CHAPTER 7

OCS ELEMENTS

POLES

Pole support systems are the single most common means of supporting overhead electrical wire. They allow the greatest flexibility in positioning, materials, height, and other component considerations.

Poles are available in a wide range of materials and finishes. The most common pole is the tubular, galvanized steel pole shown in Figure 7-1. These poles come in a variety of finishes, including bare galvanized, painted, and weathering steel. Weathering steel usually has been found inadvisable because it has a tendency to run, which stains the sidewalk and surrounding area as well as passing pedestrians. The following key elements reduce the visual impact of steel poles:

- They are round, which is a generally pleasing shape compared to a squared off or roughhewn look;
- They are thinner than other pole types—unless they serve special functions such as enclosing counterweights for constant-tension systems as shown in Figure 7-2;
- They are readily adaptable to other uses, such as carrying street lighting and traffic signals as well as OCS; and
- They can also be made in a wide variety of designs. For example, some cities use an 8-, 10-, or 12-sided faceted pole rather than a round pole as an architectural feature. Also, pole strength can be increased by either enlarging the pole diameter or the wall thickness.

Concrete is in use in several settings. Because concrete poles are bulky and white or off-white, they are usually more visually intrusive; however, there are situations where concrete may be the material of choice. Figure 7-3 presents an example of a historic concrete pole that is very attractive. Most concrete poles, however, look more like those shown in Figure 7-4. This figure illustrates several drawbacks and missed opportunities. Multiple poles are used because, individually, they are not strong enough to support all the necessary wire. In addition, a key opportunity for connecting to the highway viaduct structure is being missed here, which would eliminate the need for poles altogether. Finally, concrete poles tend to attract graffiti artists because their rough texture makes them harder to clean—each concrete pole has been marred whereas the adjacent steel pole has not. Again, the context and setting is the important element. White concrete poles would look better against a stucco building line than would green steel poles; in any given situation, all the alternatives should be weighed.

Typical wood poles appropriate in a residential suburban or rural setting are shown in Figures 2-1 and 4-3. Wood, although a more delicate material, has the advantage of being natural. In settings with many trees and greenery, a wood pole can easily be mistaken for a tree as in Figure 2-1. Wood is also a useful material in historic preservation areas where the surrounding structures are also of wood, stone, or other natural materials.

In addition to these materials, light rail systems often use H-column steel to support OCS. These poles tend to appear more massive, although they are very useful in integrating special elements, such as counterweights and electrical conduit if designed appropriately. Figure 7-5 illustrates an H-column pole with a counterweight. The sidewalk location shown in this figure is not appropriate for this type of pole. This pole design is more appropriate for a median location away from the close scrutiny of pedestrians. Figure 3-16 illustrates the problem of having the pole receive every possible use with all kinds of electrical conduit strapped to it.

Poles are only just poles when the system designers treat them that way. There are many ways to reduce the visual impact of poles. Decorations are a key way in which this can be done. Figure 7-1 presents a good decorative pole treatment, which integrates banners and street-level lighting. Figure 7-6 shows the quality of design that can be achieved with special lamps, caps, and bases to produce an attractive pole suited to historic urban areas. Some elements are built into the poles and others are added on (e.g., fluted sleeves) to produce an attractive appearance. This approach, instead of making the pole invisible, makes it stand out in a positive way.

A different, but equally striking, effect can be achieved by the use of the plain, contemporary, pole design shown in Figure 7-7. This pole focuses attention on itself so that even the overhead feeder cable becomes barely noticeable. The mast arms have been treated as part of the pole design and add to the visual effect.

Pole guying is an acceptable means of handling heavy radial loads only where the guy can be installed without interfering with sidewalk use or encroaching on private property. In general, guyed poles should be used only when the guy anchor can be located in a median or on private right of way in an area away from pedestrian crossings. Do not plan to use sidewalk guys or to place guy anchors on someone's front lawn. Pole guying is most helpful in reducing the size of poles that enclose counterweights. If the pole shown in Figure 7-2 were not guyed, it would have to be much larger.

Joint use of poles is the single most useful technique in reducing their visual impact. Joint use is defined as the process of securing agreements from public works departments, traffic agencies, and utilities to combine several different types of equipment onto one pole thereby reducing the overall number of poles in the streetscape. Installed individually, each element such as street lights, traffic signals, telephone wires, and OCS requires a separate pole for a total of four poles. A joint-use agreement could conceivably reduce the need to just one or two poles.

The joint use of poles requires a great deal of coordination and education on the part of the organizing agency because there is considerable resistance to such arrangements in some quarters. The benefits are enormous, however, as shown by many of the figures in this handbook, particularly Figures 2-2, 7-1, and 7-6.

In deciding when joint use is appropriate and practical, several key considerations must be taken into account. First, physical constraints must be identified and evaluated. Such constraints include the location of power feed risers, the strength of the poles themselves, and the height necessary for different uses. Another key consideration is maintenance access for the various pole users. Joint-use pole design must provide unimpeded access for such functions as replacing street-light bulbs. Also, urban-design issues must be considered because the process of integrating several different services onto one pole requires a massive pole that would conflict with its surroundings. (See Figure 3-16.) Finally, pole spacing needs to remain flexible so that the best integration of poles into the street environment can be achieved.

There are two requirements for developing a workable joint-use program. One of these, as previously mentioned, is developing a commitment to joint use and to minimizing pole pollution on the part of all of the cooperating agencies. As part of this commitment, a spirit of give and take—a willingness to strive for the best overall design even though parts of it may be less than optimal from the point of view of the particular organization—must be fostered. The second requirement is developing—in advance of negotiations on specific pole locations—a master agreement covering pole ownership, compensation among agencies, and maintenance responsibilities. For example, it is common practice in Seattle for the electric utility to own all poles that it uses jointly with the transit agency, and for the transit agency to own all other joint-use poles. Traffic signals, street lighting, and communications lines all are tenants on these poles.

BUILDING EYEBOLTS AND STRUCTURAL ATTACHMENTS

Building eyebolts are used by many transit systems to reduce the number of poles and the attendant clutter as well as to reduce the cost of OCS installation. Figure 7-8 shows a particularly effective use of building eyebolts in a historic downtown area. Because of eyebolt use, the street-lighting poles do not have to support the OCS, which allows the use of a short ornamental street-light pole with a top-mounted fixture.

Not all buildings are suited for eyebolts. Eyebolts are most commonly used in downtown areas where buildings with suitable height, minimal setback, and adequate structural characteristics are frequent. Building eyebolts can also be used on suitable, isolated buildings as shown in Figure 7-9.

Buildings used for eyebolts must have the following characteristics:

- Adequate height—usually at least 7.5 m (25 ft);
- Structural strength—buildings with load-bearing masonry walls (except concrete block) as well as steelor concrete-framed buildings are usually adequate for eyebolts;
- Facing material—eyebolts must pass through a curtain wall to reach structural elements. Certain curtain wall types such as glass or aluminum, which can be damaged by eyebolt installation, should be avoided;
- Setback—setback from curb, including sidewalk width, should not result in excessive span length (more than 30 m [100 ft]) or make maintenance access difficult.

Locating eyebolts on buildings requires considering both visual and structural characteristics. Columns or floor slabs are usually the only suitable attachment points on steel- or concrete-framed buildings. Masonry buildings often have heavier walls at corners. Ornamented wall areas should be avoided, although an eyebolt is less visible on a textured rather than a smooth wall. Also, eyebolts should be located so that spans are not easily reached from open windows or balconies. Examples of eyebolt installation on historic and modern buildings are shown in Figures 7-10 and 7-11.

Overhead structures such as highway and railroad viaducts are also used for OCS support. Attachment to columns of such structures is similar to building eyebolt installation. It is often necessary to attach to the underside of an overhead structure, as shown in Figure 7-12. Structure parapets can also be used for OCS attachments. Figure 7-13 shows a clamp-type attachment that can be used when a normal eyebolt is not structurally feasible. This attachment accomplishes the technical purpose and serves as an interesting visual element.

Special OCS support structures are occasionally required. The structure shown in Figure 7-14 is used to support both OCS and traffic signals in a very wide intersection. Special structures are also used where tension must be terminated over a very short distance, such as at a movable bridge. Such portal structures should be used only where absolutely necessary or occasionally as an architectural statement. Unlike the example shown in Figure 7-14, a well designed portal structure can be visually attractive; however, repetitive use as a design feature is not recommended.

SPAN-WIRE SUPPORT

Examples of direct-suspension span construction for trolleybus and rail systems have been shown in Figures 4-1 and 4-3. Both of these examples use steel span wire and insulators. The span shown in Figure 4-1 uses multiple porcelain insulators, producing the appearance of a series of lumps along the span. This is standard practice in most transit systems. Using porcelain insulators in pairs guards against the failure of this brittle material, which would allow the wire loops to touch each other.

A cleaner profile can also be obtained by using fiberglass stick or loop insulators, as shown in Figure 4-3. These do not have to be paired because there is no possibility of wires touching each other if the insulator fails. Philadelphia uses stick insulators at the pole attachment as shown in Figure 7-15, resulting in a clean span; however, this construction will not meet the safety requirements of most transit systems, i.e., placing span insulators in such a way that workers will not be able to touch the pole and the span beyond the insulator simultaneously. A fiberglass insulator located 1.5 m (5 ft) from the pole would meet this safety requirement with only a minor degradation of appearance.

Figure 7-16 shows a span using nonmetallic material, which is self-insulating. Using this material produces a cleaner appearance than that produced by using multiple porcelain insulators. It should be noted that the spans shown in Figures 4-1 and 7-16 are within a block of each other. Nonmetallic spans have not been used widely in North America, largely because of the cost, lack of durability, and the difficulty in maintaining currently available materials. The appearance benefits are minor compared to a span with a single fiberglass insulator; they should not dictate the decision to use this material.

A substantial improvement in the appearance of any span can be accomplished by careful attention to the quality of the termination assembly. Nothing degrades the appearance of span wire more than sloppy terminations with long tails of excess wire hanging from the span.

Spans for pendulum suspension are similar to direct-suspension spans except for the restriction on crossing angle already noted, as shown in Figure 4-2. A span for constant-tension direct-suspension wire is shown in Figure 4-7. A delta suspension bridle and a pulley support are used to permit longitudinal movement of the contact wire.

Span wire is very satisfactory for supporting catenary, although some designers prefer to use a massive and costly top beam. Two levels of attachment are required for catenary—one to support the messenger and the other to anchor the fixed end of the steady arms, see Figure 7-17. Span construction is an appropriate technique where center poles are not feasible. This construction can be used to avoid the cluttered look of side-pole mast arms or where poles have to be set back a substantial distance from the track.

Attachment height is a function of the height of the contact wire, the type of support, and the amount of slope desired in the span. The span tension increases as the slope is reduced, so that spans that are almost flat result in greater pole or eyebolt loadings and generally produce a slightly neater appearance. Spans for pendulum suspension, constant-tension wire, or catenary will require higher attachment points to accommodate the height of the suspension; however, a constant-tension system produces less sag between spans, thus reducing this element of height requirement.

Bracket Arms and Cantilevers

There are numerous applications for mast arm support of OCS. Among these are one-way wire, wide streets, center-pole construction, and long arms supporting two-way wire from a single arm. One school of thought prefers mast arms for OCS support in almost all locations; however, this approach is based on incorrect impressions of the relative visual impact of span wire and mast arms. In plans or renderings, the mast arm and span wire appear to have similar thicknesses. The mast-arm construction appears to have lower visual impact because it does not cross the entire street; however, a top-braced mast arm using nominal 2-in. diameter pipe (actual outside dimension of 60 mm [2⅜ in.]) has about seven times the visual mass of an 8-mm (5⁄16-in.) diameter span wire, see Figures 7-18 and 7-19. Thus, the use of mast arms on a street of typical width will degrade rather than enhance the appearance of OCS. Figure 7-18 also shows the "pointing finger" visual effect that occurs when mast arms are used with insufficient distance between the ends of the arms.

Another advantage claimed for mast arms is that they provide a means for decorative enhancement. Actually, the space available, outside of the street traffic clearance envelope, is quite limited, as shown in Figure 7-20. This figure also shows that the banners are hung separately from the mast arm to maintain the integrity of the insulated arm. In addition, installing feed and equalizer spans on mast arms is substantially more expensive because an underground conduit must be installed to connect the wire on both sides of the street. A low-cost, but much more visually obtrusive solution to this problem, i.e., using a separate feeder cable, is also shown in Figure 7-20.

Mast arms are the most frequently used support system for one-way wire because they eliminate the cost of one line of poles. Span wire is preferable only where buildings on both sides of a street can be used for eyebolts. Mast arms can also reduce the number of poles needed when center-pole construction is used. This is most common in rail systems on private right of way or in medians as shown in Figure 7-21. Mast arms can also be used for trolleybus systems where a median separates a street having a single traffic lane in each direction.

Mast arms for two-way trolleybus wire are most appropriate for use on wide streets. A general rule is that the distance from the curb to the end of the arm should be no more than 20 percent of the curb-to-curb street width. A typical mast arm extends .9 m (3 ft) beyond the wire centerline. Thus, for a wire centerline 4.0 m (13 ft) from the curb, the mast arm would extend 4.9 m (16 ft) beyond the curb and the minimum street width for mast arm use would be 24.4 m (80 ft) or at least six lanes. This relationship is shown in Figure 7-22.

Two-track mast arms can range from the clean, but massive, variety shown in Figure 7-23 to the ungainly design shown in Figure 7-24. In general, two-track arms tend to overwhelm the streetscape and should be used only when there is no feasible alternative.

Many styles of bracket arm are available. Variations include the following:

- Straight or curved arms,
- Braced or unbraced arms, and
- Pole clamp or welded stub pole attachments.

Figures 7-25 and 7-26 show two styles of curved arms. Both designs use unbraced arms, which have to be substantially thicker than braced arms. In addition, the arms shown in Figure 7-25 are extra thick so that feeder cables can be hidden inside the arms. This design feature requires such a large arm that it is a questionable visual improvement over an externally mounted cable. This is particularly the case where all arms are enlarged for standardization even though only a few contain feeder cables. External feeder cables can be located on the sides of the arms so that they are barely noticeable. The second arm shown in Figure 7-23 has a barely visible external feeder cable.

In comparing the various styles of mast arms shown in the figures, it becomes apparent that there are also many variations in the hardware used to attach the contact wire to the arm. The different attachment hardware has little effect on the visual impact of the mast arm.

Mast arms can also be used to support both trolley wire and traffic signals or signs. Such joint-use arms will have to support greater weights than single-purpose arms and will have to be specially designed. Seattle attaches trolley wire to traffic-signal arms when needed for electrical safety but provides a nearby support for the wire so that the added load is minimized.

The mast arms described previously can be used for pendulum suspension or constant-tension wire although additional height above the street would be required. Mast arms for catenary systems are generally quite different from direct-suspension mast arms. A typical example is shown in Figure 7-2. Some systems use a more massive design as shown in Figure 3-13. Much of the mass of these arms is a result of using rigid-strut top bracing. Such bracing is only necessary at the bottom of a sag vertical curve, where the wire exerts a lifting force on the arm.

Two-track mast arms for catenary are even more massive than those for direct suspension. The arm shown in Figure 7-27 is perhaps the largest structure, relative to its surroundings, ever erected to hold up wire. A much neater approach to this difficult problem is shown in Figure 7-28. This design uses the main arm to support both the messenger and steady arm. Center poles are the preferred approach wherever space permits.

CATENARY SYSTEMS

Most catenary wire construction for light rail systems is quite similar, differing only in hardware details. The principal variations occur in the types of support used, as discussed in previous sections. One difference is the weight of the messenger wire. The catenary shown in Figure 2-6 has a fairly light, unobtrusive messenger as compared to the heavy cable shown in Figure 7-27. The use of heavy messenger cable for added electrical capacity adds to the visual mass of the catenary and requires heavier support structures to handle the added weight.

Figure 7-29 shows a low-profile catenary, which some designers feel is less visually intrusive; however, the only difference is that the space between the messenger and contact wire is reduced. The number and overall size of components is no different. Low-profile catenary requires the use of slightly more frequent supports as well as somewhat heavier poles because a combination of higher messenger tension and shorter span length is required to obtain the low profile.

Two varieties of catenary, compound and inclined, are almost never used in light rail systems but are mentioned here for completeness. Compound catenary uses an intermediate messenger wire between the main messenger and the contact wire. For inclined catenary, the messenger also serves as a backbone for curve pulloffs. These systems are primarily used in railroad applications; however, inclined catenary could be useful in some light rail applications where sufficient right of way is available to permit the necessary pole setback from the track.

In general, catenary systems are not appropriate for the street environment. The quantity of hardware and wire is overwhelming in a downtown area or on a narrow urban street. Catenary can be appropriate for a wide street or a street median installation, provided that (1) a simple span wire or center-pole support system is used, (2) crossbeams and heavy mast arms are avoided, and (3) the wire is not used as a high-capacity feeder.

OCS COMPONENTS

Feed Taps and Equalizers

Feed taps are used to connect feeder cables to the contact or messenger wire. Equalizers are used to connect the contact wire in each direction on two-way direct-suspension systems in order to improve the electrical capacity of the system. Equalizers are generally used on feederless systems or where feed taps are relatively infrequent.

In catenary systems, equalizing jumpers are used to connect the messenger and contact wire. Jumpers are also used to connect sections of wire in constant-tension systems and to bypass polarity insulators in trolleybus special work.

Careful design is required to minimize the visual impact of these components. In particular, feed taps and section breaks for catenary systems can become a jungle of wire if closely spaced multiple connections between the messenger and contact wires are used, as shown in Figure 7-30. This design would be less obtrusive if the connections had been spread out over a greater distance. Another design feature to avoid is using a feed-tap cable installed above the wire support with drop wires to the contact wire, as shown in Figure 7-20. Such a design may be necessary when a feed point coincides with a curve segment or other hardware element that cannot be supported by the feed-tap cable.

Some systems have experimented with the use of minimal hardware for contact wire connections to feeders. An example of such a minimal design is shown in Figure 7-31, along with a more common type of feeder connection on the same cable. This is an example of a relatively small, but noticeable, visual improvement that can be done at very low cost.

Using an excessive number of feed taps can also produce an unsightly appearance. Such situations occur when the contact wire is too small for the application or where electrical redundancy is carried to an extreme, such as using a separate circuit for each direction of movement. The effects of these design features are shown in Figure 2-5.

As mentioned previously, installing feed taps inside bracket arms is generally counterproductive because the increased size of the arm more than offsets the mass of the feed cable. The diameter of the arm must be large enough for the feeder cable to be pulled through without excessive friction. This is of particular concern with curved arms.

Although common in Europe, installing feed risers inside or on buildings is very rare in the United States and Canada. One of two such installations is shown in Figure 7-32. Another rare but quite practical approach for feed riser installation is to use bridge columns.

Switch Control

Because the OCS serves as a guideway, trolleybus systems require that some means of controlling switches in the OCS be provided. Three types of switch control are in use:

- Directional or pole position control,
- Current draw activated or power-on/power-off control, and
- Inductive control.

Directional control is the simplest but operates reliably only on sharp turns. It is used in conjunction with the other systems in appropriate locations. This system requires only a pair of contactors on the wire as shown in Figures 3-3 and 3-10.

Current draw activated control is generally considered obsolete but is used by four of the seven U.S. and Canadian trolleybus systems—Boston, Dayton, Philadelphia, and Vancouver. It also requires a pair of contactors on the wire. These are similar in appearance, although different in function, from directional control contactors.

Inductive control requires substantially more hardware. An inductive control switch, shown in Figure 3-6, uses (1) an antenna mounted on the wire ahead of the switch, (2) a control box—usually installed on a switch support pole, and (3) cables connecting the antenna, control box, and switch. San Francisco has a few control boxes mounted directly on the wire ahead of the switch as shown in Figure 9-3; however, this installation method is used only where there is no convenient pole. The most unsightly feature of an inductive switch installation is the control box cable, with its insulating sheath. The appearance of inductive switch installations could be substantially improved if the control equipment could be integrated with the switch, thus eliminating the need for the separate box and cable. Although some suppliers have indicated interest in developing such a design, customer response has been insufficient to justify the development cost.

Automatic Rewiring Equipment

Automatic rewiring equipment is used in Seattle where it is installed in off-street locations at the ends of a tunnel used by dual-mode buses. This installation uses relatively small (610 mm [2 ft] wide; 1,829 mm [6 ft] long) V-shaped pans at a height of 4,877 mm (16 ft) to guide the poles onto the wire. It is uncertain how well this system would work in a street location. Much larger pans and wider trolley-wire spacing could be needed because it is unlikely that bus position could be as closely controlled on the street as it is in the tunnel staging areas.

Figure 7-1. Pole with banners—Vancouver. A standard steel pole has been improved with banners and a sidewalk luminaire.

Figure 7-2. Catenary pole—San Jose. Note that this tubular steel pole has been somewhat enlarged to conceal a counterweight.

Figure 7-3. Historic concrete pole—San Francisco. This is an original pole (c.1915) from the Van Ness streetcar line.

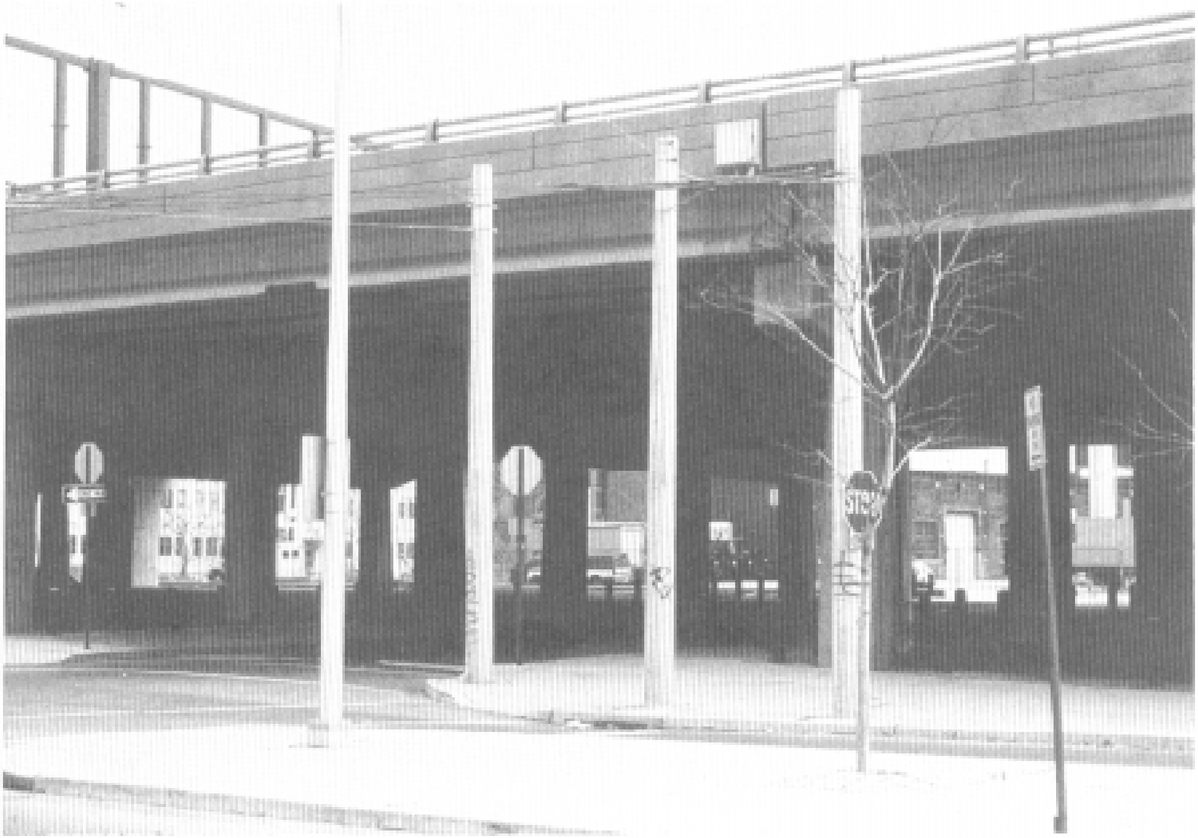


Figure 7-4. Concrete poles—Philadelphia. Note that multiple poles are used as a result of the strength limitations of the SEPTA standard concrete pole.

Figure 7-5. "H" column pole—Sacramento. Note that a counterweight is installed between the pole flanges and that the pole is located on a sidewalk at a crossing.

Figure 7-6. Decorative steel pole—San Francisco. This design uses a replica of a historic street-light fixture and a decorative base on a high-strength, small-diameter pole.

Figure 7-7. Contemporary pole design—Edmonton. The tall square poles are the predominant element in the streetscape. Their impact is enhanced by the placement of the pole faces at 45° to the curb line.

Figure 7-8. Street with eyebolts—Seattle. Note that eyebolts are an integral part of the design and that span wire does not cause a problem with trees in the median.

Figure 7-9. Eyebolt in isolation—Sacramento. An effective use of an eyebolt on a suitable building even though the nearby buildings are not appropriate for eyebolts.

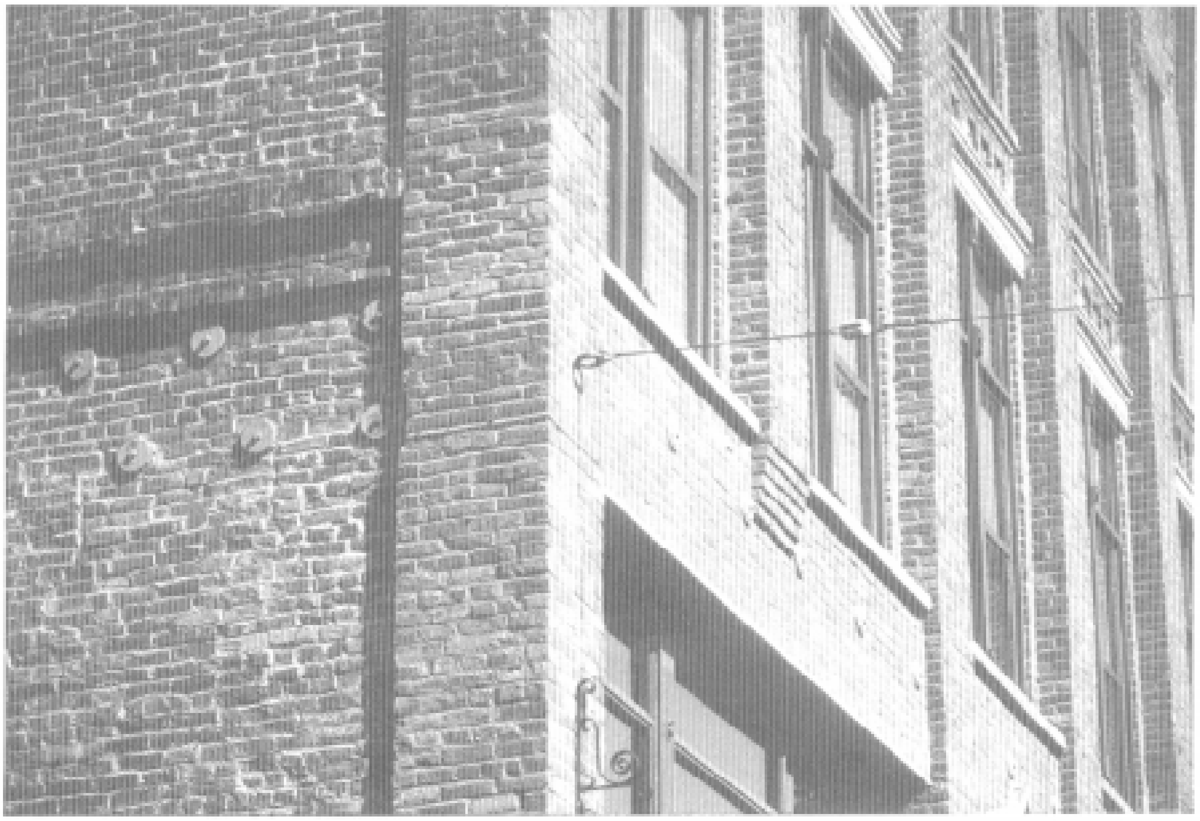


Figure 7-10. Eyebolt detail, historic building—Seattle. Note that the eyebolt is installed in a corner column.

Figure 7-11. Eyebolt detail, modern building—Seattle. Note that two eyebolts are attached to the building. The lower eyebolt is for OCS support, the upper eyebolt supports traffic signals.

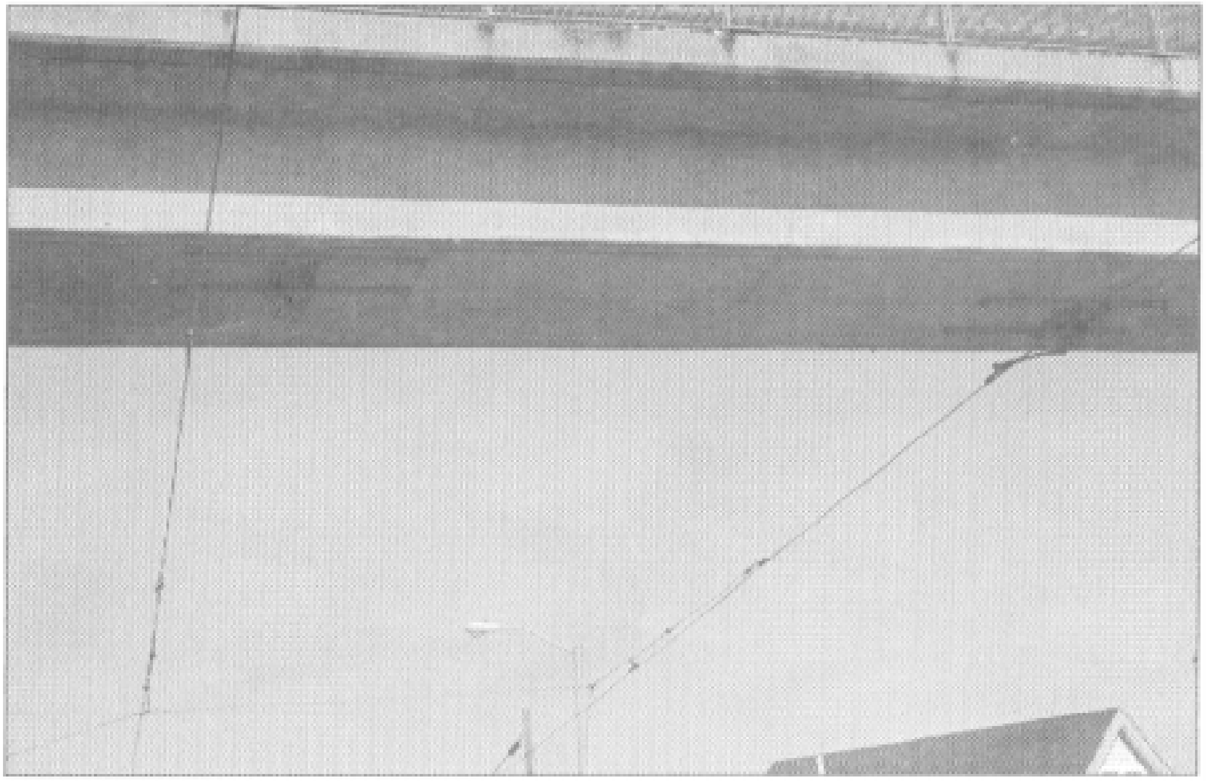


Figure 7-12. Attachment to underside of pedestrian bridge—San Francisco. Note the absence of insulating boards and the use of torsion arm hangers.

Figure 7-13. Side clamp wire support—Dusseldorf. This is a unique design for use where a bridge parapet would not hold an eyebolt.

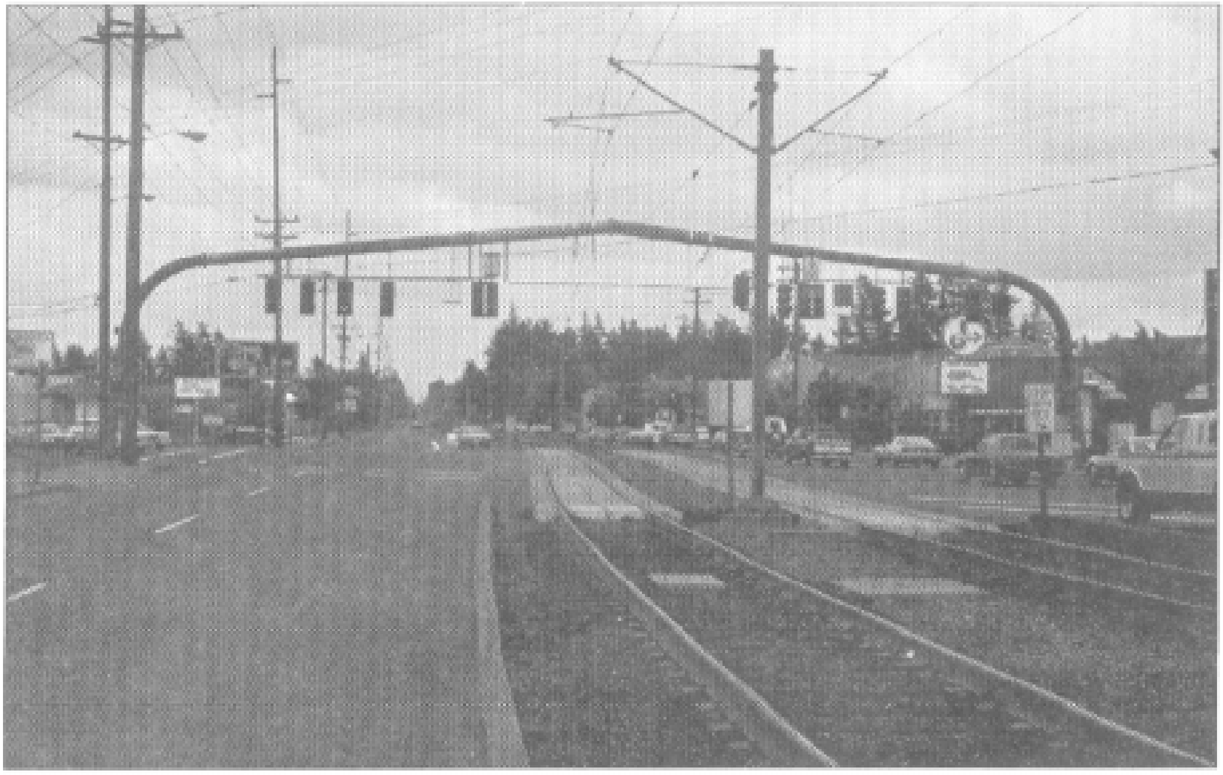


Figure 7-14. Portal structure—Portland. The large pipe used in this combined OCS and traffic signal support structure illustrates the use of a heavy structure where wire support would be less obtrusive.

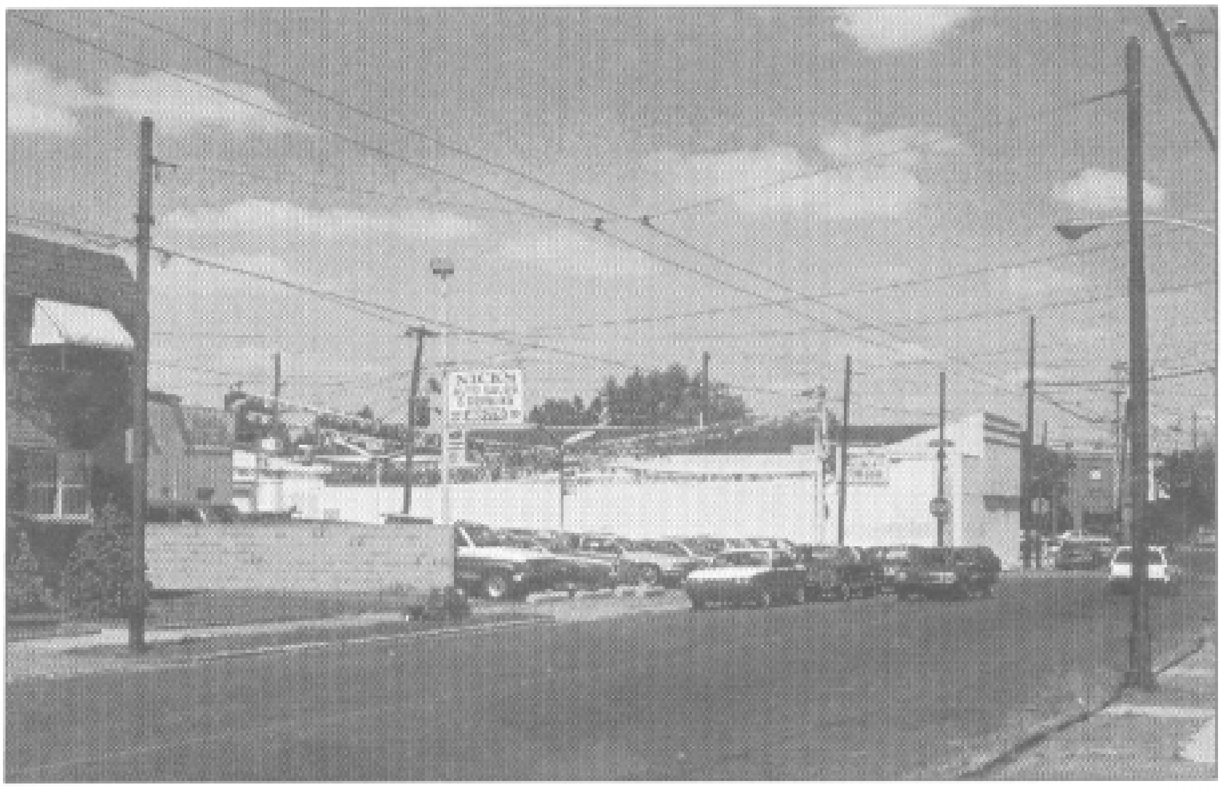


Figure 7-15. Clean trolleybus span—Philadelphia. Note that fiberglass stick insulators at the pole produce a clean span using steel guy wire.

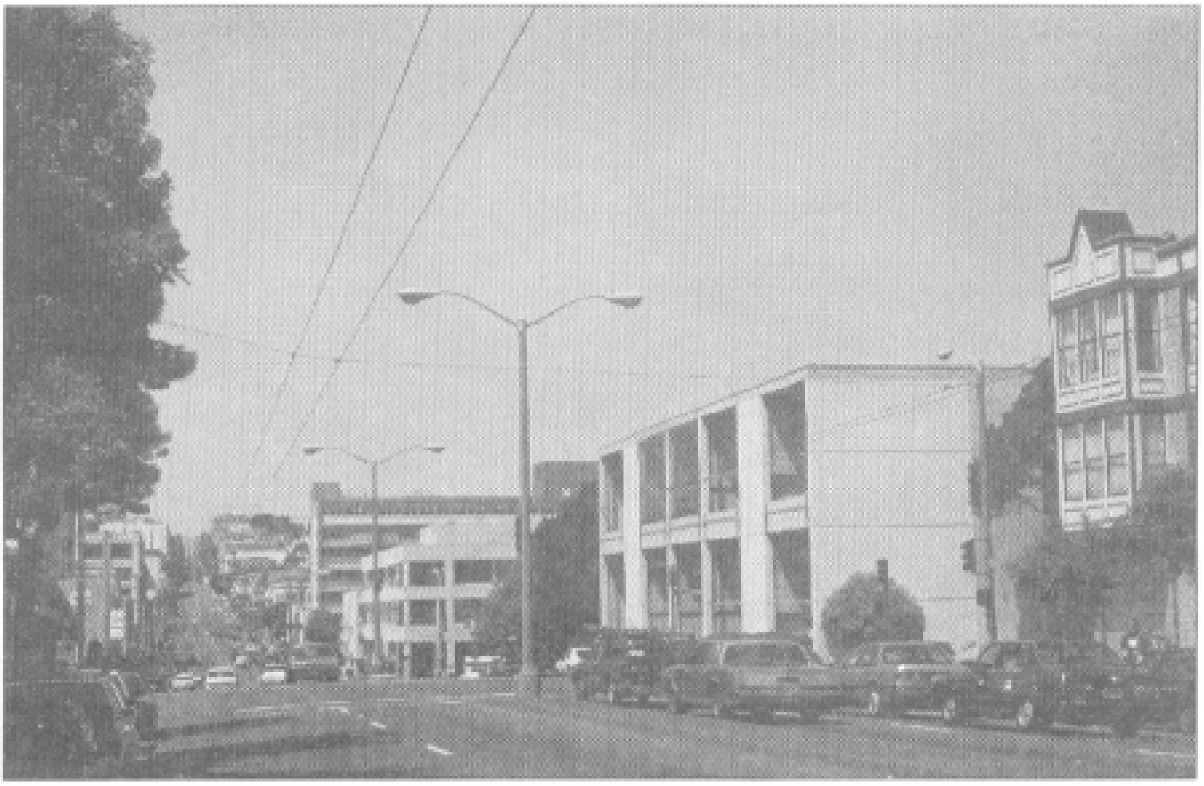


Figure 7-16. Nonmetallic trolleybus span—San Francisco. Note the complete absence of insulators produces a very clean appearance.

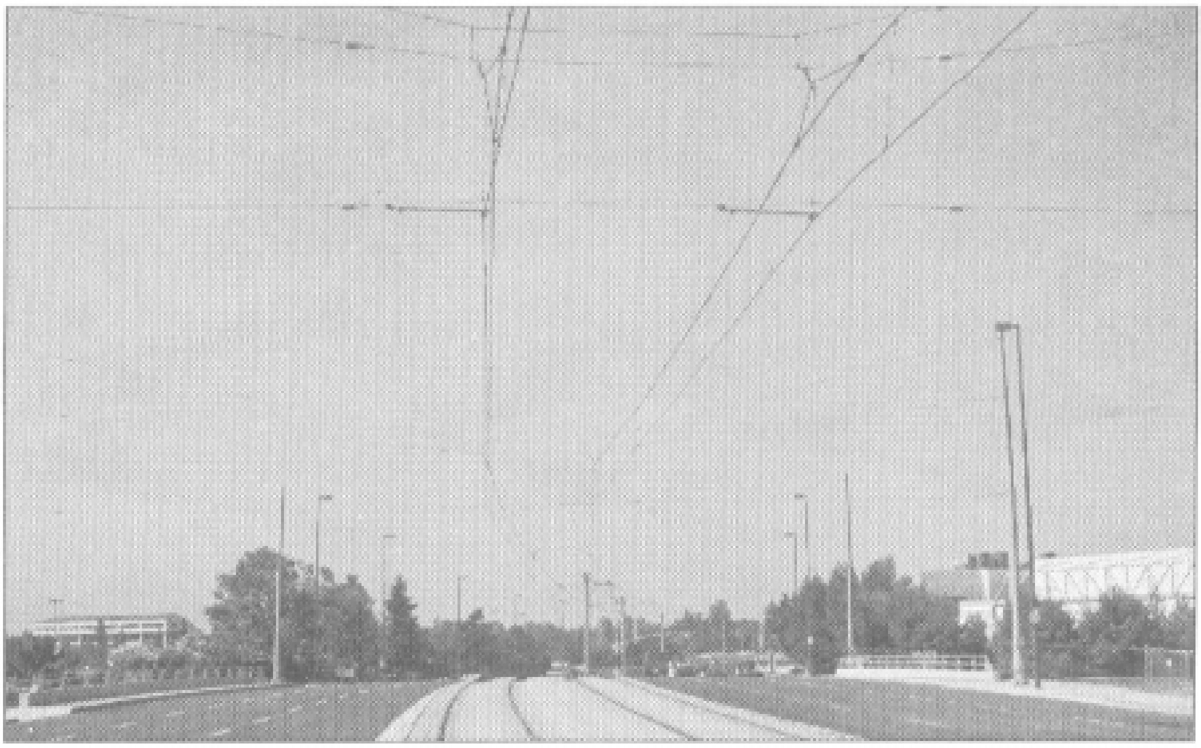


Figure 7-17. Catenary span—San Jose. A narrow median at a bridge forced the use of long span support. Although three levels of span are used, the result is acceptable on this wide street.

Figure 7-18. Mast arms on narrow street—Vancouver. Note the "finger pointing" effect of mast arms on a narrow street and the barely noticeable span wire in the foreground.

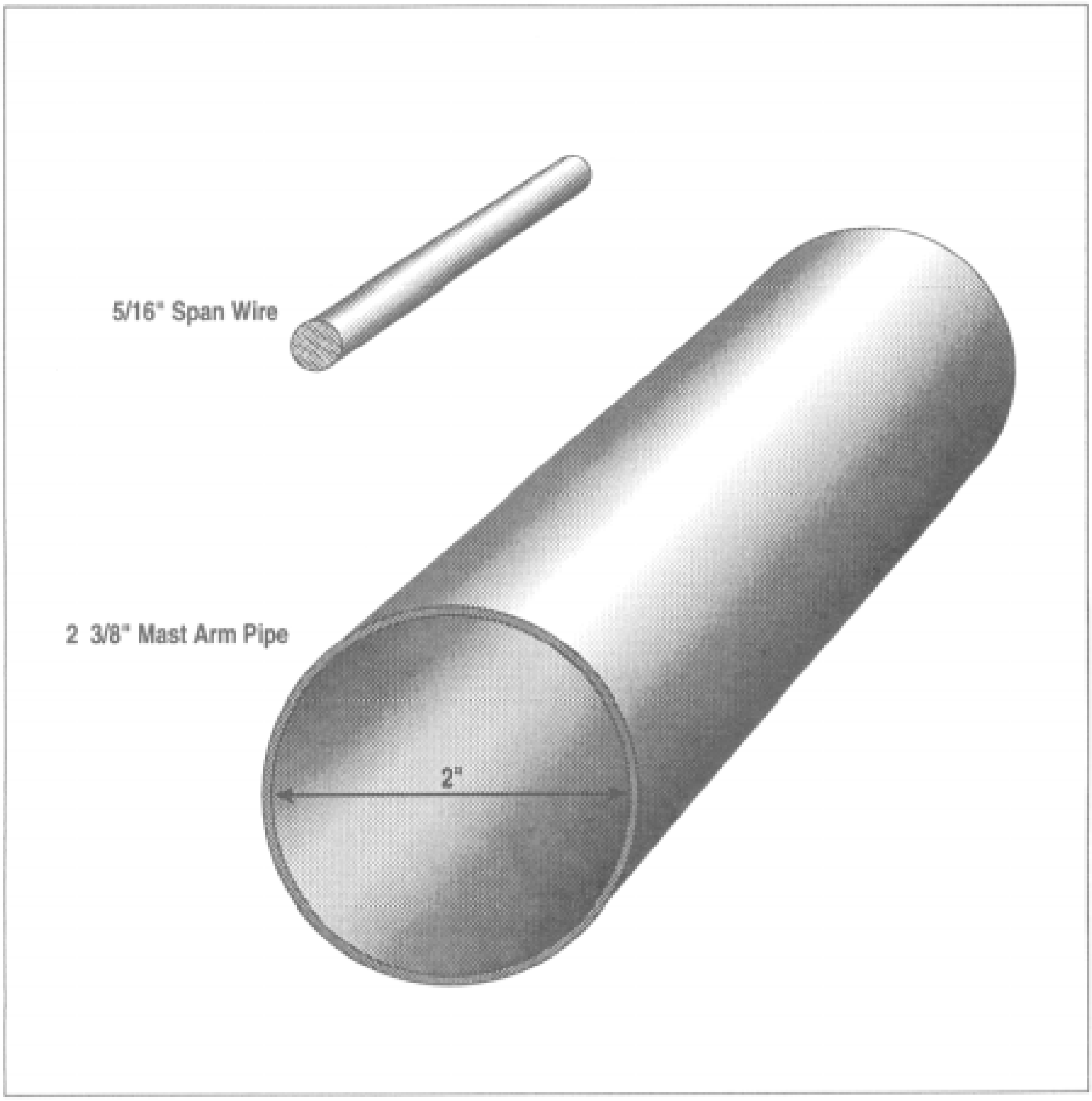


Figure 7-19. Comparison of span wire and mast arm size.

Figure 7-20. Mast arms—Vancouver. Note that the banners are supported separately from the mast arms and that an overhead feed tap crosses the street above the mast arms.

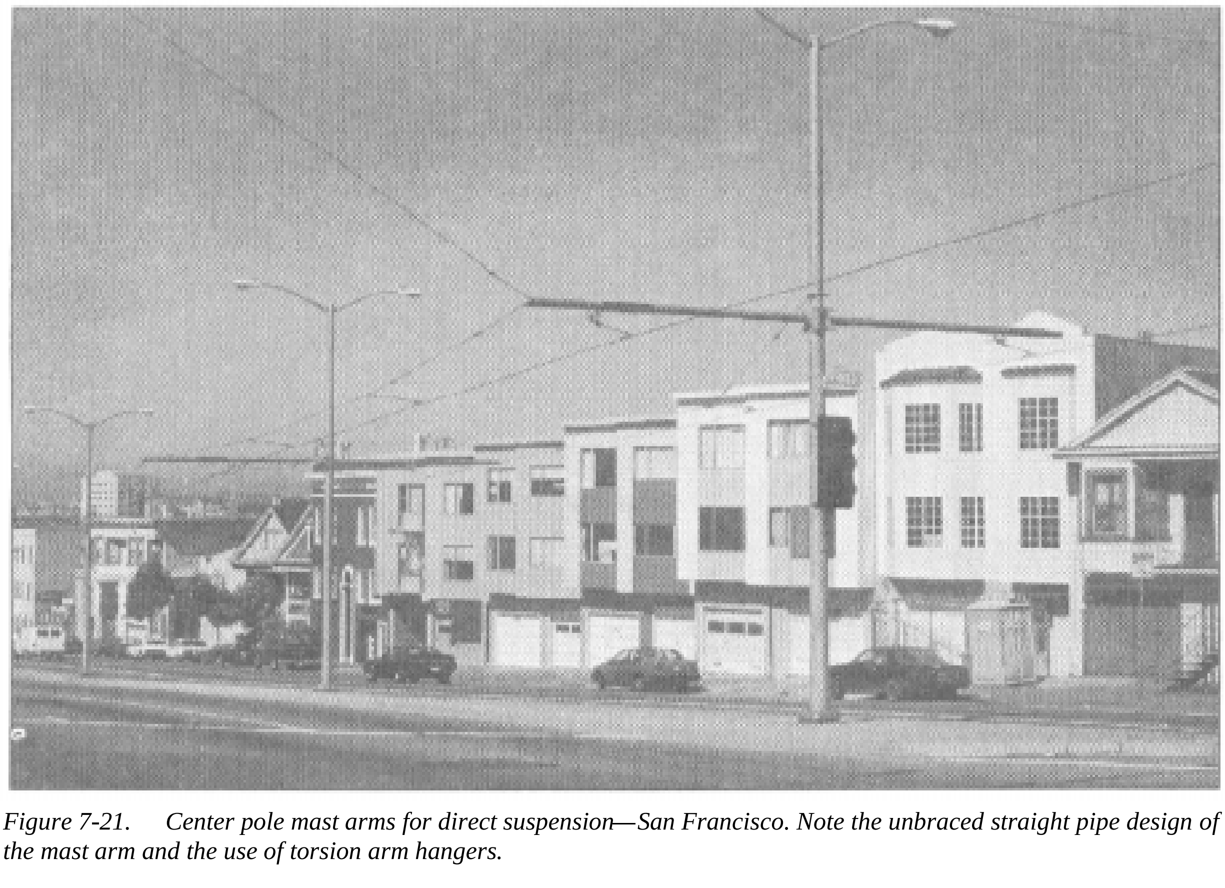


Figure 7-21. Center pole mast arms for direct suspension—San Francisco. Note the unbraced straight pipe design of the mast arm and the use of torsion arm hangers.

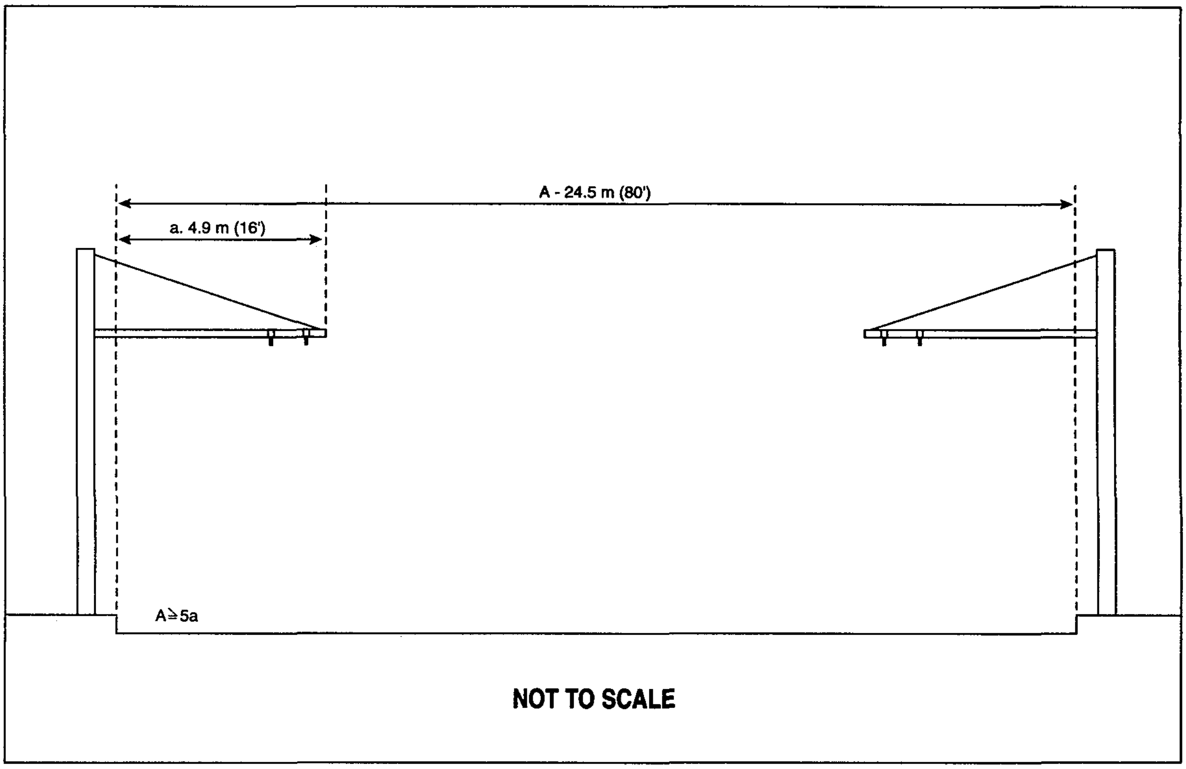


Figure 7-22. Minimum street width in relation to mast-arm length.

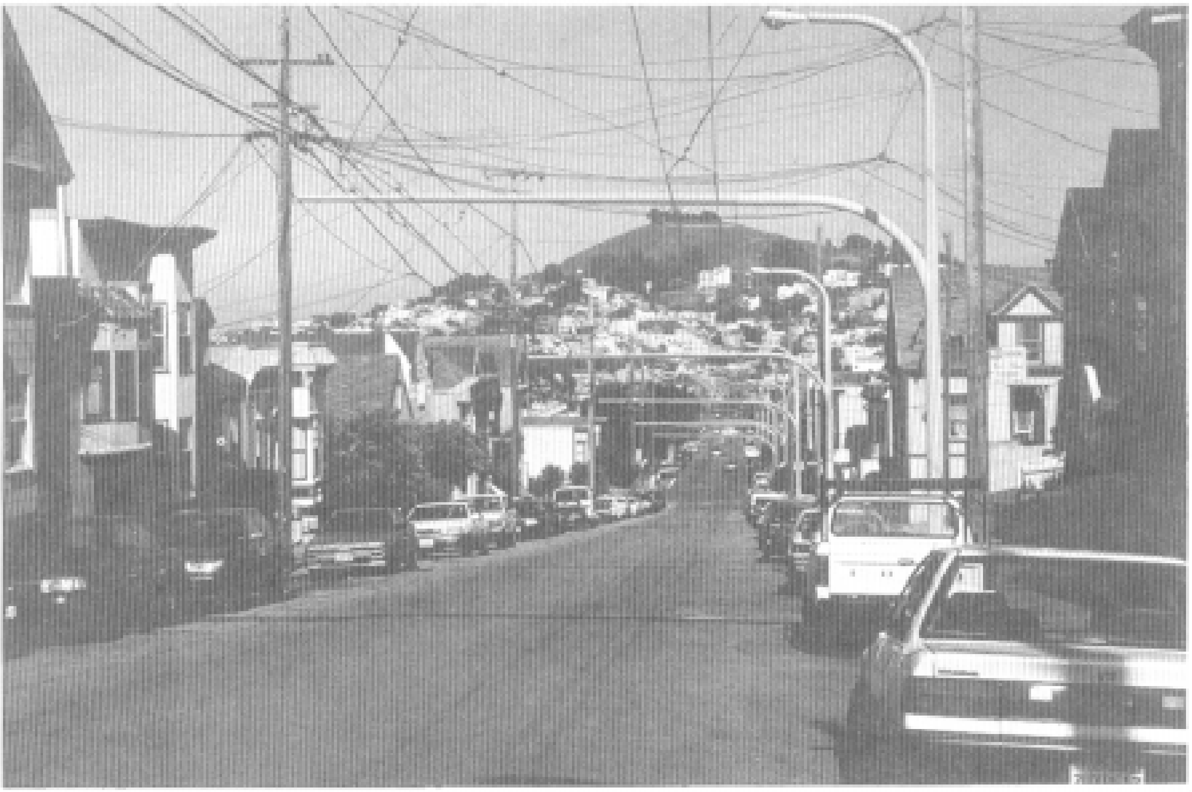


Figure 7-23. Two-track mast arm—San Francisco. This style of mast arm, while an attractive design, overwhelms the urban residential setting, producing almost the effect of a roof.

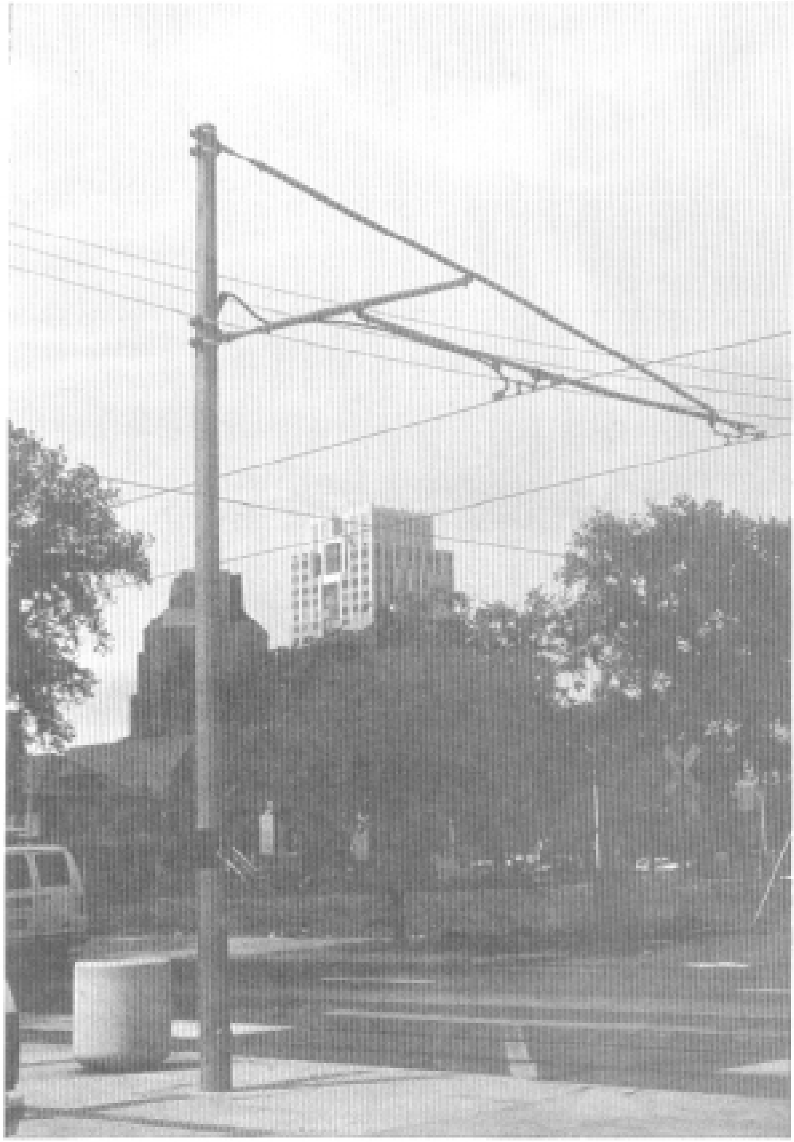


Figure 7-24. Two-track mast arm—Sacramento. Although a rather graceless collection of pipe, this arm is more in scale with the street than the arm in Figure 7-23.

Figure 7-25. *Gull-wing mast arm—Long Beach, CA. This attractive design is enlarged so that feed taps can be placed inside the arm.*

Figure 7-26. *Curved, unbraced mast arm—San Francisco. The singletrack version of the arm shown in Figure 7-23 is much more in scale with the street.*

Figure 7-27. Double-track catenary arm—Pittsburgh. This arm is massive by any standards. In a narrow street setting, it is overwhelming.

Figure 7-28. Double-track catenary arm—Boston. This is a good solution to a difficult situation. The attachment of the steady arms to a center fitting produces a clean design.

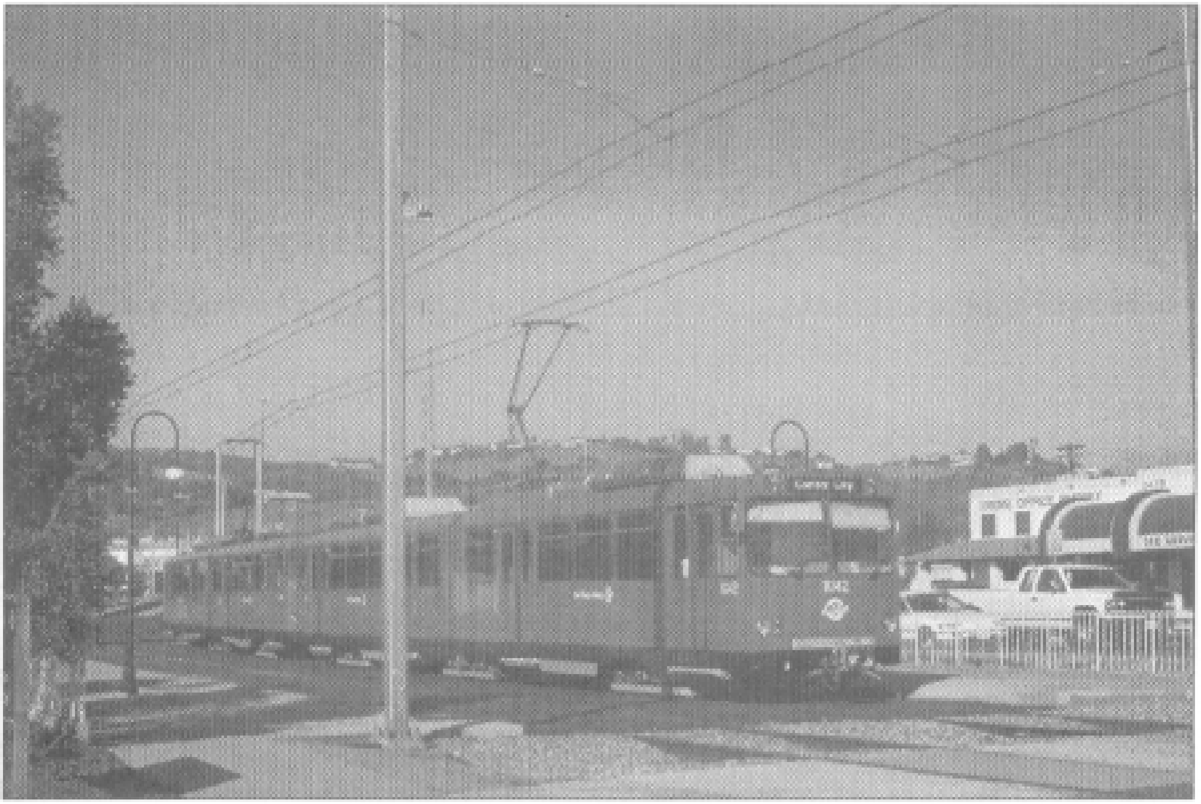


Figure 7-29. Low-profile catenary—San Diego. The lower cross section somewhat reduces the visual impact of the catenary but requires more frequent support poles.

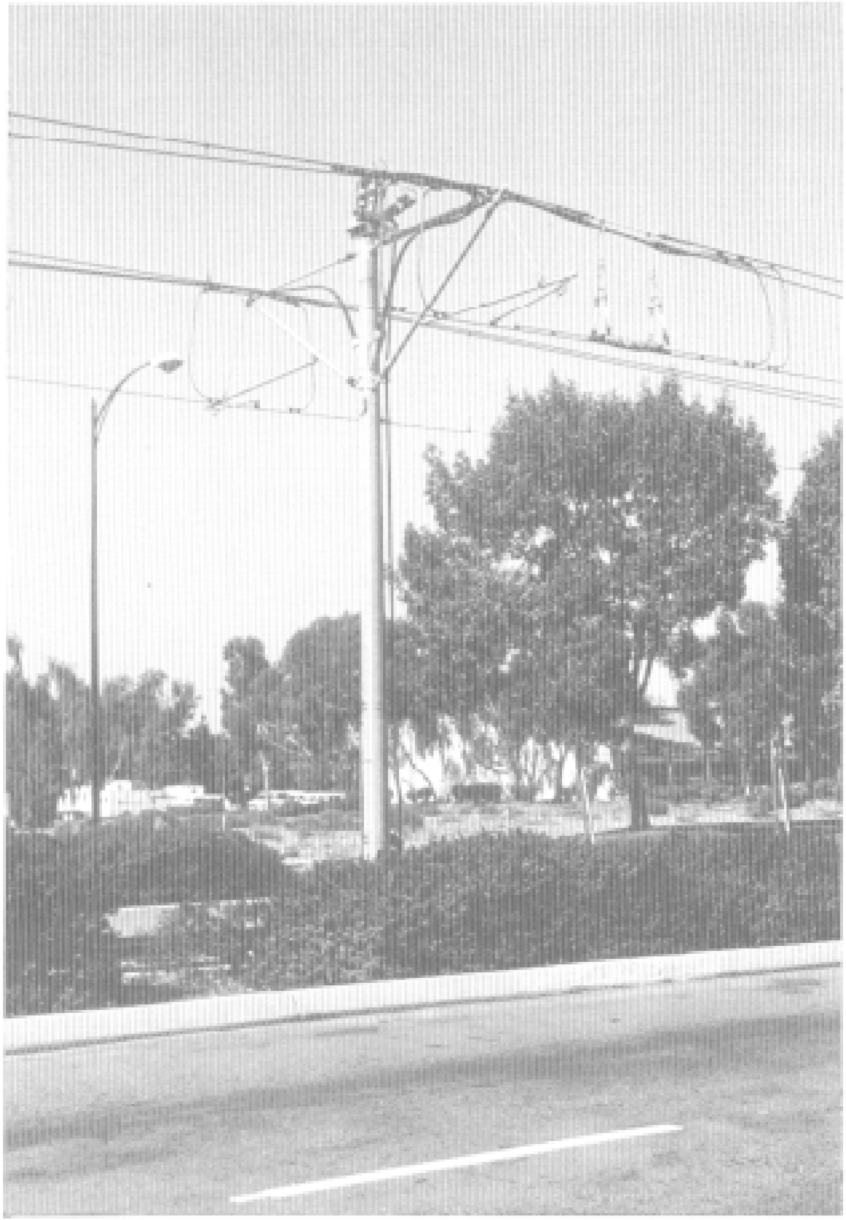


Figure 7-30. Catenary feed taps, section insulator, and emergency sectionalizing switch—San Jose. The concentration of all these elements at one pole produces a jungle of wire. The appearance could be improved by using adjacent poles.

Figure 7-31. Feed span with two types of feed hanger—San Francisco. Note the conventional feed hangers on the right and the minimal hardware, low-profile hangers on the left.

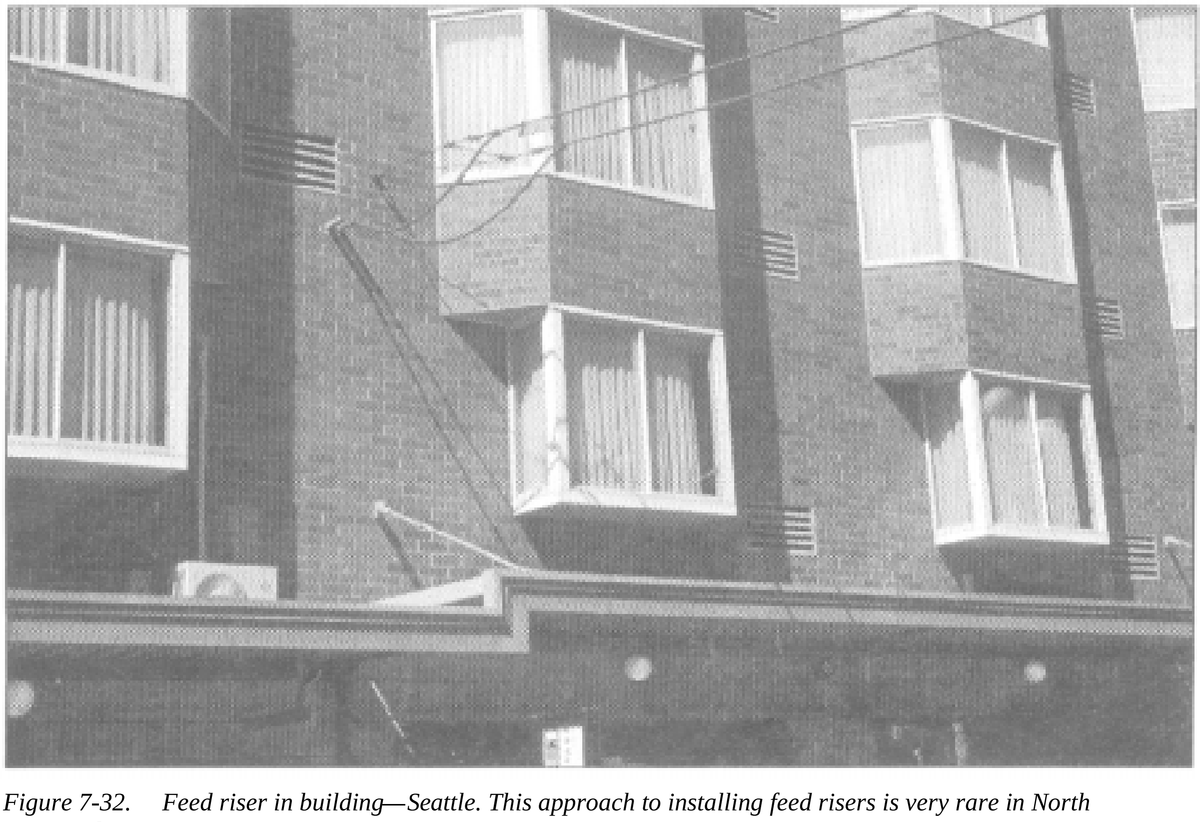


Figure 7-32. Feed riser in building—Seattle. This approach to installing feed risers is very rare in North America but common in Europe.

CHAPTER **8**

STREETSCAPE IMPROVEMENTS

An important technique for improving the visual quality of OCSs is to concentrate on the street environment surrounding them. Various improvements can be made to obscure OCS elements, enhance them, or make them part of a comprehensive street theme. The use of each of these methods depends on the opportunities available and the effect desired.

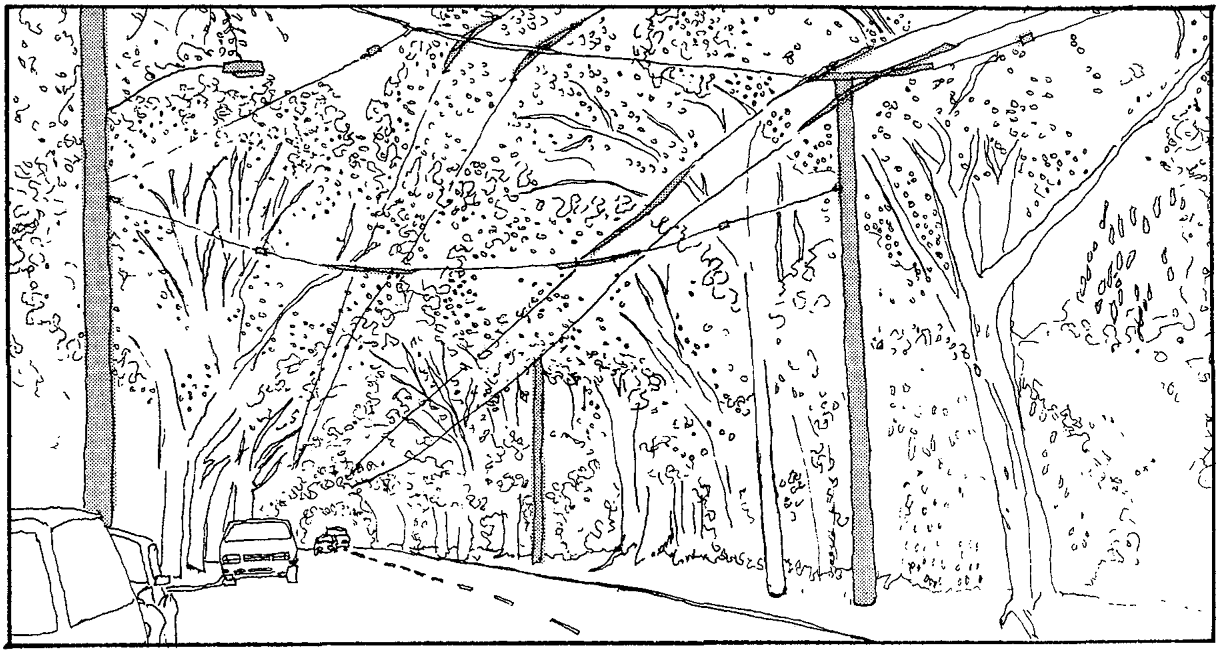
For example, the generous planting of trees and shrubbery will enhance any street environment, but it is particularly helpful in hiding OCS support poles. Figure 2-1 presents a classic example of this technique.

On the other hand, the attractive pole shown in Figure 7-6 draws attention to itself and its interesting base, detailing, and lamps. One would never think of placing this pole among a stand of trees where it would become totally obscured.

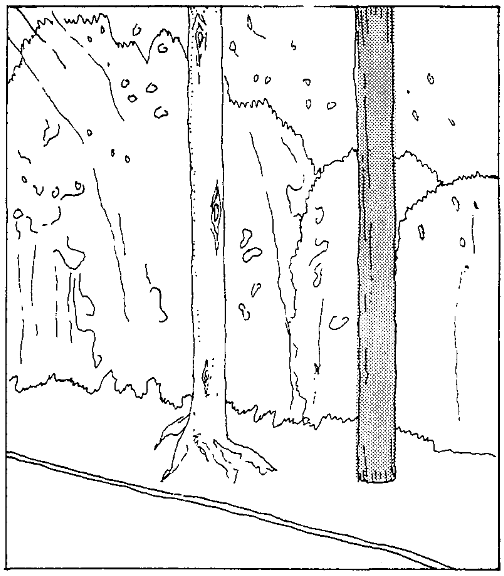
The following series of artist's renderings and descriptions (Figures 8-1 through 8-8) takes a number of photographs presented as figures in this report and illustrates the ways in which streetscape improvements can be used to enhance the visual quality of OCS through design, landscaping, and the consolidation of various street-furniture elements. Appearing after these figures is Table 2, a quick-reference matrix that allows one to look up any given OCS element to find its general suitability in terms of location and design considerations.

Table 2 summarizes the relationship between some of the more significant OCS elements, the type of adjacent land use, and street characteristics appropriate for use of the element.

- Simple, economical solution
- Materials appropriate to context
- Dense landscaping obscures cables and support structure



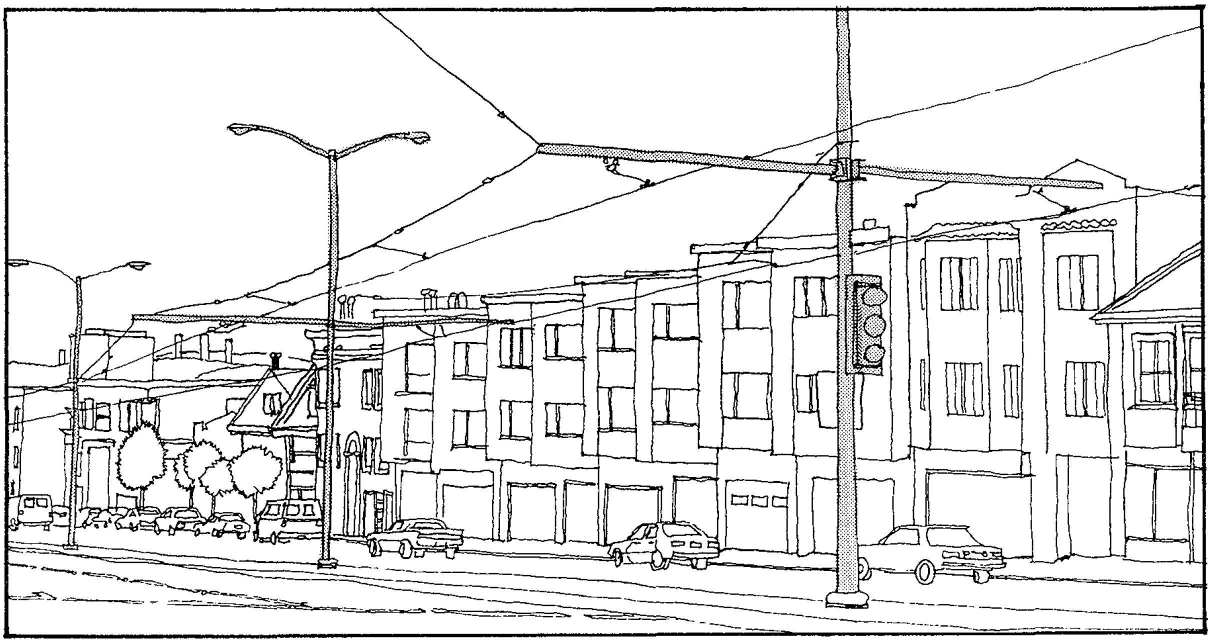
The simple, low-tech solution—plain, wood poles with minimal wiring strung between them—is an affordable and appropriate one for this densely wooded, residential neighborhood. The cables and supports are almost completely obscured by the foliage. A more elaborate or ornamental solution would not only have been more expensive, but it would have drawn attention to an element of the streetscape that, in this location, is better left as obscure and innocuous as possible.



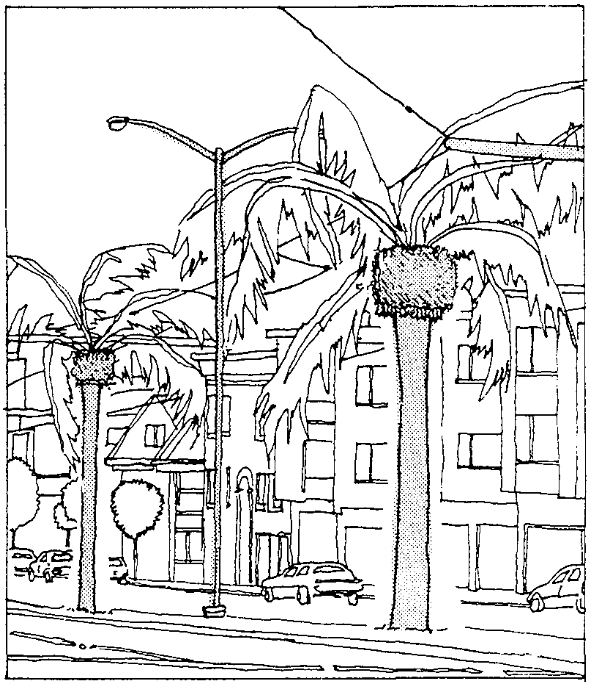
The simple wood pole blends in with the trunks of the adjacent trees.

Figure 8-1. Low-density residential area.

- Common-use poles combine cables, lighting, and traffic signals
- Center median installation eliminates sidewalk clutter
- Street trees obscure wires and supports



This clean installation accomplishes most major goals for a well-designed installation, albeit in a very utilitarian manner. The common-use poles are completely uniform; they support all necessary above-ground street elements, including street lighting, traffic signals, and cables. The center median allows for a single line of these poles down the center of the street, freeing the sidewalks from excessive clutter and obstructions.



A simple improvement to this installation would be the introduction of street trees, as illustrated with a variety of palm currently in use in San Francisco, to obscure the wires and their supports.

Figure 8-2. Medium-density residential area.

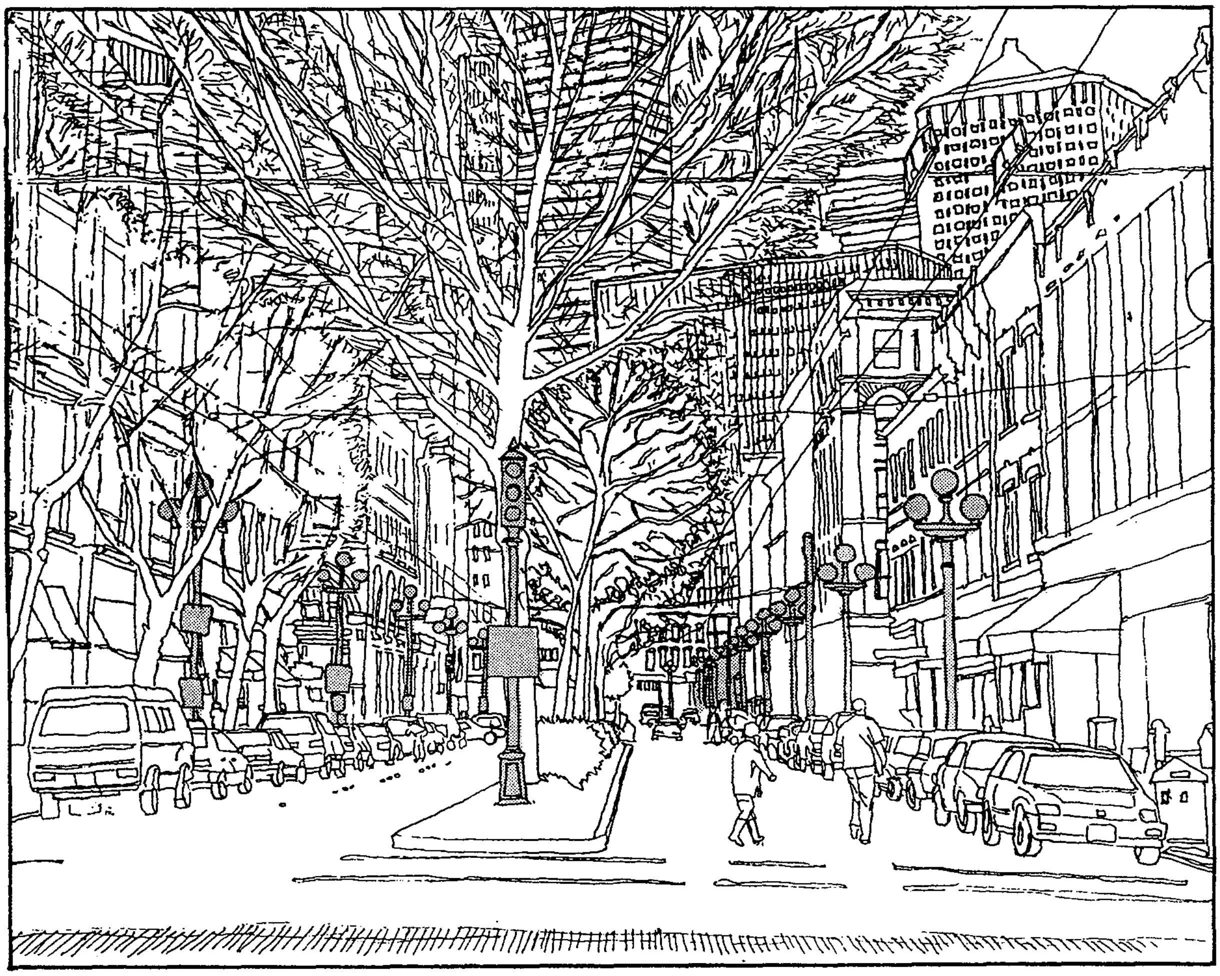
- Introduce common-use poles; cable suspension, traffic signals, telephone, signage, street lighting
- Introduce ornamental elements; style consistent with local vernacular and street-light design consistent with poles

A potentially cohesive streetscape is disrupted by a multiplicity of poles of differing styles and designs. However, a consistent streetwall and existing mature street trees provide a framework for a more effective approach.

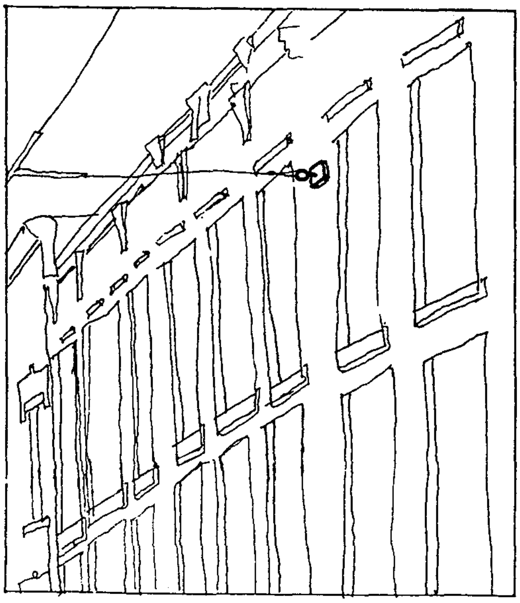
Introducing common-use poles can eliminate a great deal of visual clutter. The consistent architectural vocabulary of the street lends itself to the use of historically inspired ornamental pole design, which can enhance a basically successful streetscape.

Figure 8-3. Medium-density residential area.

- Eyebolt connections to adjacent facades eliminate support poles
- Landscaped center median enhances streetscape; trees, traffic signals, shrubs, signage



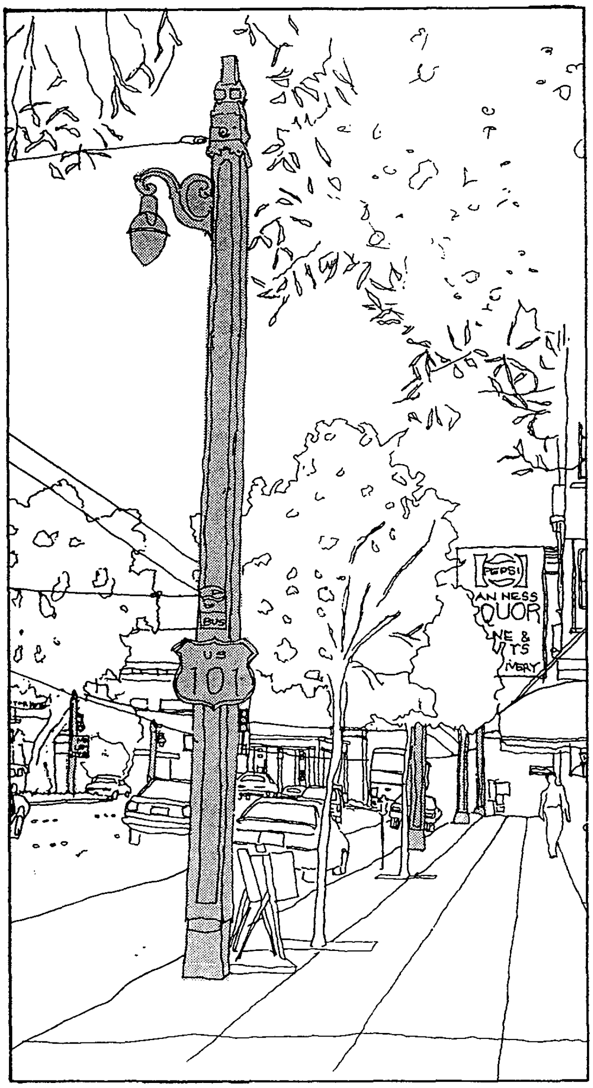
Masonry facades from various periods line both sides of the street. These are supplemented by trees and shrubs along the center median, which help to obscure the cables. The independence of utilities such as cable suspension, street lighting, and traffic signals is appropriate in the context because the diverse streetscape lends itself to the integration of independent elements.



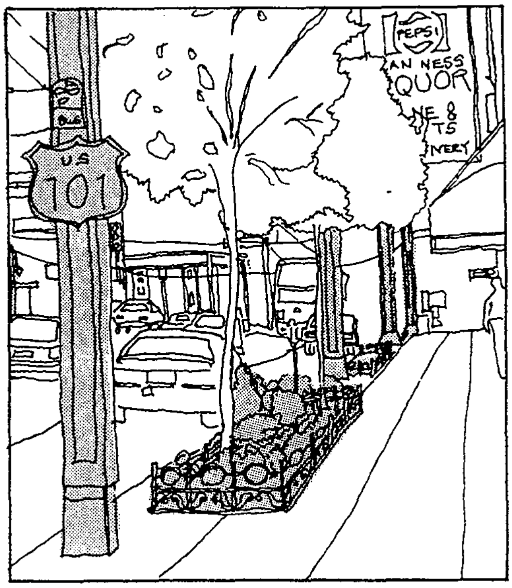
The use of eyebolt connections to support spans of cable between building facades is an efficient, low-cost method of overhead cable support in dense downtown areas with streetwall buildings.

Figure 8-4.High-density central business district and core area.

- Use original 1915 common-use pole; cable suspension, signage, street lighting



- Introduce additional ornamental landscaping around existing trees

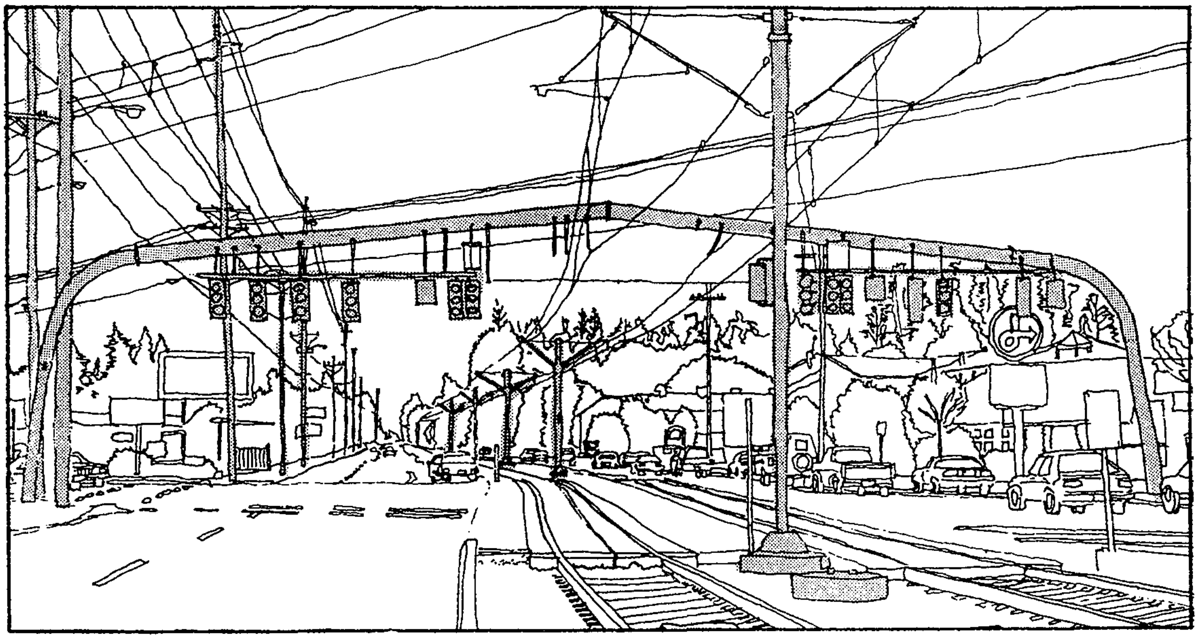


A simple, low-cost improvement can be considered for even the most attractive locations. Putting ornamental planting beds around existing trees would enhance the pedestrian environment.

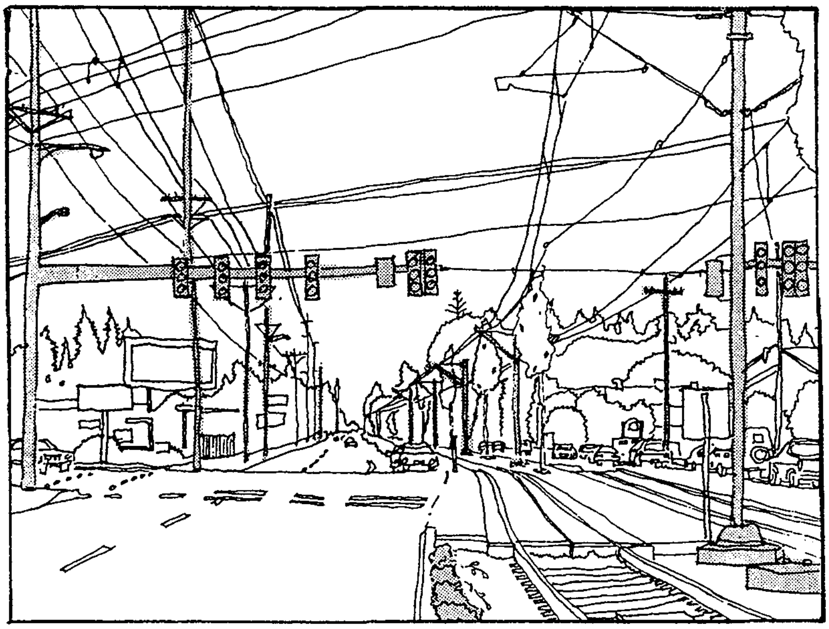
This installation is an excellent example of an ornamental common-use pole still in use. The pole (c. 1915) defines the street edge in a style that is consistent with the adjacent architecture. Cable suspension, street lights, and signage are all incorporated into this single pole, resulting in a clean and uncluttered streetscape. The cable is suspended from an ornamental cap that incorporates the anchor as an integral part of the design.

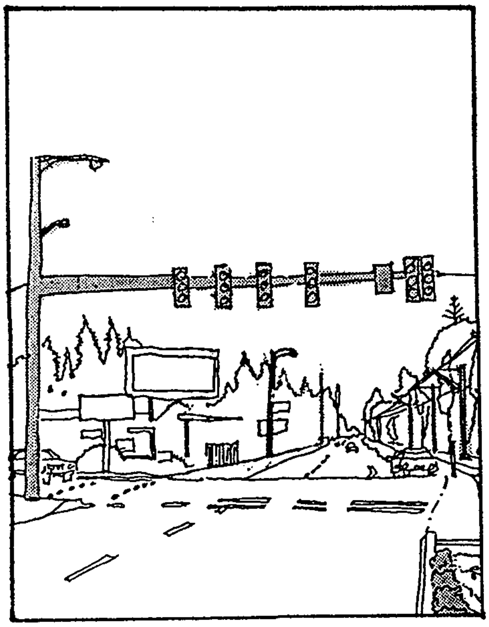
Figure 8-5. Medium-density commercial and residential strip.

- Introduce common-use poles; cable suspension, telephone cables, street lighting, signage
- Eliminate industrial-quality portal
- Introduce street trees and shrubs



The visual impact of the portal structure spanning the intersection overwhelms the streetscape without introducing any positive elements. This design adds a heavy structural thickness and weight into the myriad of cables, utility poles, tracks, and signage.

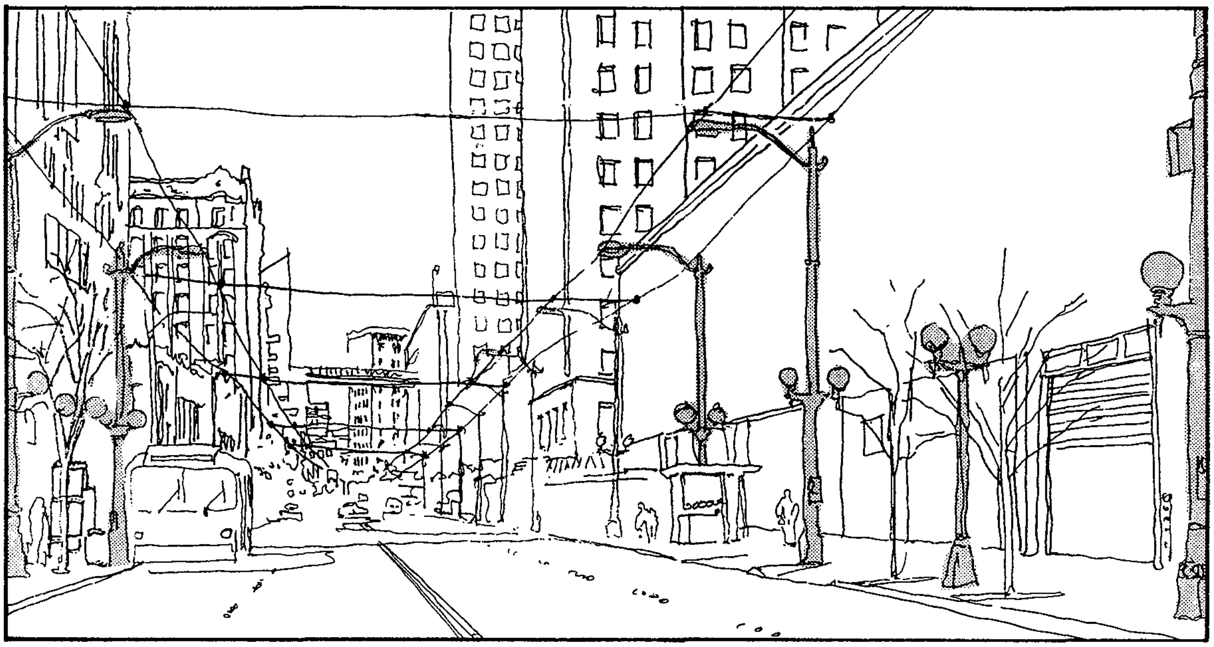




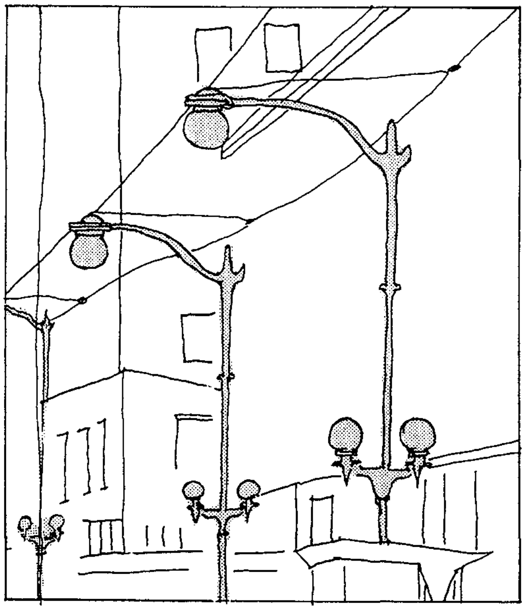
Cantilevered bents joined by a tension wire can support various utilities and services as well as traffic signals and signage, thereby minimizing structure and reducing the number of supports. Landscaping the center median conceals masts and overhead cables. Replacing the overhead utilities with underground services would also improve the visual character of the corridor.

Figure 8-6. Low-density commercial and industrial strip.

- Common-use poles combine cables, lighting, and traffic signals
- Ornamental elements replace modern fixtures; globe lamps are maintained throughout



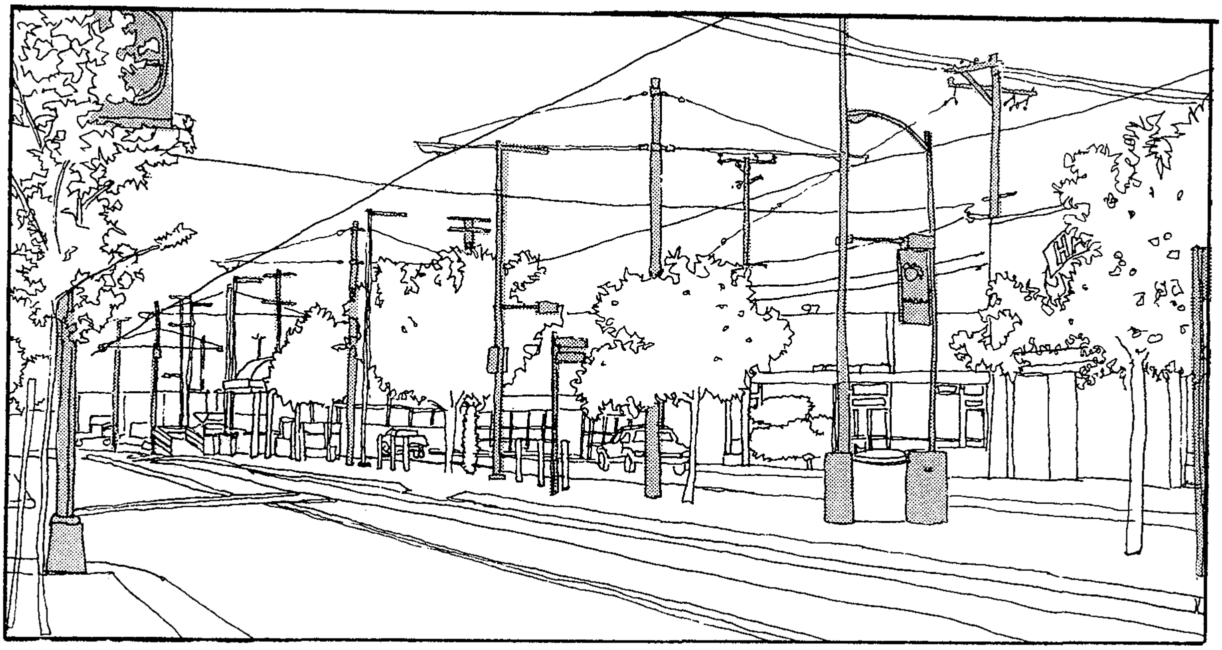
This existing installation successfully organizes cables, lighting, and traffic signals with ornamental common-use poles. Combining cable suspension, street lighting, sidewalk illumination, and signage on a single pole maintains an orderly network of utilities and services on a narrow sidewalk. The use of ornate historic reproductions for the poles and light fixtures introduces visual interest and character to an otherwise barren streetscape.



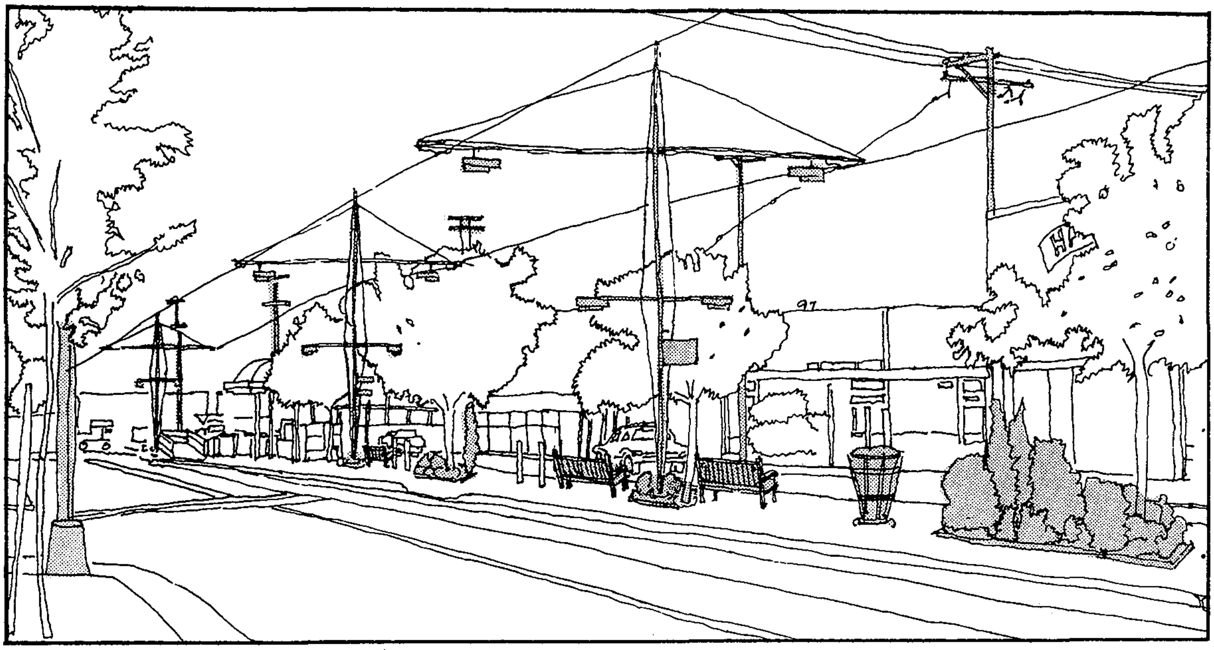
The modern cobra-head fixture at the top of the street-lighting shafts, however, is an anachronism that taints an otherwise extremely effective installation. Replacing these modern fixtures with globe-shaped ones that harmonize with the currently used sidewalk fixtures would be an improvement.

Figure 8-7. High-density central business district and core area.

- Introduce common-use poles; cable suspension, station lighting, street lighting, signage
- Eliminate clutter by using center median
- Introduce street furniture; wooden benches, garbage bins
- Introduce additional landscaping around existing trees



Each urban utility is supported as an independent object, resulting in a multitude of different poles and fixtures cluttering the street. Cable suspension and signage remain independent from the combined station- and street-lighting poles. Randomly placed trees also contribute to the visual chaos of independent objects.



The existing heavy-duty light poles on the center median can be used as the framework to combine diverse elements into one installation, dramatically reducing the number and type of support poles and structures. Introducing station amenities such as additional landscaping around existing trees, wooden benches, and decorative garbage bins give character to an otherwise anonymous strip.

Figure 8-8. Medium-density commercial strip.

TABLE 2 OCS design and land-use matrix

OCS ELEMENT	LAND USE	APPROPRIATE USE
Wood poles	Low-density residential Parks Campuses	Areas with buildings set well back from sidewalk and extensive landscaping such as single-family residential, parks, and campuses.
Concrete poles	Industrial High-density residential Commercial	Only for tangent spans and similar low-strength applications.
Tubular steel poles	Commercial Residential Industrial	Suitable for almost all areas.
H-column steel poles	Industrial	Private right of way or in-street medians where pole will be viewed only from a distance May be appropriate in industrial areas with heavy truck traffic because such poles are more impact resistant.
Building eyebolts	Commercial Residential	Areas with multistory buildings and minimal setback from sidewalk.
Mast arms	Commercial High-density residential	Wide streets, one-way wire, center poles on medians and private right of way.
Two-track mast arms	Commercial Residential Industrial	Narrow streets and right of way where mast arm can be less than about 7 m (21 ft).
Portal structures	Industrial Commercial	Where absolutely necessary or as an occasional architectural statement.
Catenary	Commercial Low-density residential Industrial	Private right of way, medians, and very wide streets with side poles and span wire. Do not use in confined areas.

CHAPTER **9**

PRESENTATION TECHNIQUES

How OCS is presented to communities, elected officials, and transportation decision makers affects whether it will be accepted or rejected. Many tools and media are effective in presenting OCS. Some of them are more appropriate than others, depending on the audience being addressed.

Photographs give the most accurate portrayal of actual OCS appearance and are the medium to which the public most readily relates. A photo closely mimics field conditions in terms of color, shading, scale, and texture. Photographs provide the best representation of the visual impact of different OCS elements. In some cases, standard color prints mounted on a board can produce satisfactory results for side-by-side comparisons by a small group. For a more elaborate and comprehensive presentation, slides may be the medium of choice, especially when there is a large audience. For a document intended for wider dissemination, such as this report, computer-scanned slides reproduced on a laser copier provide good quality at a reasonable price.

There are, however, pitfalls that must be avoided with the use of photos. Figures 9-1 and 9-2 illustrate the difference in perception resulting from perspective and camera angle of the photos. Care must always be taken to present the most honest, evenhanded view that neither exaggerates nor understates the impact of OCS. Exposure and lighting must also be controlled because under- or overexposed photos, as well as photos with excessive or insufficient contrast, will tend to obscure details. Sunlight and shade also need to be considered because the reflectivity of system components varies and can change with the different background light conditions during the course of the day.

Telephoto lenses are used to obtain clear photos of OCS details such as switches and eyebolts for presentation purposes as shown in Figure 9-3. However, they should not be used to show an overall perspective as in Figure 9-4 where the telephoto lens is distorting the actual presence of the poles and bracket arms in the streetscape. Please refer to Figure 7-23, which shows the same bracket arms using a standard lens. The poles and brackets are represented in a fashion that is much closer to the way the human eye perceives them in the field. Technical plans and elevations are useful and necessary when addressing transportation professionals. They can, however, intimidate the public, and their use should be minimized at community board hearings and other such forums. In addition, technical drawings tend to equalize the impact of vastly different elements because of the limited range of line weight. In other words, a mast arm and a wire look almost the same on paper whereas the wire could be nearly invisible in the street environment. The view that is presented in a drawing can never duplicate what exists in the real world.

Computer-generated drawings fall victim to the same limitations, although they do have uses in preparing three-dimensional perspectives and certain details more efficiently. The setting, audience, and subject matter are critical to deciding whether computer-generated graphics are useful and appropriate. Computer-generated composite photographs are useful in showing heavier elements such as poles. The present level of this technology cannot produce the fine line work needed to portray wire accurately, although future software improvements will undoubtedly enhance this ability.

Artist's renderings and art work definitely have a place in the presentation of OCS techniques. As can be seen in Chapter 8 of this handbook, they are particularly useful in creating a common baseline on which the effect of various improvements and changes to the OCS, streetscape, and background setting can be illustrated. They do, however, suffer from similar problems that beset technical drawings. The relative visual impact of elements can be distorted, art work tends to overstate the size of contact wire and guying because of the difficulty inherent in working with sufficiently thin line weights, and the choice of perspective can vary the perceived impact significantly. They are best used in conjunction with other media, particularly photos, to highlight specific elements and solutions that can be readily referred to a real-world condition in a photograph.

Figure 9-1. Fourth and Market Sts.—San Francisco. This view shows that the OCS is readily noticeable against the sky and the white building.

Figure 9-2. Fourth and Market Sts.—San Francisco. This view shows that the OCS is much less noticeable against the multicolored building background.

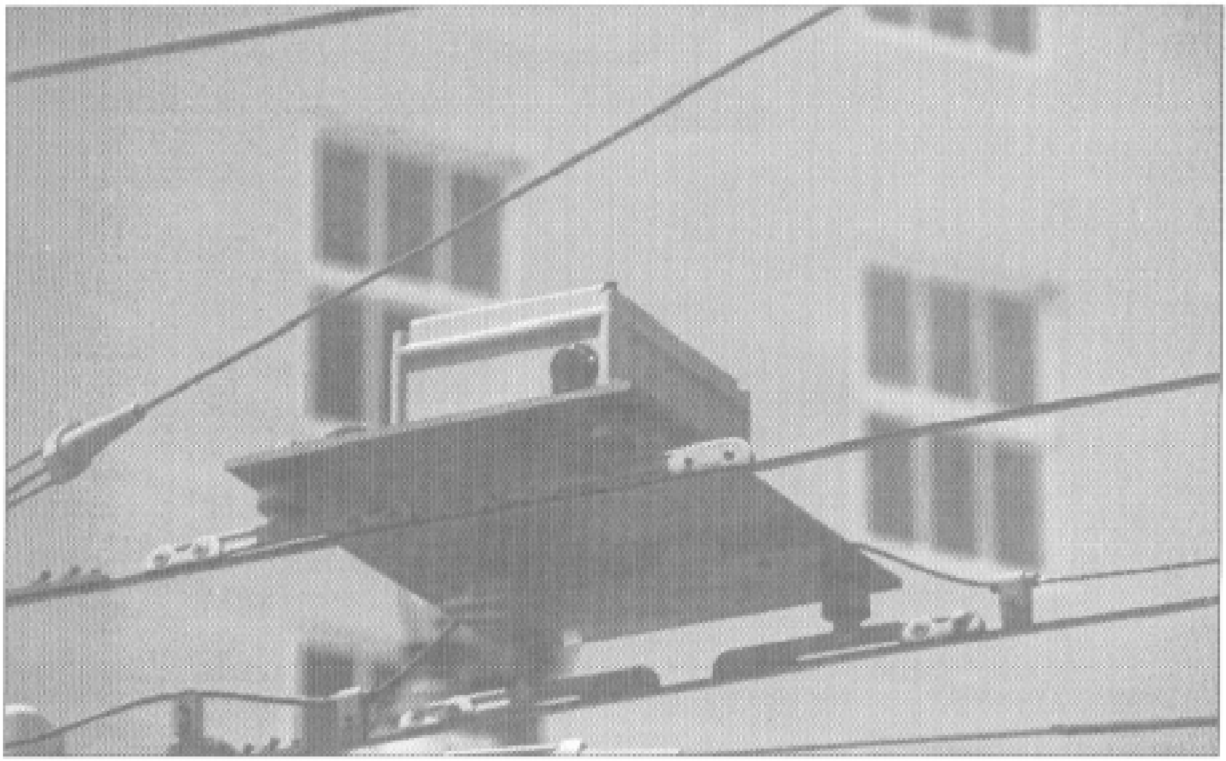


Figure 9-3. Telephoto view, wire-mounted control box—San Francisco. Note that the perspective is not noticeably distorted. Also, the out-of-focus background emphasizes the hardware element being shown.

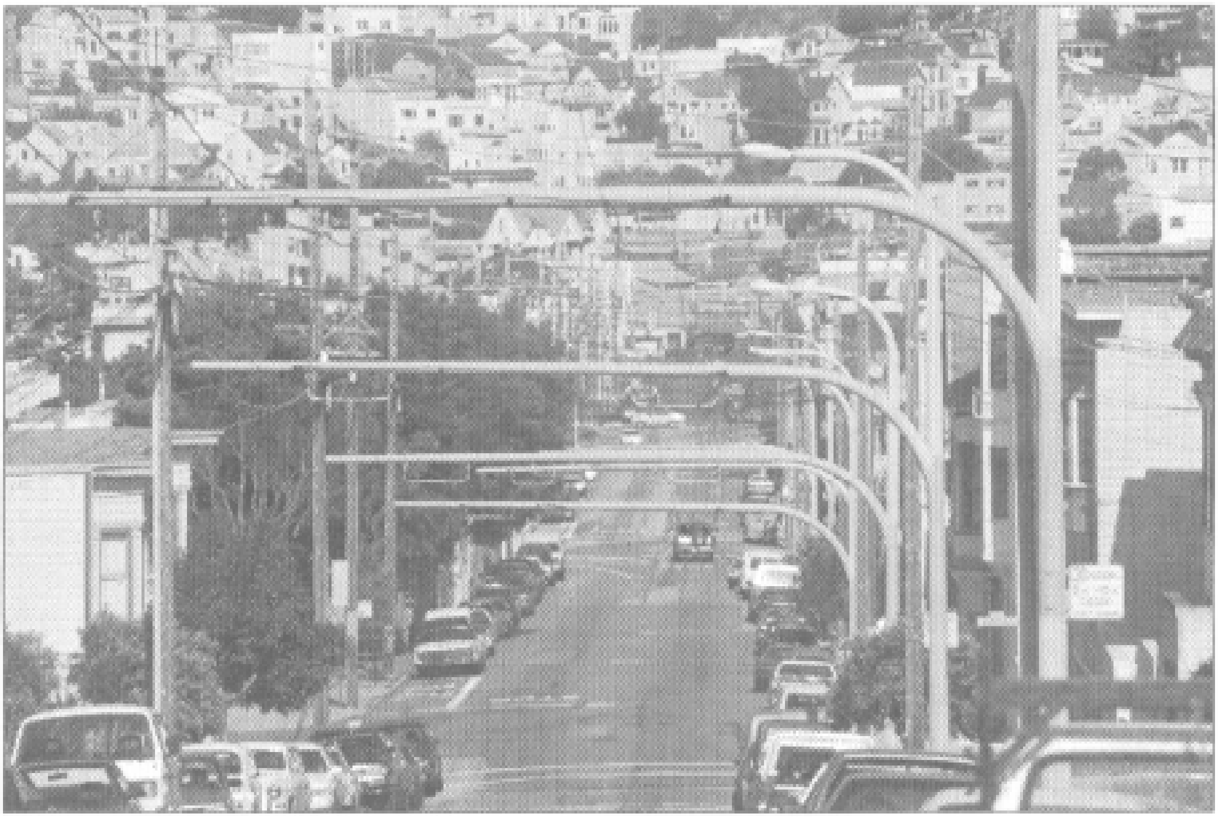


Figure 9-4. Telephoto view, bracket arms—San Francisco. Compare this view with the one in Figure 7-23 to get a better understanding of the foreshortening effect.

CHAPTER **10**

THE REGULATORY ENVIRONMENT

As the world becomes increasingly complex, the introduction of overhead wire for transit systems becomes more complex as well. The regulatory process for installing OCS in transit agencies with and without OCS needs to be thoroughly researched and detailed before initiating installation. There will be jurisdictional and procedural questions regarding pole location, building-code requirements, electrical-code requirements, safety regulations, zoning laws, environmental regulations, and other such issues. Figure 10-1 presents a typical process for developing an OCS project. Keep in mind that this is just a general guide. Each transit agency will need to identify the specific steps to follow in its own municipal setting and tailor the process to its needs.

State and local electrical-code requirements are probably the most important regulatory elements to consider. Environmental regulations, however, follow a close second — particularly when the OCS will be installed near sensitive land uses such as schools, hospitals, and historic areas. Street-use permits will need to be secured to install poles and wire, which means the departments of transportation or public works will need to be involved. Zoning regulations in some jurisdictions oversee the installation of street furniture and OCS elements thereby requiring special review by a zoning body. Installations in historic districts will require the review of a landmarks commission or historic preservation department. A route installed along a shoreline could require special clearance from a waterfront office.

The key to organizing a thorough regulatory review is cross checking. Each agency contacted should be polled about which other agencies need to be contacted. In this manner, a systematic cross checking occurs, which ensures that all the necessary elements are included. Furthermore, a specific checklist of required documentation should be developed for all agencies and reviewed with them before the requisite work is done. Finally, interagency conferencing is useful for enabling the key organizations to discuss the procedures and components that comprise an OCS project. This promotes a sense of cooperation among the various agencies and lays the groundwork for continued cooperation when issues such as joint use of poles and eyebolt installation agreements come to the fore.

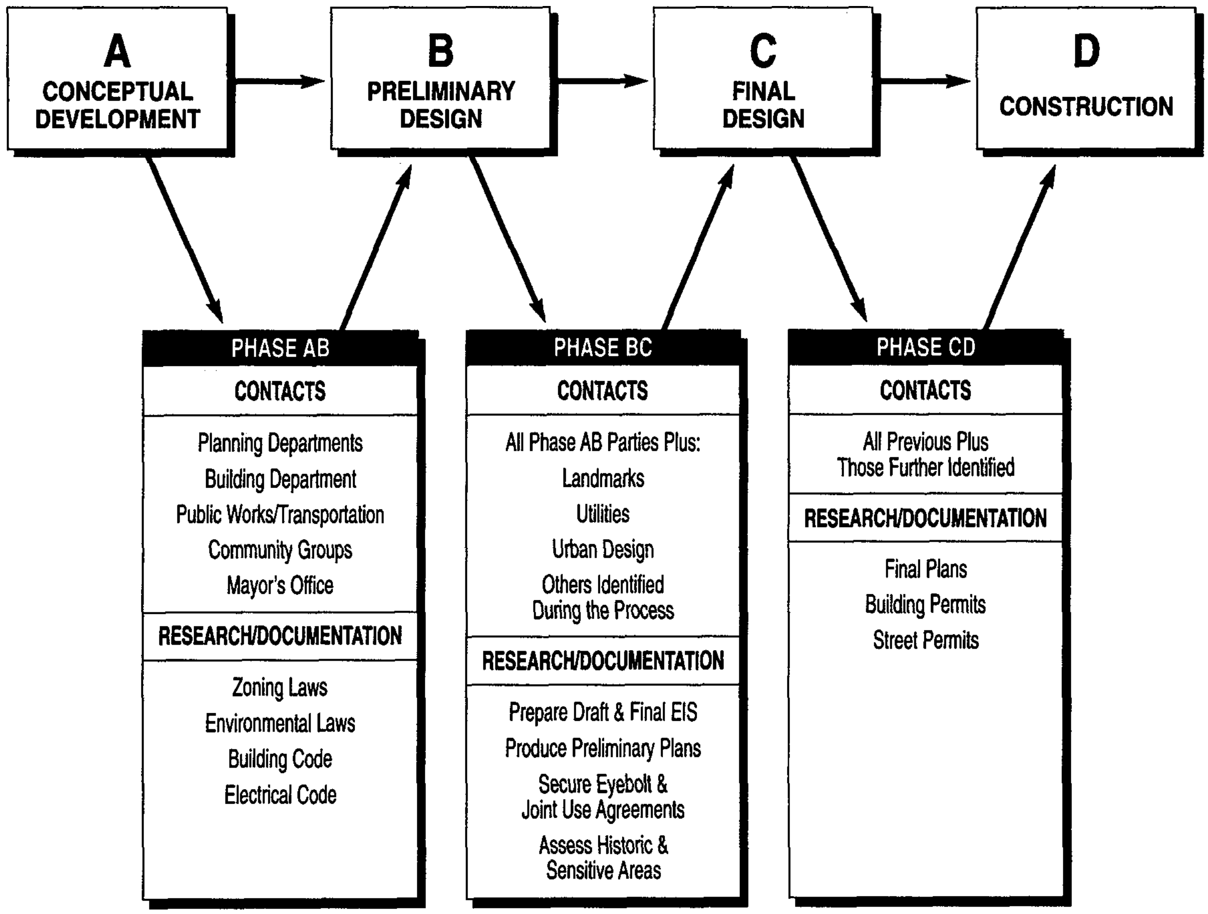


Figure 10-1. Prototypical regulatory process.

CHAPTER **11**

CONCLUSIONS

Designers of the OCS for earlier transport systems were, understandably, not overly concerned with added visual pollution. Unfortunately, some of that insensitivity has been carried over to recent OCS designs. Insufficient attention has been given to the obtrusiveness or visual impact of the contact wires and of the equipment that supports them both electrically and mechanically. Meanwhile, many power and communications lines are now placed underground and are no longer there to act as camouflage. In numerous locations the transit OCS is the only visible wiring. The time has come for designers of LRT and trolleybus systems to become more sensitive to visual pollution and take steps to reduce it.

In conclusion, the following suggestions are offered as a means of achieving the least visually intrusive OCS design:

- Promote a commitment to minimizing visual impact as a major goal of the design process. All personnel should be committed to this goal.
- Use a multidisciplinary approach to OCS design, including both engineers and urban-design professionals; however, be careful not to let any one point of view dominate the design. Include the operations and maintenance people in the design process—they will have to live with the results.
- Reach out to other agencies and community groups early in the process. Keep them informed and seek their advice. Do not introduce a full-blown design for the first time at the public hearing or permit approval stage.
- Learn from other OCS designs. There are many more examples of both intrusive and nonintrusive design than can be covered in this handbook. There is no substitute for seeing a system firsthand.
- Do not overdesign. Remember that less is better when it comes to the visual impact of OCS. Do not include rarely needed redundancy or design for extreme worst-case conditions.
- Be flexible and innovative in the design process. OCS design is not a "one size fits all" exercise. Be sensitive to the specific conditions of the route and learn the route environment in detail.
- Minimize the use of large obtrusive hardware.
- Use buildings, street elements, innovative designs, and landscaping to hide and camouflage OCS.

APPENDIX A

GLOSSARY

Advance turn wire: A pair of trolleybus wires, leading to a diverging route, that runs parallel to the main route wires.

Automatic rewiring: A system for raising and lowering trolley poles that allows trolleybus drivers to perform these functions without leaving their seats.

Auxiliary power unit (APU): A source of power carried by a trolleybus that provides limited speed and range for use in (1) emergencies, (2) infrequent moves, and (3) movement in servicing facilities. The power source may be batteries or a small internal combustion engine.

Backbone: The portion of a pulloff assembly that is roughly parallel to the contact wire. (See Pulloff.)

Catenary: An assembly of overhead wires consisting of, at a minimum, a slack messenger wire supporting vertical hangers that support a taut contact wire in a level profile.

Commutating insulation: Insulation between electrical sections where the current collector is in momentary contact with both sections.

Constant-tension OCS: A means of compensating for variations in wire tension—resulting primarily from temperature—by use of counterweights and sheaves to produce a constant force on the wire.

Counterweight: See Constant-tension OCS.

Crossover: In trolleybus OCS, the hardware assembly used for crossing two pairs of wires. The equivalent component in rail trackwork is called a diamond.

Current control: A trolleybus or street railway switch control system in which switch position is set by the amount of current being drawn by the vehicle as it passes under a contactor in the OCS.

Delta suspension: A type of OCS in which the contact wire is supported from span wires or mast arms by an inverted V-shaped sling.

Dewirement: The accidental loss of contact between a trolley pole and the contact wire, requiring driver intervention to restore power to the vehicle.

Directional control: A trolleybus switch control system in which switch position is set by the lead/lag of the two trolley poles resulting from bus position as the poles pass under a pair of contactors in the OCS.

Direct suspension: A type of OCS in which the contact wire is directly attached to supporting span wires or mast arms.

Dual-mode vehicle: A vehicle capable of operation both as a trolleybus and as a motor bus.

Eyebolt: The component used to connect span wire directly to a building or bridge structural member. A similar component is used for attachments to wood poles.

Feeder: A cable that carries current between a substation and intermediate point or points along a rail or trolleybus route.

Feed riser: The vertical part of a feeder cable system that connects underground and overhead cables.

Feed tap: The wire connecting a feeder cable with the contact wire.

Frog: The fitting used to direct the trolley pole in the appropriate direction at a diverging point in the OCS.

Grand union: In trolleybus or street railway systems, the intersection of 2 two-way routes where all eight possible turn movements are installed. If turns are installed in only two or three of the four quadrants, then the intersection is called a ½ or ¾ grand union.

Headway: The scheduled time between vehicles on a transit route.

Inductive control: A trolleybus switch control system in which switch position is set by a signal transmitted from the bus to an antenna attached to the contact wire.

Joint use: The process of securing agreements among several agencies to combine different uses such as OCS, street lighting, traffic signals, and utility lines onto one set of poles.

Jumper: A piece of wire used to provide an electrical connection between OCS elements.

Light rail: A rail transit system that is not fully grade separated and uses equipment that is smaller than standard railroad equipment. It is usually operated with electrically powered single cars or short trains.

Mast arm: An arm or arm assembly used to support contact wire or catenary from a pole.

Messenger wire: See Catenary.

Nonrevenue wire: Wire in a trolleybus system not used in regular passenger service, including garage access wire, emergency wire, and wire used to turn buses.

Overhead contact system (OCS): A system that delivers electric power from overhead wires to trolleybuses or rail vehicles operating beneath the wires.

Pantograph: A device mounted on the roof of a rail vehicle consisting of spring-loaded hinged arms that press a wide, flat collector shoe against an overhead contact wire.

Pendulum suspension: A form of trolleybus OCS in which the contact wire is supported by parallel arms that are free to move laterally.

Pulloff: Wire or wires connecting support structures with contact wire or catenary that aligns the OCS on curves.

Shoe: The contact surface of a pantograph or trolley pole. It is usually made of a carbon material and is designed to be a readily renewable component, reducing wear on the OCS.

Span wire: Wire used to connect contact wire or catenary to support structures such as poles or eyebolts.

Special work: The hardware used to construct intersections or turns, including switches, crossovers, and curve hardware in trolleybus OCS. In rail trackwork, these assemblies are called turnouts and diamonds.

Streetscape: The on-street environment perceived by pedestrians. This includes buildings, street furniture, roadways, sidewalks, trees, and all related details.

Street furniture: A generic term used to describe streetscape elements such as phone booths, planters, benches, and trees.

Switch: The hardware assembly used to connect diverging or converging pairs of trolleybus wires. The equivalent assembly in rail trackwork is called a turnout.

Trolleybus: A mass transit vehicle that draws power from electrical overhead wires but operates on rubber-tired wheels just as a standard transit bus does.

Trolley pole: A pivoting tubular arm attached to a spring device mounted on the roof of a trolleybus or rail vehicle that presses a grooved contact shoe against an overhead contact wire.

Wire centerline: An imaginary line exactly centered between the positive and negative wires of trolleybus OCSs.

Wye: In trolleybus or street railway systems, a diverging point in a two-way route where all four possible turn movements are installed. If the diverging route is one way, the intersection is called a half wye.

APPENDIX B

LIST OF TROLLEYBUS AND LIGHT RAIL SYSTEMS

Trolleybus Systems

Boston
Dayton
Edmonton
Philadelphia
San Francisco
Seattle (see Note 1)
Vancouver

Historic Streetcar Lines (see Note 4)

Detroit
Memphis
New Orleans
San Francisco
Seattle

Heavy Rail Systems with OCS

Boston
Chicago (see Note 2)
Cleveland

Light Rail Systems

Baltimore
Boston (see Note 3)
Buffalo
Calgary
Cleveland
Dallas (under construction)
Denver
Edmonton
Los Angeles
Newark (see Note 4)
Philadelphia (see Note 3)
Pittsburgh
Portland
Sacramento
St. Louis
San Diego
San Francisco
San Jose
Toronto (see Note 4)

This list includes only public transit systems. It does not include lines operated by private or nonprofit organizations or electrified commuter railroads.

Rail systems use pantographs except as noted.

Note 1: Also operates a separate system with dual-mode buses that use electric power in a downtown subway.

Note 2: Several sections of this system are not fully grade separated.

Note 3: Some routes use trolley-pole current collection.

Note 4: Uses trolley-pole current collection.

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. It evolved in 1974 from the Highway Research Board which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research and recognizes the superior achievements of engineers. Dr. Harold Liebowitz is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Harold Liebowitz are chairman and vice chairman, respectively, of the National Research Council.