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INTRODUCTION AND SYSTEM DESCRIPTION

Several equipment systems are employed to facilitate the overall operation of the Seattle and Mercer Island Tunnels.

These systems are as follows:

1. Tunnel Lighting
2. Traffic Control and Incident Detection
3. Tunnel Ventilation
4. Power Distribution
5. Fire Protection
6. Central Control and Monitoring
7. Communications

1. Tunnel Lighting System

The tunnel lighting is divided into four zones within each tunnel, with each zone providing a decreasing level of illumination in the direction of travel from the tunnel entrance, to minimize the visibility problems that occur when a motorist enters the tunnel. The four zones are: threshold zone, transition zone, adaption zone, and the tunnel interior.

The level of luminance in each zone is controlled based on the exterior luminance. See Chapter 1, "Tunnel Lighting System" for a detailed system description and modes of operation.

2. **Traffic Control and Incident Detection**

The purpose of the traffic control system is to convey messages to motorists, alerting them to potentially hazardous situations in the tunnel.

The system consists of: Traffic signal heads, neon portal signs, variable message signs and traffic data stations.

The traffic signal heads are located at intervals through each tunnel cell, and can be automatically or manually controlled.

The neon portal signs are located at each tunnel entrance. When activated, these signs will alternately flash "TUNNEL CLOSED" and "DO NOT ENTER". The neon portal sign is also controlled automatically or manually.

The variable message signs (VMS) are located at a distance from the tunnel entrance to provide sufficient time for motorists to react to the messages being displayed. The signs are controlled from the central control room, but local control is also provided at each sign base.

The traffic data stations are located within the tunnel cells and at ramp entrances. Their function is to monitor current traffic conditions regarding the number of vehicles and traffic speed in the tunnel.

See Chapter 2 "Tunnel Traffic Control and Incident Detection System", for detailed system descriptions and modes of operation.

3. **Tunnel Ventilation System**

Each tunnel is provided with a mechanical ventilation system to supply fresh outside air and extract contaminated air from the tunnel.

The capacities of the fans are variable from approximately 20% to 100% of full rating.

The capacity of each ventilation system is automatically controlled, based on peak hour traffic conditions, and the level of carbon monoxide in the tunnel cells, but can also be controlled manually. The exhaust fans are designed to provide additional capacity to clear smoke from the tunnels in the event of a fire.

See Chapter 3, "Tunnel Ventilation System", for detailed system descriptions and modes of operation.

4. **Power Distribution System**

The main power supplies to the tunnels consist of two separate feeders for redundancy.

In the event of a total power failure, standby diesel generators are available to provide power to vital functions such as lighting, traffic controls and minimum ventilation.

See Chapter 4, "Power Distribution System" for detailed system description and modes of operation.

5. **Fire Protection System**

A foam sprinkler system is installed in the east and westbound tunnel cells. It is activated automatically by rate-of-rise temperature sensors, but can also be manually activated. Alarms and wet pipe sprinklers are provided in the fan rooms. Control rooms and computers are protected by high pressure Halon systems. See Chapter 5, "Fire Protection Systems" for more detail.

6. **Central Control and Monitoring System**

The tunnel equipment is controlled by a network of programmable logic controllers (PLC's) and a MicroVax II host computer. These provide control of tunnel lighting levels, fan speeds, traffic signals and message signs, and also produce print outs of daily activities. A brief overall description is contained in Chapter 6, Control System.

Complete instructions for operating and maintaining the tunnel control system are given in Sverdrup Corporation's publication entitled "Control Software Reference Manual."

7. **Communication System**

Each tunnel is equipped with a telephone and radio communication network for routine and emergency operations. Telephones are provided along the roadways, in the control rooms, fan rooms and in equipment spaces and utilidors. Radios are provided to allow the operator to talk to vehicles in the tunnels as well as allowing communications for fire and police department, WSDOT, Metro and other emergency and maintenance services. See Chapter 7, "Communication Systems" for complete descriptions of the communication systems.

1. **TUNNEL LIGHTING SYSTEM**

1.1 **System Description**

The tunnel lighting system is designed to provide the necessary illumination required for good visibility at the tunnel entrance and throughout the interior. There are unique visibility problems in tunnels, especially when the luminance level of the tunnel interior is substantially lower than that of the outdoors. Without special lighting motorists entering the tunnel will experience a temporary visual problem due to the sudden darkness. Therefore, the design philosophy adopted for the tunnel lighting system is to provide a gradual decrease in the lighting levels in steps to allow the motorists sufficient time to adapt to the lower luminance levels of the tunnel interior.

Each tunnel is divided into four lighting zones, each zone having a lower lighting level than the previous, in the direction of traffic. The four zones are: The Threshold Zone, the Transition Zone, the Adaption Zone and the Tunnel Interior.

In addition to the different illumination levels between the zones, the illumination levels of the threshold, transition and adaption zones are also varied, according to the exterior luminance. The threshold zone is the first 200 to 300 feet into the tunnel. The lighting level of this zone follows the outdoor lighting level and is changed in steps as the exterior luminance intensity varies. The next 200 to 300 feet is the transition zone, and is illuminated at 60% of the threshold zone level. The adaptation zone is the next 200 to 300 feet of the tunnel and has a luminance level 50% of the transition zone. The last zone is the tunnel interior which extends from the adaptation zone to the tunnel exit. The tunnel interior has a luminance level of 2 candela per square meter (cd/m2) at night and 4 cd/m2 during the day.

Table I illustrates the relationship between the exterior luminance, the luminance level of each zone and the corresponding step.

TABLE I
RELATIONSHIP OF EXTERIOR TO INTERIOR ZONE LUMINANCE

EXTERIOR LUMINANCE CD/M2	TUNNEL ILLUMINATION STEP	ZONE LUMINANCE CD/M2 THRESHOLD ZONE	TRANSITION ZONE	ADAPTATION ZONE	INTERIOR ZONE
0-52	NIGHTTIME & EMERGENCY	2	2	2	2
48-1050	STEP 1 & DAYTIME	50	30	15	4
950-2625	STEP 2	100	60	30	4
2375-4200	STEP 3	150	90	45	4
3800-	STEP 4	200	120	60	4

NOTES:

1. The daytime panels are turned on with Step 1
2. The nighttime panels are on at all times.
3. The emergency panels are on at all times.
4. A ten minute delay will occur between step changes when under automatic control.

The tunnel lighting consists generally of two rows of light fixtures per tunnel cell with the exception of the two existing bores through Mount Baker, which have one row each. The light fixtures are mounted in various patterns to provide the required lighting density in each zone. See Figure 1-1 and 1-2 at the end of this section for light fixture configurations in each tunnel. While the operation of the lighting systems is normally done automatically, manual overrides are also available in the control rooms for special circumstances.

1.2 Operational Philosophy

The operational philosophy adopted for the tunnel lighting system, is based on providing decreasing light levels, allowing a motorist time to adapt gradually to lower luminance levels as he travels through a tunnel, as described above in 1.1 System Description.

For this purpose, controls are provided to operate the system automatically, with manual intervention required only in the case of malfunction of any vital component, or in case of an emergency.

The exterior and interior luminance levels are being measured by photocells, strategically located throughout the tunnel facility. See Figure 1-3 and 1-4 for photocell locations.

The measurements are analog output values, and are transmitted to the Programmable Logic Controllers (PLC's) in the control room. The controllers will determine, through the logic software, the proper lighting step by making validation comparisons between external and internal photocells. If the comparative measurements indicate a change required the PLC output value will signal the transfer to a higher or lower lighting level.

1.3 Control and Operation

As described above, in 1.2, Operational Philosophy, the routine operation of the lighting systems is done automatically by photo cells measuring the exterior and interior light levels, and feeding those values into the PLC's, which in turn operate the system through the logic software. (The nighttime and emergency lighting panels are not switched since they remain on at all times). Manual control is available through the keyboards on control console CP2. The status of the tunnel lighting, such steps as on or off, can be monitored from the lighting screen on the CP2, monitor, or from indicating lights on the Environmental Control Panel CP1. The CRT monitor displays also footcandle readings as measured by the photocells.

For the details of keyboard operation and a thorough description of the system software, refer to the Control Software Reference Manual.

Switching of the lighting steps is done with Tunnel Lighting Contactors (TLC's) which supply Tunnel Lighting Panels (TLP's). The entire lighting panel is switched on and off by means of a contactor controlled by the PLC's in response to signals from the photocells.

The TLCs and TLP's are located in the tunnel electrical rooms and throughout the electrical utilidors. Each contactor is equipped with a Hand-Off-Auto switch or a Local-Remote switch plus On-Off pushbuttons. These controls can be used to operate the tunnel lighting manually if automatic operation or operation from the CP2 keyboard is not possible. Figures 1-5 and 1-6 show which TLCs to operate for each step of lighting required.

A small portion of the tunnel lighting is energized through Uninterruptable Power Supplies located in the electrical rooms. These lights remain on at all times and provide emergency lighting in the event of a power failure, until the diesel generators can restore the balance of the lighting.

1.4 **Maintenance**

Maintenance of the luminaires will be limited to periodic cleaning and replacement of lamps as required or in accordance with a prearranged schedule. Maintenance of Tunnel Lighting Contactors and panels should be done in accordance with the manufacturers recommendations.

Note: All lighting steps should be exercised (turned on and off) from the keyboard every month to verify proper operation.

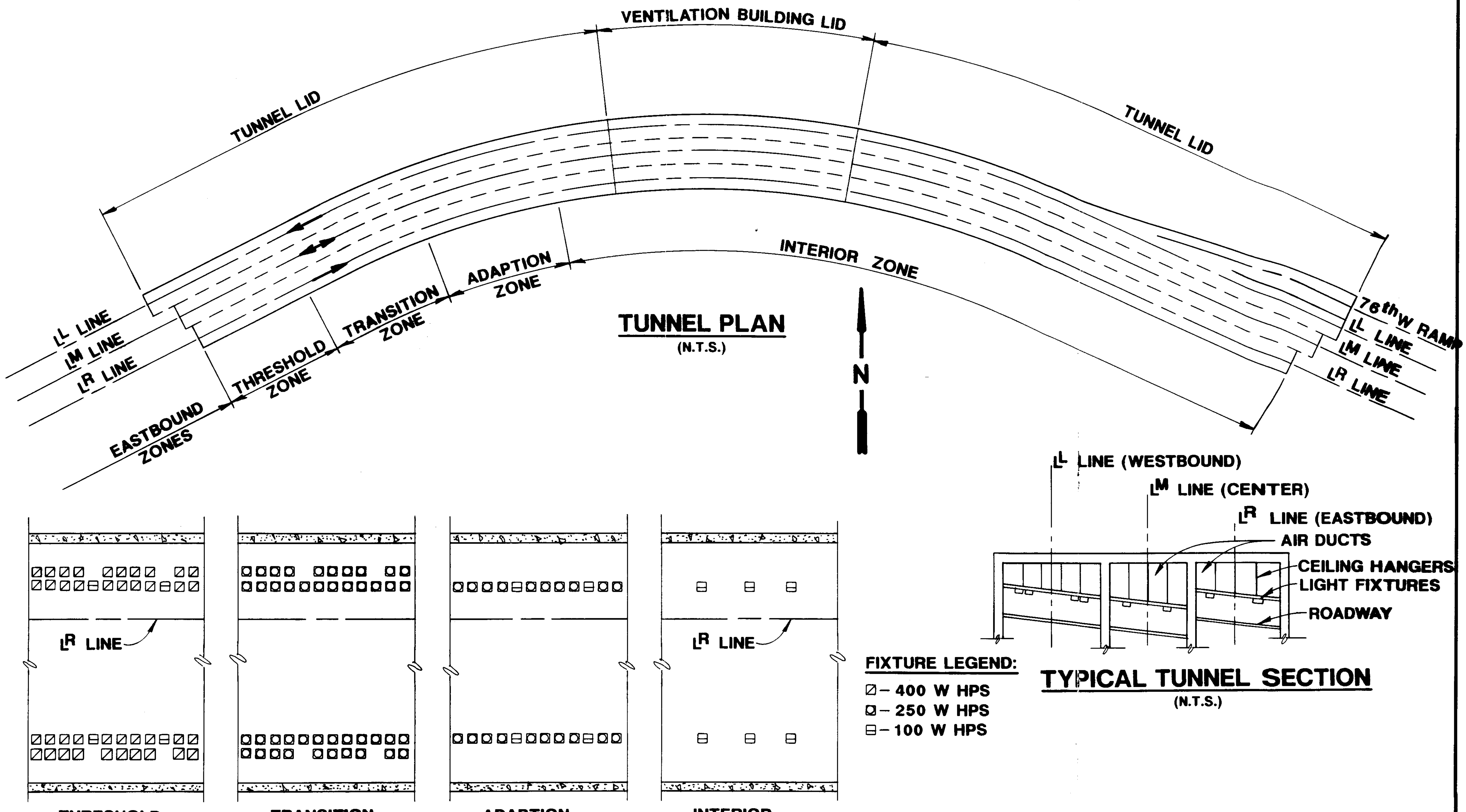


FIGURE 1-1

MERCER ISLAND TUNNEL
LIGHTING FIXTURE CONFIGURATION

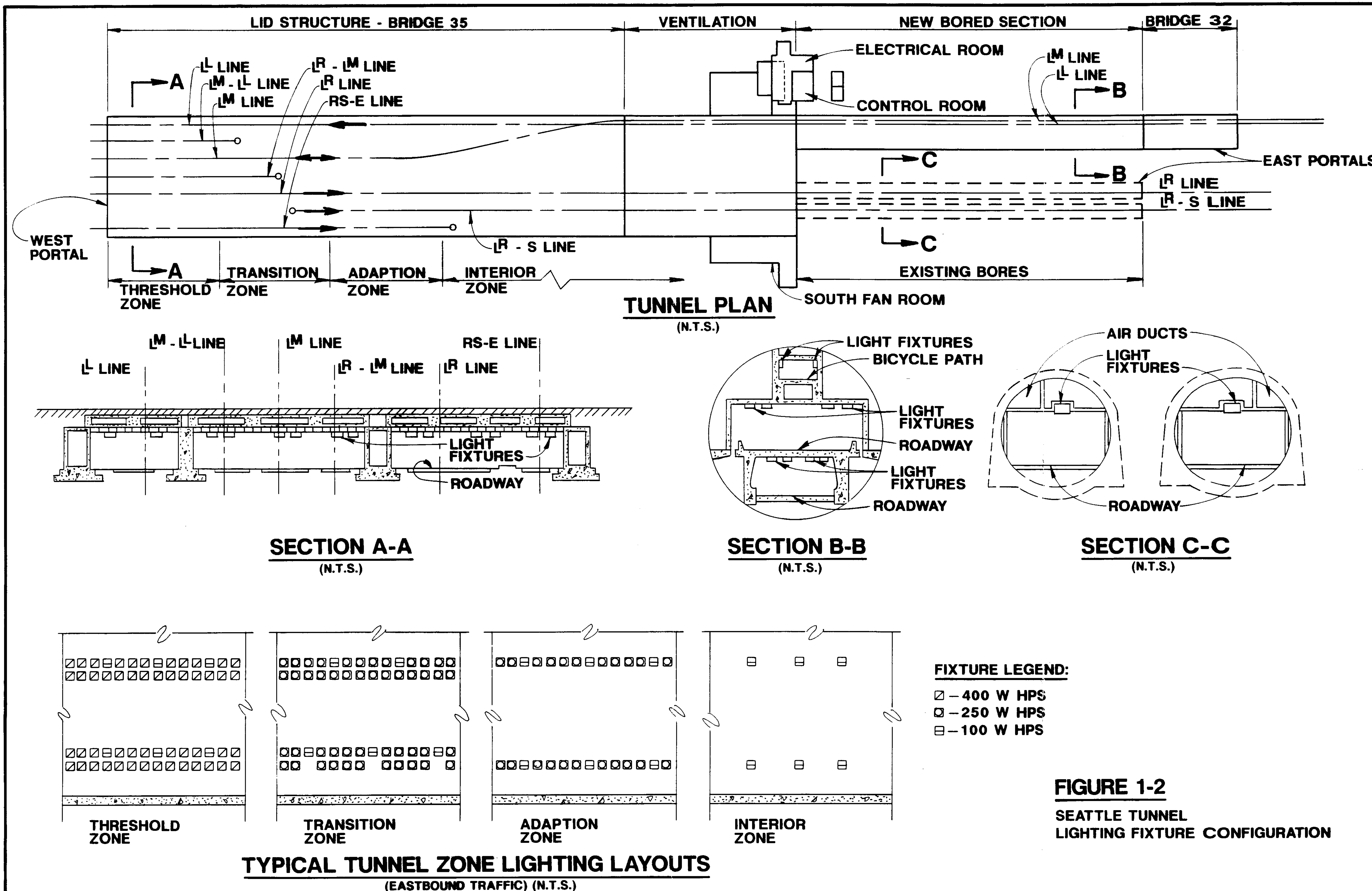


FIGURE 1-2

SEATTLE TUNNEL LIGHTING FIXTURE CONFIGURATION

NOTE: SEE AS-BUILT DRAWINGS FOR DETAILED INFORMATION.

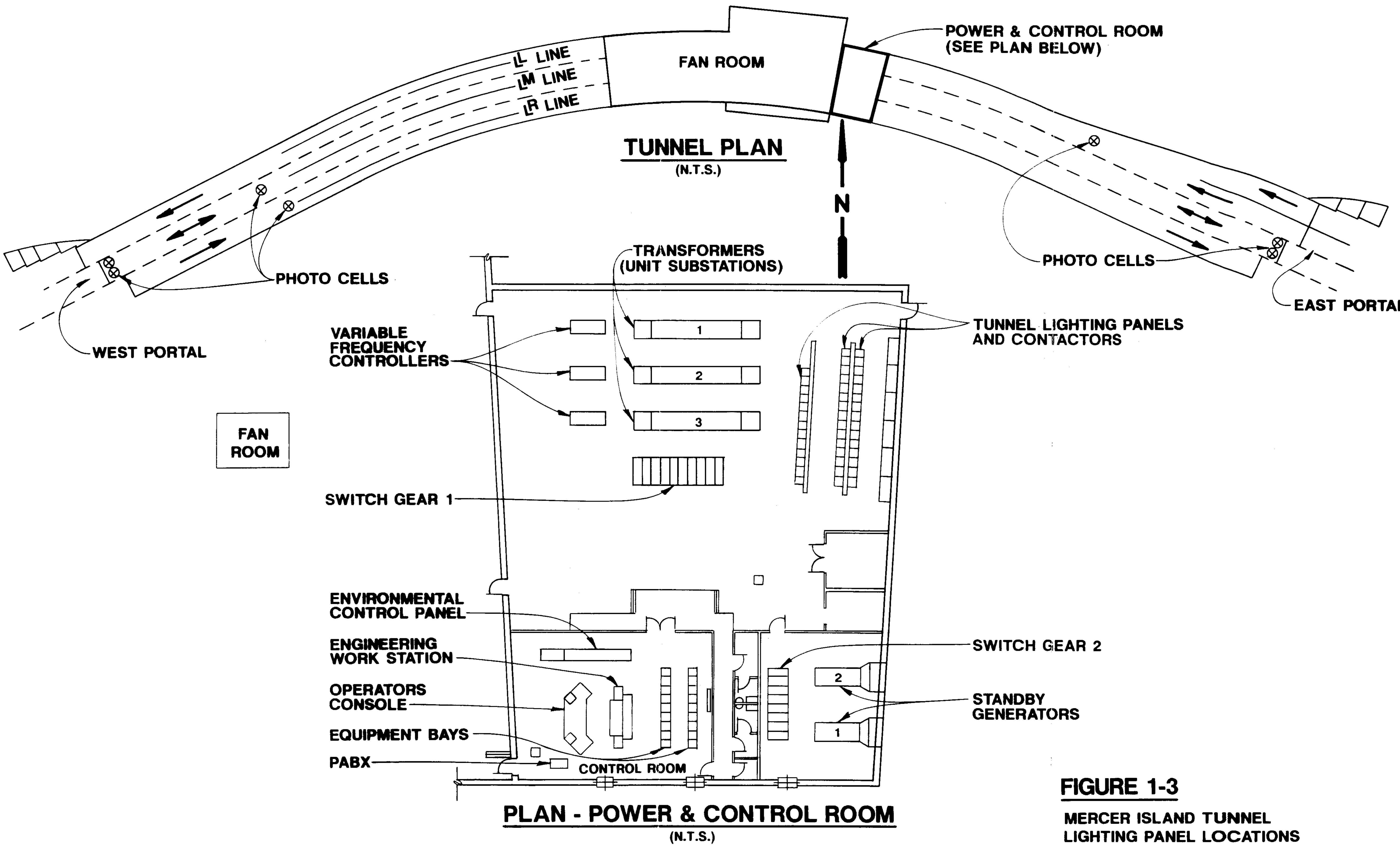


FIGURE 1-3

MERCER ISLAND TUNNEL
LIGHTING PANEL LOCATIONS

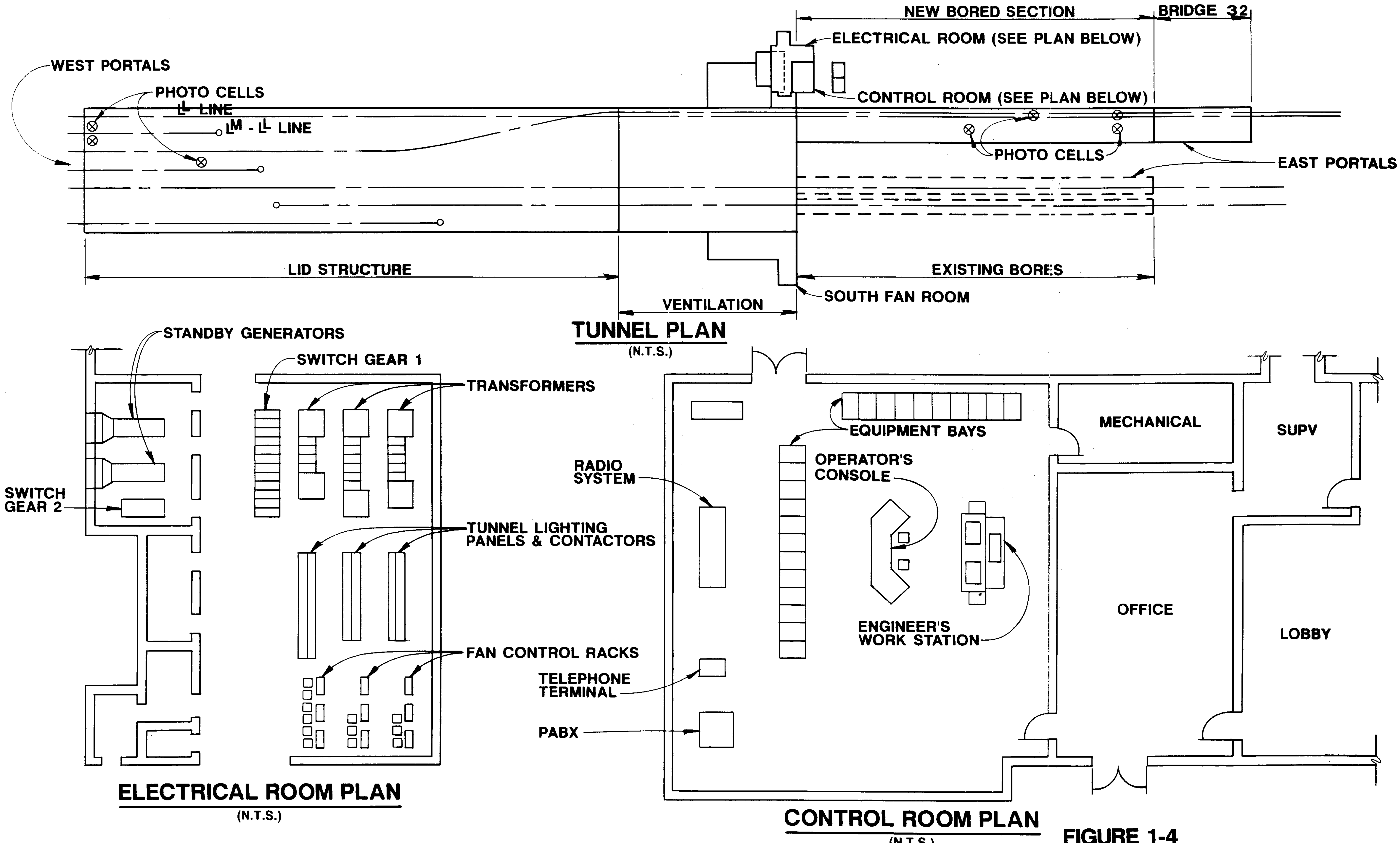


FIGURE 1-4

SEATTLE TUNNEL LIGHTING PANEL LOCATION

MERCER ISLAND TUNNEL LIGHTING STEPS	EMERGENCY LIGHTING PANELS	TLP - TUNNEL LIGHTING PANELS					
	ELP	NT	DT	1	2	3	4
LR INTERIOR - NORTH	4	16	15	-	-	-	-
LR INTERIOR - SOUTH	1	19	18	-	-	-	-
LR WEST PORTAL - NORTH	-	-	-	21	22	23	24
LR WEST PORTAL - SOUTH	-	-	-	31	32	33	34
LM INTERIOR - NORTH	6	6	5	-	-	-	-
LM INTERIOR - SOUTH	5	9	8	-	-	-	-
LM WEST PORTAL - NORTH	-	-	-	1	2	3	4
LM WEST PORTAL - SOUTH	-	-	-	11	12	13	14
LM EAST PORTAL - NORTH	-	-	-	41	42	43	44
LM EAST PORTAL - SOUTH	-	-	-	50	49	48	47
LL INTERIOR - NORTH	3	26	25	-	-	-	-
LL INTERIOR - SOUTH	2	29	28	-	-	-	-
LL EAST PORTAL - NORTH	-	-	-	35	36	37	38
LL EAST PORTAL - SOUTH	-	-	-	39	40	45	46

NOTES:

1. EMERGENCY LIGHTING PANELS ARE POWERED BY UPS UNITS AND REMAIN ON AT ALL TIMES. THEY CAN ONLY BE SHUT DOWN WITH THE LOCAL DISCONNECT SWITCH.
2. TUNNEL LIGHTING PANELS ARE SWITCHED BY CONTACTORS, BEARING THE SAME NUMBER AS THE PANEL, LOCALLY OR FROM THE CONSOLE.

FIGURE 1-5

SEATTLE TUNNEL LIGHTING STEPS	EMERGENCY LIGHTING PANELS	TLP - TUNNEL LIGHTING PANELS					
	ELP	NT	DT	1	2	3	4
LR INTERIOR - NORTH	48	47	46	-	-	-	-
LR INTERIOR - SOUTH	49	50	51	-	-	-	-
LR WEST PORTAL - NORTH	-	-	-	45	44	43	42
LR WEST PORTAL - SOUTH	-	-	-	41	40	39	38
LM INTERIOR - NORTH	28	27	26	-	-	-	-
LM INTERIOR - SOUTH	29	30	31	-	-	-	-
LM WEST PORTAL - NORTH	-	-	-	25	24	23	22
LM WEST PORTAL - SOUTH	-	-	-	21	20	19	18
LM EAST PORTAL - NORTH	-	-	-	35	36	37	53
LM EAST PORTAL - SOUTH	-	-	-	32	33	34	54
LL INTERIOR - NORTH	6	5	4	-	-	-	-
LL INTERIOR - SOUTH	7	8	9	-	-	-	-
LL EAST PORTAL - NORTH	-	-	-	14	15	16	17
LL EAST PORTAL - SOUTH	-	-	-	10	11	12	13
BIKE PATH	1	2	3	-	-	-	-
APPROACH STRUCTURE	-	60	-	-	-	-	-

NOTES:

1. EMERGENCY LIGHTING PANELS ARE POWERED BY UPS UNITS AND REMAIN ON AT ALL TIMES. THEY CAN ONLY BE SHUT DOWN WITH THE LOCAL DISCONNECT SWITCH.
2. TUNNEL LIGHTING PANELS ARE SWITCHED BY CONTACTORS, BEARING THE SAME NUMBER AS THE PANEL, LOCALLY OR FROM THE CONSOLE.

FIGURE 1-6

2. TUNNEL TRAFFIC CONTROL AND INCIDENT DETECTION SYSTEM

2.1 Description

There are three different means of controlling traffic at the Seattle and Mercer Island Tunnels.

They are: Traffic signal heads, neon portal signals and variable message signs.

The traffic signal heads are located at increments throughout the tunnels. See Figures 2-1 and 2-2 for signal head locations. Their primary function is to stop traffic from entering or proceeding through the tunnels in case of emergency.

The neon portal signs are located at each tunnel roadway entrance. Their purpose is to inform motorist's of individual tunnel roadway closures. When activated, these signs will alternately flash "TUNNEL CLOSED" and "DO NOT ENTER".

The variable message signs (VMS) are located at the approaches to the tunnels. A variety of messages can be displayed by these signs from a database which can be updated as the need arises. See Figure 2-1 and 2-2 for variable message sign locations.

2.2 Control and Operation

Traffic signal heads, neon portal signs, and variable message signs are used to caution traffic of maintenance work or lane obstructions in the tunnel. Critical incidents requiring tunnel cell closure will be handled by automatic or manual control from the tunnel control console.

a. The traffic signal heads are controlled by two independent PLC's (Programmable Logic Controllers). The failure of one PLC will result in partial loss of signal heads through a given cell.

Each row of signal heads in a cell, facing the same direction, and located side by side, will be controlled to signal identically. Therefore, there are no individual lane signal heads in the tunnel cells. Traffic signal heads will be monitored from the tunnel control console and can be operator-controlled or automatically controlled in response to a fire system signal.

In response to a tunnel fire in a cell, the PLC will cause all signal heads in the direction of upstream traffic will simultaneously turn to a steady amber. After five seconds of steady amber, the neon portal signal will be activated to announce tunnel closure, simultaneously with all upstream signal heads turning red. All signal heads downstream of the incident area will remain deenergized. The control operator will be able to manually override the PLC logic from the tunnel control console. After the emergency situation ends, the operator will manually turn signal heads to green and the signals will automatically return to the normal "off" condition after 30 seconds.

During maintenance or minor incident periods, the operator can manually set any number of signal heads in the flashing amber mode from the control console.

b. The neon portal signs can also be manually activated by an operator at the tunnel console. The neon portal signal will still be automatically activated by the PLC upon a signal from the fire protection system.

c. During normal operations the variable message signs (VMS) will be monitored and controlled by an operator in the tunnel control room through the VMS Central Controller. Capabilities available through this mode of control include:

- Creating and storing messages on the VMS Central Controller hard disk.
- Retrieving stored messages from the disk for review or modification.
- Initiating display of messages on the VMS signs.
- Causing messages to flash and controlling the beacons.
- Viewing the current status of each sign including what message is currently being displayed.
- Scheduling messages for display on the signs on a time-of-day, day-of-week basis.
- Requesting a failure report for all signs in the system.

Additionally, the operator may view the status of the signs through the tunnel computer console. Backup control of the VMS signs will be available through the tunnel computer console in the event of failure of the VMS Central Controller. A copy of the VMS Central Controller message database will be periodically updated on the tunnel computer. If the VMS Central Controller fails, the operator may use the tunnel console to initiate display of any of these prestored messages and may extinguish the display on any sign.

Complete instructions for operating all of the traffic control systems are given in the Control Software Reference Manual.

2.3 Incident Detection

Normally, the location of a fire or traffic incident is detected by the fire monitoring and control system, by the incident algorithms in the computer, or by CCTV observation by the operator. If the tunnel computer is inoperative, the incident algorithms are not available as a means of incident detection and normal control of signs and signal heads are not available through the computer. The Environmental Control Panel has switches to allow manual inputs to control the critical signs and signal heads.

Consult the Control Software Reference Manual for detailed instructions for monitoring and operating the incident detection system.

2.4 Traffic Data Stations

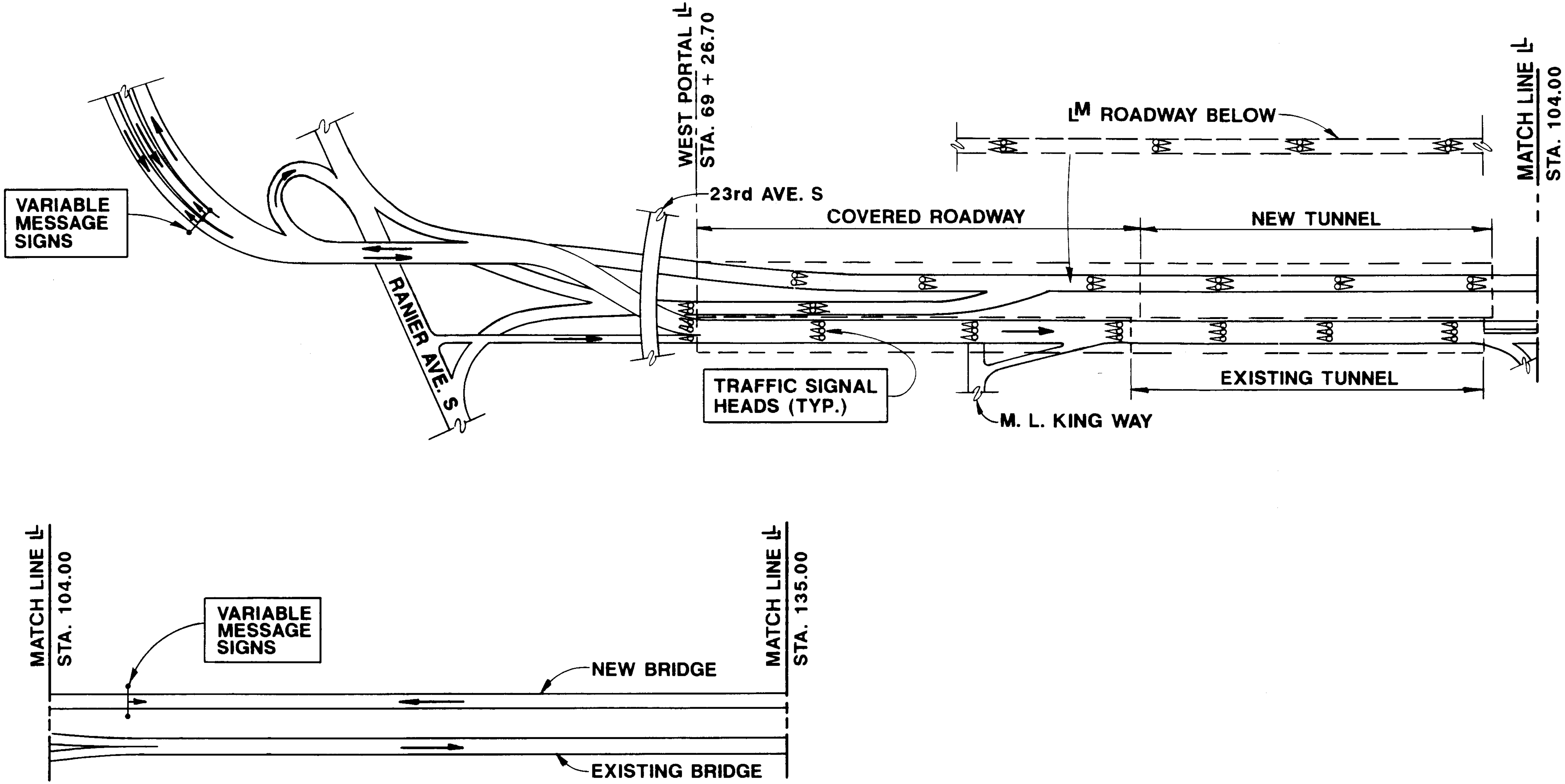
Traffic data stations, located within the tunnel cells and at ramp entrances, monitor traffic conditions by accumulating traffic counts and computing average speeds or the presence of vehicles that are not moving. The tunnel operator may then access this information through the control console or by past printed daily reports. Incident algorithms, executing periodically on the tunnel computer, alert the operator when the relative traffic measures reported by adjacent traffic data stations suggest the presence of an incident. These algorithms will not be able to detect all incidents but will give some indications during heavy traffic periods. Neither the traffic data stations nor the incident algorithms will control any of the traffic lights within the tunnel.

2.5 Maintenance

The traffic signal heads, portal neon signs and variable message signs require little maintenance other than periodic cleaning to maintain visibility. Consult the manufacturers instructions for inspecting and maintaining the electrical systems and electronic controls.

Note: Since the signals and signs may be inactive for prolonged periods they should be exercised from the console keyboards on approximately a monthly basis, when traffic conditions permit.

The traffic data stations and incident detection software require no regular maintenance as long as the interiors of the cabinets remain clean and dry. Proper operation can be verified during periods of heavy traffic. Manual control can be exercised from the environmental control panel (CP1) when traffic conditions permit.



SR 90 LAY-OUT

(N.T.S.)

0 200 400
SCALE IN FEET

FIGURE 2-1

SEATTLE TUNNEL
TRAFFIC CONTROLS

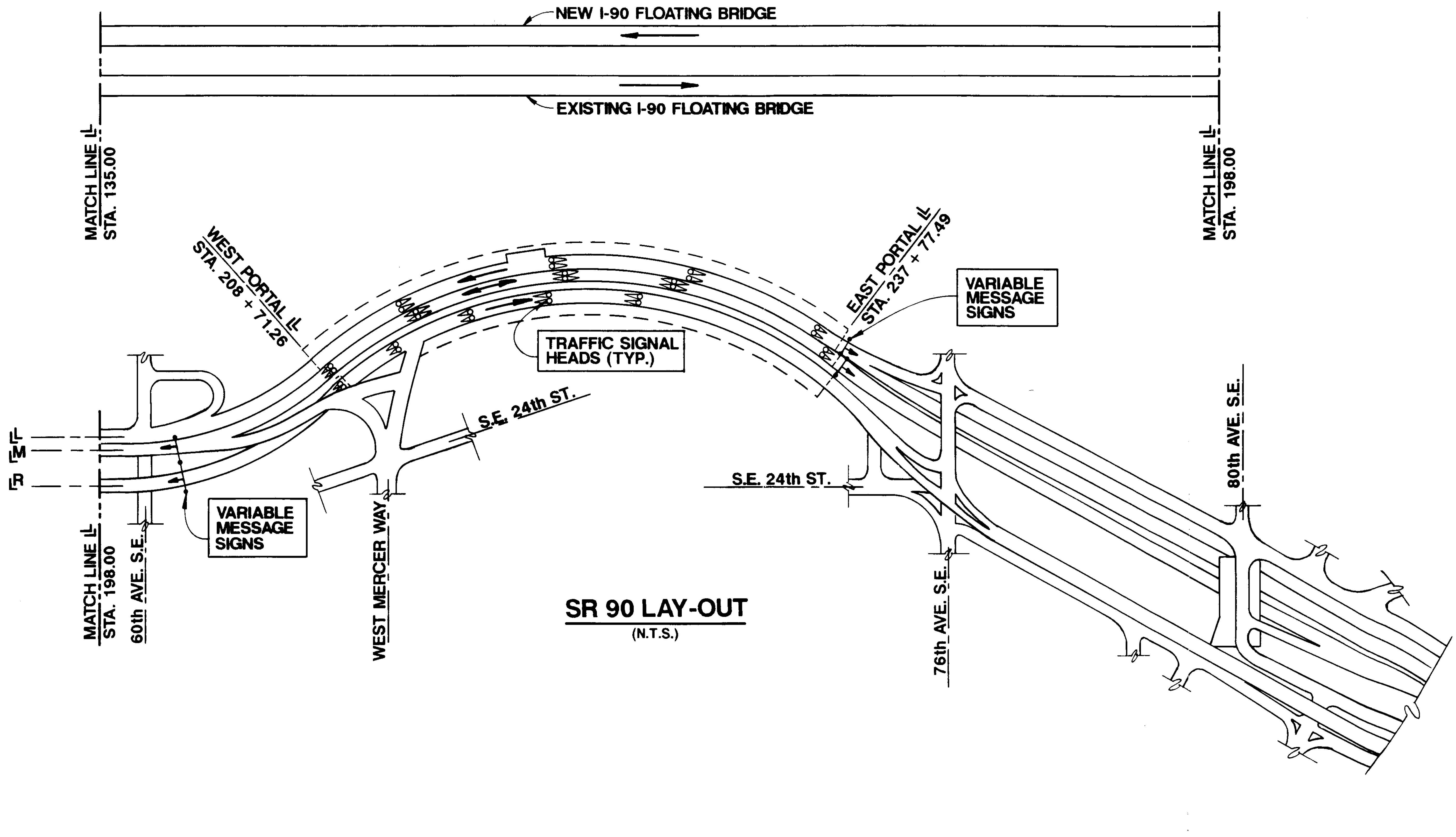


FIGURE 2-2

MERCER ISLAND TRAFFIC CONTROLS

3. **TUNNEL VENTILATION SYSTEM**

3.1 **Description**

There are a total of eighteen supply fans and twenty one exhaust fans to provide the ventilation for the Seattle and Mercer Island tunnels. Each tunnel roadway has three supply and three exhaust fans, with the exception of the eastbound roadway in the Mt. Baker Ridge tunnel, which has six exhaust fans.

The ventilation system is configured as follows:

Seattle (Mount Baker) The North Fan Room contains supply fans SF-1 through SF-6. Fans SF-1 through SF-3 supply air to the L^L roadway tunnel. Fans SF-4 through SF-6 supply air to the L^M roadway tunnel.

The Central Fan Room contains exhaust fans EF-10 through EF-18. Fans EF-10 through EF-12 exhaust air from the L^L roadway tunnel, EF-13, EF-14 and EF-15 exhaust air from the L^M roadway tunnel below L^L, east of the fan room, and EF-16, EF-17 and EF-18 exhaust air from the L^M roadway west of the fan room.

The South Fan Room contains supply fans SF-7, SF-8 and SF-9. They provide supply air to the L^{RN} and L^{RS} eastbound existing bores.

The 30th Avenue Fan Room contains exhaust fans EF-19, EF-20 and EF-21. They exhaust air from the L^{RN} and L^{RS} eastbound existing bores. See Figure 3-1 for Seattle ventilation system layout.

Mercer Island (First Hill)

The First Hill Fan Rooms contain supply fans SF-22 through SF-30 and exhaust fans EF-31 through EF-39. Supply fans SF-22, SF-23 and SF-24 supply air to the L^{L} roadway tunnel. Fans SF-25, SF-26 and SF-22 supply air to the L^{M} roadway tunnel. Fans SF-28, SF-29 and SF-30 supply air to the L^{R} tunnel. Fans EF-31, EF-32 and EF-33 exhaust air from the L^{L} roadway tunnel fans EF-34, EF-35 and EF-36 exhaust air from the L^{M} roadway tunnel and fans EF-37, EF-38 and EF-39 exhaust air from the L^{R} roadway tunnel. See Figure 3-2 for Mercer Island ventilation system layout.

3.2 **Operational Philosophy**

The supply fans bring in fresh outside air while the exhaust fans remove contaminated air. The exhaust fans are considerably oversized for normal ventilation, in order to effectively remove smoke in case of a fire in the tunnel.

The controlling parameter for the amount of ventilation air being introduced is the concentration of Carbon

Monoxide (CO) within the tunnels. Fan speeds are normally varied automatically, but manual control is available at the CP2 console. Fans can also be controlled at the variable speed drive by putting the drives LOCAL-REMOTE switch in LOCAL and using the cover-mounted controls.

3.3 Control and Operation

The capacity of the ventilation system is controlled by the use of variable frequency drives and conventional squirrel-cage fan motors. Fan speeds are normally regulated based on the time of day and typical traffic loads. However, variations in these loads, carbon monoxide (CO) levels, environmental conditions, or tunnel emergencies will necessitate changes in fan speed.

The speed of each fan may be adjusted from approximately ten percent to full speed, though the automatic program does not go below 20%. The exhaust system is sized larger than the supply system to help clear the tunnel of smoke during a fire.

As mentioned previously, each fan is capable of being operated under manual control, independent of other fans. This control may come from the tunnel control console operator, the environmental control panel, or from the Traffic System Monitoring Center. Fans may also be controlled locally from their individual whats. Lockout for maintenance purposes is possible locally at the fans.

Each fan is monitored for speed, vibration, bearing temperature, and motor winding temperature. These values are displayed on the tunnel console monitor. They will also be periodically placed in a historical file for later evaluation. Additionally, independent contacts for vibration and temperature are monitored for alarm conditions.

Normal Operation

The most efficient mode of operation is to run as many fans as possible at the lowest possible speed. Since the lowest continuous safe speed is 20 percent, and the fans are sized for emergency conditions, the software program will often shut down one of each set of three to conserve electricity.

Note: It is recommended that all three exhaust and supply fans in each tunnel cell be run at 100% speed for five minutes a month to blow accumulated dust out of the air ducts. Do not blow out more than one roadway at a time, or exceed five minutes of full speed operation, to prevent excessive electrical demand charges.

Tunnel Cell Fire

Fires within the tunnel are monitored by the fire control system which operates independent of the tunnel computers. The fire system provides fire alarm and location information to the tunnel computer and also generates a fire alarm input to the ventilation fan PLC's. The PLC logic will set the speed for the supply fans at 20% and the exhaust fans at 100% speed within the effected tunnel cell. The other cells will be pressurized to control smoke. When the emergency is cleared, the operator can reset the fire alarm signal and the PLC logic will automatically return the fan speed to normal.

Power Loss

In the event that a power failure occurs on both of the incoming utility lines, a standby generator system will be brought on line. This system is sized to provide enough power to operate the ventilation fans at reduced speeds. If a fire should occur while the tunnel is on generator power, priority will be given to maintain the exhaust fans for the effected cell at their maximum possible speed. Use of supply and exhaust fans in other cells will be controlled so that the total power demand does not exceed the generator capacity.

Details of the load shedding program are given in the Controls Software Reference Manual.

3.4 Dampers

There are two types of dampers in the system, fan isolation dampers and system balancing dampers.

The fan isolating dampers are motorized and interlocked with the fans so that they open during the operation of a fan, and close when the fan shuts down.

The balancing dampers are located throughout the system for balancing purposes. The exhaust system balancing dampers are motorized and will operate automatically to divert the maximum possible exhaust flow through an affected area in case of a fire. After a fire, the dampers must be returned to the original position manually.

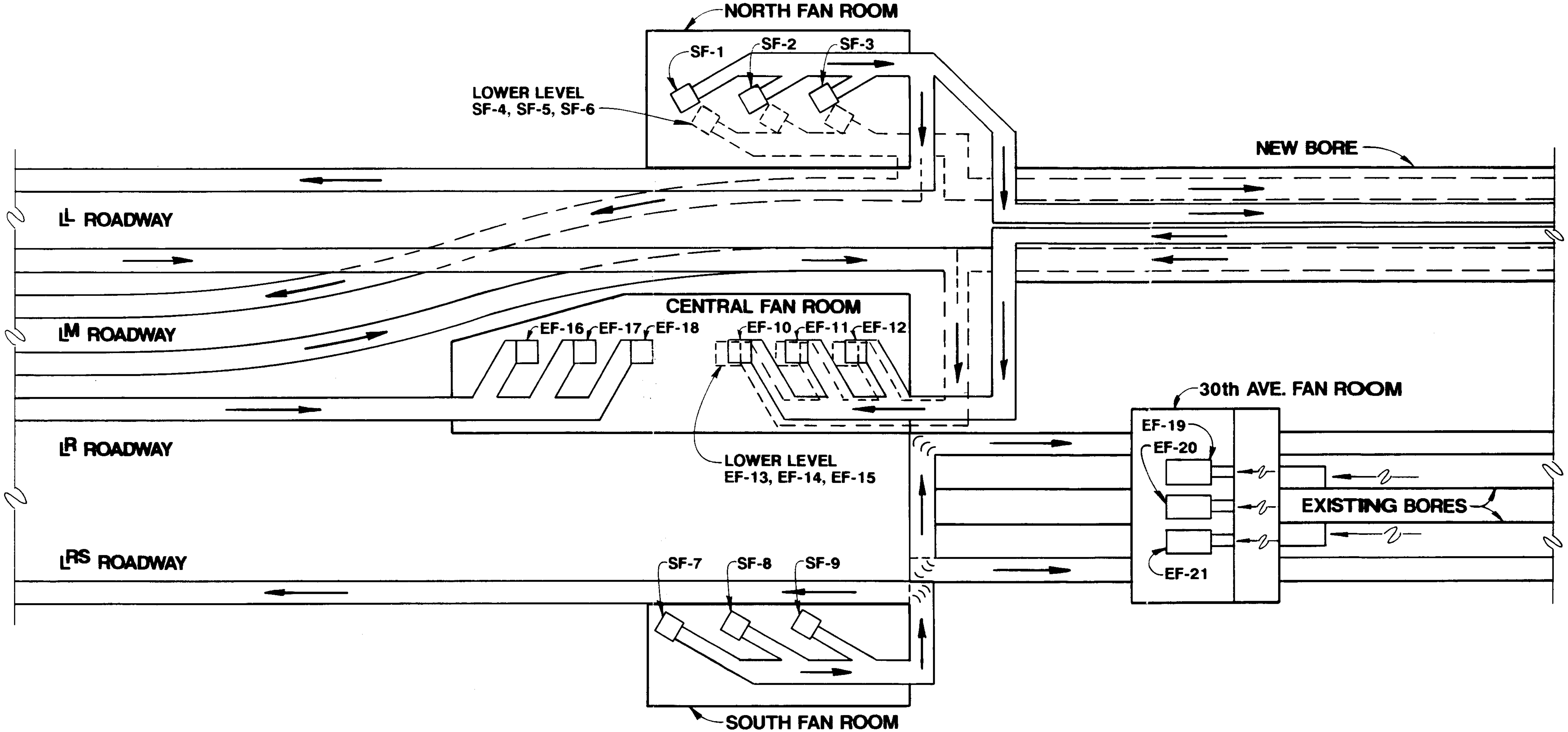
All supply air system dampers are manually set and operated.

See Figures 3-1 and 3-2 for damper locations in the Seattle and Mercer Island tunnels respectively.

3.5 **Carbon Monoxide (CO) Monitoring**

Each traffic cell has three or four CO detectors monitored by the tunnel control system. Carbon monoxide values are available for display on the CRT, environmental control panel, and CO equipment rack. If the CO concentration of an area within a traffic cell should exceed 125 ppm, the normal fan speed control will be overridden and the supply and exhaust fans for the cell will be increased to maximum speeds. This will be maintained until the CO level decreases to below 90 ppm at which time the normal control will resume operation. This will also cause an alarm at the control console.

The algorithm for the CO monitoring alarms is given in the Control Reference Software Manual.

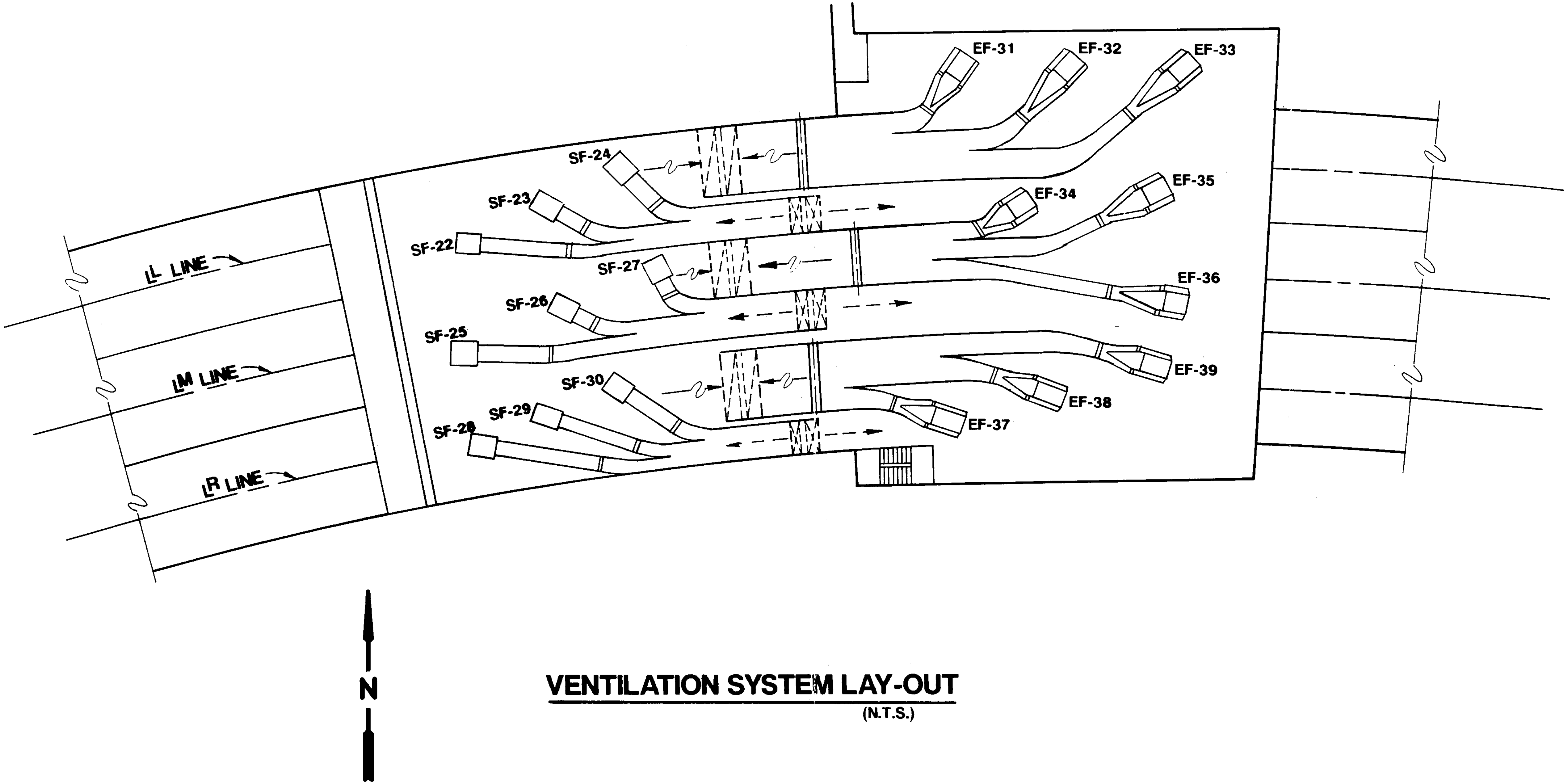


VENTILATION SYSTEM LAY-OUT

(N.T.S.)

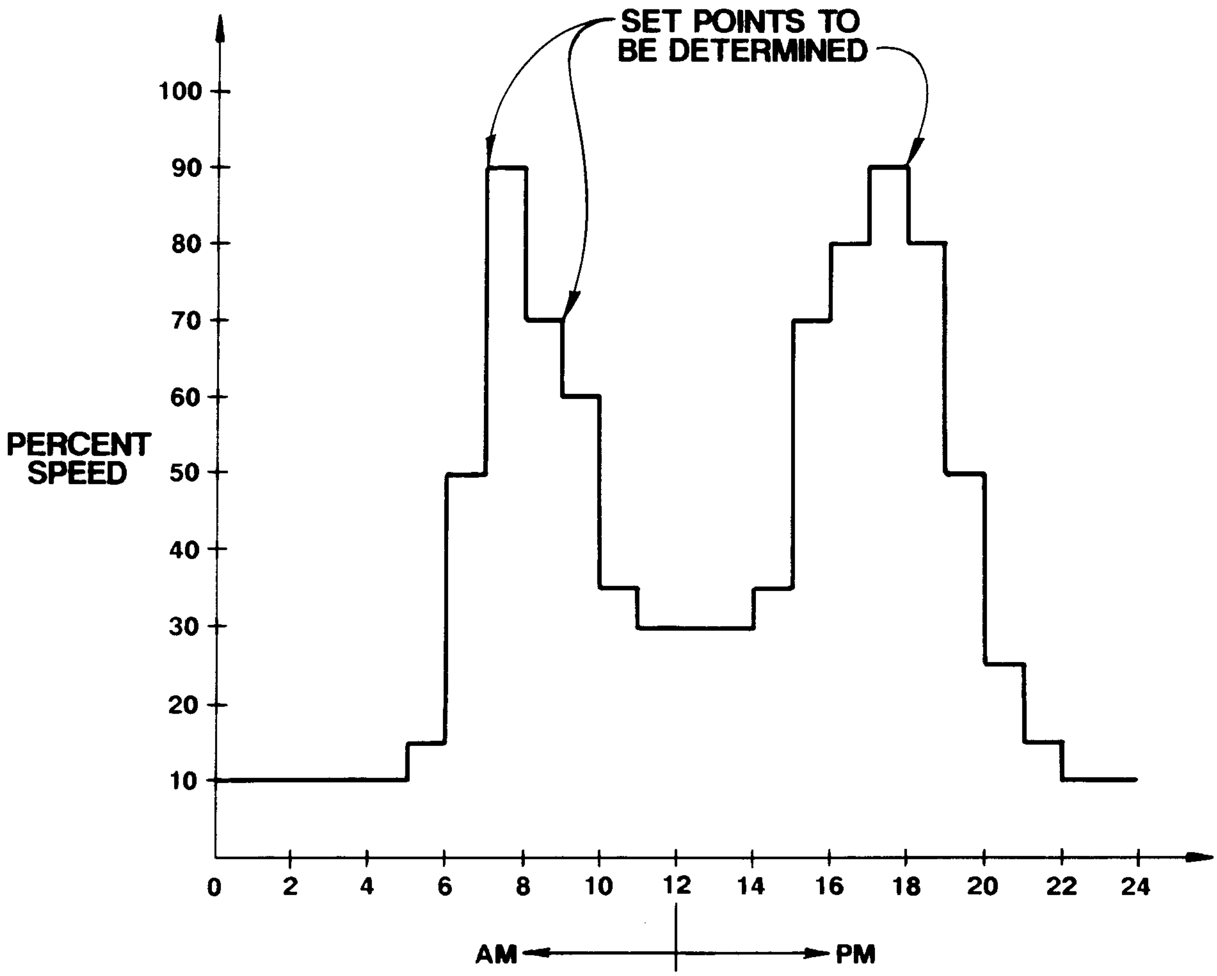
FIGURE 3-1

SEATTLE TUNNEL
VENTILATION SYSTEM
CONFIGURATION



VENTILATION SYSTEM LAY-OUT
(N.T.S.)

FIGURE 3-2
MERCER ISLAND VENTILATION SYSTEM CONFIGURATION



TYPICAL FAN SPEED VARIATIONS - WEEKDAYS

FIGURE 3-3

4. POWER DISTRIBUTION SYSTEM

4.1 Description

The electrical power systems for the tunnels include the incoming utility company feeders, the medium voltage switchgear, the unit substations, the engine-generators and associated switchboard, the station battery, the uninterruptible power supplies, an assortment of automatic transfer switches, transformers, and panels, miscellaneous control equipment, and all the necessary cables and conduits. Refer to one line diagrams, Figures 4-1, 4-2, and 4-3 for the Seattle Tunnel and Figures 4-4, 4-5, and 4-6 for Mercer Island.

4.2 Utility Power Supplies

Mt. Baker Ridge Tunnel

Power supply for the Mt. Baker Ridge Tunnel is furnished by Seattle City Light on overhead lines at 26,000 volts with transformation on site to 13,800 volts, 3 phase, 4 wire, 60 Hertz. There are two incoming lines, each capable of supplying 100% of the tunnel loads. Under normal conditions these lines each carry roughly 50% of the total tunnel load. With the failure of either incoming line, the total load at the tunnel would be transferred to the remaining energized line.

Mercer Island Tunnel

Power supply for the Mercer Island Tunnel will be furnished by Puget Power at 12,470 volts, 3 phase, 4 wire, 60 Hertz. There will be two overhead lines with similar capabilities as described for the Mt. Baker Ridge Tunnel.

Power Sources

The utility company incoming lines for each tunnel provide the greatest possible geographical, physical, and electrical separation that is practical to minimize outages from lightning and wind storms.

4.3 Medium Voltage Switchgear - 15kV Class

The medium voltage switchgear utilizes two incoming line main circuit breakers, one bus tie circuit breaker, six feeder breakers, and all related protective relays, transformers, control switches, meters, etc. The main and bus tie breakers are electrically interlocked to ensure that only two of the three circuit breakers will be closed at any one time. Automatic transfer equipment is included in the switchgear. Upon loss of an incoming line, the switchgear will automatically open the associated main breaker and close the bus tie breaker. On restoration, the reverse sequence will take place.

The basic interrupting capacity of the switchgear has been determined from a short circuit study using utility company data for the particular points of connection to their system. Standard metal clad construction having porcelain bus insulators and insulated power buses is utilized for maximum safety. Copper buses with silver-to-silver bus joints are employed to reduce heating and power loss. The switchgear is constructed to accommodate one circuit breaker per full height vertical cubicle.

The circuit breakers are the vacuum break type which can be moved into the connected position on guide rails. Test and disconnected positions are provided including provisions for padlocking in these positions. All circuit breakers are electrically operated from the 125 volt DC station battery. The actuating mechanism is the spring-operated stored-energy type where the DC power charges a spring immediately after it is used. A closing DC solenoid trips the spring mechanism to close the breaker. An opening DC solenoid trips the spring mechanism to open the breaker.

4.4 Load-Center Unit Substations - 480/277 Volts

From the medium voltage switchgear, power is distributed through cables in conduits (or trays) to the three 480/277 volt load-center unit substations at each tunnel. These unit substations each contain two indoor ventilated dry type transformers complete with a 15kV primary non-fused load-break switch having padlocking provisions. These transformers have a delta connected primary winding and a wye connected secondary, solidly grounded. Provisions for fan cooling is included.

All circuit breaker compartments of the 480/277 volt switchgear are of grounded metal-enclosed construction with draw-out provisions for breaker units. Circuit breakers are the spring-operated stored-energy type. The main, tie, emergency power, and tunnel lighting feeder breakers are electrically operated. The remaining feeder breakers are manually operated. The interrupting capacity of the breakers has been determined by a short circuit study.

The circuit breakers utilize solid state adjustable trip devices to provide the desired circuit and equipment protection, as well as coordination with other electrical system protective devices.

The two transformer secondary main circuit breakers and the bus tie circuit breaker are electrically interlocked to prevent having more than two of these breakers closed at any one time. (Interlocking is also provided to ensure that the standby breaker cannot be closed unless the two main breakers are open.) The tie breaker in the unit substations does not automatically close upon failure of one source. Electrically operated substation breakers can be operated from the control console keyboard. Consult the Controls Software Reference Manual for details of keyboard operation.

4.5 Low Voltage AC Power Distribution Systems

General

Low voltage power is distributed from the various sources such as the substation breakers and power panels to loads through wires and cables contained in galvanized steel ducts, embedded plastic ducts, and cable trays. Wires and cables are 600 volt types RHH and THW rated 90°C copper temperature.

Lighting and power panelboards utilize high quality one, two, or three pole circuit breakers as the situation requires.

Lighting and power transformers are the indoor dry type.

Power distribution panelboards are the fusible switch type with flexible design which permits the incorporation of motor starters and/or circuit breakers in the assembly as a standard feature. Most panelboards are provided with a fusible incoming line main disconnect switch. All fuses are dual-element.

Automatic transfer switches are mechanically held, electrically operated, and mechanically interlocked so that only one of the two positions is possible.

The fan drive systems utilize variable frequency motor controllers which convert the available 480 volt, 3 phase, 60 Hertz power to adjustable voltage and frequency, 3 phase, AC power. (The controllers provide continuous speed adjustment from 10 percent to 100 percent speed.)

Motors 1/2 horsepower and larger are rated 460 volts, 3 phase, 60 Hertz. Motors under 1/2 horsepower are rated 120 volts, single phase, 60 Hertz. Motor starters are the combination fused-switch type. All fuses are dual-element.

<u>Load-Center Unit Substation Loads</u>

Each unit substation supplies power to a group of six ventilation fans (3 supply and 3 exhaust) and a group of tunnel lighting panels. Substation 1 powers the fans and lighting panels for the westbound lanes;

Substation 2, the fans and lighting panels for the transit lanes; and Substation 3, the fans and lighting panels for the east-bound lanes. Substation 4 at Mt. Baker Ridge is associated with the loads for the lanes in the existing bores.

At each substation, two exhaust fans, one supply fan, and half of the tunnel lights (north row) are connected to Bus 1 breakers, and one exhaust fan, two supply fans, and the other half of the tunnel lights (south row) are connected to Bus 2 breakers. This arrangement provides for maximum reliability. In case of a fault, at least half of the exhaust and supply fans will continue to run, and at least half of the tunnel lights will continue to burn.

In addition to the fan and lighting loads, Substation 2 at each tunnel has a "Bus 1" and "Bus 2" breaker assigned to supply redundant power to the fire protection system. Another set of "Bus 1" - "Bus 2" breakers provide redundant power to the vent building power panels and to two 480-208/120V transformers. The secondaries of these transformers connect to an auto transfer switch. The load side of the switch supplies power to the very important "Essential Services" panel. This transfer switch has no "preferred" position but switches to the first side that is energized.

4.6 DC Power Supply and Distribution Systems

General

The station battery for each tunnel is located inside a specially ventilated room adjacent to each electrical room. The battery charger and DC power distribution panelboard are located on a wall outside these rooms. The DC system will provide power for operating the switchgear and load center circuit breakers. Batteries are utilized so that switching will continue during a power failure, without interruption.

Station Batteries

The battery system at each tunnel is the lead-acid, calcium alloy, flat plate type in clear plastic containers, 125 volts, and has an ampere-hour rating sized for the expected load demands. The calcium battery was selected because it has the lowest water loss, highest one-minute ratings, and the lowest maintenance requirements of all batteries available. The expected battery life is 20 years.

Battery Racks

The battery rack is designed for Seismic Zone 4.

Battery Charger

The battery chargers are floor-standing, heavy-duty, solid-state units which automatically regulate the output voltage and current to meet the demand of the battery and/or load. The units are designed to automatically carry the normal DC loads should the battery fail or be disconnected for maintenance reasons. The units are supplied with alarms for charge failure, low DC voltage, high DC voltage, AC failure, and circuit ground conditions.

DC Power Distribution Panelboards

All DC panelboards are fusible and utilize two-element cartridge fuses. Panelboards are fitted with one main fused switch and have separate fused branch switches to serve the medium voltage switchgear, unit substations, and miscellaneous other loads. The switches are the quick-make, quick break action type. The fuses are selected to coordinate properly in the event of a branch circuit problem.

Cables and Fuse Ratings

All DC system distribution cables are considerably oversized. The fuses are sized to protect the oversized cables. This oversizing is intended to eliminate unwanted interruptions, and the fuses will operate only as a last ditch type of protection.

All cables of the DC distribution system are enclosed in a galvanized steel conduit system except for a short length at the battery position which is open wiring.

4.7 Standby AC Power Supply Systems

Two automatically synchronized diesel driven generators are installed inside a separate room of the ventilation building at each tunnel. These generators provide standby power for tunnel ventilation, tunnel lights and auxiliary loads in accordance with a load-shedding schedule in the tunnel software. The program contains different scenarios for power failure, power failure with a fire in one tunnel cell, power failure with multiple fires, and failure of one generator.

Details of the load shedding programs are found in the Controls Software Reference Manual.

The Mercer Island generators are rated 600 kw each. The Seattle units are each rated 800 kw.

The generators will produce full power at the generator switchboard bus within 10 seconds of an outage. Two smaller size generators, with automatic synchronizing controls, are used rather than one large unit in order to provide greater reliability in the case of the failure (or maintenance) of one unit. One large underground fuel storage tank, sized for a weeks fuel supply, is installed outside each vent building. Fuel transfer pumps and day tanks are provided in the Generator Room.

Note: The generators should be exercised with at least 60% load for three or four hours each month.

A generator control board houses the controls, synchronizing equipment, and the standby power switchgear. The switchgear circuit breakers are stored-energy draw-out similar to the unit substation 480V switchgear.

Power feeders from the standby AC power systems are routed in conduits from the load side feeder breakers at the Generator Control Board to the "emergency power" circuit breakers at the unit substations. One power feeder is also rerouted to designated tunnel lighting panels and to a number of uninterruptible power supplies through an arrangement of fused disconnect switches and automatic transfer switches.

4.8 **Uninterruptible Power Supplies**

For Tunnel Lighting

In the event of a utility company power outage. Uninterruptible power supplies with 90 minute battery sources and DC to AC inverters will ensure a continuous source of AC power to a selected number of high pressure sodium lights in the tunnels.

These power supplies continuously float on the line. When loss of normal power occurs, a continuous flow of power to the critical connected loads is maintained from the battery source through the inverter.

For Computers and Associated Equipment

Uninterruptible power supplies are installed in each of the tunnel control rooms to supply continuous high quality 120 VAC power (completely isolated from the utility line fluctuations) to the traffic computer, the environmental graphic panel, the PLC's and related equipment. Audible and visual alarms are also provided for the inverters.

4.9 **Control and Operation**

Normal Conditions

Under normal conditions (for both tunnels), the following conditions exist:

- The switchgear main breakers are closed, the tie breaker is open, and all feeder breakers are closed.
- The unit substation primary disconnect switches are closed, the transformer main secondary breakers are closed, the bus tie breakers are open, the emergency power breaker is open, and all feeder breakers are closed.
- All 480V system fused disconnects ahead of transformers, panelboard, and automatic transfer switches (A.T.S.) are closed.
- All automatic transfer switches are in the normal position. (Note: the critical ATS has no normal or preferred position.)
- All panelboard breakers are closed
- The diesel generators are not operating and the associated switchgear main breakers are open, the breakers to the tunnel lighting panels are open, and the breakers to the three substations are closed.

Loss of One Utility Company Feeder

With the loss of one utility company main feeder for either tunnel, the following will occur:

- The automatic transfer arrangement in the 15kV switchgear will open the circuit breaker of the deenergized main feeder and close the bus tie breaker after a brief delay. This transfer will reenergize all switchgear feeders.

- With the short duration outage described above, one-half of the tunnel lights, (except the emergency lights connected to the uninterruptible power supplies) will go out. Once power is restored, the lights will re-strike and after about 45 seconds, return to full brilliance.
- The related vent fans would not have been affected noticeably although they would have gone through a momentary loss of power.
- The related automatic transfer switches would not have transferred because of built-in pre-set time delays.

Loss of Both Utility Company Feeders

The following will occur when both utility company feeders fail:

- All fans will begin to coast to a stop.
- All tunnel lights will go out except those connected to the U.P.S. equipment.
- All traffic lights and lane-use signals will go out.
- Fire alarm and telephone systems (including emergency phones) will switch over to battery backup.

- The fire suppression system will have no power to operate (foam pumps have no power supply).
- Vent building lights and HVAC equipment will lose power.
- Individual battery operated lights in the control room, switchgear room, generator room, and passageways will turn on.
- The C.O. monitoring system will stop functioning.
- The station battery will remain fully charged and available to open and close breakers.
- The batteries associate with the U.P.S. in the Control Room will feed power to the control equipment.
- The loss of voltage relays in the 15kV switchgear will send a signal to the generator switchgear to initiate a generator start-up sequence which will do the following:
  a. Open all electrically operated breakers at the switchgear, unit substations, and generator switchboard.
  b. Start generators and close both generator main breakers to energize the 480V standby bus in the generator switchgear.
  c. Close the bus tie breaker at each unit substation.

d. In sequence, and with a set time delay, close the emergency power breaker at each of the unit substations.

The electrical system will then be operating on generator power, and the tunnel facility will be completely operational but at a reduced level of ventilation and lighting. All controls will be available. The graphic panel at the tunnel and the environmental CRT monitor at Roanoke will display the status of the electrical system (which breakers are closed, which fans are running, etc.).

With resumption of service from one or both of the utility company lines, the relays in the switchgear will send a signal to the programmable controller to initiate a "Generator Shutdown" sequence.

Operating Modes

The tunnel power distribution system can be operated in the following modes:

- Automatically through commands sent out from the programmable controller. This is the normal mode.
- Automatically through the controller with input from the local control room operator. This would also be to override the controller program.

- Manually by operating the various pieces of equipment (switchgear, substations, generators, fan controllers, etc.). This would by-pass the programmable controller and would be the last means of operating the system.

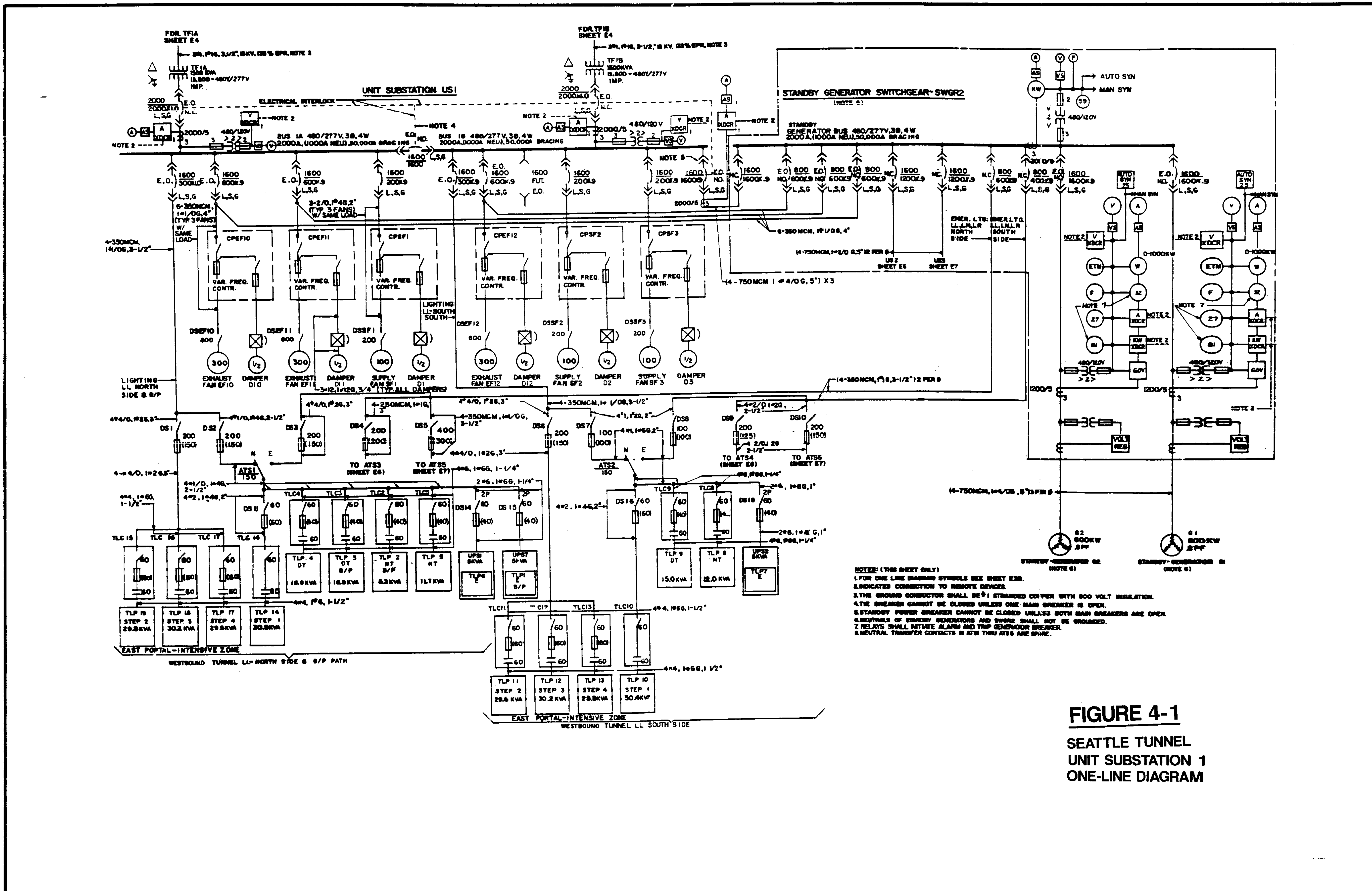


FIGURE 4-1

SEATTLE TUNNEL
UNIT SUBSTATION 1
ONE-LINE DIAGRAM

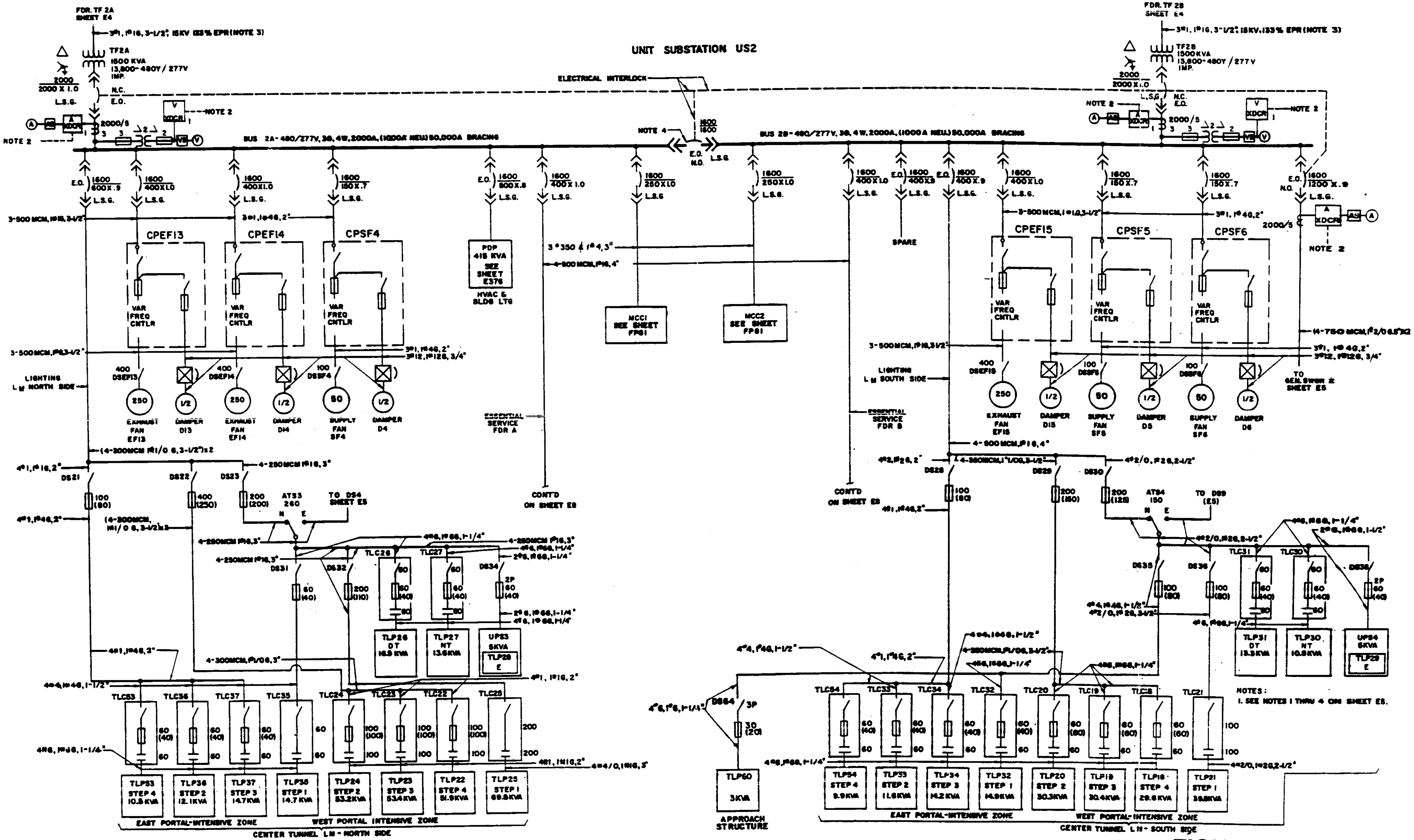


FIGURE 4-2

SEATTLE TUNNEL
UNIT SUBSTATION 2
ONE-LINE DIAGRAM

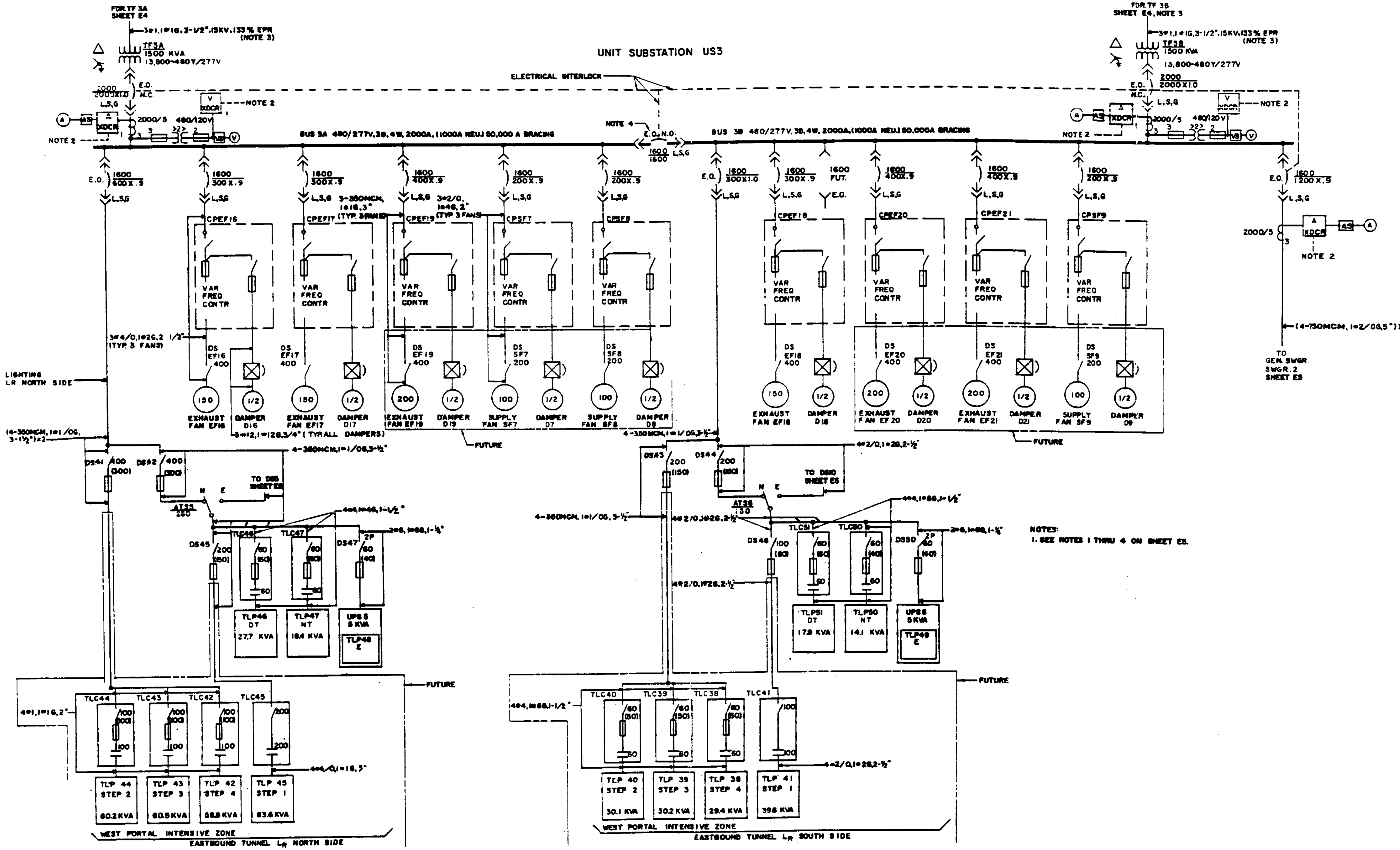


FIGURE 4-3
SEATTLE TUNNEL
UNIT SUBSTATION 3
ONE-LINE DIAGRAM

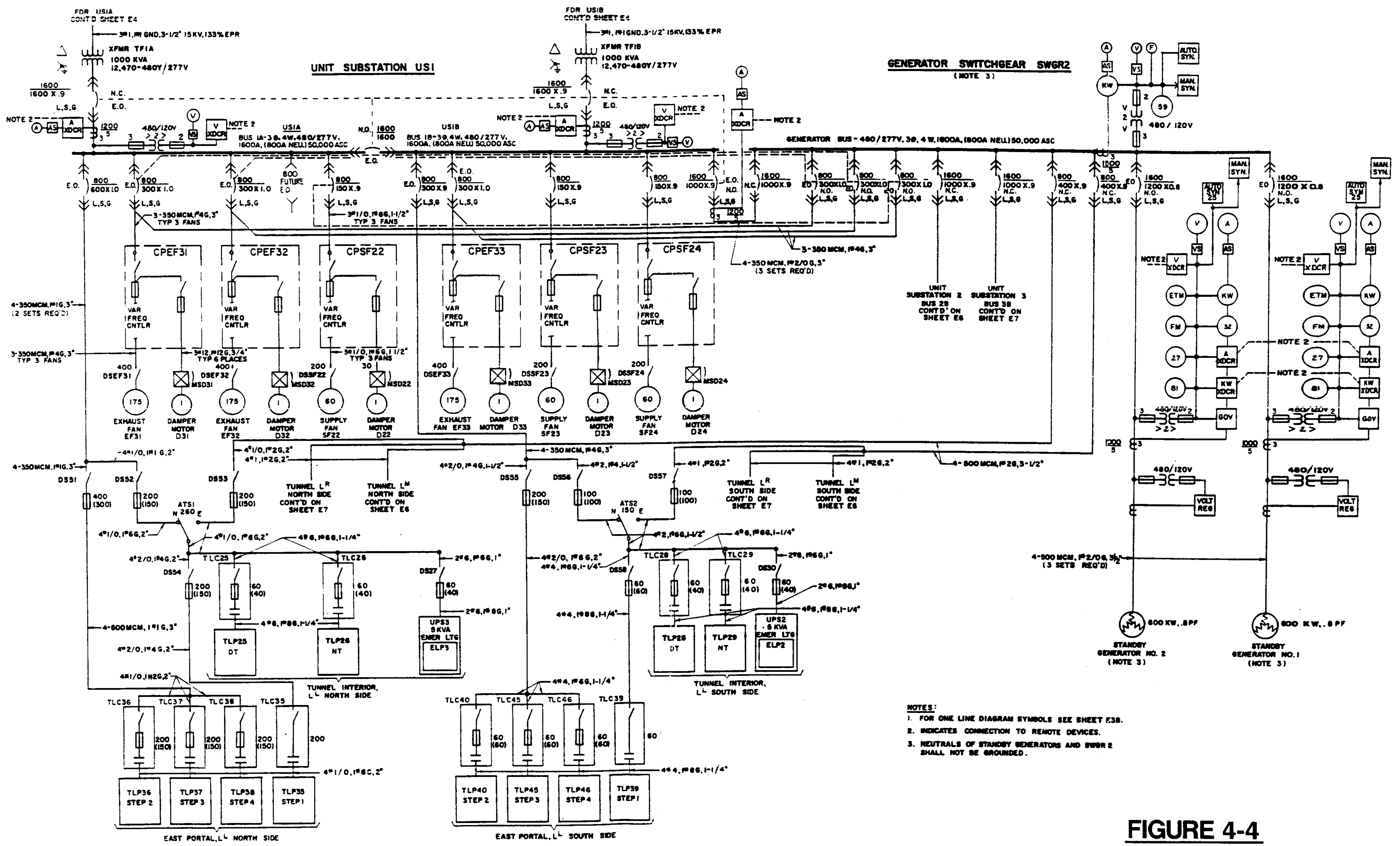


FIGURE 4-4

SEATTLE TUNNEL UNIT SUBSTATION 1 ONE-LINE DIAGRAM

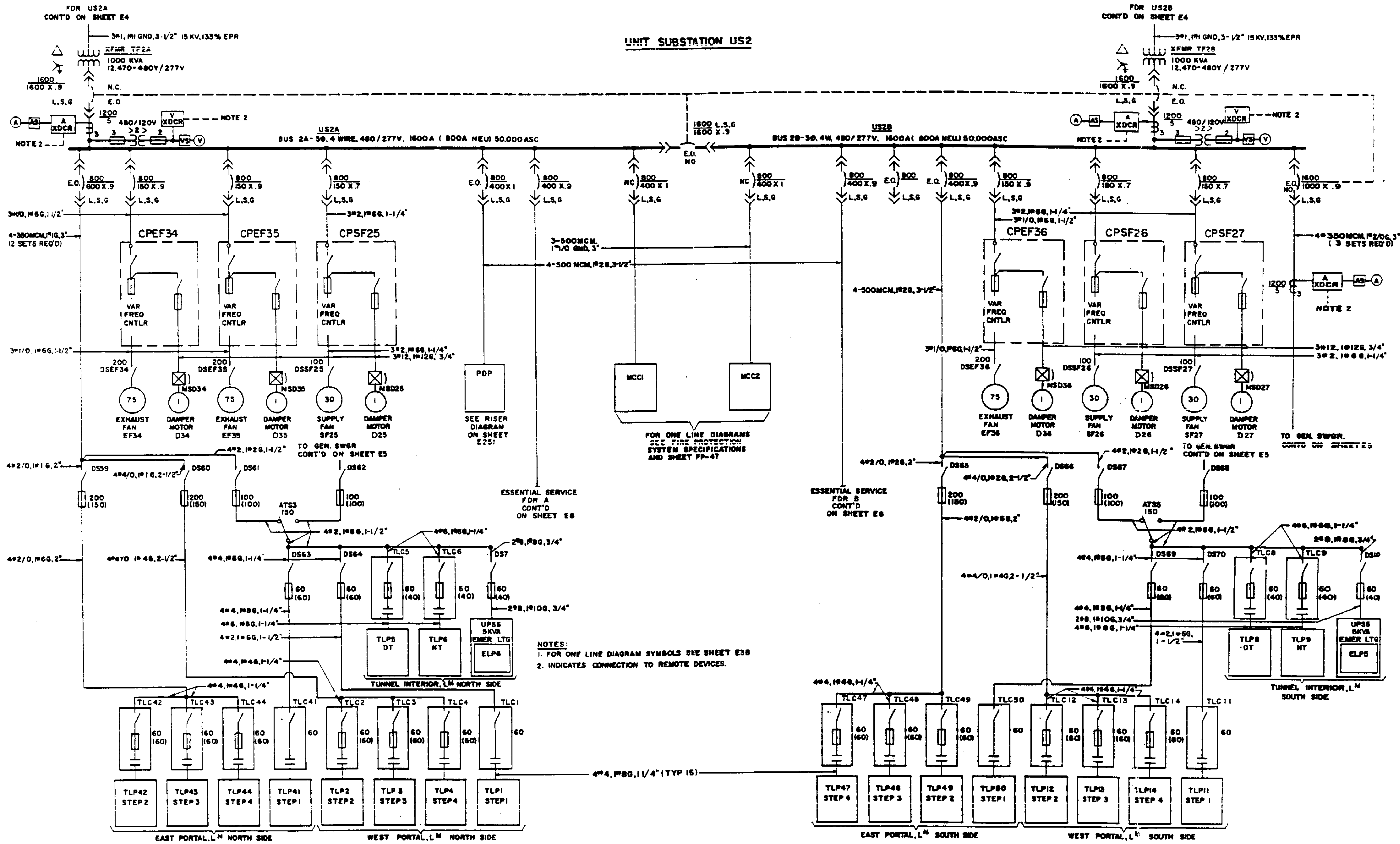


FIGURE 4-5

SEATTLE TUNNEL
UNIT SUBSTATION 2
ONE-LINE DIAGRAM

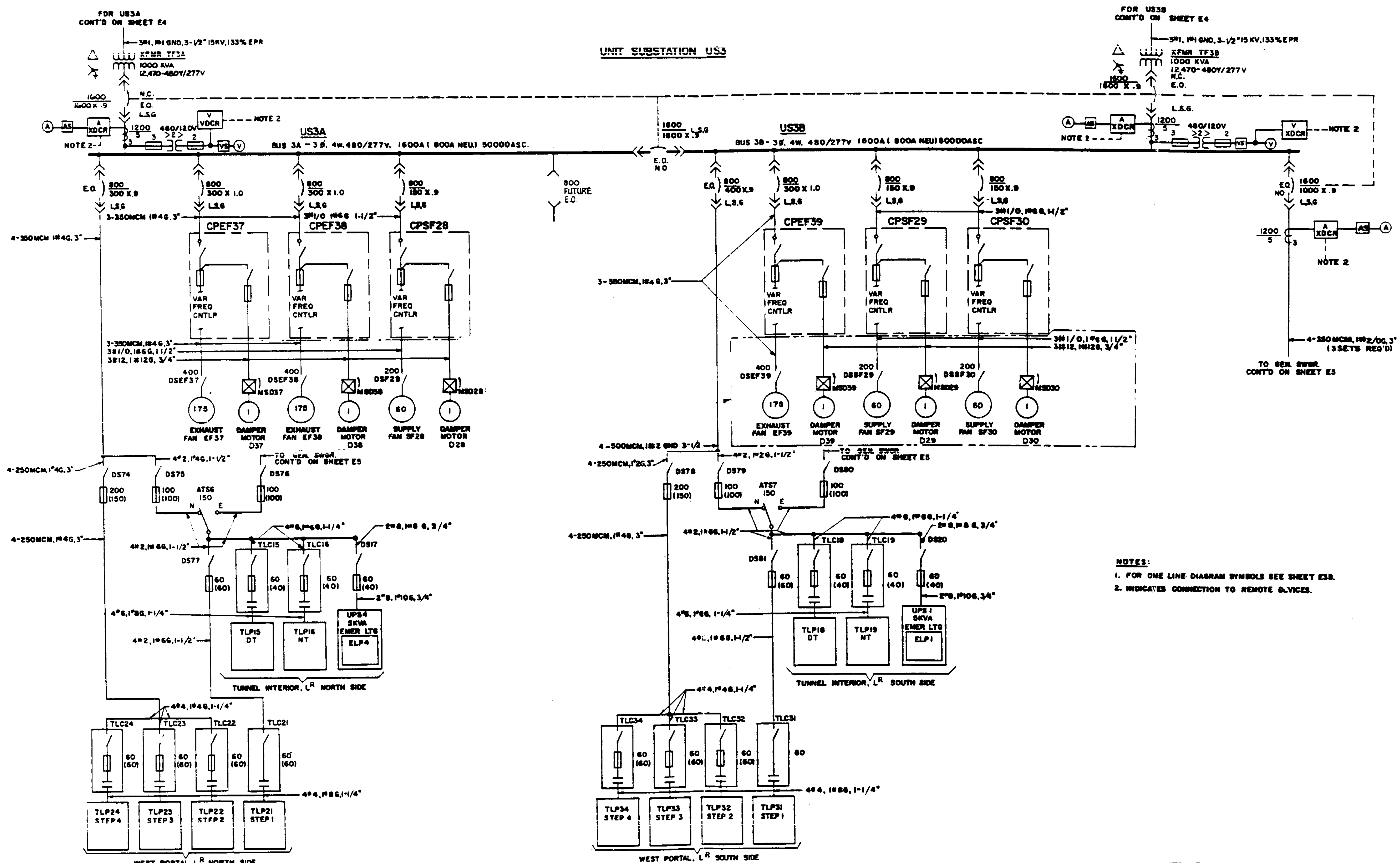


FIGURE 4-6
SEATTLE TUNNEL
UNIT SUBSTATION 3
ONE-LINE DIAGRAM

5. FIRE PROTECTION SYSTEMS

5.1 Description

Tunnel Fire Detection and Suppression System

The tunnel fire detection and suppression system consists of ceiling mounted heat detectors, fire alarm pull stations, portable extinguishers, foam pumps, a network of foam pipes, release valves, sprinkler heads, a foam controller, and a number of fire alarm controllers.

Fire Suppression System

The tunnels are divided into 150 foot fire suppression zones (Figures 5-1 and 5-2). Each eastbound and westbound zone contains a ceiling mounted array of dry pipe and sprinkler heads. The dry pipe arrays are connected through a proportioner to two-position valves which in turn connect to water and foam headers. The Fire Monitoring System in the control room starts the foam pumps and opens the valves to discharge foam into the 150 foot zone where the fire was detected. The foam used is of the aqueous film-forming type. The fire system logic will only allow two zones to be sprayed simultaneously, to preserve water pressure. To follow a moving fire the operator can use the ABORT/RESET button.

Emergency Stations

Emergency stations are located on both sides of the tunnel roadways, directly opposite each other every 600 feet as shown in Figures 5-1 and 5-2. They consist of a wall mounted cabinet containing a manual fire alarm pull station, an emergency telephone, and a portable fire extinguisher (see Figure 5-3). Extinguishers are multi-purpose dry chemical most effective in fighting the variety of fires that may occur in the tunnels. Ten pound portable extinguishers, with a gross weight of twenty pounds, are light enough for most individuals to handle with ease.

The cabinets are clearly marked and the extinguisher compartment has a door switch that provides a fire system trouble signal to the control room.

Fire Detection System

An array system of fire detectors is installed on the tunnel ceiling to provide input to the fire monitoring and control system. Each tunnel cell is divided into zones which are generally 120 feet to 150 feet in length (see Figures 5-1 and 5-2). All detectors in a given zone are connected to a zone controller which generates the necessary trouble, pre-alarm, and alarm signals.

The tunnel fire detectors are self contained units with dual rate-of-rise elements and a backup fixed temperature element. The units are ceiling mounted, generally in a two row configuration spaced about 50 feet apart (see Figure 5-4).

Interfaces with Other Systems

The Fire Monitoring and Control System is interlocked with the tunnel ventilation system and the tunnel traffic control system. When a fire occurs in the tunnel, the fire monitoring system will signal the tunnel ventilation system to switch all supply fans in the affected tunnel cell to 30% speed and all exhaust fans in the affected cell to 100% speed, and to the traffic control system to stop tunnel traffic upstream of the fire. Adjacent cells will be pressurized with supply air to help control smoke migration.

Ventilation Building Fire Detection and Suppression System

General

The ventilation building fire detection and suppression system consists of ceiling mounted heat, smoke, and ultra-violet detectors; fire alarm pull stations; alarm bells; portable extinguishers; fire suppressant tanks; a network of piping and sprinkler heads; fire alarm period, the battery backup units supplied with the fire alarm system provide power.

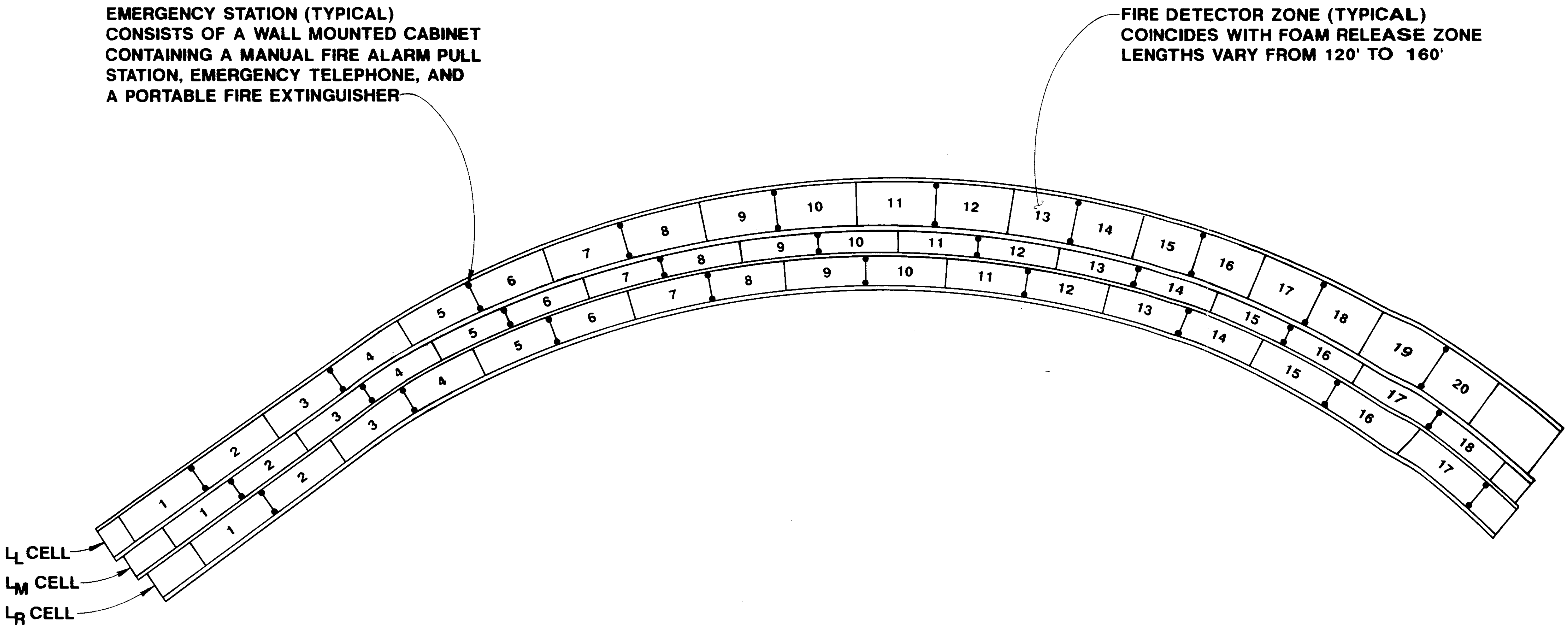
5.3 Control and Operation

Foam Sprinkler System

When a tunnel fire alarm is triggered, the typical duties of an operator are as follows:

1. Silence the alarm.
2. Determine the alarm location from the CRT monitor.
3. Check the monitor to determine the extent and magnitude of fire.
4. Evaluate the fire situation and determine one of the following:
    a. Let the foam release sequence proceed normally in the Auto mode.
    b. Abort the automatic foam release sequence and go to (or remain in) Manual mode.
    c. Speed up the release-of-foam.
5. Telephone the appropriate fire department via the direct line and describe the condition.
6. Continue to monitor the progress of the fire emergency and shut off the foam release as soon as the fire is extinguished.
7. Institute standard WSDOT procedures as posted.
8. Continue to monitor the fire on the CRT and on the fire department radio channel.

Note: The operator has the option to manually release the foam in any zone at any time. This would be utilized, for instance, if fuel is spilled on the roadway with no fire. The logic behind the foam release sequence is shown on Figure 5-5. Instructions for manual operation, as posted in the control rooms, are given on Figure 5-6.

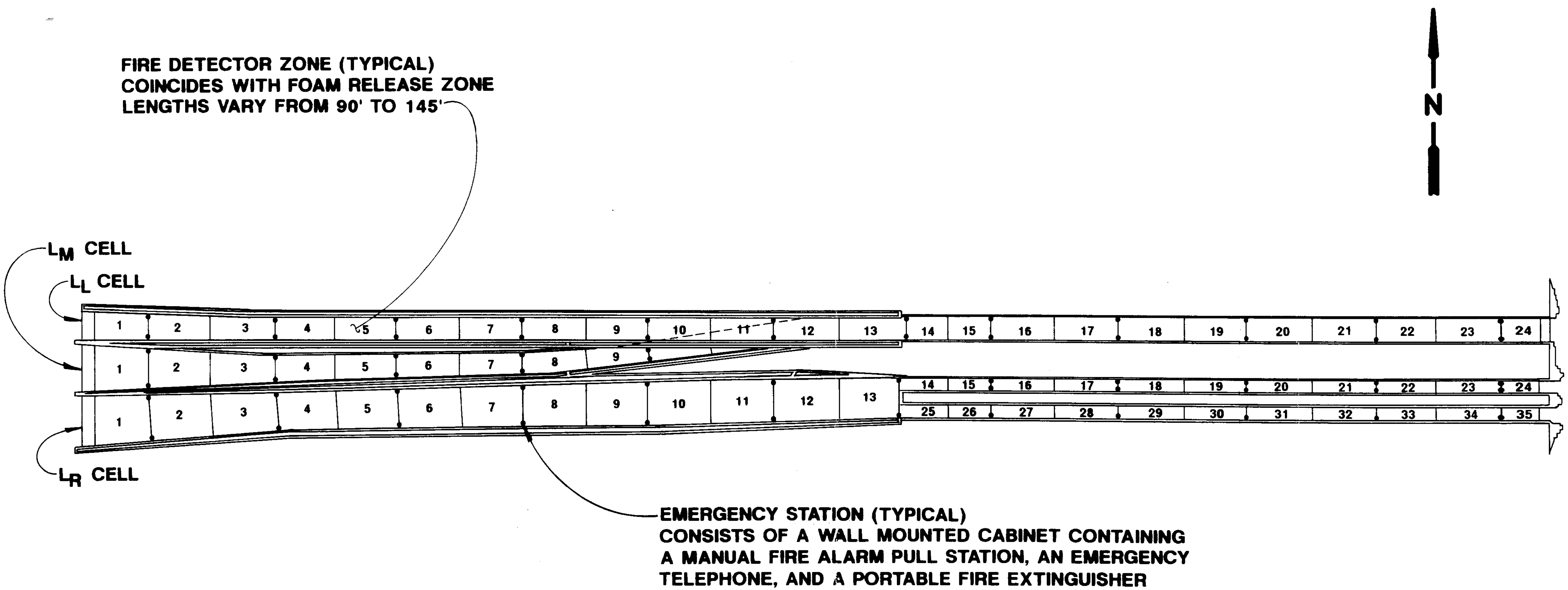


FIRE ZONE & EMERGENCY STATION LOCATION

FIGURE 5-1

MERCER ISLAND TUNNEL

FIRE ZONES AND
EMERGENCY STATION LOCATIONS



FIRE ZONE & EMERGENCY STATION LOCATION

FIGURE 5-2

SEATTLE TUNNEL
FIRE ZONES AND
EMERGENCY STATION LOCATIONS

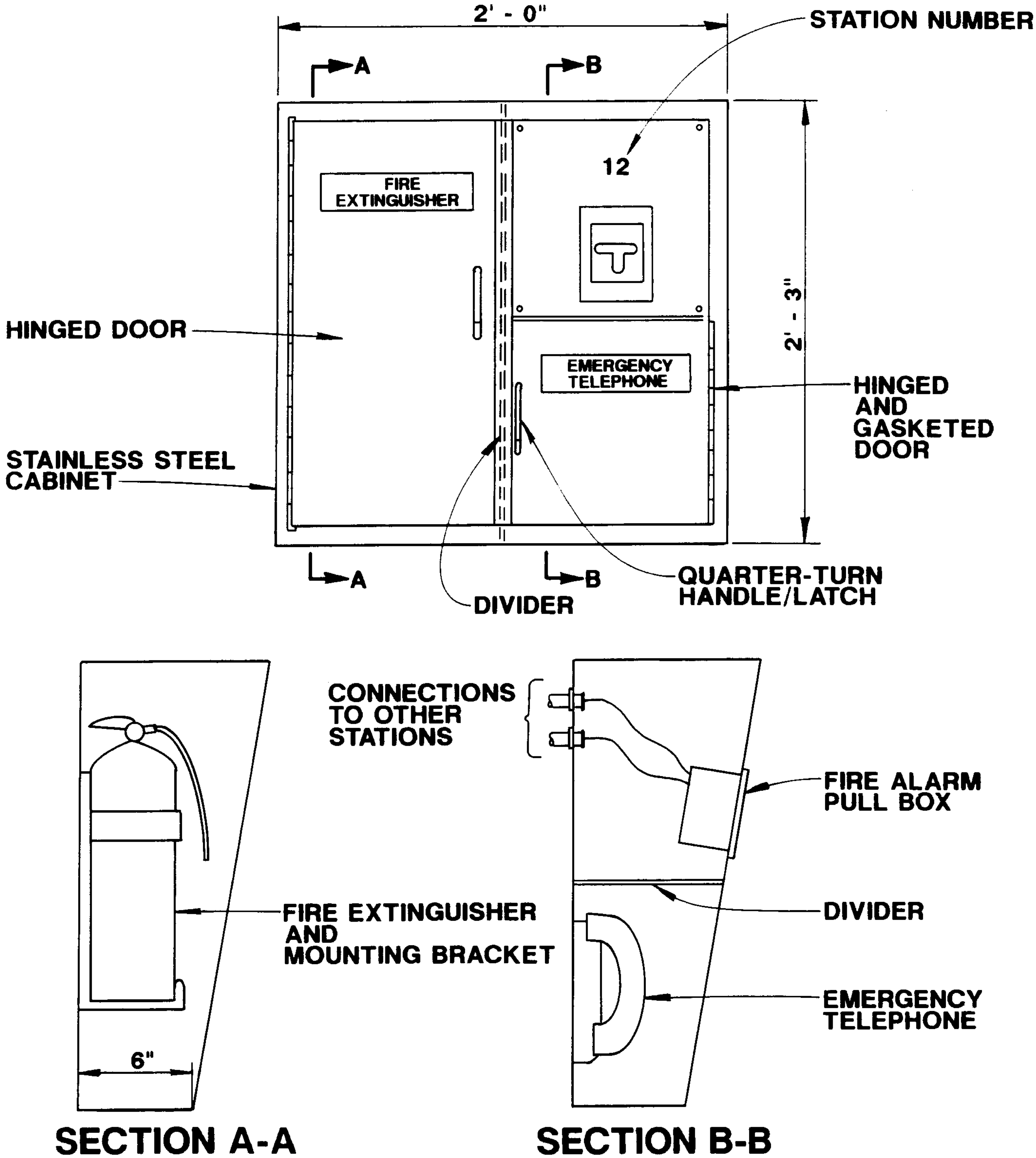


FIGURE 5-3

EMERGENCY STATION CABINET

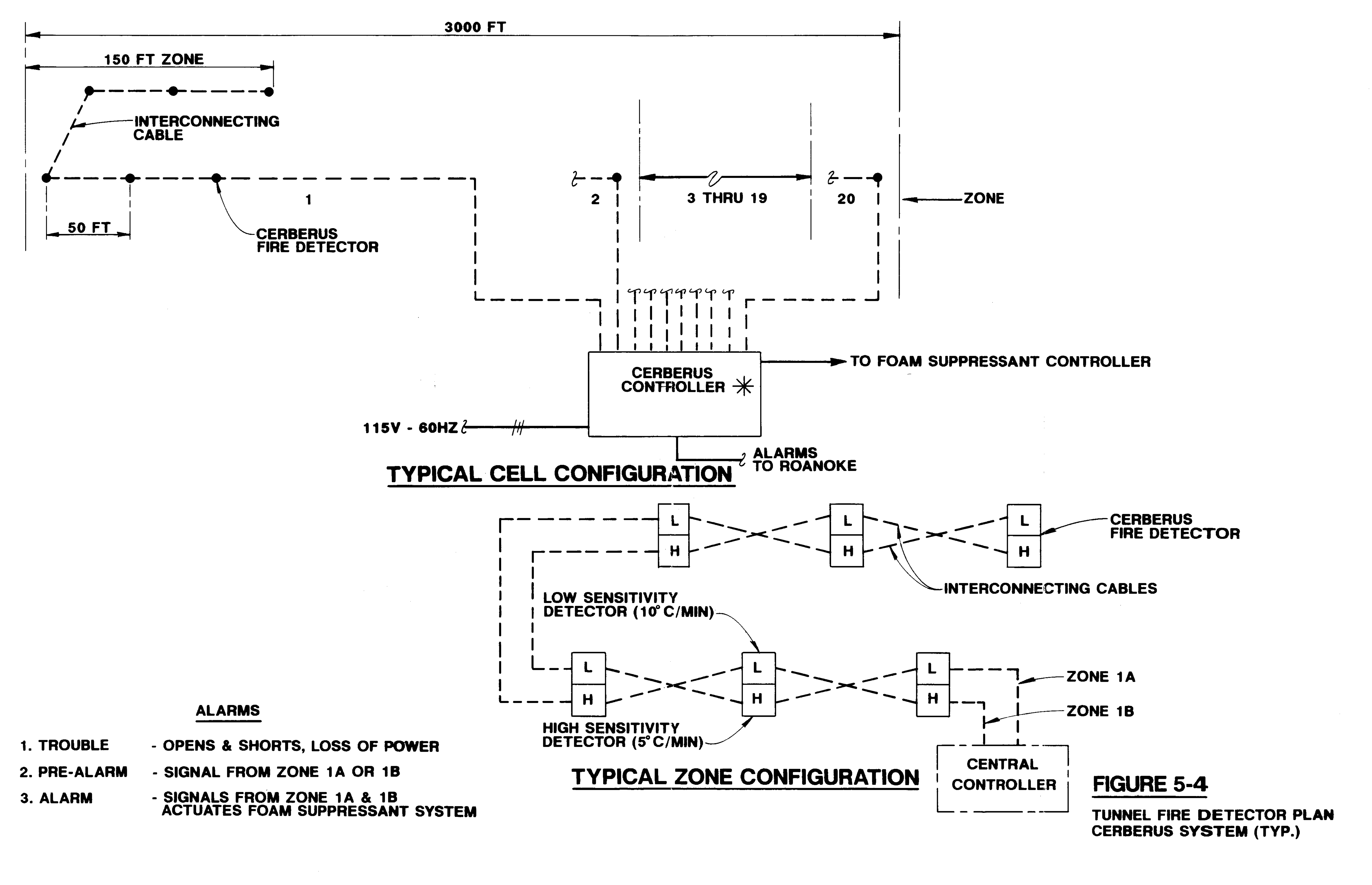
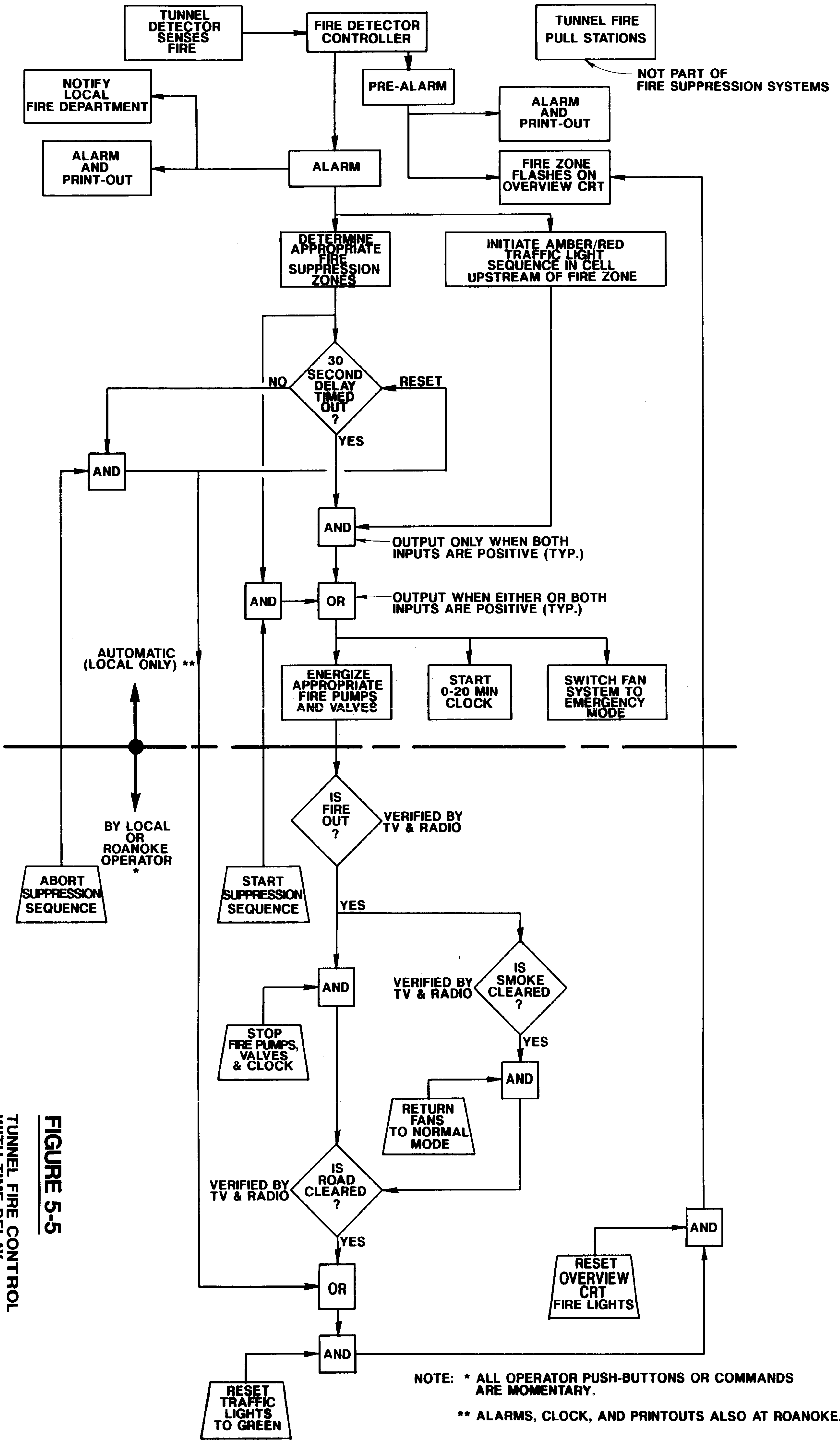


FIGURE 5-4

TUNNEL FIRE DETECTOR PLAN
CERBERUS SYSTEM (TYP.)



NOTE: * ALL OPERATOR PUSH-BUTTONS OR COMMANDS ARE MOMENTARY.

** ALARMS, CLOCK, AND PRINTOUTS ALSO AT ROANOKE.

FIGURE 5-5

TUNNEL FIRE CONTROL WITH TIME DELAY

FM & CS SPECIAL INSTRUCTIONS

1. TO CHANGE SYSTEM MODE FROM "AUTO" TO "MANUAL", GO TO THE BAY 7 CUBICLE AND PUSH THE RED BUTTON MARKED "MANUAL" UNTIL THE BUTTON LIGHT COMES ON. THIS CAN BE DONE DURING A COUNT DOWN SEQUENCE. IN MANUAL MODE, THE ZONE CAN BE ACTIVATED BY THE ZONE SWITCH BELOW IF THE ZONE IS IN ALARM. WHEN THE MODE SWITCH IS RETURNED TO "AUTO", AN AUTOMATIC SYSTEM WIDE RESET WILL BE INITIATED.

2. TO ACTIVATE A ZONE WITHOUT A FIRE ALARM, THE OPERATOR MUST BE SIGNED ON. ENTER "DATA ACCESS" TO DISPLAY THE MAIN DATA ACCESS MENU. SELECT #5 TO ENTER THE SUB-MENU SECTION ENTITLED "MANUAL DUMP INITIATION". SELECT THE ROADWAY THAT CONTAINS THE ZONE TO BE ACTIVATED. NEXT SELECT THE ZONE TO BE MANUALLY ACTIVATED AND COMMAND ON. WARNING: COMMANDING THIS ZONE ON WILL OPEN FOAM AND ARRAY VALVES FOR THE ZONE IN ALARM AND START THE FOAM PUMP.

3. BEFORE STARTING ANY FOAM PUMP MANUALLY, PUT THE SYSTEM IN MANUAL MODE BY PRESSING THE "MANUAL" SWITCH AT THE BAY 7 CUBICLE. RUNNING A FOAM PUMP LOCALLY AT THE PUMP STARTER WILL BY PASS THE COUNT DOWN TIMER IN THE EVENT OF AN ARRAY ALARM IF THE SYSTEM IS IN THE "AUTO" MODE.

FIGURE 5-6

6. CENTRAL CONTROL AND MONITORING SYSTEMS

6.1 Introduction and Control Philosophy

There are numerous control subsystems involved in the Seattle and Mercer Island Tunnels. These provide monitoring and control functions for tunnel lighting, traffic control, ventilation, communications, and power distribution. Each subsystem is a part of the overall system which controls the tunnel.

The control systems are electronic and operate analog signals, discrete (voltage level) signals, and digital signals. Analog signals are produced by sensors measuring light intensity, carbon monoxide levels, voltage, current, power consumption, fan speeds, and various other parameters. Most of these are available for the operator to monitor directly through the tunnel computer system. Also, some equipment parameters, such as fan speed, are controlled by analog signals. Typically, these signals are 4-20 milliamps or 0-10 volts, d.c. The distal signals are provided by contacts opening or closing.

The following pages give a brief overview of the control system. For complete details, consult the Control Program Reference Manual.

6.2 **Programmable Logic Controllers (PLC's)**

The PLC's are stand-alone subsystems and normally perform control functions based on their inputs from field sensors. They also accept inputs from the tunnel computer system regarding new control parameters or setpoints. The PLC's communicate directly with each other and with the tunnel computer.

Communication between PLC's and the tunnel computer or PLC to PLC is performed digitally using the PLC manufacturer's high-speed data bus network. Communication from PLC processors to their respective remote input/output chassis operate at a slightly slower speed which increases reliability.

All PLC's are of the same make and model. This allows PLC modules to be interchanged from one to the next and results in easier maintenance and a reduction of necessary spare parts. In terms of the number of addressable input/output (I/O) points, these systems seem very large. However, complex programming along with future system expansion capability require much of the usual memory.

Each of the PLC's contains its own logic software stored in non-volatile memory and can operate independently from all other PLC's and the tunnel computer. However, each PLC can readily obtain information from any other PLC through the communications network. The division of control among the PLC's is discussed in more detail in the Control Program Reference Manual.

6.3 **Tunnel Computer System**

The tunnel computer operates primarily on data supplied by the operator, the PLC's, and other subsystems. It is used to supervise the operation of the PLC's and make setpoint control changes as determined by the operator. The computer system also handles data gathering and historical files, alarm/status logging, and report generation.

Some basic (hard wired) control decisions are resident locally in the switchgear and other equipment. If any field device is in the "local" mode, no external control is possible. In most cases, status indication of the device's controllability is displayed on the tunnel computer monitor.

6.4 **Environmental Control Panel**

A separate control panel is located in the control room with limited monitoring and control capabilities. This is known as the Environmental Control Panel or Control Panel 1 (CP1). The panel has a dual purpose. Its first is to give personnel a status report of tunnel operating conditions without requiring operational knowledge of the CRT/tunnel computer system. The purpose is to provide control of critical functions in the event of system control failures or during maintenance work periods on various control equipment. The Environmental Control Panel alone is not intended for long term control of the tunnel.

A key switch on CP1 must be activated before the PLC will accept control inputs from CP1. Inputs from CP1 will override the PLC program and control from the computer. The graphic screens will notify the operator of limitations to the computer control capabilities because of CP1 activation.

6.5 Switchgear Control

Electrical power for operating the tunnel facilities is normally supplied through two separate utility power lines. IF power is lost on both of these lines, a standby generator system will provide power to all critical loads including power for monitoring and control functions.

The power distribution system consists of the 15 kV (main) switchgear, unit substations, and standby generator switchgear. Control of the 15 kV switchgear is resident within the switchgear. Control of the substation switchgear may be performed at the switchgear, from the Environmental Control Panel, or from the tunnel computer system TSMC. Control of the standby generator switchgear is accomplished through the programmable logic controllers or the local generator controls.

The facilitate automatic transfer operations and generator load testing, some of the unit substation and generator switchgear breakers are electrically-operated and can be controlled from a remote location as well as locally. All switchgear breakers have status indications available at the CP2 console as follows:

- OPENED
- CLOSED
- TRIPPED
- OUT-OF-SERVICE

In addition the 125 VDC battery control power has an associated low control voltage alarm for each switchgear or substation.

<u>15 kV (Main) Switchgear</u>

The main 15 kV-rated switchgear distributes utility power and consists of two main breakers, a tie breaker, and six feeder breakers. All are electrically-operated and controlled locally at the switchgear. On loss of an incoming line, the transfer equipment will automatically open the associated main breaker and close the bas tie breaker. Upon restoration of power, the reverse sequence will take place. On loss of power from both utilities, the main switchgear will isolate the tunnel power system from the utility lines and give a start signal to the standby generators. The PLC does not control any of the main switchgear but main switchgear status indications are provided for the tunnel control console and CP1.

Substation Switchgear

There are three double-ended unit substations within the tunnel facility each consisting of two stepdown transformers and one 480/277 volt switchgear. Each supplies power to one of the trafficways, westbound, center, or eastbound, along with various other loads.

The substation 480/277 volt switchgear consists of two main breakers and one tie breaker, each electrically-operated, and several feeder breakers, of which some are electrically-operated. In addition, one E.O. breaker is connected to the standby generator switchgear. Interlocks are locally "hard wired" to prevent the tie breaker from being closed if both main breakers are closed. Another interlock is provided so that the generator breaker cannot be closed if there is utility power on that bus, to insure that normal and generator power supplies are isolated from one another.

Under normal conditions, the standby generators will not be running while power is still available on either one of the two utility lines. If power is lost on either unit substation bus, the PLC logic will allow manual control by the operator (from CP1 or from the computer) of substation main breakers, the bus tie breaker, and the necessary feeder breakers in order to restore power to the effected bus.

Each unit substation contains two E.O. breakers feeding the tunnel lighting loads, one for the north row and one for the south row of lights for the associated roadway. These breakers are normally closed but can be opened to test the automatic transfer switches (ATS) for the lighting when the generator is running. The PLC and tunnel computer system have no direct control over the ATS's, but indicate their position only. A failure of the transfer switches will be indicated on the CRT and printed out.

6.6 Video Control

Visual monitoring is required to detect incidents in the tunnel that are not alarmed by the fire detection, emergency telephone, or incident detection systems. A vigilant operator watching the video monitors may locate an incident before the incident detection system has activated. The operator could then initiate safety or corrective actions at the earliest possible time. In the event an incident is visually detected the operator will be able to manually control monitors pan, tilt, and zoom functions on certain cameras to determine the nature of the incident.

Visual monitoring of the tunnel will be accomplished by approximately 30 video cameras and 5 video recorders. About half of these cameras are fixed. The control of cameras with pan, tilt, and zoom can be the tunnel computer or manually from the video system controller.

All of the cameras will be monitored simultaneously on video monitors mounted above the operator's console - CP2 (see Figure 6.2). These monitors use Multiplex screens to present video from multiple cameras on a single monitor. One monitor is devoted to each portal and one is devoted to each directional cell (eastbound, center, and westbound). Any camera can be selected for display on the master video screen located on the control console. The screen display will include date, time, and location titler information. All composite screen sections will also include a location designator for quick operator identification when selecting input to the master monitor.

Pan, tilt, and zoom (PTZ) control will be possible by manual operator control or automatic preset positioning. In the manual mode, the operator can select any of the PTZ cameras and control these functions through the tunnel computer keyboard. The automatic preset position commands will be initiated by the operator through the tunnel computer software. These positions ar preprogrammed in the PTZ controller.

A total of ten different positions are programmable for each camera. Of these ten, one will be a "home" position. In the event the camera is moved out of the "home" position, it will remain at this position for 3 minutes before an automatic homing signal will sound. If the operator does not delay this signal, the camera will automatically return within 30 seconds to its home position. This function is to prevent inadvertent loss of tunnel video coverage.

Video recording is accomplished by five independent VCR's. These units will normally run in an elapsed time recording mode. When a real time recording signal is received, the tunnel computer will direct the desired VCR's to begin continuous recording. At the end of a tape the VCR will automatically rewind and then begin to record again.

6.7 **Monitored Parameters**

Some variables such as alarms are printed as they occur. Others are printed periodically for reports. Variables are sampled and stored on a hard disk so that they may be analyzed in detail at a later date.

6.8 **Data Storage, Logging, and Report Format**

Data Storage

The tunnel computer located in the tunnel control room performs all data storage duties. These duties consist of hard copy printout and recording all operator initiated actions, all automatic actions, and system detected occurrences. All actions and occurrences are printed as they occur with date and time.

Data Logging

All alarms, actions, and system detected occurrences are logged on the printer in a logger format.

Reports

Several report formats are provided as guides for the tunnel operations manager. In addition, these instructions provide examples of accessing and plotting analog data values versus time for trending analysis.

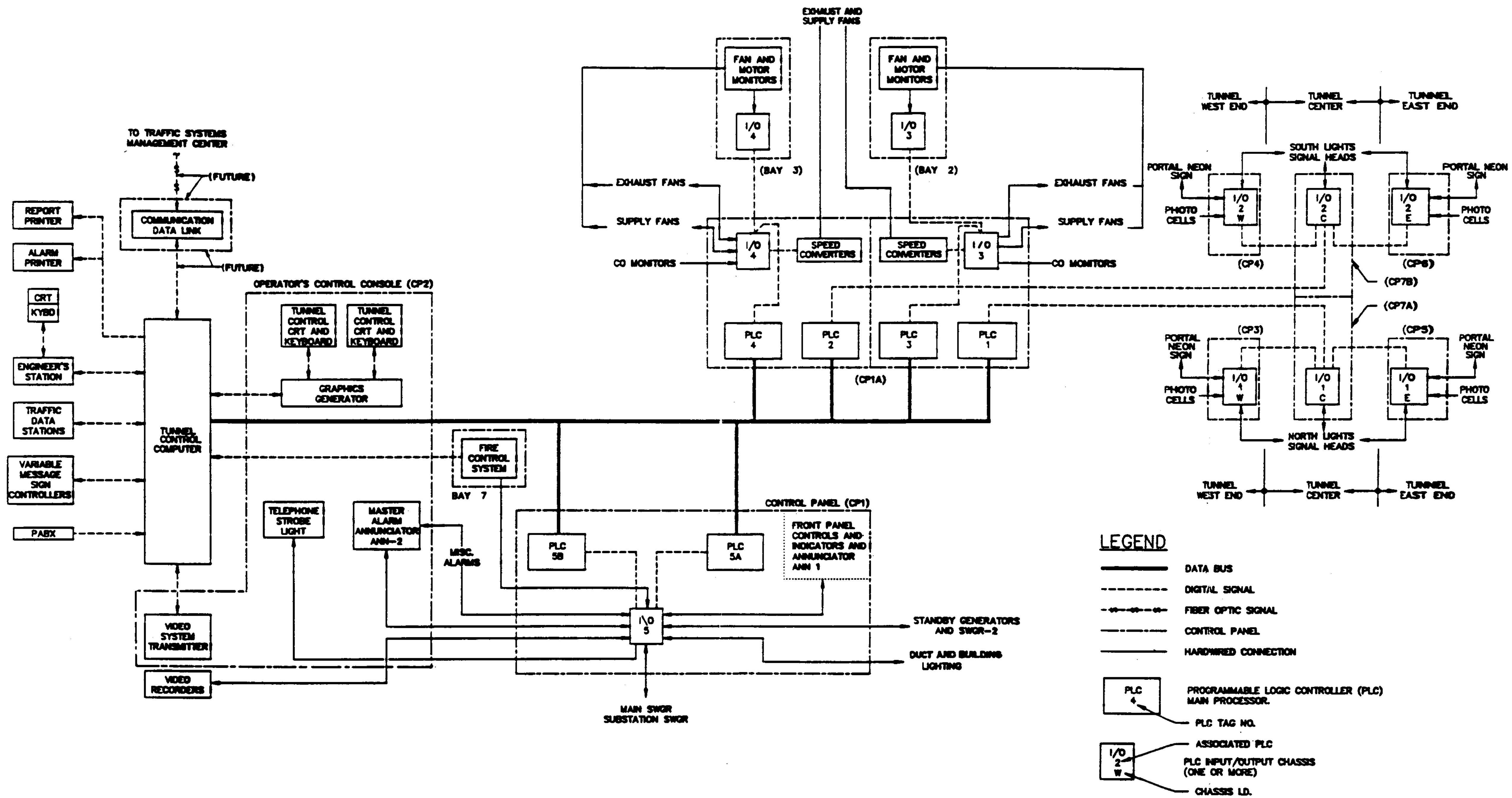
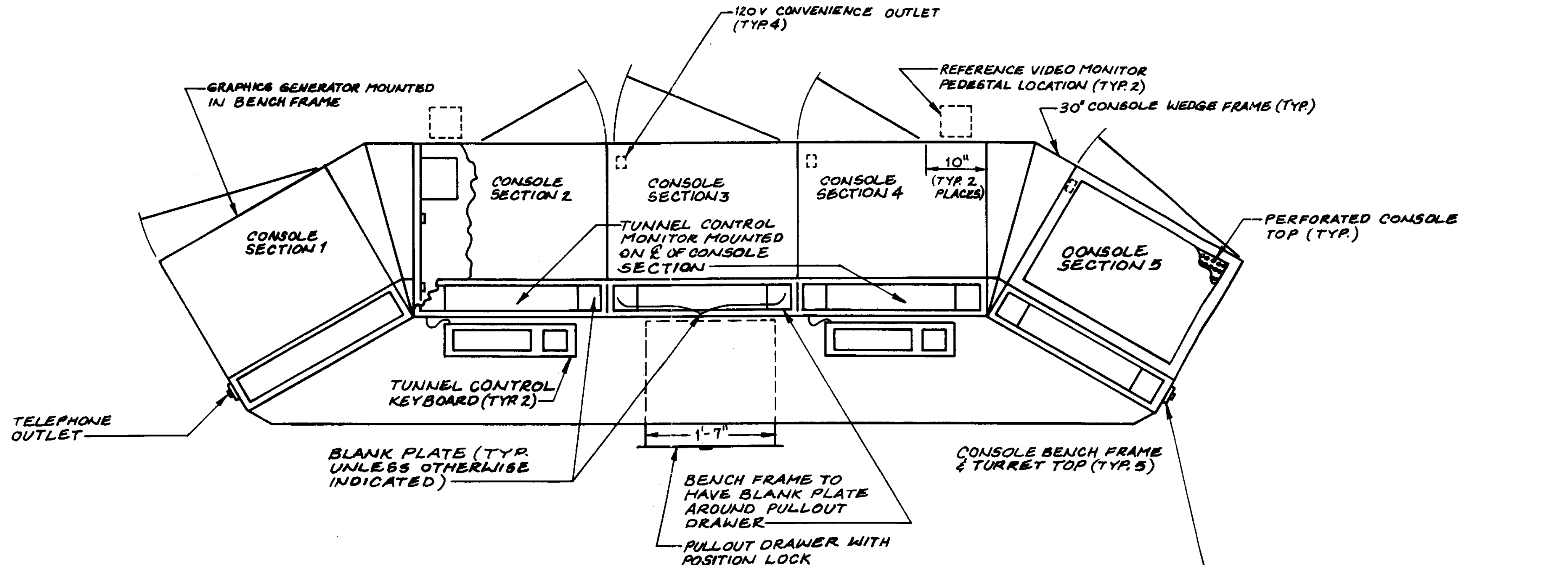
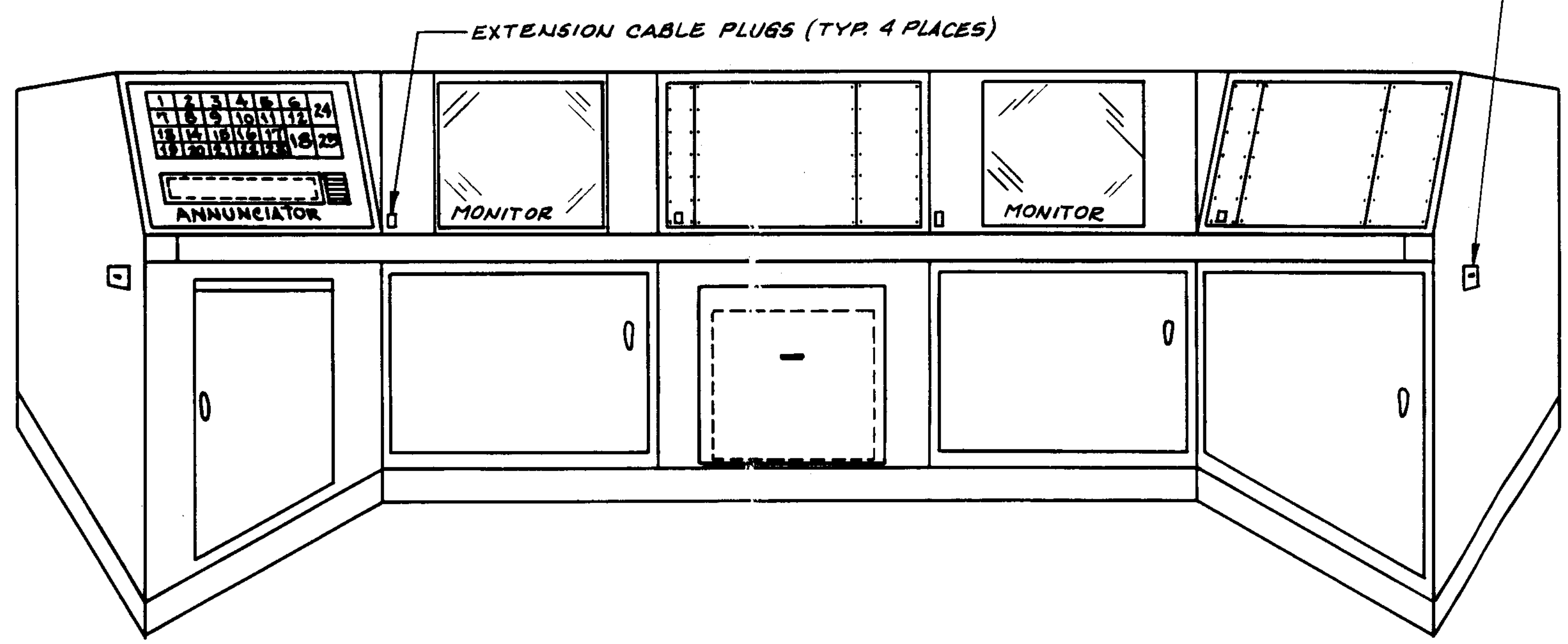


FIGURE 6-1

TUNNEL CONTROL SYSTEM CONFIGURATION



PLAN - OPERATORS CONSOLE CP2



ELEVATION - OPERATORS CONSOLE CP2

FIGURE 6-2

TYPICAL CONTROL PANEL CONFIGURATION

7. COMMUNICATIONS SYSTEMS

7.1 Description

Communication within the tunnel complex is provided by a telephone network and two radio subsystems. These are each described in detail below.

7.2 Telephone Systems

Emergency telephones are located in the FTC stations along the roadways. These ring directly to the 911 center, indicating westbound, center, or eastbound roadway. The operator will be alerted to use of an emergency phone by a light on the console. The location of the phone in use will be shown on the CRT's.

Utility telephones are provided throughout the complex in the offices, equipment rooms, fan rooms, and utilidors. These ring directly to the control room. The control room and office area phones have access to outside lines. In addition, the CP2 console has a red phone directly connected to the local fire department and a blue phone direct to the Traffic System Monitoring Center.

7.3 Entertainment Radio System

Both tunnels are equipped with systems to rebroadcast entertainment radio.

In the Mercer Island Tunnel, 20 preselected AM broadcast channels are continuously retransmitted into the roadway cells. The individual frequency settings can be read on the face of the units in the radio bay.

In the Seattle Tunnel, all AM (535-1600 khz) and all FM (88-108 khz) broadcast stations are rebroadcast into the tunnels.

In both tunnels the operator can broadcast messages over the entertainment frequencies using a handset on CP2.

7.4 Operations Radio System

Each tunnel is equipped with an operations radio system that provides 12 channels for communication between official vehicles in the tunnels and their base stations or dispatchers. The agencies provided for include WSDOT maintenance, the Washington State Patrol, METRO, King County Police, Bellevue Police, and the Police and Fire Departments of Seattle and Mercer Island.

The operations radio system is designed to <u>only</u> provide communication between an agency dispatch center and vehicles in the tunnel. It does <u>not</u> facilitate communication between vehicles.

Signals to and from the dispatchers are carried to the radios in the tunnel control room over leased telephone lines.