right]$$

$$\text{CLOSER FORCE} = C_F = \frac{[258 - 77]\ \text{IN·LB}}{8\tfrac{11}{16}''} = \underline{20.8\ \text{LBf}}$$

b. AT SUCTION OF 1.45 PSF IN EXHAUST MODE, THE PUSH FORCE (P_F) TO SET THE DOOR IN MOTION IS:

$$\Sigma M = 0 = P_F \times 28\tfrac{1}{2}'' + \left[1.45 \times \frac{16\tfrac{1}{4} \times 84}{144} \times 8\tfrac{1}{8}''\right] - \left[1.45 \times \frac{29\tfrac{3}{4} \times 84}{144''} \times 14\tfrac{7}{8}''\right] - 20.8(C_F) \times 8\tfrac{1}{8}''$$

$$\text{PUSH FORCE} = P_F = -\frac{[111.7 - 374.3 - 180.7]\ \text{IN·LB}}{28\tfrac{1}{2}''} = \underline{15.63\ \text{LBf}}$$

THE MAX. FORCE REQUIRED TO SET THE DOOR IN MOTION IS 15.63 LBf.

ACCORDING TO NFPA LIFE SAFETY CODE 101-10, SECTION 5-2.1.4.3 THE FORCES REQUIRED TO SET THE DOOR IN MOTION SHALL NOT EXCEED 30 LBf

$P_F = 15.63\ \text{LBf} < 30\ \text{LBf}$ ∴ Q.E.D.

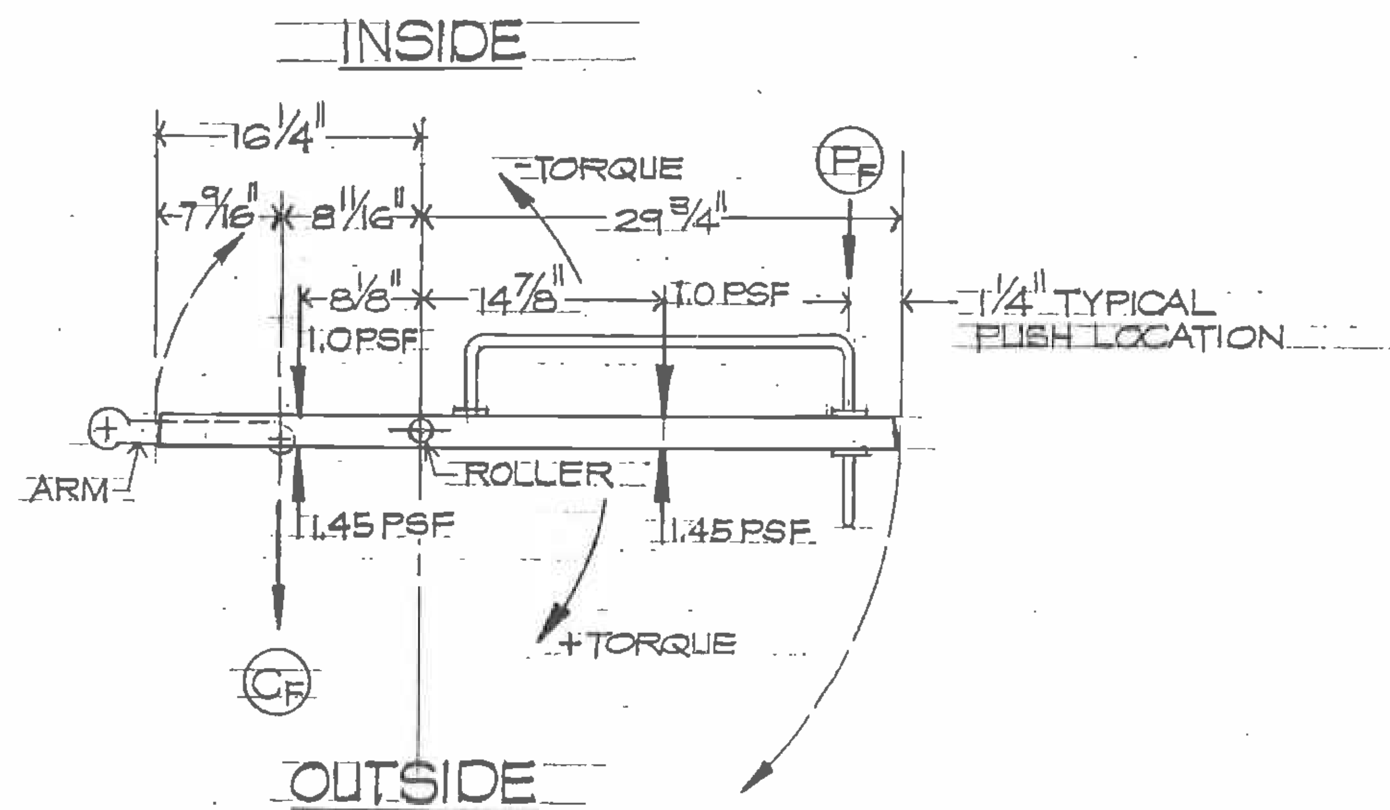


FIGURE - 1

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Flower Street Subway Segment

Special Study/Support Task 104A

Environmental Control System (ECS) Concept Study

November 1, 1985

Prepared by

Parsons Brinckerhoff Quade & Douglas, Inc.

New York, N.Y.

Prepared for

Metro Rail Transit Consultants

Los Angeles, California

LB-LA RAIL TRANSIT PROJECT
Flower Street Subway Segment
Special Study/Support Task 104A

Environmental Control System (ECS) Concept Study

November 1, 1985

1.0 INTRODUCTION

This report describes the analyses and results from a study of the proposed Environmental Control System (ECS) for the Flower Street Subway Segment under normal and emergency operating conditions. The analyses have been performed by applying the Subway Environment Simulation (SES) computer program.

The purpose of this study was to evaluate the ability of the proposed ECS concept to:

- o Provide sufficient ventilation during a subway fire to control the spread of smoke while examining the impact of the various entrance configurations being considered.
- o Meet station air temperature (89°F), station air velocity (1,200 fpm, maximum) and air pressure change (2.8 in. wg) criteria during normal operations.
- o Purge the subway in the event that the presence of methane gas is detected.

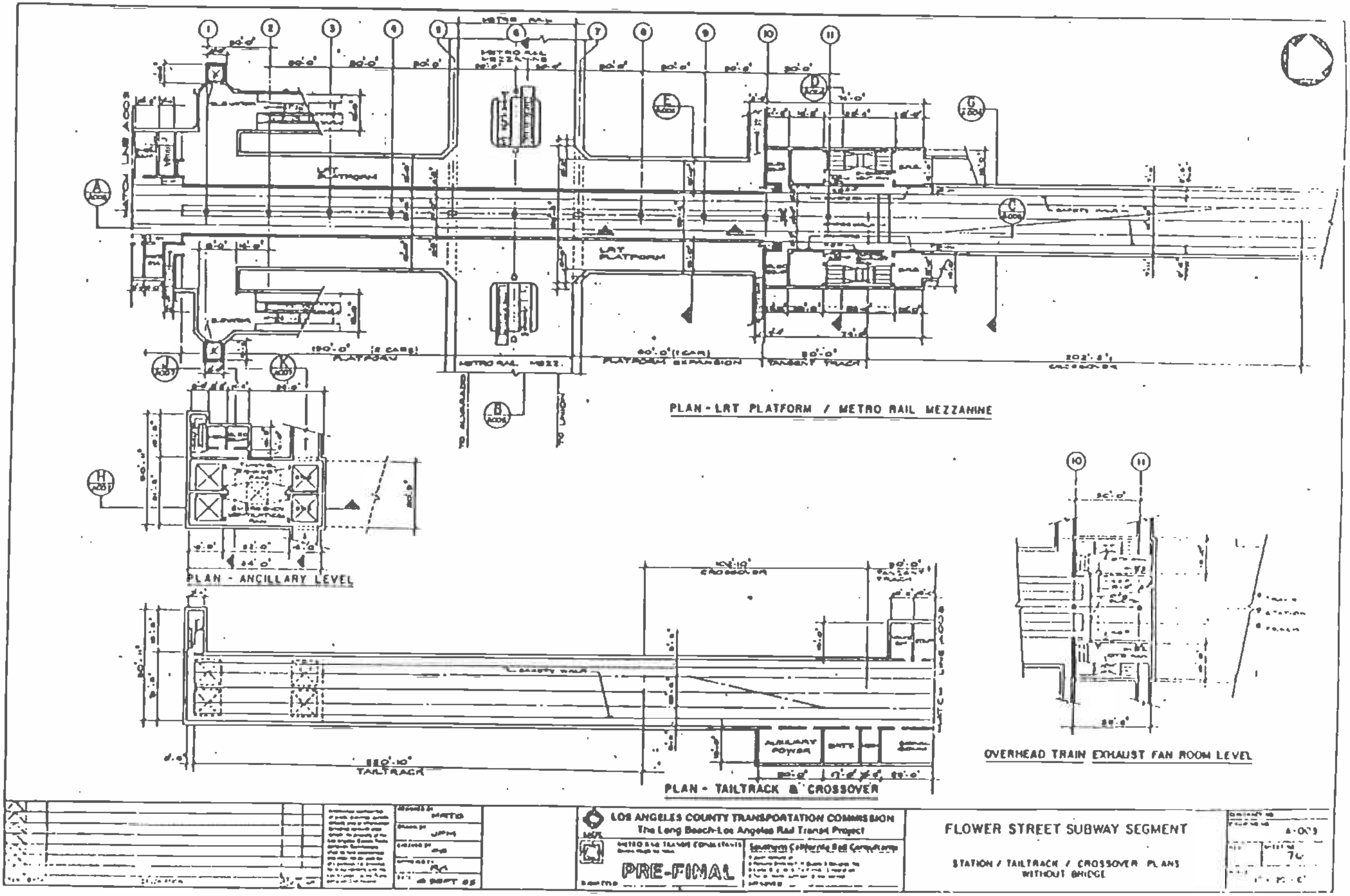
2.0 BACKGROUND

The underground section of alignment alternative LA-2 consists of a cut-and-cover subway section and one station initially. The cut-and-cover subway extends approximately 2,600 feet from the portal near 11th Street and proceeds in a north-south direction under Flower Street.

The general arrangement of the station, the approach subway and the tail-track north of the station is shown on Figure 1.

The location of the ventilation shafts (two shafts at the south end of the station and two at the north end of the tail-track) is also shown.

The station is an integrated two-level structure and serves as a transfer point between the LRT and Metro Rail transit lines. The LRT platform is at the mezzanine level and the Metro Rail platform is one level below.


PLAN - LRT PLATFORM / METRO RAIL MEZZANINE
METRO RAIL MEZZANINE
LRT PLATFORM
LRT PLATFORM
PLATFORM
METRO RAIL MEZZ.
PLATFORM EXPANSION
TANGENT TRACK
CROSSOVER
PLAN - ANCILLARY LEVEL
PLAN - TAILTRACK & CROSSOVER
TAILTRACK
CROSSOVER
AUXILIARY POWER
OVERHEAD TRAIN EXHAUST FAN ROOM LEVEL
LOS ANGELES COUNTY TRANSPORTATION COMMISSION
The Long Beach-Los Angeles Rail Transit Project
Southern California Rail Consultants
PRE-FINAL
FLOWER STREET SUBWAY SEGMENT
STATION / TAILTRACK / CROSSOVER PLANS
WITHOUT BRIDGE

Access between the mezzanine and the Metro Rail platform is provided by four escalator/stairways. Metro Rail will build two entrances leading from the mezzanine level to the surface: an east entrance at 7th and Hope Street; and a west entrance at 7th and Figueroa Street. Additional entrances providing direct access to the LRT platforms have been proposed. Currently, six alternative configurations are under consideration. As described in Reference 1, these alternatives consist of providing either two, one, or no additional entrances in combination with or without a bridge connecting the LRT platforms.

3.0 ENVIRONMENTAL CONTROL SYSTEM (ECS) CONCEPT

The subsurface LRT station(s) will not be air conditioned. Control of environmental conditions (air temperature, air velocity, air pressure, smoke removal, etc.) in the station(s) and subway line sections will be provided by the following systems:

- Overhead Track Exhaust (OTE) System: Consists of ducts and exhaust grilles, over each platform edge and two vaneaxial exhaust fans, one per trackway, to capture heat released by the braking resistors and air-conditioning condensers located on the LRT vehicle roof top. The heat captured is discharged outdoors via two OTE shafts, one at each end of a station. The fans will be rated for an ambient operating temperature of 300°F, since the OTE system may be used to supplement the emergency ventilation system capability.

- Blast and Relief Shafts: A blast shaft and a relief shaft are located south of the station and at the north end of the tail track (4 shafts, total). Blast shafts provide a means for expelling air from the system with an approaching train and relief shafts provide a means for drawing outside air into the system in the wake of a train. The shafts also provide an intake path for some of the make-up air exhausted by the OTE system.

- Subway Exhaust Fans: Two axial, reversible fans will be provided, one at each end of the station. The fans will be selected to provide approximately 65 percent of the exhaust capacity when operating in the supply mode. Each fan will be connected to a blast shaft. These fans can be activated periodically to exhaust heat from the subway, to purge methane gas, or to purge smoke or supply outside air to the system during a fire. The fans will be rated for an ambient operating temperature of 300°F.

- Emergency Ventilation Fans: Two axial, reversible fans will be provided, one at each end of the station. The fans will be of special design and ~~should~~ will be specified to 90 percent of the exhaust capacity when operating in the supply mode. Each fan will be connected to a relief shaft. These fans will be activated during a fire emergency to purge smoke or to supply outside air to the system. These fans will also be rated for an ambient temperature of 300°F.

- Track and Bypass Dampers: Each ventilation shaft is provided with one track and one bypass damper to control air flow through the shaft. Normally, the bypass damper is open to allow piston air flow through the shaft and the track damper is closed to isolate the fan (i.e., emergency or exhaust fan) from the airstream. When a fan is activated, the bypass damper is closed and the track damper is opened. In this mode, the air flow "circuit" is through the track damper, the fan and through the shaft.

The functional requirements and the controls for each of the above systems are more fully described in References 2 and 3. Tentative equipment capacities are also presented in the Mechanical Design Criteria (Ref. 2), subject to change based on the findings reported herein.

4.0 INPUT DATA

The following information has been used in the computer simulations described herein:

- System Geometry: Station and tunnel dimensions, entrance configurations and tunnel alignment, as shown on Pre-Final Flower Street Subway Segment drawings, dated September 16, 1985, have been modelled. Data for the section of the Metro Rail modelled were taken from in-progress drawings for Contract A-167 which were obtained from MRTC in February, 1985.

- Outdoor Temperature: 84°F dry bulb at 5:00 P.M. (based on 5 percent frequency of occurrence)

- Ventilation System: This consists of four reversible axial fans with a nominal capacity of 150,000 cfm each. The proposed fan capacities were used as the starting point in this study. Two of the fans are of special design and can deliver 90 percent of the exhaust air flow rate when operating in the supply mode. The remaining fans are conventional axial fans and can deliver approximately 65 percent of the exhaust flow rate when reversed. One of each of the above fan types (total of two fans) is located at the tail-track and the other pair of fans is located at the south end of the LRT station.

o OTE System:

- Capacity: Two fans at 50,000 cfm each (per Reference 2.)

- Heat Capture Efficiency: 65 percent of the heat released by the roof-mounted braking resistors and air-conditioning condensers of the LRT vehicles is captured by the OTE. This value has been assumed based on information contained in Reference 6 which indicates that the above value can be achieved by an underplatform exhaust (UPE) system. Since warm air rises, the OTE system should be at least as effective, if not more so.

o Vehicle Data:

- Frontal Area: 90 sq ft
(Note: Data for a number of LRV's were reviewed and the frontal area was found to range between 80 and 88 sq ft)

- Length: 90 ft per car (per vehicle procurement specifications).

- Weight Per Car: 45 tons per empty car and 59.2 tons with 76 passengers (AW1 weight).(Per vehicle procurement specifications)

- Propulsion System: (assumed by PBQ&D)
Chopper controlled vehicle with four traction motors (Westinghouse, type 1462) per car, with no regeneration capability.

- Braking Resistors: (assumed by PBQ&D)
Roof-mounted, natural convection braking resistors were used.

- Air-Conditioning Capacity: 20 tons per car (installed capacity per information received from MRTC). However, PBQ&D used an average value of 14 tons.

o LRT Train Operations: (per MRTC)

- Headway: 3-car trains operating on a peak 6-minute headway.

- Turn-Back Time: 11 minutes (average)

o Tunnel Cross-sectional Area:

- Two-Cell Box: 428 sq ft (w/perforated dividing wall).

(Note: Scale model tests (Ref. 4) indicate that a tunnel behaves aerodynamically like an undivided tunnel when the percentage of open area in the dividing wall is 5 percent or more. For this project, the openings comprise about 30 percent of the dividing wall.)

- Blockage Ratio: 0.210
  (Note: Blockage ratio is defined as the ratio of the train frontal area to tunnel cross-sectional area)

- Fire Heat Release Rate: A value of 85.3 million Btu/hr has been used. Assumptions and calculation method are shown in Appendix A.

- Number of Trains in Incident Tunnel: One 3-car train was assumed to be in the incident tunnel during a fire. However, some simulations were performed with additional trains stopped in the LRT station and in the tail-tracks; but the effect on subway ventilation was found to be negligible, because of the low blockage ratio (i.e., the ratio of the train frontal area and the tunnel area.)

5.0 EMERGENCY VENTILATION

As previously noted, six alternative configurations for additional station entrances are under consideration. The total number of "openings" at the Flower Street Station (i.e., either entrances leading to street level or escalator/stairways leading to the Metro Rail platform) will have an impact on the ability to ventilate the subway section between the LRT station and the portal during a fire emergency. An additional air flow path is introduced with each "opening," thereby reducing the air flow available for ventilating the "incident" subway section. Therefore, the ventilation system capacity must be increased to offset the air flow "lost" through each additional entrance. Determining the required increase in ventilation system capacity for a given number of entrances is the subject of this emergency ventilation study.

5.1 STUDY APPROACH

The Subway Environment Simulation (SES) computer program has been used to predict the subway air flows during fire conditions. This computer model accounts for the "throttling" effects of a fire (i.e., increased pressure losses), the buoyancy effects of the hot smoke which tends to flow "uphill," heat transfer to the tunnel walls by convection and radiation, and changes in the exhaust fans' performance while handling hot (i.e., less dense) gases.

The computer simulations focused on predicting the magnitude of the air velocity approaching a burning 3-car train stalled in a subway section. The magnitude of the approach velocity indicates whether the spread of smoke can be confined downstream of the fire site, thus protecting the upstream evacuation route, or whether the potential for smoke spreading contrary to the forced ventilation exists (a phenomenon called "back-layering"). To prevent back-layering, the approach air velocity must be greater than a "critical" value whose magnitude depends on the fire heat release rate, the tunnel grade, and the tunnel area.

For the subway line section south of the LRT station, the critical velocity is 515 feet per minute based on the open tunnel cross-section. This value has been calculated (see Appendix A) based on a 1.5 percent grade, a fire heat release rate of 85.3 million Btu/hr and the dimensions of the two-cell box structure with a perforated dividing wall. The above heat release rate corresponds to the heat output from two fully-involved cars with a combustible loading of 60 million Btu per car (Ref. 5). At the crossover and tail track tunnels north of the LRT station, required air velocities of 425 and 510 feet per minute, respectively, have been calculated based on the annulus area alongside the train. Note that in line sections without a dividing wall or with a solid dividing wall, the control point for halting the spread of smoke is the train/tunnel annulus. In line sections with a perforated dividing wall, the control point is the upstream end of the incident train since some of the air flow approaching the train will be diverted into the unoccupied trackway via the wall openings.

The area modelled encompassed the entire Flower Street Subway and the portion of the Metro Rail system between Wilshire/Alvarado and Fifth/Hill stations.

The SES program has been applied iteratively to determine the required fan capacity for a given station entrance configuration. When the results of a simulation predicted an approach air velocity below the required value with the proposed fan capacities (i.e., two 150,000 cfm fans at the tail-track and an equal capacity at the south end of the LRT station), then the fan capacities were increased and the simulation repeated until the required air velocity was reached or exceeded.

The starting point in this study was the case with two additional entrances, which is identified as Alternative B in Reference 1. This is the "worst case" with respect to subway ventilation for the reasons previously stated.

5.1.1 Emergency Scenarios Examined

Simulations have been performed for a fire incident occurring in the subway line section south of the LRT station, in the tail tracks north of the LRT station and within the station itself.

During a fire incident south of the LRT station, the conditions modelled are as shown in Figure 2. The incident train is assumed to be located at Sta. 17+90 and direction of ventilation is toward the portal. Therefore, all the fans (LRT and Metro Rail) are operated in the supply mode. This is considered a "worst case" because the ventilation is directed downgrade against the buoyant effect of the hot smoke.

North of the LRT station, two cases were considered. The first case examined the resulting conditions when the burning cars were located in one of the tail track tunnels where the trackways are separated by a solid dividing wall. In the second case, the burning cars were located at the crossover tunnel where there is no dividing wall. In both instances, the fans at the tail track were operated in the exhaust mode, while the fans at the south end of the LRT station and the Metro Rail fans were operated in supply mode.

If a train fire occurs in the LRT station, the ventilation concept is to draw in outside air through the entrances, sweeping it through the public area, and exhausting it through the ventilation shafts at both ends of the station. Hence in the station ventilation simulations, both fans at the tail track and both fans south of the station were operated in exhaust mode. The OTE system was not operated. Also, the Metro Rail fans were operated in supply mode. Note that the station ventilation simulations do not consider the thermal effects of a fire, since modelling fires in large "enclosures," such as a station, is beyond the capability of the SES computer program. However, the simulations performed do give a good estimate of the station ventilation rates which can be achieved.

5.2 EMERGENCY VENTILATION SIMULATION RESULTS

5.2.1 Fire Incident South of LRT Station

The results of the SES simulations modelling a fire incident south of the LRT station are summarized on Table 1. For each case tabulated, the number of additional station entrances, the nominal fan capacity used, the predicted approach air velocities with and without a fire, and the required air velocity to prevent back-layering are shown. Note that only three station entrance alternatives had to be evaluated, since the presence of a bridge between the LRT platforms will not affect subway ventilation.

The results indicate that the air velocity required for smoke control cannot be achieved with the current station configuration and with the proposed fan capacities (i.e., 150,000 cfm per fan) regardless of whether 2, 1, or no additional entrances are provided.

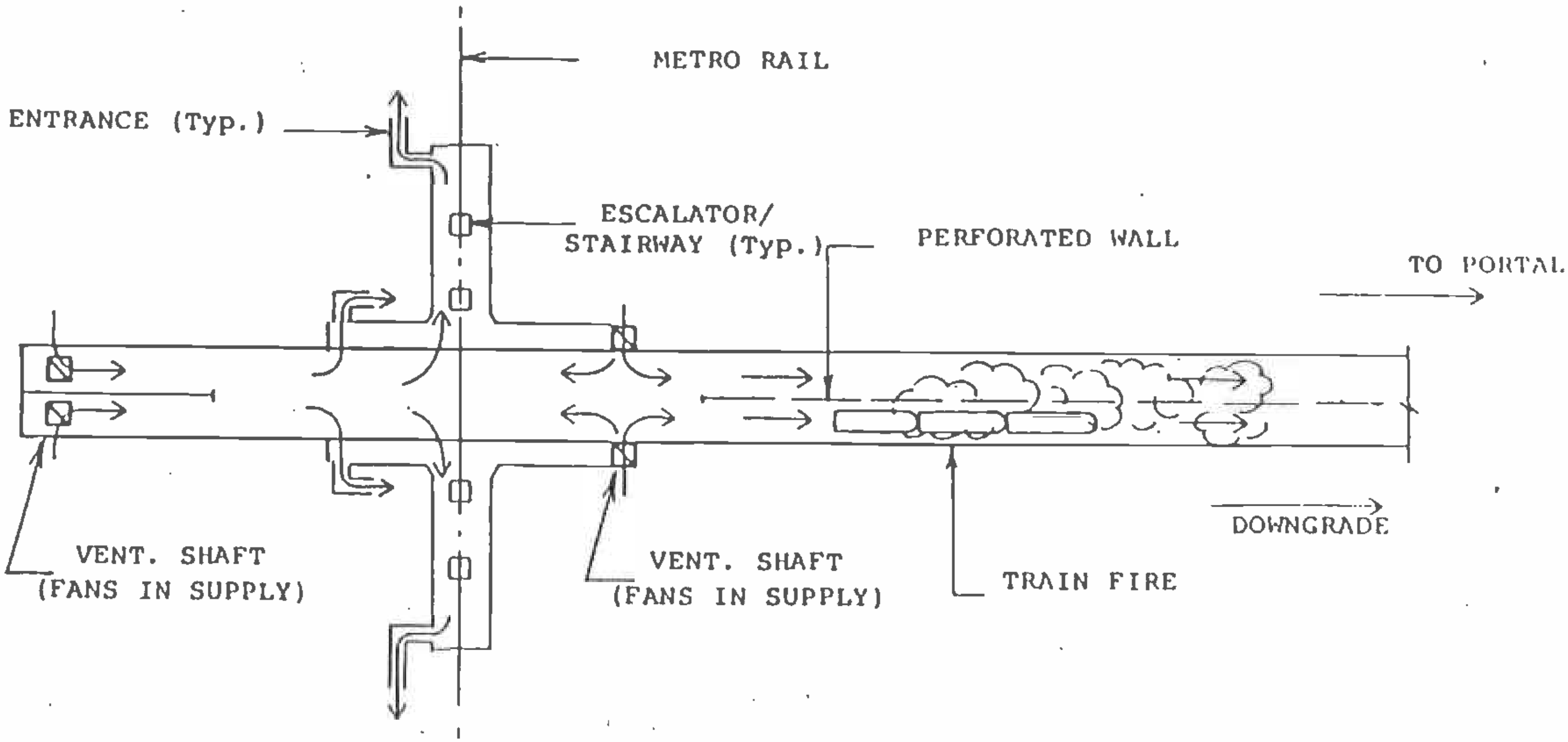


Figure 2. Emergency Condition Simulated ("worst case")

TABLE 1

LB-LA RAIL TRANSIT PROJECT

SUMMARY OF SES RESULTS FOR A FIRE INCIDENT SOUTH OF LRT STATION

Case No.	Add'l. Entrances	Nominal Fan Capacity (cfm)	Predicted Air Velocity (fpm) w/o Fire	Predicted Air Velocity (fpm) w/Fire	Req'd. Velocity	Remarks
1A.	2	150,000	217	20	515	Below Criterion. (See Note 1.)
1B.	2	150,000	455	195	515	Below Criterion.
1C.	2	320,000	725	547	515	O.K.
2A.	1	150,000	530	300	515	Below Criterion.
2B.	1	265,000	724	549	515	O.K.
3A.	-0-	150,000	620	425	515	Below Criterion.
3B.	-0-	210,000	715	546	515	O.K.
4A.	2	150,000	542	400	515	Below Criterion. (LRT isolated)
4B.	2	190,000	661	541	515	O.K. (LRT isolated)
5.	1	150,000	700	621	515	O.K. (LRT isolated)

Notes:

1. For Case 1A and Cases 4A through 5 (with the LRT isolated), only the LRT fans were operated. Both the LRT and MRT fans were operated for the remaining cases.

2. The above results are for a fire with a heat release rate of 85.3 million Btu/hr.

3. The air velocities tabulated above are measured in the open tunnel.

This finding is a direct result of the large quantity of air which flows out through the station entrances. As shown on Table 2, between 43 and 98 percent of the total air flow supplied by the fans is lost through the entrances depending on the conditions simulated.

The benefit of also operating the Metro Rail fans to reduce the air flowing down through the four escalator/stairways can be seen by comparing the results for Case 1A (without MRT fans) and Case 1B (with MRT fans).

As shown on Table 1, the following combinations of entrances and fan capacities can satisfy the smoke control requirements in the event of a subway fire if the Metro Rail fans are also operated:

1. With two additional entrances (Case 1C), a fan capacity of 320,000 cfm per ventilation shaft is required. To produce this air flow rate, two (2) fans per shaft (8 fans total at 160,000 cfm each) would be required, doubling the fan room space requirement currently allocated.

2. With one additonal entrance (Case 2B), a fan capacity of 265,000 cfm per ventilation shaft is required. As above, two (2) fans of similar size per shaft (8 fans total at 132,500 cfm each) would be required.

3. With no additional entrances (Case 3B), a fan capacity of 210,000 cfm per ventilation shaft would be required. With regard to the two "subway exhaust fans" which are conventional axial fans with a reverse flow capacity of 65 percent of the forward flow, the above flow rate can be produced with a single fan. However, the "emergency fans" which are specially designed to meet the 90 percent reversibility requirement are a border line case. It appears that the 210,000 cfm flow rate can be produced by a single emergency fan, but this would have to be verified by each fan manufacturer. If one fan per shaft can handle the load, no additional fan room space would be required.

As an alternative, if some physical means for separating the LRT platform from the Metro Rail station can be provided during an emergency, then the following results apply:

4. With two additional entrances (Case 4B), a fan capacity of 190,000 cfm per ventilation shaft would be required. This flow rate can be provided by a single fan of similar size currently used for the preliminary fan layouts.

TABLE 2

LB-LA RAIL TRANSIT PROJECT

PERCENT OF AIR FLOW LOST THROUGH STATION ENTRANCES

Case No.	Add'l. Entrances	Nominal Fan Capacity (cfm)	Total Air Flow** Delivered (cfm)	Percent of Air Flow* Lost Thru Entrances
1A.	2	150,000	465,000	98%
1B.	2	150,000	465,000	82
2A.	1	150,000	465,000	72
3A.	-0-	150,000	465,000	61
4A.	2	150,000	465,000	63
5.	1	150,000	465,000	43

*During a fire condition

**Total Air Flow Supplied = Nominal Fan CFM x (2 x 0.9 + 2 x 0.65) where 0.9 and 0.65 are fan reversibilities.

5. With one additional entrance (Case 5), the proposed fan capacities (i.e., 150,000 cfm per shaft) can satisfy the smoke control requirements in the line section south of the LRT station. However, as discussed in the following section, the fan operating temperature would exceed 300°F with 150,000 cfm per fan if an 85.3 million Btu/hr train fire occurs north of the station, since all the heat generated by the fire will be processed by the exhaust fans (i.e., less the heat transferred to the tunnel walls).

One approach for separating the LRT platform from the Metro Rail station is by providing a solid barrier such as a roll-down door at the two locations where the mezzanine joints the LRT platform. Normally, this "barrier" would be in the open position. However, the barrier could be closed, once station evacuation was completed, if a fire occurred between the LRT station and the portal. The barrier could be activated by a local control provided in the Fire Management Panel for use by the firemen at the scene.

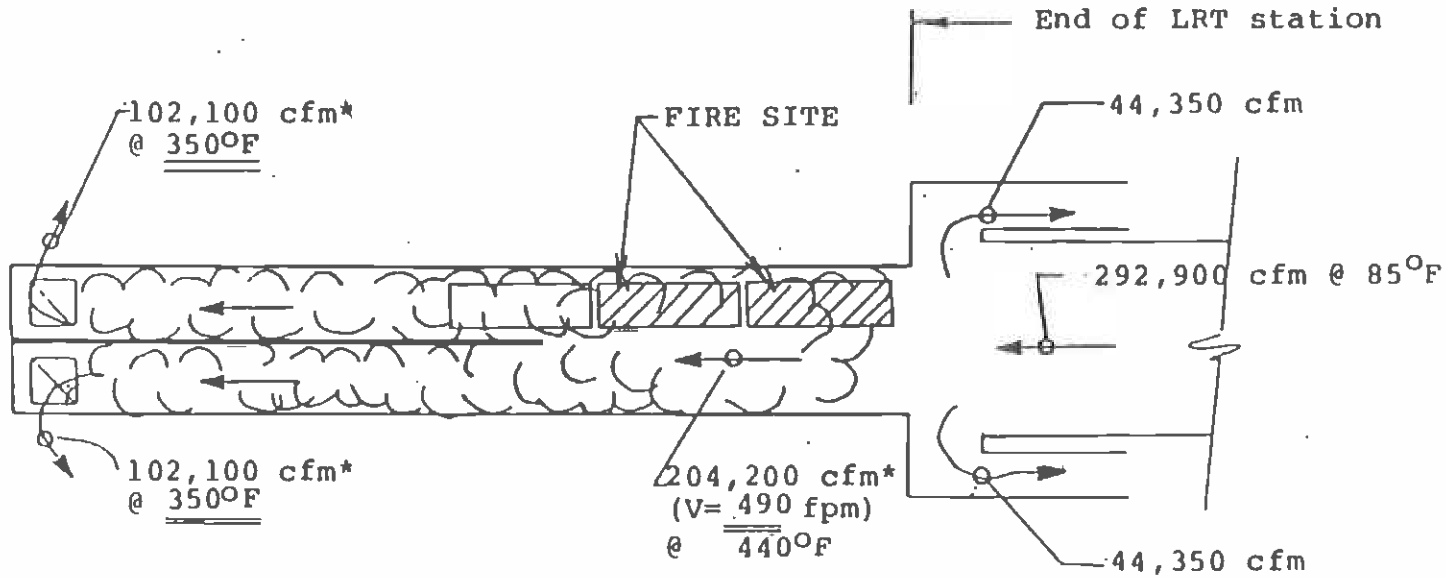
5.2.2 Fire Incident North of LRT Station

The results for a fire occurring at the crossover tunnel are shown schematically in Figures 3 and 4. The air flows marked by an asterisk are given in terms of an "equivalent CFM" at ambient temperature, since the actual volumetric flow rate at a given location downstream of the fire varies with the absolute temperature at that location.

The air flows depicted in Figure 3 are based on a nominal capacity per fan of 150,000 cfm. An air flow rate of 204,200 cfm is predicted past the incident train resulting in an average smoke temperature of approximately 440°F just downstream of the fire site. The results indicate that smoke flow can be channelled away from the station as long as the exhaust fans continue operating, since the predicted air velocity alongside the train (i.e., 490 fpm) exceeds the locally required air velocity of 425 fpm. However, a smoke temperature of 350°F is predicted at the exhaust fans which exceeds the 300°F rating of the fans, possibly leading to fan failure.

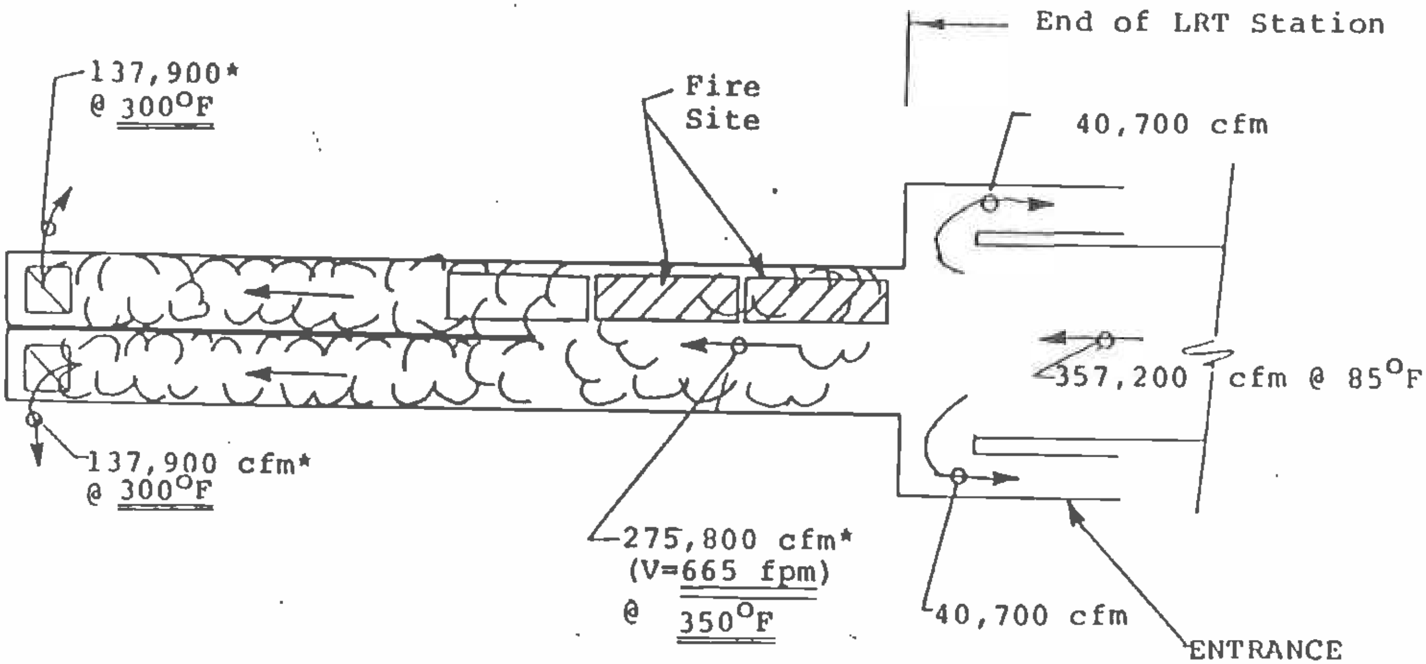
Figure 4 shows the corresponding results when the nominal capacity per fan is increased to 190,000 cfm. An air flow rate of 275,800 cfm past the train is predicted in this case, resulting in a lower average smoke temperature of approximately 350°F just downstream of the fire site. A further reduction in smoke temperature occurs as heat is transferred to the tunnels resulting in a smoke temperature of approximately 300°F at the exhaust fans which is equal to the rated temperature of the fans.

Figure 5 shows the resulting conditions when a fire occurs within one of the tail track tunnels. In this case, only one exhaust fan, with an assumed capacity of 190,000 cfm, is



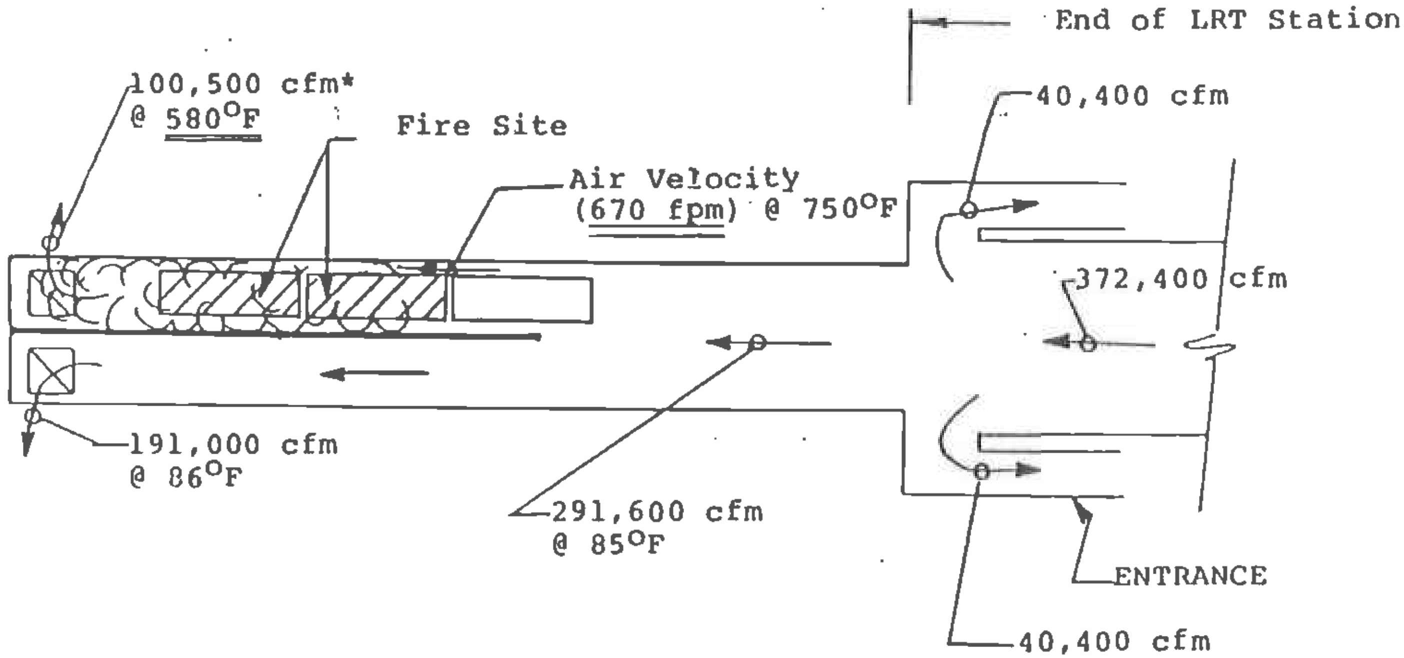
* (Equivalent CFM at ambient temperature)

Figure 3. Results for Fire Incident at Crossover.
(w/nominal 150,000 cfm per fan)



* (Equivalent CFM at ambient temperature)

Figure 4. Results for Fire Incident at Crossover
(w/nominal 190,000 cfm per fan)



* (Equivalent CFM at ambient temperature)

Figure 5. Results for Fire Incident at Tail Track
(w/nominal 190,000 cfm per fan)

available for smoke purging because the trackways are separated by a solid dividing wall. As a result, an air flow rate of 100,600 cfm past the incident train is predicted producing an average smoke temperature of approximately 750°F at the fire site. At the exhaust fan, an average smoke temperature of approximately 580°F is far in excess of the 300°F fan rated temperature.

The above conditions can be remedied by making both fans available for smoke purging. This can be accomplished by one of the following methods:

- Providing a common intake plenum at fan room level from which both exhaust fans draw equal air quantities and by adding an operating mode to allow for the closing of the track damper connecting to the unaffected trackway. Hence, both fans could be used to purge the incident tunnel.

- Providing a common intake plenum, as above, and using a perforated dividing wall between the trackways, rather than a solid wall. This change would promote mixing between the hot smoke at the fire site and the air flowing along the unaffected trackway to reduce the temperature at the exhaust fans. The openings in the dividing wall would also provide firefighters with access to the fire site via the unaffected trackway, rather than approaching along the walkway in the incident tunnel.

With either of the above alternatives, the results shown in Figure 4 suggest that a nominal fan capacity of 190,000 cfm (per fan) will be required, as a minimum, to satisfy both the smoke control velocity and the fan temperature rating of 300°F (i.e., if a fire generating 85.3 million Btu/hr were to occur).

5.2.3 Fire Incident in LRT Station

The results for a simulation modelling the station ventilation concept, which consists of drawing outside air through the entrances, sweeping it through the public area, and exhausting it through the ventilation shafts at the ends of the station, are shown in Figure 6. The results are based on a nominal fan capacity of 190,000 cfm at each of the four ventilation shafts. Of the total air quantity exhausted by the four LRT fans, the results show that 15 percent enters through the portal, 18 percent is drawn in through the LRT entrances, and 67 percent enters the LRT station via the mezzanine.

The air quantities entering through the portal and entrances are not available for station ventilation because that air is drawn immediately toward the adjacent ventilation shafts. The air quantity entering the LRT station through the mezzanine, which amounts to 514,700 cfm, splits almost equally in both

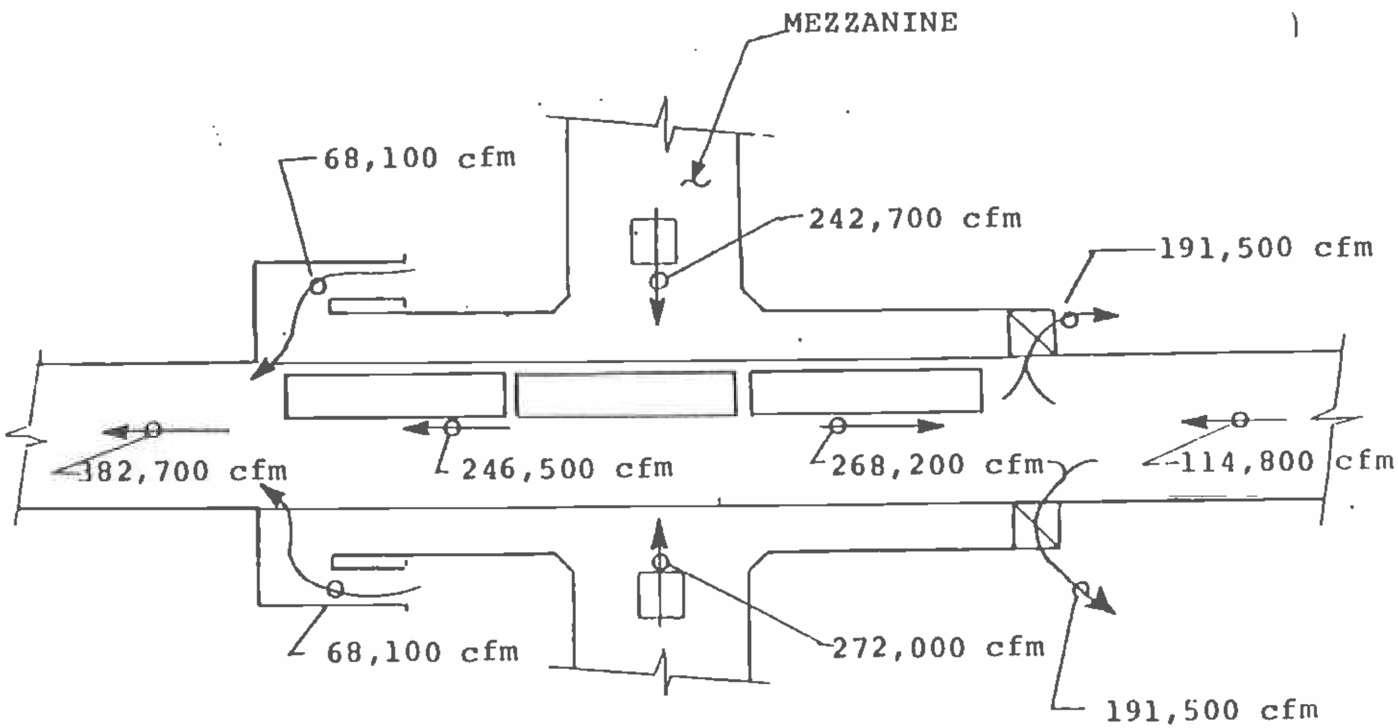


Figure 6. LRT Station Emergency Ventilation
(w/ nominal 190,000 cfm per fan)

directions flowing along the station platform and sweeping smoke toward the ends of the station to be exhausted by the fans.

Based on a station cross-sectional area of 850 sq ft and a 280 ft platform, the 514,700 cfm results in about 130 air changes per hour which is considered a more than adequate ventilation rate. Air velocities with this ventilation rate are about 300 fpm which will not hinder passenger evacuation.

The predicted air flow pattern suggests that the safest evacuation path from the station is through the mezzanine and out through the Metro Rail entrances. Hence, if the smoke barrier described in Section 5.2.1 is implemented, it should not be used during a station fire.

6.0 NORMAL OPERATIONS

The SES computer program has been used to model normal system operations in the Flower Street Subway Segment. This computer program can predict the resultant air temperatures and air velocities throughout a network of interconnected stations, tunnels and ventilation shafts as a consequence of train operations, forced ventilation, heat removal by OTE systems, miscellaneous heat sources (e.g., equipment, lighting, people, etc.) and the heat sink effect of the tunnel structure and surrounding soil.

In this section, the results of the computer simulation are presented, compared with Project Design Criteria and conclusions concerning the performance of the proposed ECS concept are discussed.

6.1 CONDITIONS MODELLED

The area modelled consists of the Flower Street subway line section, the combined LRT and Metro Rail station at Seventh/Flower, and the Metro Rail line sections between Wilshire/Alvarado and Fifth/Hill stations.

The period simulated corresponds to a summer evening rush hour when the outdoor temperature is 84^{o}F, per current design criteria.

The OTE system at the LRT station is assumed operating and the four ventilation shafts are in bypass mode. Thus the bypass dampers are open, the subway exhaust and emergency fans are "off", and the track dampers are closed. At the Metro Rail station, the underplatform exhaust (UPE) system (128,000 cfm) and the supply air units (150,000 cfm) are operating. Similarly, the ventilation shafts at both ends of the Metro Rail station are in bypass mode.

Train operations along the LRT system consist of 3-car trains with 76 passengers per car (AW1 load) operating on a 6-minute headway. During the simulation, trains are "dispatched" from Pico Blvd. station, proceed northbound, enter the portal reaching a maximum speed of 55 mph underground and brake to a stop at the northbound (inbound) platform. The train is assumed to dwell at the station for 4 minutes and then proceed toward the tail track at 10 mph, reversing direction and stopping at the crossover tunnel. After approximately 1½ minutes, the southbound train enters the station, dwells for 4 minutes and exits the station. The total elapsed time, from the moment the train stops at the inbound platform to the moment it leaves the outbound platform, is about 11 minutes.

Train operations along the Metro Rail system are modelled simultaneously, and consist of 6-car trains operating on an average peak hour headway of 4½ minutes in both direction and a station dwell time of 30 seconds which corresponds to Design Year (DY) operations.

6.2 RESULTS DURING NORMAL OPERATIONS

6.2.1 Air Temperatures

The average air temperature along the LRT platform is predicted to range between a high of about 88°F at the north end to a low of about 83°F at the south end. The predicted temperatures are below the design temperature of 89°F when the outdoor temperature is 84°F.

In the subway line section south of the LRT station, the average air temperature is predicted to range from about 83°F near the portal to about 80°F near the crossover or 1° to 4°F below outdoor temperature. Hence, the heat sink effect of the subway structure and the surrounding soil can effectively off-set the heat dissipated in the subway for the level of train service simulated.

North of the LRT station, at the tail-track and at the crossover, the average predicted air temperature ranges from about 94°F to 101°F which is below the average design value of 104°F per current design criteria. The higher air temperature predicted in this section of the system can be attributed to the higher train occupancy in this area. During turn-back operations, each train is assumed to spend about 3 minutes per 6-minute headway, or about 50 percent of the time, occupying this area while heat is continuously dissipated from the braking resistors and air conditioning condensers. Also, the subway exhaust fan at the tail-track was not operating during the simulation. This fan is available for heat removal purposes and can be periodically operated in exhaust mode if air temperatures of the magnitude predicted are found to occur during revenue service.

6.2.2 Air Velocities

High sustained air velocities at station platforms and entrances can be a source of discomfort to subway patrons. However for this Project, the low blockage ratio (i.e., 0.21) and the short train consists (3-car trains) result in low piston-generated air velocities which will not adversely affect subway patron comfort.

The predicted average and maximum air velocities along the LRT station platform are below 90 fpm and 220 fpm, respectively. These values are well within the criteria of 600 fpm (average) and 1,200 fpm (maximum).

The predicted air velocities at station entrances also meet criteria as shown on Table 3. Note that the direction of air flow alternates between outflow (i.e., leaving the station) and inflow (i.e., entering the station) at the entrances depending whether a train is entering the station or leaving the station, respectively, and different criteria apply in each instance.

6.2.3 Air Flow Through Blast and Relief Shafts

As previously noted, the air flows produced by the piston-action of moving trains are low, because of the low blockage ratio and short train consists. Hence, the air flows processed by the blast relief shafts are also low.

A maximum of about 40,000 cfm per shaft is predicted for the shafts at the south end of the station and about 33,000 cfm per shaft at the north end. Therefore, the ventilation shafts and discharge gratings at the surface should be sized using the fan (i.e., emergency and subway exhaust fans) air flow rates.

6.2.4 Pressure Transients

Trains moving through a subway system can cause rapid pressure changes which can be sensed by passengers on-board a train or at a station. If sufficiently large, these pressure changes can be a source of passenger discomfort and affect train- or tunnel-mounted equipment.

The criterion for rapid pressure change, applicable when the total change in pressure is greater than 2.8 in. wg (0.10 psi), is that no person, patron or employee, shall be subjected to a rate of pressure change greater than 1.7 in. wg per second (0.06 psi per second).

TABLE 3

LB-LA RAIL TRANSIT PROJECT

PREDICTED ENTRANCE AIR VELOCITIES

AT 7TH/FLOWER STATION

	Air Velocity* (fpm)			
	Outflow		Inflow	
Entrance	Maximum	Average	Maximum	Average
1. Bank of America Building	190	110	410	195
2. Roosevelt Building	190	110	410	195
3. 7th/Hope (MRT)	270	180	405	215
4. 7th/Figueroa (MRT)	220	150	300	160
* Criteria (fpm):	500	350	1,200	600

For the Flower Street Subway, the two cases with the most potential for creating uncomfortable conditions occur when two trains pass in the tunnel or when a train enters the portal. These conditions have been examined by using the calculation procedures presented in the Subway Environmental Design Handbook (Ref. 6).

The air pressures experienced on-board the front and rear cars, while two trains pass, are shown in Figure 7. The calculations are based on a train speed of 55 mph and treat the tunnel with the perforated dividing wall as a single undivided tunnel for the reason stated in Section 4.0. As shown in Figure 7, all pressure changes are below 2.8 in. wg. Thus, the criteria will be satisfied.

The pressure change criteria will be satisfied during portal entry, also, even during a "worst case" condition when the tunnel air flow ahead of the train is assumed to remain zero. In this instance, the total change in pressure experienced on-board the train is only about 0.54 in. wg.

7.0 METHANE PURGING

The presence of methane gas along certain sections of the Metro Rail alignment was established during preliminary design for that system. The vicinity of the 7th/Flower Street Station was one of the areas where high concentrations were found. It was also established that air velocities of at least 100 fpm must be maintained to prevent the formation of methane layers along the tunnel ceiling.

Provisions for purging methane gas from the LRT system include the OTE system at the LRT station and the two subway exhaust fans, one at each end of the station.

7.1 CONDITIONS MODELLED

An SES simulation was performed to estimate the air flows produced throughout the LRT system by operating the ventilation equipment available for methane purging.

The simulation assumes that methane gas has been detected somewhere along the LRT system and, thus, no Metro Rail fans have been operated. Furthermore, it is assumed that train operations have ceased. Therefore, the air flows predicted are those produced by fan operation only.

The applicable ECS components have been operated in the following manner:

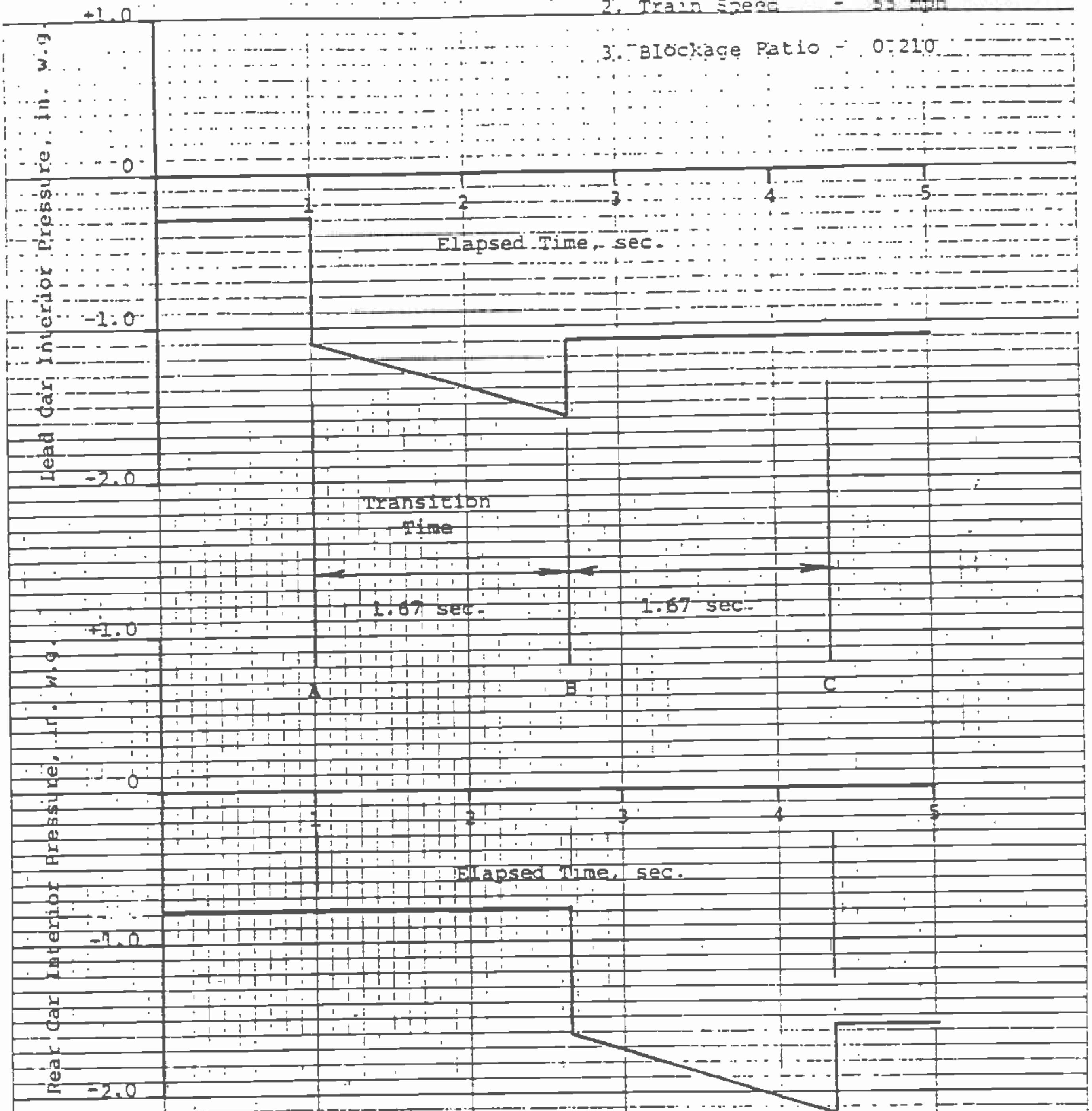
- o OTE system (100,000 cfm) is activated.

Based on:

1. Train Length - 270 ft.

2. Train Speed - 55 mph

3. Blockage Ratio - 0.210



A. The front of the trains pass.

B. The front of train #1 passes rear of train #2.

C. The rear of the trains pass.

Figure 7. Pressure Transients Experienced On-Board a Train when Trains Pass in Tunnel.

- The subway exhaust fan (190,000 cfm) at the south end of the station is activated, its track damper is open and its bypass damper closed.

- The south emergency fan is "off" and the corresponding track and bypass dampers are closed.

- The subway exhaust fan (190,000 cfm) at the tail track tunnels is activated and exhausts from both tunnels. The adjacent emergency fan is "off" and the bypass dampers are closed. Note, it has been assumed that both track dampers are open and that a common intake plenum has been provided so that both tail track tunnels can be purged by the subway exhaust fan.

7.2 RESULTS FOR METHANE PURGING

The resulting air flows throughout the LRT system are shown in Figure 8. The tunnel air velocities corresponding to the predicted air flows range from about 100 fpm near the future turn-out close to the portal, to about 400 fpm at the tail track tunnels.

The maximum methane infiltration rate which can be diluted to a methane concentration of 0.25 percent (Metro Rail design value) by the 87,000 cfm predicted between the portal and the LRT station is about 218 cfm (i.e., 87,000 cfm x 0.0025). In the tail track tunnels north of the station, about 238 cfm of methane can be handled per tunnel.

8.0 CONCLUSIONS

8.1 EMERGENCY VENTILATION

Smoke control cannot be achieved with the current station configuration and with the proposed fan capacity of 150,000 cfm per fan if a train fire with a heat release rate of 85.3 million BTU/hr occurs in a subway line section.

The above finding is the result of the following:

- About 43 to 98 percent of the total air flow supplied by the fans is lost through the station entrances depending on the number of openings.

- Exhaust air temperatures may exceed 300°F, leading to possible fan failure, if a train fire occurs north of the LRT station.

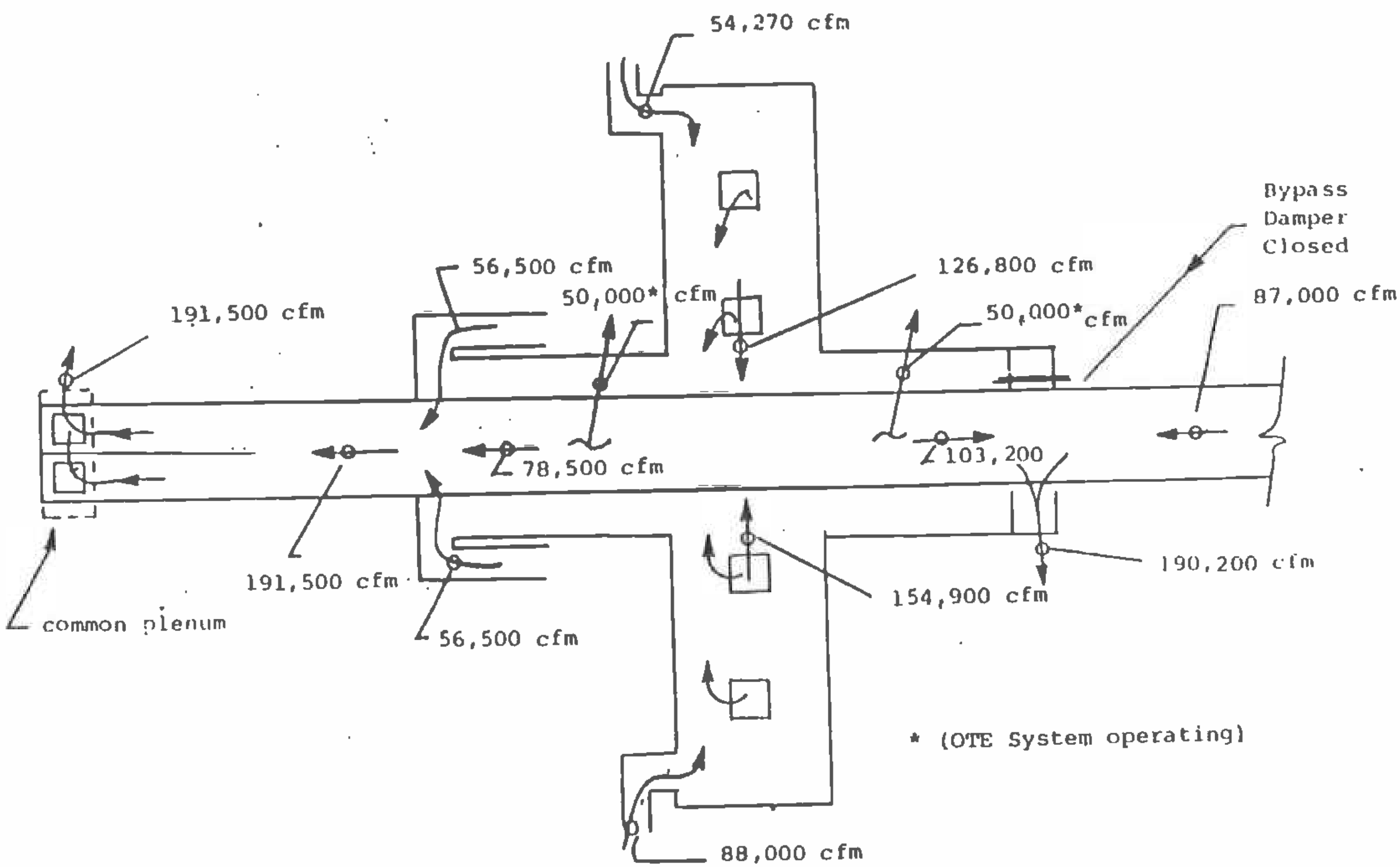


Figure 8. Methane Purging for Flower Street Subway Segment
(w/nominal 190,000 cfm per fan)

8.1.1 Required Fan Capacities

The smoke control criteria can be satisfied by the following combinations of fan capcity and number of additional station entrances, if the Metro Rail fans are also operated:

1. With two additional entrances, a fan capacity of 320,000 cfm per shaft is required.

2. With one additional entrance, a fan capacity of 265,000 cfm per shaft is required.

3. With no additional entrances, a fan capacity of 210,000 cfm per shaft is required.

If the LRT station can be physically separated from the Metro Rail station during a tunnel fire emergency, then the following alternative applies:

4. With two additional entrances, a fan capacity of 190,000 cfm per shaft is required. Note, that with fewer entrances, 190,000 cfm would still be required, primarily to limit exhaust air temperatures as discussed below.

8.1.2 Implication of Ventilation Alternatives

Alternatives 1 and 2, above, require two fans per shaft to deliver the 320,000 cfm and 265,000 cfm, respectively, per shaft. This amounts to doubling the number of fans and the fan room space currently allocated.

Alternative 3 appears to be within the capacity range of a single fan, hence no additional fan room space would be required. However, this must be verified by each fan manufacturer.

The flow rate in alternative 4 can be provided by a single fan of 190,000 cfm capacity which is the same size fan used for the preliminary fan layouts.

8.1.3 Separation Barrier between LRT and MRT stations

One approach for implementing Alternative 4, if selected, is to provide a solid barrier, such as a roll-down door, at the two locations where the mezzanine joins the LRT platform. The barrier would function in the following manner:

- Normal Operations - the barrier is in the open position.

- Train Fire between Portal and LRT Station - the barrier is closed, once station evacuation is completed.

- o Train Fire in LRT Station - the barrier is in the open position to enhance station ventilation.
- o Train Fire North of LRT Station - the barrier is closed after station evacuation.

The barrier would be activated by a local control which can be included in the fire management panel for use by the firemen at the scene.

8.1.4 Limiting Fan Operating Temperature

A nominal fan capacity of 190,000 cfm per fan will be required, as a minimum, to limit the fan operating temperature to 300°F if a train fire should occur north of the LRT station.

Furthermore, one of the following changes must be implemented to limit fan temperature by making full use of the available fan capacity, if a fire occurs in one of the tail-track tunnels:

- o Provide a common intake plenum at fan room level from which both exhaust fans draw equal air quantities, and provide an operating mode to allow the closing of the track damper connecting to the unaffected trackway. Hence, both fans could be used to purge the incident tunnel.
- o Provide a common intake plenum, as above, and use a perforated dividing wall between the trackways, rather than a solid wall. This change would reduce the temperature at the exhaust fans by promoting mixing between the hot smoke and the air flowing along the unaffected trackway. The openings in the dividing wall would also provide firefighters with access to the fire site via the unaffected trackway, rather than approaching along the walkway in the incident tunnel.

8.1.5 Station Ventilation

A ventilation rate of about 130 air changes per hour can be achieved in the LRT station by using a nominal capacity per fan of 190,000 cfm and by operating the LRT and Metro Rail fans in the appropriate modes. This ventilation rate is considered more than adequate for smoke control.

8.2 NORMAL OPERATIONS

The proposed ECS concept can satisfy the applicable air temperature, air velocity and pressure transient criteria during normal system operations. The heat sink effect of subway structure and the surrounding soil has been found to be very effective for controlling subway air temperatures. Also, the use of a perforated dividing wall which reduces the effective blockage ratio has resulted in air velocities and pressure transients which are well within the comfort range.

8.2.1 Expected Air Temperatures

The average air temperature predicted along the LRT platform ranges from 88°F to 83°F when the outdoor temperature is 84°F which is below the design temperature of 89°F.

In the subway line sections, the following average temperature ranges are predicted:

- South of LRT Station - 80°F to 83°F
- North of LRT Station - 94°F to 101°F
  (Note: the corresponding design criterion is 104°F, average)

8.2.2 Expected Air Velocities

The predicted average and maximum air velocities along the LRT station platform are below 90 fpm and 220 fpm, respectively. These values are well below the applicable criteria of 600 fpm (average) and 1,200 fpm (maximum).

The predicted air velocities at the station entrances are also low. The maximum air velocities are 270 fpm (outflow) and 410 fpm (inflow). The applicable criteria are 500 fpm and 1,200 fpm, respectively.

8.2.3 Magnitude of Expected Pressure Transients

The magnitude of pressure changes caused by train operation is below the 2.8 in. wg criterion, hence passenger comfort will be satisfied. The largest pressure change experienced by a passenger on-board a train is estimated to be about 1.4 in. wg while two trains pass in the tunnel at 55 mph.

8.2.4 Sizing Ventilation Shafts and Discharges at Surface

Ventilation shafts and the discharge gratings at the surface are normally sized by using the highest expected air flow rates during normal (piston air flows) and emergency (fan air flows) operations and applying the appropriate design velocity for each mode of operation. The largest area computed will govern the size of each element.

For the LRT system, the ventilation shafts and discharge gratings at the surface should be sized using a minimum fan capacity of 190,000 cfm because the piston air flows through each shaft are predicted to be low.

A maximum piston air flow of about 40,000 cfm per shaft is predicted for the shafts at the south end of the station and about 33,000 cfm per shaft at the north end.

8.3 Methane Purging

Provisions for purging methane gas from the LRT system include the OTE system at the LRT station and two subway exhaust fans, one at each end of the station.

Tunnel air flows, ranging between 87,000 cfm and 95,000 cfm, can be achieved by simultaneously operating the above systems. Tunnel air velocities corresponding to the predicted air flows range from about 100 fpm to 400 fpm which should be adequate for preventing the formation of methane layers along the tunnel ceiling.

The maximum methane infiltration rates which can be diluted to a methane concentration of 0.25 percent (Metro Rail design value) by the predicted air flow rates are 218 for the south subway section and 238 cfm per tunnel in the tail tracks north of the station.

9.0 RECOMMENDATION

In view of the preliminary nature of some of the parameters which affect the emergency ventilation system capacity (e.g., fire heat release rate, vehicle frontal area, number and configuration of entrances), we recommend that SES simulations be performed during Final Design once these parameters have been more firmly established.

REFERENCES

1. Public Access to LRT, Special Study/Support Task 105, draft letter report prepared by MRTC, dated August 28, 1985.

2. Mechanical Design Criteria, Section 14, prepared by Parsons Brinckerhoff Quade & Douglas, Inc., dated October 25, 1983.

3. Environmental Control Systems (ECS), Special Study/Support Task 104A, report prepared by MRTC, dated July 1, 1985.

4. Development Sciences, Inc, "Double Track Porosity Testing," City of Industry, 1975, Technical Report No. UMTA-DC-06-0010-7544.

5. Memorandum from P. McCauley (SCRC) to R. Keenan, dated September 3, 1985. (Included in Appendix A).

6. Associated Engineers, a joint venture of Parsons Brinckerhoff Quade and Douglas, Inc., De Leuw Cather and Company, and Kaiser Engineers, Subway Environmental Design Handbook, Volume I, Principles and Applications, Second Edition, National Technical Information Service, 1976.

<u>ATTACHMENT 1</u>

- Estimate of Smoke Control Velocity
- Estimate of Fire Heat Release Rate

Subject LB-LA RTP
ESTIMATE OF AIR VELOCITY REQUIRED FOR SMOKE CONTROL

DATA:

- TUNNEL GRADE : 1.5% ⇒ GRADE FACTOR ≈ 1.05 (FROM GRAPH)
- TUNNEL CROSS-SECTIONAL AREA : 214 ft² (per track)
- TUNNEL HEIGHT : 15 ft
- TRAIN FRONTAL AREA : 90 ft²
- AMBIENT AIR DENSITY : 0.075 lbm/ft³ } "STANDARD"
- AMBIENT AIR TEMPERATURE : 70 °F } CONDITIONS
- FIRE HEAT RELEASE RATE : 85.3 ×10⁶ Btu/hr

NOTE: A HEAT RELEASE RATE OF 85.3 ×10⁶ Btu/hr CORRESPONDS TO THE THERMAL OUTPUT FROM TWO FULLY-INVOLVED CARS, FOR A COMBUSTIBLE LOAD OF 60 MILLION BTU PER LRV, AS SHOWN ON ATTACHED MEMO. THE ABOVE HEAT LOADING APPEARS HIGH FOR AN LRV AND IS EQUAL TO THE VALUE USED FOR THE METRO RAIL VEHICLE. HOWEVER, SINCE NO ADDITIONAL INFORMATION IS AVAILABLE AT THIS TIME, WE WILL USE THE SAME ASSUMPTIONS & CALCULATION PROCEDURE USED IN THE METRO RAIL STUDY (SEE ATTACHED CALCULATIONS.)

GOVERNING EQUATIONS (REF. SES USER'S MANUAL CHAPTER 16)

$$V_c = 0.61 \times K_g \left[\frac{g\, H\, \dot{Q}}{\rho_\infty\, c_p\, A\, T_f}\right]^{1/3} \qquad \text{EQ'N (1)}$$

&

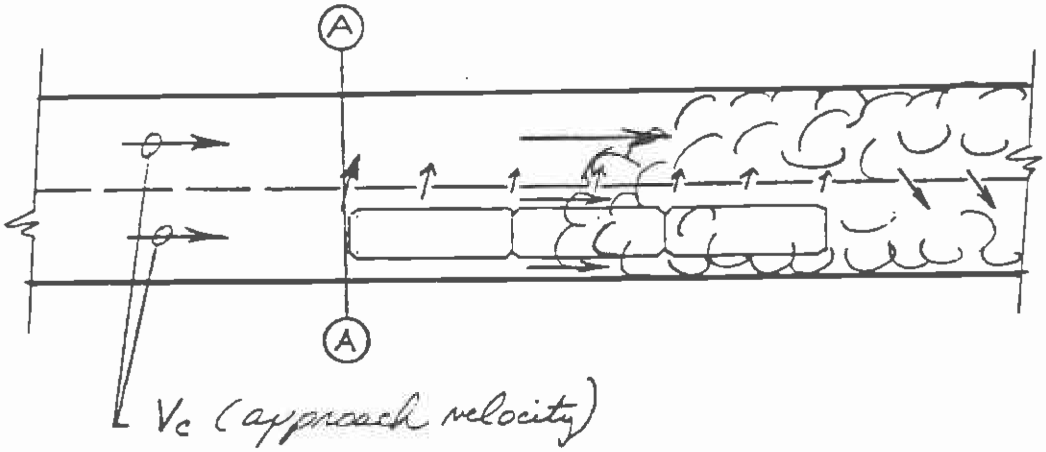
$$T_f = \left[\frac{\dot{Q}}{\rho\, c_p\, A\, V_c} + T_\infty\right] \qquad \text{EQ'N (2)}$$

WHERE:

V_c = CRITICAL VELOCITY, FT/SEC
g = ACCELERATION OF GRAVITY, FT/SEC²
A = NET AREA OF TUNNEL, FT²
H = TUNNEL HEIGHT, FT.
$\dot{Q}$ = FIRE HEAT RELEASE RATE, BTU/SEC
T_f = AVERAGE SMOKE TEMPERATURE, °R
T_∞ = AMBIENT AIR TEMPERATURE, °R
ρ_∞ = AMBIENT DENSITY, lbm/FT³
C_p = SPECIFIC HEAT OF AIR, BTU/lbm-°R
K_g = GRADE CORRECTION FACTOR,

IN THE TWO-CELL BOX STRUCTURE, THE DIVIDING WALL HAS OPENINGS (4' W x 14.75' H) EVERY 12.5 FT. THEREFORE, IN THE VICINITY OF THE TRAIN, THE OPENINGS WILL ALLOW SOME OF THE AIR TO BE DIVERTED INTO THE UNOCCUPIED TRACKWAY. HENCE, THE CONTROL POINT FOR SMOKE WILL BE AT THE END OF THE TRAIN (POINT (A) ON FOLLOWING FIGURE), AND THE CRITICAL APPROACH VELOCITY WILL BE COMPUTED BASED ON THE OPEN TUNNEL AREA, RATHER THAN THE ANNULUS.

Subject LB-LF RTP



SUBSTITUTING INTO EQ'N (1) & (2):

$$V_c = 0.61 \times 1.05 \left[\frac{(32.2\ ft/sec^2)(15\ ft)\left(\frac{85.3\times10^6\ Btu/hr}{3600}\right)}{(0.075\ lb_m/ft^3)(0.24\ Btu/lb_m\text{-}°R)(214\ ft^2)\ T_f}\right]^{1/3}$$

$$\boxed{V_c = 92.08 \times \frac{1}{T_f}^{1/3}}$$

&

$$T_f = \frac{(85.3\times10^6\ Btu/hr\ /3600)}{(0.075\ lb_m/ft^3)(0.24\ Btu/lb_m\ °R)(214\ ft^2)\ V_c} + 530°R$$

$$\boxed{T_f = \frac{6{,}151.2}{V_c} + 530°R}$$

SOLVING THE ABOVE EQUATIONS SIMULTANEOUSLY, THE FOLLOWING VALUES ARE OBTAINED:

$$V_c = 8.55\ ft/sec \Rightarrow 513\ FT/MIN.$$

∴ THE REQUIRED AIR VELOCITY, SAY, **515 FT/MIN** (*)

&

$$T_f = 1250\ °R \Rightarrow \underline{790}\ °R$$

NOTE: SINCE THE OPENINGS IN THE DIVIDING WALL REPRESENT ABOUT 30% OF THE WALL AREA, THE TUNNEL WILL BEHAVE AERODYNAMICALLY AS A SINGLE TUNNEL. THEREFORE, THE ABOVE APPROACH AIR VELOCITY WILL HAVE TO BE MAINTAINED OVER BOTH TRACKWAYS.

∴ THERE REQUIRED AIR FLOW RATE IS:

$$Q = 2 \times 214\ ft^2 \times 515\ ft/min$$

$$Q = \underline{220,420\ CFM}$$

THE ABOVE VALUE MUST BE MAINTAINED DURING THE FIRE TO PREVENT BACK-LAYERING.

Note: This curve has been adapted from data presented in, "Methane Roof Layers" by Bakke and Loach, S.M.R.E. Research Report No. 195, Sheffield, 1960.

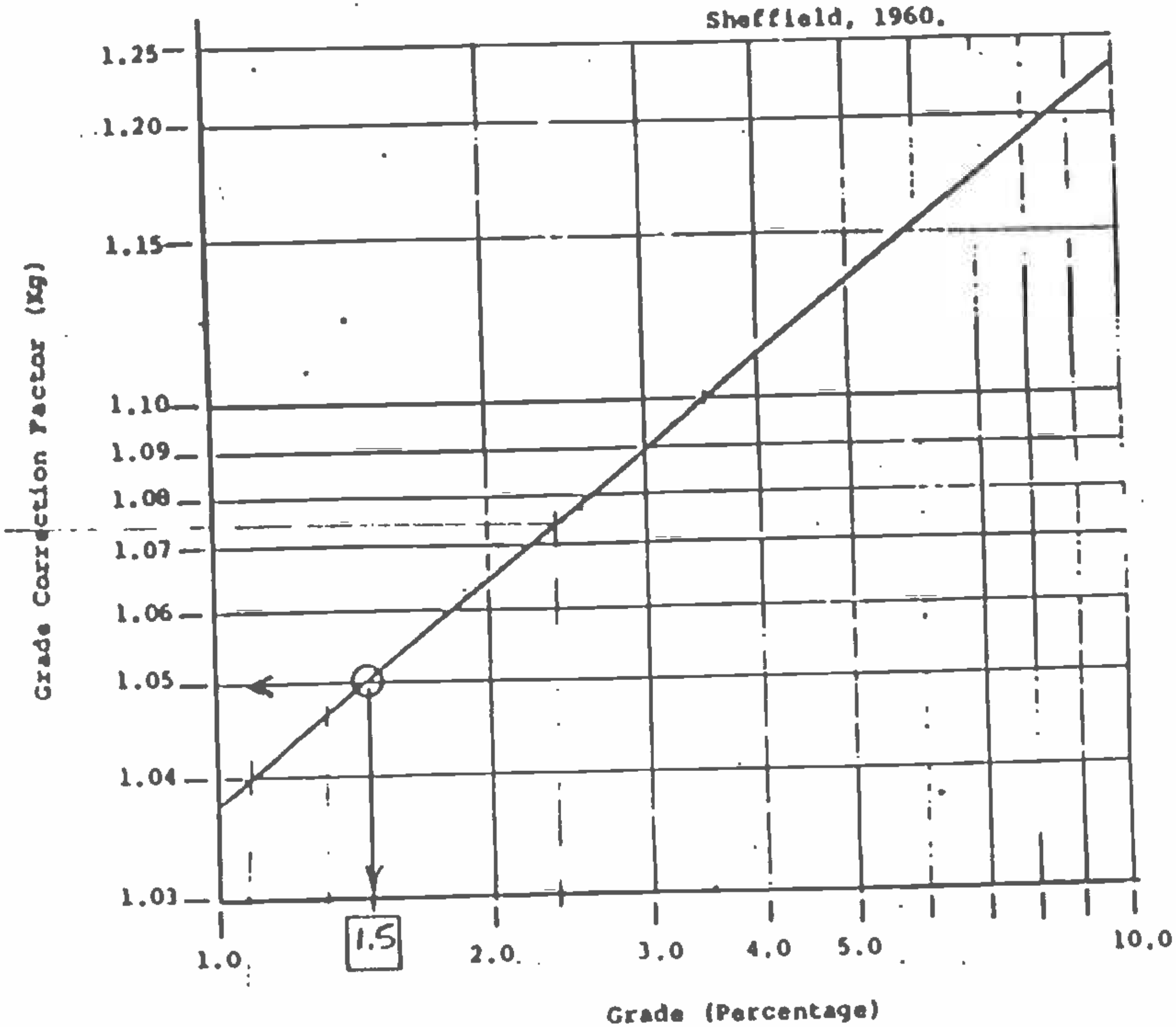


FIGURE 16-3 GRADE CORRECTION FACTOR

REQUIRED AIR VELOCITY AT CROSSOVER TUNNEL

GRADE ⇒ 0.7%, BUT AN UPGRADE.

∴ ASSUME LEVEL TUNNEL ⇒ $K_g = 1.0$

TUNNEL AREA = 505 ft²

BASE CALCULATIONS ON ANNULUS AREA, SINCE NO ... TUNNEL.

$$\therefore \quad A = (505^{\#} - 90^{\#}) = 415^{\#} \quad \& \quad h \cong 15'$$

$$\therefore \quad V_c = 0.61 \times 1.0 \times \left[\frac{32.2 \times 15' \times \frac{55.3 \times 10^6 \text{ Btu/hr}}{3600}}{0.075 \times 0.24 \times 415^{\#} \times T_f} \right]^{1/3}$$

&

$$T_f = \left[\frac{55.3 \times 10^6 / 3600}{(0.075)(0.24) \times 415^{\#} \times V_c} + 530^\circ R \right]$$

$$\begin{cases} V_c = 70.32 \times \dfrac{1}{T_f}^{1/3} \\ T_f = \dfrac{3171.95}{V_c} + 530^\circ R \end{cases}$$

Solving for V_c & T_f:

$V_c = 7.09$ ft/sec ⇒ 425 ft/min, in annulus

$T_f = 978\ ^\circ R$ ⇒ 518 °F

REQUIRED AIR VELOCITY IN TAIL-TRACK TUNNEL

ASSUME LEVEL GRADE, AS BEFORE $\Rightarrow K_g = \underline{\underline{1.0}}$

WITH SOLID DIVIDING WALL, USE ANNULUS AREA

$$\therefore \quad A = (240^{\#} - 90^{\#}) = \underline{\underline{150^{\#}}}$$

$$V_c = 0.61 \times 1.0 \times \left[\frac{32.2 \times 15 \times 85.3 \times 10^6 / 3600}{0.075 \times 0.24 \times 150^{\#} \times T_f} \right]^{1/3}$$

&

$$T_f = \left[\frac{85.3 \times 10^6 / 3600}{(0.075)(0.24)(150^{\#}) V_c} + 530°R \right]$$

$$\begin{cases} V_c = 98.72 \times \dfrac{1}{T_f^{1/3}} \\ T_f = \dfrac{8,775.72}{V_c} + 530°R \end{cases}$$

solving for V_c & T_f:

$V_c = 8.51$ ft/sec $\Rightarrow$ $\underline{\underline{510}}$ ft/min, in annulus

& $T_f = 1560°R$ $\Rightarrow$ $\underline{\underline{1,100}}$ °F

RK→ W. Metsch

SCRC

Southern California Rail Consultants

Memorandum

To: Robert Keenan

From: Paul McCauley

Date: September 3, 1985

Subject: Long Beach-Los Angeles Transit Project
Flower Street Subway Segment/Support, Task: 104A
Environmental Control Systems (ECS) Analysis.

For the SES analysis of Flower Street Subway Segment, Parsons, Brinckerhoff, Quade & Douglas, New York, should be informed to use 60,000,000 Btu combustible loading per LRV. This is the maximum value allowed by SCRC Fire/Life Safety criteria.

Please call if you need any further information regarding this matter.

PM:ea

cc: C. Andersen
D. Kravif
K. Sain
G. STanske
M. Sulkin

RECEIVED
SEP - 6 1985
W. W. METSCH

APPENDIX A

ESTIMATED FIRE HEAT RELEASE RATE

BASIS OF COMPUTATIONS:

The computation method used herein follows the procedure used in the following memoranda:

1. Memo to H.J. Chaliff from W.W. Metsch, April 6, 1983
2. Memo to W.W. Metsch from J.W. Guinan, March 7, 1983

Briefly, the above memoranda assume that a train fire evolves in the following manner.

1. The fire begins under a car and burns at an initial rate, I. The fire continues to burn at the initial rate until the car floor is penetrated and the fire spreads to the car interior leading to "flashover." Flashover is an event when the whole interior of the car erupts in flame. This period - from the onset of the fire to flashover - is estimated to last 20 minutes.

2. At flashover, the fire burns at a higher rate, F1, for the next 60 minutes. During this period, all combustibles above and below the car floor and one-half of the floor material are burned (less what was burned during the initial period).

3. Flashover will be caused in succeeding cars every 20 minutes. However, in the second and succeeding cars, only the combustibles above the floor are assumed to burn. Therefore, the second and succeeding cars will burn at a rate, F2, for a period of 60 minutes.

CAR HEAT LOAD DISTRIBUTION (Per Reference 17)

(i)	Total Car Heat Load	-	60×10^6 Btu
(ii)	Interior Heat Load (above floor)	-	33×10^6 Btu
(iii)	Heat Load of Car Floor	-	17×10^6 Btu
(iv)	Exterior heat Load (below Floor)	-	10×10^6 Btu

ASSUME, the initial burn rate, I, equals 2.4×10^6 Btu/hr.

Therefore, based on the assumed fire scenario, F1 and F2 are computed as follows:

$$F1 = \frac{\text{Interior Load} + \text{Exterior Load} + \frac{1}{2} \times \text{Floor Load} - I \times \frac{20\ \text{Min.}}{60\ \text{min./hr}}}{1\ \text{hour}}$$

$$F1 = \frac{33 \times 10^6\ \text{Btu} + 10 \times 10^6\ \text{Btu} + \frac{1}{2}\ 17 \times 10^6\ \text{Btu} - 800{,}00\ \text{Btu}}{1\ \text{hour}}$$

$$F1 = \underline{50.7 \times 10^6}\ \text{Btu/hr.}$$

$$F2 = \frac{\text{Interior Load} - I^* \times \frac{20\ \text{Min.}}{60\ \text{Min./hr}}}{1\ \text{hour}}$$

$$F2 = \underline{32.2 \times 10^6}\ \text{Btu/hr.}$$

*Note: In this instance, I, is taken as the initial burn rate for the second and succeeding cars and for convenience is also assumed to be 2.4×10^6 Btu/hr.

Therefore, the total heat generated as a function of time is as follows:

					ELAPSED TIME (MINUTES)		
Car No.	0		20		40		60
1		2.4×10^6		50.7×10^6		50.7×10^6	
2				2.4×10^6		32.2×10^6	
3						2.4×10^6	
Total (Btu/hr)		2.4×10^6		53.1×10^6		85.3×10^6	

Therefore, the peak heat release rate during the first 60 minutes is estimated to be 85.3×10^6 Btu/hr, during which two cars are fully involved (i.e., flashover has occurred).

ATTACHMENT 2

LB-LA RAIL TRANSIT PROJECT

Emergency Ventilation Study for a Fire Incident in a Metro Rail Tunnel

March 20, 1986

Prepared by

Parsons Brinckerhoff Quade & Douglas, Inc.
New York, N.Y.

Prepared for

Metro Rail Transit Consultants
Los Angeles, California

LB-LA RAIL TRANSIT PROJECT

Emergency Ventilation Study

for a

Fire Incident in a Metro Rail Tunnel

March 20, 1986

INTRODUCTION

Scope

This report describes analyses performed to investigate the effect of building the Flower Street Subway Segment on the performance of the emergency ventilation system during a train fire in a Metro Rail tunnel adjacentto 7th/Flower Station.

Background

The LB-LA light rail transit (LTR) system intersects the Metro Rail syste at 7th/Flower Station. This station is an integrated two-level structure which serves as a transfer point between the two transit lines. The LRT platform is at the mezzanine level and the Metro Rail platform is one level below.

Access between the mezzanine and the Metro Rail platform is provided by four escalator/stairways. Metro Rail will build two entrances leading from the mezzanine level to the surface: an east entrance at 7th and Hope Street and a west entrance at 7th and Figueroa Street. Two additional entrances will provide direct access to the LRT platforms.

The emergency ventilation system for the Metro Rail was analyzed during Final Design for that project and the results are reported in the Final ECS Report, dated August 23, 1985 (Ref. 1). That study assumed that the LRT system had not been built.

During preliminary design for the LRT, the emergency ventilaton system serving the LRT level was examined and the results are described in the ECS Concept Study dated November 1, 1985 (Ref. 2). The LRT study considered the integrated station at 7th/Flower (both levels) including a section of the Metro Rail system extending from Fifth/Hill Station to Wilshire/Alvarado station. However, only fire incidents occuring at the LRT level were examined.

The study described herein completes the verification process by examining the performance of the emergency ventilation system for the combined LRT and Metro Rail systems during a fire incident in a Metro Rail tunnel.

ANALYSIS FOR COMBINED LRT AND MRT SYSTEMS

The Subway Environment Simulation (SES) Computer program has been used to examine the performance of the emergency ventilation system during a train fire in a Metro Rail tunnel. One tunnel section adjacent to 7th/Flower station was selected for analysis because any adverse effect on emergency ventilation caused by the LRT system would be more evident in the vicinity of that station. Four simulations were performed to determine whether sufficient air flow could be maintained past the incident train to control the spread of smoke. These simulations examined the following conditions:

- <u>Evacuation towards 7th/Flower</u>
  - Operating Metro Rail fans only.
  - Operating LRT fans to supplement Metro Rail fans.

- <u>Evacuation towards Wilshire/Alvarado</u>
  - Operating Metro Rail fans only.
  - Operating LRT fans to supplement Metro Rail fans.

Extent of Area Simulated

The area modelled with the SES program includes the entire LRT system from the portal near 11th Street to the tail tracks north of the LRT station and along the Metro Rail system from a point approximately 500 feet west of Union Station up to and including Wilshire/Alvarado station as shown on Figure 1.

Wilshire/Alvarado was modelled as a terminal station (i.e. the limit of MOS-1). This configuration results in lower tunnel air flows as compared to when the system is extended as demonstrated by results presented in Table 3.8 of Reference 1.

Entranceways at 7th/Flower

Ventilation studies performed for the LRT system indicated that doors at two of the four entranceways serving 7th/Flower station would be required to satisfy emergency ventilation criteria in the tunnels between the LRT station and the portal. However, all four entranceways have been assumed open for this study.

Location of Incident Train

The incident train was assumed to be located approximately midway between 7th/Flower and Wilshire/Alvarado stations on the AR track (ie., outbound route). The results would have been identical if the incident train had been located on the AL track in the parallel bore.

A tunnel between 7th/Flower and Wilshire Alvarado was selected rather than a tunnel between 5th/Hill and 7th/Flower because the former tunnel is approximately twice the length of the latter tunnel (i.e., 5,450 ft vs. 2, 425 ft). Therefore, if the emergency ventilation system can satisfy criteria in the longer tunnel, then by extrapolation, the criteria in a tunnel half the length can also be satisfied. Also simulations had been performed in the selected tunnel. Those simulations which did not include the LRT system serve as a basis for comparison with the simulations performed during this study.

Conditions Simulated

In each simulation performed, a six-car train was assumed stalled in the affected tunnel between 7th/Flower and Wilshire/ Alvarado and burning with a design heat release rate of 85.3 million Btu per hour. This rate corresponds to the heat release from two fully involved subway cars. All other assumptions made regarding the number of open cross-passages, other trains in the system, and fan capacities for the Metro Rail system are as described in Reference 1.

The number of emergency fans operated and their operating mode are shown on Table 1. Also the VPE systems (128,000cfm) were activated at the Metro Rail station(s) whose emergency fans were operating in the exhaust mode. The LRT fans were not activated in two simulations. In those cases, the bypass dampers for the LRT shafts were assumed to remain open.

A nominal capacity of 210,000 cfm (in exhaust mode) per fan was used for each of the four LRT fans. Nominal fan capacities of 189,000 cfm (90% of exhaust flowrate) and 136,500 cfm (65% of exhaust flowrate) were used for the two emergency fans and the two tunnel exhaust fans, respectively.

RESULTS

The results of the four simulations performed are shown on Table 2. For comparison, the results of the previous simulations performed between 7th/Flower and Wilshire/Alvarado, without the LRT system, are also included. The previous simulations correspond to cases 5(a) and 5(b) in Table 3.8 of Ref.1.

The results clearly indicate that air velocities exceeding the 590 fpm required in the annulus of the incident train to control the spread of smoke can still be achieved with the presence of the LRT system. Air velocities of 730 fpm (with LRT and MRT fans operating) and 620 (with MRT fans only) are predicted for the case where the emergency fans at 7th/Flower station are operating in the exhaust mode. When the emergency fans at 7th/Flower are operating in the supply mode, air velocities of 810 fpm (with LRT and MRT fans operating) and 760 fpm (with MRT fans only).

CONCLUSION

The presence of the LRT system will not adversely affect the performance of the emergency ventilation system for the Metro Rail tunnels. This conclusion is supported by the results of four SES computer program simulations performed as part of this study.

REFERENCES

1. "Environmental Control System, Final Report", dated August 23, 1985, prepared by Parsons Brinckerhoff Quade & Douglas, Inc., for Metro Rail Transit Consultants.

2. "Environmental Control System (ECS) Concept Study", dated November 1, 1985, prepared for Parsons Brinckerhoff Quade & Douglas, Inc., for Metro Rail Transit Consultants.

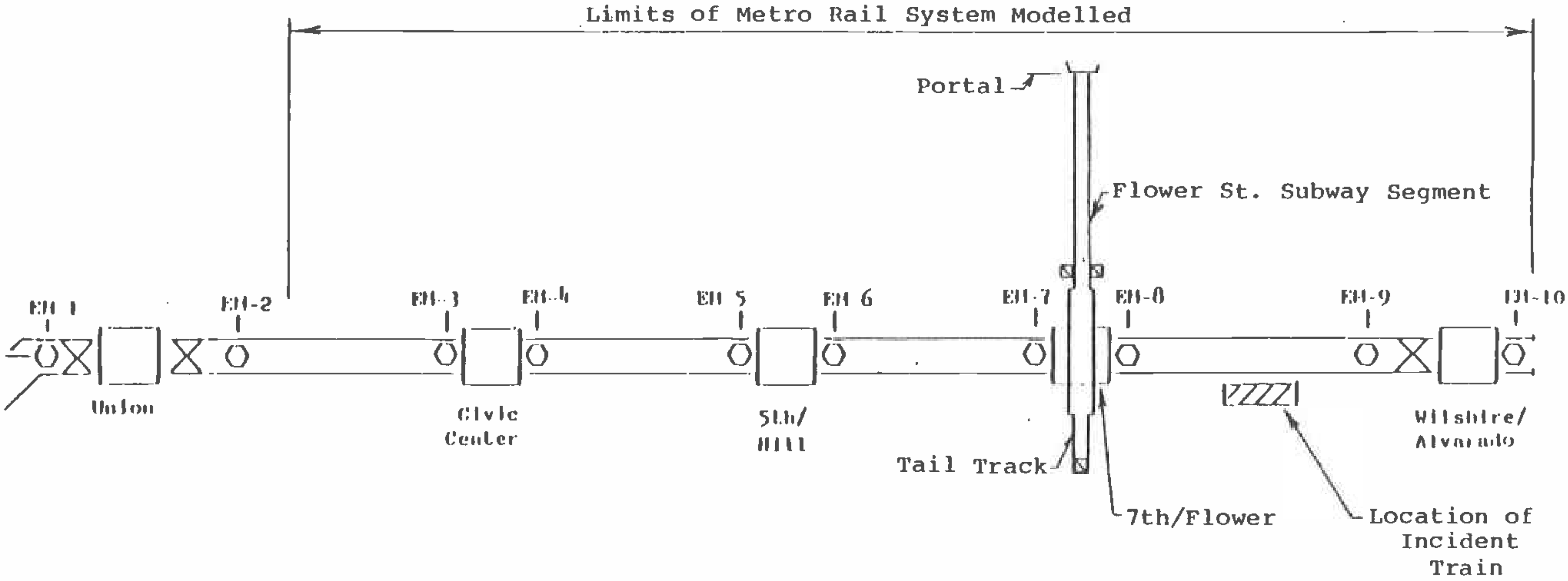


Figure 1 Limits of Study Area

Table 1

Emergency Fan Operating Mode

Evacuation Toward	Operating Mode Supply	Exhaust
7th/Flower	EM-5, EM-6, EM-7 EM-8 & LRT fans	EM-9 & EM-10
Wilshire/Alvarado	EM-9 & EM-10	EM-5, EM-6, EM-7 EM-8 & LRT fans

Notes:

1. See Figure 1 for location of designated fans.
2. All four (4) LRT fans were operated simultaneously.

TABLE 2

Results of SES Simulation

for the Combined LRT/MRT System

Fan Operating Mode	Predicted Air Velocity in Annulus (fpm)			Required Air Velocity (fpm)
	Combined LRT and MRT			
	LRT & MRT Fans	MRT Fans Only	MRT System Only	
1. Exhaust at 7th Flower	730	620	690	590
2. Supply at 7th Flower	810	760	790	590

Note

Results are based on an 85.3 million Btu/hr fire.

ATTACHMENT 3

Parsons Brinckerhoff 100 YEARS

LB-LA RAIL TRANSIT PROJECTS

Study of Pressure on Station Doors

Prepared for

Metro Rail Transit Consultants
Los Angeles, California

Prepared by

Parsons Brinckerhoff Quade & Douglas, Inc.
New York, New York

January 17, 1986

A Century of
Engineering Excellence

INTRODUCTION

The issue of providing doors at the 7th/Flower station entrance was discussed in November 1985 as an alternative to providing a roll-down barrier separating the LRT and the Metro Rail stations. The roll-down barrier had been suggested in Reference 1 as a means for reducing the leakage of air through the station entrances while tunnel ventilation fans operate in an emergency mode. The doors would serve a similar function. Without the means of closing off at least some of the station entrances, the leakage would be so severe that emergency ventilation criteria could not be met.

It is envisioned that normally the doors could be held in the open position by a suitable electro-mechanical device. In the event of a tunnel fire requiring emergency fan operation, the doors would be remotely released and automatically shut.

Per Reference 2, the maximum force required to set a door in motion should not exceed 30 pounds. Therefore, it had to be considered whether the force required to overcome the pressure differential developed across a closed door, plus the restraining force produced by the "door closer" device, would be below the allowed maximum.

INTRODUCTION (cont'd)

The total force required to open the first door is a function of pressure and door size. The larger the door area, the larger the total force required to open it. Accordingly, the analysis described herein evaluated the required force not only on the basis of the number of doors, but also on the basis of their size (see Table 2.)

ANALYSIS

The subject of station pressures and forces on doors has been addressed by performing four (4) simulations using the SES computer program. Simulations were performed for two cases:

(1) With closed doors at the two Metro Rail entrances only, and thus allowing air to leak through the two remaining entrances.

(2) With closed doors at all four entrances.

For each case, one simulation was performed with all the fans (i.e., LRT and Metro Rail) operating in the supply mode and another with all the fans operating in the exhaust mode. A nominal fan capacity of 190,000 cfm was assumed for each of the LRT fans in each of the simulations. At the Metro Rail

ANALYSIS (cont'd)

level, two fans with a nominal capacity of 150,000 cfm per fan were operated at each end of the 7th/Flower Station (4 fans total).

RESULTS

The resulting pressure in the station for the four cases evaluated is shown on Table 1. The corresponding force required to open the first door has been estimated as shown in the attached calculations and summarized in Table 2 for various size doors. The force required to open subsequent doors would be less, because opening of the first door would relieve excess pressure. The calculations assume that doors are of the standard swinging type, hinged along one edge, and that all doors open outward in the direction of egress.

As expected, the highest pressure on station surfaces and doors will be encountered with all four (4) station entrances closed off (see Table 1). And since the force required to open a door is directly proportional to its face area, the largest door requires the largest force (see Table 2).

TABLE 1

LB-LA RAIL TRANSIT PROJECT

STATION PRESSURES PREDICTED

BY SES SIMULATION

	Conditions Evaluated	Fan Operating Mode	Station Pressures (PSF)
1.	Doors at the 2 Metro Rail Entrances, only.	Supply	+ 1.0
		Exhaust	- 1.45
2.	Doors at all 4 entrances	Supply	+ 2.1
		Exhaust	- 3.0

Notes:

1. All LRT fans (@ 190,000 cfm each) and the Metro Rail fans at 7th/Flower were operated simultaneously and in the same mode in each simulation.

2. Pressures tabulated are measured with respect to the outdoor pressure.

TABLE 2

LB-LA RAIL TRANSIT PROJECT

ESTIMATED FORCE REQUIRED

TO OPEN FIRST DOOR

vs.

DOOR AREA

	Door Area (sq ft)	Required Force (lbs) w/doors @ 2 entrances	Required Force (lbs) w/doors @ 4 entrances
1.	36.0 (9'H x 4' W)	48.6	101.2
2.	25.7 (7'H x 3'-8" W)	34.7	72.1
3.	21.0 (7'H x 3' W)	28.4	59.0

Notes:

1. All fans are operating in exhaust mode.
2. Conventional swinging doors hinged at one edge are assumed.
3. Forces tabulated are sum of "door closer" and pressure differential load.

CONCLUSIONS

As can be seen from Table 2, the maximum allowable force of 30 lbs to open a door is exceeded in all cases analyzed, except the case with two (2) closed entrances where an individual door has a face area of no more than 21.0 sq ft.

The closure of two (2) entrances while the emergency ventilation system is in operation will increase the tunnel air velocities sufficiently to control the flow of smoke and heat-laden air in case of a fire involving LRV's with a 60 million Btu inventory of combustibles.

RECOMMENDATIONS

In the interest of fire/life safety, it is recommended that two of the four station entrances be provided with doors which can be closed (remotely) in an emergency.

In order to be compliant with the NFPA Life Safety Code (Ref. 2), individual door face areas must be limited to 21.0 sq ft. The force required to open a door of that size under the described conditions will then be approximately 28 lbs, or 2 lbs below the allowable maximum.

REFERENCES

1. "Environmental Control System (ECS) Concept Study", dated November 1, 1985, prepared by PBQD.

2. N.F.P.A., Life Safety Code (1985), Section 5-2.1.4.3.

ATTACHMENT

Estimate of Door Opening Forces

Parsons Brinckerhoff Computation Sheet

Subject: LB-LA RAIL TRANSIT PROJECT
ESTIMATE OF DOOR OPENING FORCES

 3872
Made by [illegible]
Date JAN. 7, [illegible]
Checked by C.E.C.
Date JAN. 17, 1986

ASSUMPTIONS:

(1) DOORS ARE HINGED ALONG ONE EDGE.
(2) DOORS OPEN OUTWARD IN THE DIRECTION OF EGRESS.
(3) DOORS ARE HELD OPEN BY A SUITABLE ELECTRO-MECHANICAL DEVICE AND THE DOORS CLOSE, WHEN RELEASED, BY THE FORCE EXERTED BY A "DOOR CLOSER" DEVICE.

ANALYSIS

- THE MAXIMUM FORCE REQUIRED TO OPEN A DOOR OCCURS WHEN THE AIR PRESSURE INSIDE THE STATION IS BELOW THE OUTDOOR PRESSURE. THIS OCCURS WHEN FANS ARE OPERATED IN EXHAUST MODE. IN THIS CASE, THE FORCE REQUIRED TO OPEN A DOOR MUST EXCEED THE LOAD PRODUCED BY THE PRESSURE DIFFERENTIAL ACROSS THE DOOR PLUS THE DOOR "CLOSER" FORCE.

- THE DOORS MUST BE ABLE TO CLOSE WHEN THE STATION IS "PRESSURIZED" AS THE RESULT OF OPERATING THE FANS IN SUPPLY MODE. THEREFORE, THE DOOR "CLOSER" MUST EXERT A FORCE EXCEEDING THE AERODYNAMIC LOAD TENDING TO KEEP THE DOOR OPEN.

Subject LB-LA RAIL TRANSIT PROJECT

THE FOLLOWING RESULTS WERE OBTAINED FROM SES SIMULATION:

CONDITION EVALUATED	FAN OPERATING MODE	STATION PRESSURE (lb_f/ft^2)
DOOR AT 2 MRT ENTRANCES, ONLY	SUPPLY EXHAUST	+ 1.0 - 1.45
DOORS AT ALL 4 ENTRANCES	SUPPLY EXHAUST	+ 2.1 - 3.0

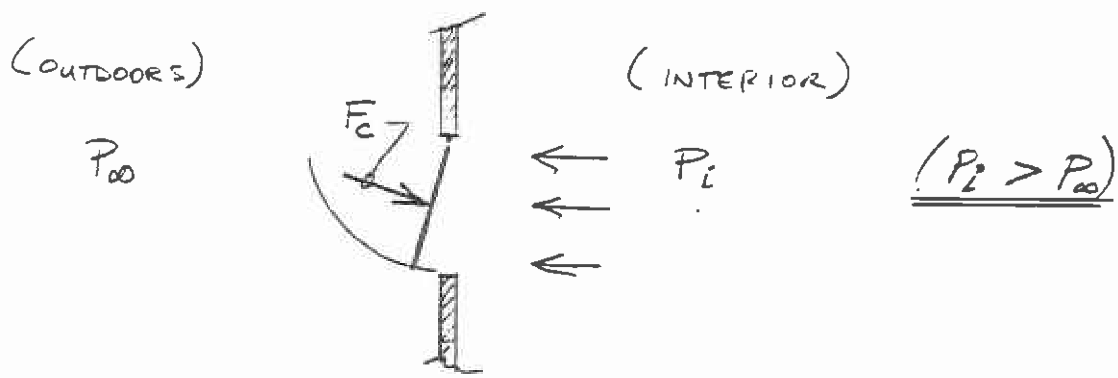
DOOR "CLOSER" FORCE: "F_C" IS DETERMINED BY;

$$F_C = (\Delta P_{SUPPLY}) \times A_D$$

WHERE,

ΔP_{SUPPLY} = STATION "PRESSURIZATION" PREDICTED BY SES PROGRAM. (PSF)

A_D = DOOR AREA (FT^2)



Parsons Brinckerhoff **Computation Sheet**

Subject LB-LA RAIL TRANSIT PROJECT

 3272

Made by J.A.G.
Date JAN. 7, 1986
Checked by C.E.C.
Date JAN. 17, 1986

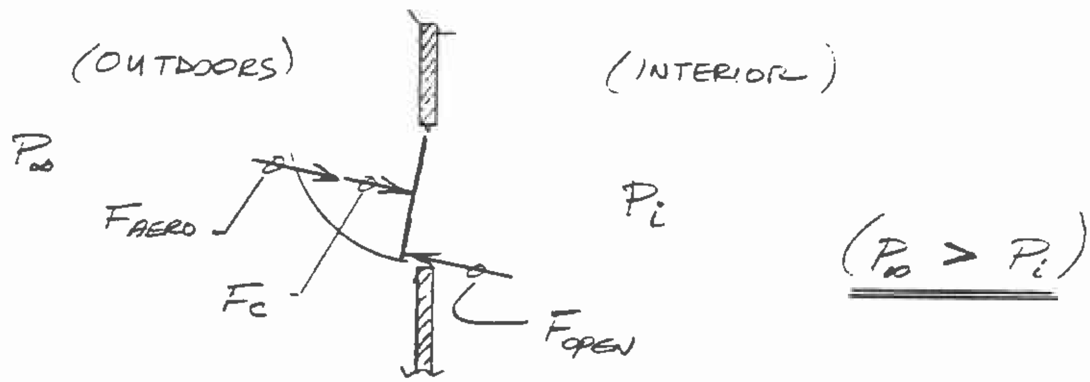
AERODYNAMIC LOAD :

THE MAXIMUM AERODYNAMIC LOAD OCCURS WHEN THE DOORS ARE CLOSED AND THE FANS ARE OPERATED IN EXHAUST MODE. THEREFORE, "F_{AERO}" IS DETERMINED BY :

$$F_{AERO.} = (\Delta P_{EXH.}) \times A_D$$

WHERE,

$\Delta P_{EXH.}$ = STATION UNDERPRESSURE PREDICTED BY SES PROGRAM.



∴ THE TOTAL RESISTING FORCE, "F_R", IS :

$$F_R = F_{AERO} + F_C$$

&

$$F_R = \Delta P_{EXH} \times A_D + \Delta P_{SUPPLY} \times A_D$$

$$F_R = A_D \times (\Delta P_{EXH.} + \Delta P_{SUPPLY})$$

NOTE: THE ABOVE EQUATION ASSUMES THAT "F_C" IS APPLIED ALONG THE CENTERLINE OF THE DOOR, THUS PASSING THROUGH THE CENTER OF PRESSURE.

∴ F_R IS GIVEN BY:

(i) W/ DOORS AT 2 ENTRANCES

$$F_R = A_D \times (1.45 + 1.0)$$

$$F_R = 2.45 \times A_D$$

(ii) W/ DOORS AT 4 ENTRANCES

$$F_R = A_D \times (3.0 + 2.1)$$

$$F_R = 5.1 \times A_D$$

DOOR OPENING FORCE:

THE DOOR OPENING FORCE IS LESS THAN THE TOTAL RESISTING FORCE, SINCE THE POINT OF APPLICATION IS NOT CO-INCIDENT WITH THE CENTER OF PRESSURE AND IS USUALLY NEAR THE EDGE OF THE DOOR.

∴ THE SUMMATION OF MOMENTS ABOUT THE DOOR HINGES GIVES: (LET W = DOOR WIDTH)

$$W \times F_{OPEN} = F_R \times W/2$$

$$F_{OPEN} = 0.5 \times F_R$$

ALLOWING, SAY, 10% FOR FACT THAT THE OPENING FORCE IS NOT APPLIED EXACTLY AT THE EDGE OF THE DOOR,

THEN,

$$F_{OPEN} > 0.55 \times F_R$$

WHERE, F_{OPEN} IS THE FORCE REQUIRED TO BEGIN OPENING THE FIRST DOOR.

AND,

F_{OPEN} IS CALCULATED BY USING :

(i) W/DOORS AT 2 ENTRANCES

$$F_{OPEN} > 0.55 \times (2.45 \times A_D)$$

$$F_{OPEN} > 1.35 \times A_D$$

(ii) W/DOORS AT 4 ENTRANCES

$$F_{OPEN} > 0.55 \times (5.1 \times A_D)$$

$$F_{OPEN} > 2.81 \times A_D$$

ALLOWABLE OPENING FORCE

PER N.F.P.A., LIFE SAFETY CODE, SECTION 5-2.1.4.3, THE MAXIMUM FORCE REQUIRED TO SET A DOOR IN MOTION SHOULD NOT EXCEED 30 POUNDS.

∴ TO LIMIT F_{open} TO 30 lb_f, THE DOOR AREA, A_D, SHOULD BE:

(i) W/DOORS AT 2 ENTRANCES

$$30\ lb_f > 1.35 \times A_D$$

OR,

$$A_D < 22.2\ ft^2,$$ FEASIBLE

(E.G., ≃ 7' × 3' DOOR)

(ii) W/DOORS AT 4 ENTRANCES

$$30\ lb_f > 2.81 \times A_D$$

OR,

$$A_D < 10.7\ ft^2,$$ NOT PRACTICAL

(E.G., ≃ 7' × 1.5' DOOR)

Parsons Brinckerhoff **Computation Sheet**

Subject LR-LA RAIL TRANSIT PROJECT

Made by J.A.E.
Date JAN. 7, 1986
Checked by C.E.C.
Date JAN. 17 1986

THE REQUIRED DOOR OPENING FORCE CORRESPONDING TO THE FOLLOWING TYPICAL DOOR DIMENSIONS IS GIVEN BELOW:

(A) $A_D = 9'H \times 4'W = \underline{36}\ ft^2$

(B) $A_D = 7'H \times 3'\text{-}8''W = \underline{25.7}\ ft^2$

(C) $A_D = 7'H \times 3'W = \underline{21.0}\ ft^2$

DOOR AREA	REQUIRED OPENING FORCE (lbs) w/DOORS @ 2 ENTRANCES	w/DOORS @ 4 ENT.
$36\ ft^2$	48.6	101.2
$25.7\ ft^2$	34.7	72.1
$21.0\ ft^2$	28.4	59.0

Parsons Brinckerhoff Computation Sheet

Subject LB-LA RAIL TRANSIT PROJECT

Made by J.A.G.
Date JAN. 7, 1986
Checked by C.E.C.
Date JAN. 17, 1986

CONCLUSION

PROVIDING CONVENTIONAL SWINGING DOORS AT THE ENTRANCES FOR 7TH/FLOWER ST. STATION IS FEASIBLE, UNDER THE FOLLOWING CONDITIONS:

- AT MOST, DOORS ARE PROVIDED AT 2 OF THE 4 ENTRANCES.
- THE DOOR AREA IS LIMITED TO ABOUT 22 SQ FT. IN TERMS OF STANDARD DOOR DIMENSIONS, THIS WOULD MEAN USING A 7'(H) BY 3'(W) DOOR.

ATTACHMENT 4

Parsons Brinckerhoff

Memo

to K. V. Sain

from W. W. Metsch

subject LB-LA LRT System
7th & Flower Street
Project No. 3872

date May 1, 1986

This memorandum addresses comments which you transmitted to us on 4/23/86.

1. Results of the most recent SES computer runs completed as of 4/30/86 (to be summarized in a letter report next week) indicate that the configuration with an opening at the end of the tail track dividing wall, will produce insufficient air flow in the affected track.

   A second analysis, in which the wall is carried to the end of the tail track and air is exhausted from the affected track only (with the track damper to the adjacent track closed) will increase the air flow in the affected tunnel to the point where maximum velocity criteria in the annulus is exceeded, but exhaust temperature would also be excessive (325°F+).

   Consequently, the dividing wall in the tail track should have 30% openings (similar to the wall between the station and the portal) in order for the ventilation system to meet current criteria.

   If fire protection for rolling stock stored in the tail track is required, then a wet sprinkler system should be considered. Such a system would, of course, only be required until the LB-LA LRT is extended beyond 7th and Flower Street.

2. The basic and original concept called for a tunnel (subway) exhaust fan on the east side and for an emergency fan on the west side. Subsequently, a stand-by fan was added, in case one of the two fans should fail. All three are open to a common "plenum", namely, the cross-over track.

   There is no basis or requirement for modifying that concept or the type of fan(s).

3. Location of shafts is dictated by site constraints at gı. Location of fans is dictated by station configuration be. This results in more air flow direction changes in some : than in others.

4. Dampers can be installed in horizontal or vertical plane: at any angle in between, since they are motorized and doı. rely on gravity for closure. Data on dampers are readily available from manufacturers and from systemwide procurer documents prepared by Metro Rail.

5. The stand-by fan will stand-by until one of the two othe fans fails. At that time, it will be called into servic

6. Screens are provided to keep people and debris out of an air intake or discharge plenum and to isolate them from t rotating parts of a fan.

W. W. Metsch

WWM:jsd

cc: HJC KNM JAG

C: KNM
C: KVS
RK
ing PB

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RECEIVED
MAY 09 1986

Parsons Brinckerhoff

Memorandum

to H. J. Chaliff

from W. W. Metsch

subject LB-LA LRT
7th & Flower St. Subway
Project No. 3872

date May 6, 1986

The ECS Concept Study, dated November 1, 1985, concluded that "smoke control cannot be achieved with the current station configuration and with the proposed fan capacity of 150,000 cfm."

Since then, a number of design concept changes have been evaluated with the SES and either have been or are in the process of being implemented in final contract documents. These are:

1. Two out of four station entrances (namely the LRT entrances) will be provided with doors to prevent air leakage.

2. Subway fans and emergency fans will have their capacity increased to 210,000 cfm each.

3. Two stand-by fans have been added, one at each end of the station, to enhance system reliability.

4. Operating procedures will require evacuation from both levels of the integrated MRT/LRT station in case of a fire at either one of the two levels.

As part of our current work order, we are re-evaluating various aspects of the emergency ventilation system as concepts are finalized or revised. The latest such analysis was completed yesterday. It dealt with the non-revenue section (tail track) north of the station.

The results of the analysis showed that emergency ventilation criteria cannot be met with a solid dividing wall between the tracks. Details of these results are being forwarded under separate cover. The dividing wall will have to be provided with openings totalling about 30% of the total wall area.

If the above provisions are made, then the emergency ventilation system will preclude smoke infiltration into the station and exhaust temperatures will be kept below 300°F, based on results from SES analyses undertaken to model system performance.

It should be noted, that the foregoing conclusions are based on the conservative assumption (as directed) that the worst case scenario for the LPI system is based on the same 6? million Btu vehicle as the MRT.

W. W. Metsch

WWM/pp

CC: JEM, NHD, JAG