CHAPTER 5

SIGNALS

A. GENERAL

When the Southern Pacific Railroad (SP) owned and operated the Caltrain corridor, the signal system had been designed based on the mixed operation of freight and passenger trains. The signal system spacing was based upon single direction running, with braking distances for 80 Ton per Operative Brake (TPOB) freight trains at 60 MPH (miles per hour).

The Santa Clara, College Park, Fourth Street, and San Jose operators' positions were consolidated into a single dispatch center, with Centralized Traffic Control (CTC) from Santa Clara (Control Point or CP Coast) to CP Tamien. San Francisco Control Points, namely Fourth Street, Potrero, Bayshore, and Brisbane were operated as Manual Interlockings under the control of the San Jose Dispatcher with bi-directional automatic block signaling between Fourth Street and Potrero, and single direction running between control points from Potrero southward. After State Department of Transportation (Caltrans) completed the freeway I-280 retrofit, bi-directional CTC was in effect between Fourth Street and Bayshore.

Between 1992 and 1997, signal design was performed by various designers, as a by product of third party contracts on the railroad. There was little consistency between projects, and little overview as to how the projects tied together, and how they would fare with future projects. In 1997, the Caltrain's two signal engineering designers, and the contract operator developed the Caltrain Signal Engineering Design Standards. The new standards have become one of migration.

1.0 SIGNAL SYSTEM MIGRATION

The migration of the Caltrain Signal System was defined as follows:

a. Replacement of Relay Based Systems with Microprocessor based ones: All areas outside the San Francisco and San Jose Terminals completed in 2006.

b. Replacement of telephone leased lines with Advanced Train Control System (ATCS) Radio: ATCS Radio is the primary medium of train control communication with Telco connectivity at 80% of the Control Points completed in 2003.

c. Replacement of dc track circuits and line circuits with Electronic Coded Track circuits: OS (On Station) tracks remain dc and there are some dc track circuits in locations where the coded track is on line circuits completed in 2003.

d. Replacement of system of single direction running ABS (Automatic Block System) with double direction running CTC: Completed in 2003 with the completion of the construction of Caltrain CTX projects.

e. Installation of a Positive Train Control System.

f. Implementation of a signal system that will also function in an electrified environment.

By defining the path of migration, projects today will lay the groundwork for future projects. Since the railroad was originally defined as single direction running, many highway grade crossings were designed for greatly reduced speeds in the reverse direction. In times where one track is removed from service due to construction, or operational difficulties, the service disruption was magnified by the reduced speed required over these crossings.

Once the path of migration was defined as a bidirectional running railroad on both tracks, grade crossings were designed to accommodate the ultimate 79 MPH (miles per hour) operation on both tracks. Non-signaled moves are limited by Federal regulation to 59 MPH. The crossings were designed to allow for 79 MPH operation when the track became signaled in both directions. This approach avoided costly retrofit or replacement when the implementation of the signal migration for the whole corridor took place.

Caltrain has successfully migrated to Centralized Traffic Control (CTC). With the construction of express tracks and a track structure of number 20 (Limited Speed), 14 (Medium Speed) and 10 (Slow Speed) powered turnouts, it became apparent that the Route Signal Aspects would not support the optimal operation. Speed Signaling was placed in service north of CP Coast. Speed Signaling alerts the train operator when the train is approaching a higher speed turnout. Different aspects are displayed for moves through number 20 turnouts, number 14 turnouts, and number 10 turnouts. In a Route Signal System, a train only knows it is to take a diverging route and must approach a control point with different sized turnouts prepared to take the turnout at the lowest speed of any turnout, which can be reached, from that signal.

The original system was one of route signal aspects. After the system was upgraded to bidirectional CTC, the signal system aspects were converted to speed signal aspects north of CP Coast to take advantage of the high speed turnouts installed. Signal system logic was configured during the CTX projects to allow for the initial route signal aspects, and to convert to speed signal aspects with the minimum amount of change and retest.

Control Points have been designed to accommodate the presently funded projects, and as much as possible, facilities were sized to allow for future projects. Currently trains are governed by wayside signals. In the future, there will be some on board enforcement of signal indications. With increased rail traffic, this important safety feature will be necessary. Express train operation may call for trains to operate at greater than 79 MPH. This too will require on board control of locomotives by the signal system. The present system has been designed to allow for the addition of the new equipment.

The Caltrain Board of Directors has mandated future electrification of the Caltrain corridor. Equipment installed today must be sized to allow for the addition of necessary filtering and other equipment required for operation in a high noise traction power environment. Funding guidelines prohibit purchasing equipment for projects other than that funded. However, an intelligent design with a defined path of migration, allows for the future projects to build upon the present projects, and for newly installed equipment to be reused as much as possible.

The migration path has been defined as moving the Caltrain signal system from a single-direction running automatic block between Control Points, to one of bi-directional CTC with express tracks. This has been accomplished. Relay logic is being replaced with programmable solid state microprocessor based logic. Leased telephone lines are being replaced with ATCS radios. The Caltrain signal system uses Electrode 4+ Code Rates to convey aspect and occupancy information. While this is a system manufactured by General Electric Transportation Systems (GETS), the code rate structure is an open architecture and can be emulated by competitive vendors. This equipment can be augmented to operate in an electrified environment, and it can support on board train control equipment.

In addition to the high number of motor vehicles which cross the railroad, there are a large number of pedestrians who cross the Caltrain tracks. The safest crossing for both pedestrians and motorists is one which is at a separate grade, either over or under the tracks. The ideal scenario is to have no at-grade crossings. In the meantime, necessary crossing points for pedestrians are to be treated in the same manner as necessary crossings for motorists. These will have microprocessor based Constant Warning Time systems, and pedestrian gates. When Caltrain is electrified, the Constant Warning Time Devices of today will no longer be a viable option, and will need to be replaced as part of a program in conjunction with the Electrification project. At stations, and on sidewalks where major work is taking place, auxiliary sidewalk gate arms will be added to the roadway gate, and a new gate assembly will be installed in the off quadrant on the sidewalk for pedestrians.

This document incorporates many lessons learned from recent projects, a commitment to the judicious use of public funds by defining the migration path, and recognizing the risk inherent to pedestrians and vehicles crossing the railroad at grade.

B. DESIGN GUIDELINES

The designer shall specify equipment and applications that will not only provide optimum safety, but will maximize the efficiency and reliability of the commuter system. The design shall incorporate systems and equipment that have been proven to be reliable, durable, and effective on other rail networks. The design shall incorporate features that aid signal personnel in the inspection, testing, repair, and overall maintenance of the system. Application logic software shall be "safe" and conform to all applicable regulatory rules and regulations but "simple in form" so as to be easily understood by personnel responsible for the maintenance and care of the system. As much as is practical, within the scope of a project, equipment to be installed shall be scalable for future expansion, and the signal houses shall be sized accordingly.

Where these criteria make reference to system logic and design criteria utilizing vital relays, the same logic shall be applied to solid-state electronic interlocking application programs. All designs shall adhere to the rules and regulations contained in Title 49, Code of Federal Regulations, Parts 234, 235, and 236. Signal design criteria shall incorporate the rules and instructions as contained in the most current issue of the California Public Utilities Commission General Orders, General Code of Operating Rules (GCOR), Caltrain General Orders, Timetable, and Special Instructions, and AREMA Communications and Signals Manual of Recommended Practices. Where the AREMA Manual is used, "may" and "should" are to be interpreted as "shall" unless in conflict with these standards or otherwise directed by Caltrain's Manager Engineering, Signals and Communications. Note that the Caltrain General Orders, Timetable and Special Instructions supersede the General Code of Operating Rules (GCOR) where they are in conflict with GCOR.

Both the wayside signaling system and the crossing warning systems are present on the Caltrain tracks. Any modifications to the wayside signaling must consider any impact to the grade crossing warning systems. Design criteria for the grade crossing warning systems are covered in the **CHAPTER 7 – GRADE CROSSINGS**.

1.0 STANDARDS, CODES, AND GUIDELINES

The latest editions of the following standards, codes and guidelines shall be used, as applicable, for the design and implementation of the Signal system.

a. Federal Railroad Administration (FRA) CFR; Title 49; Parts 234, 235 and 236
b. American Railway Engineering and Maintenance of Way Association (AREMA)
c. California Public Utilities Commission (CPUC)
d. General Code of Operating Rules (GCOR)
e. General Orders
f. Timetable
g. Special Instructions
h. National Electrical Code (NEC)
i. Institute of Electrical and Electronics Engineers (IEEE)
j. American National Standards Institute (ANSI)
k. Electronic Industries Association (EIA)
l. Federal Communications Commission (FCC)

C. SAFE BRAKING CRITERIA

1.0 SIGNAL SPACING

Signal spacing shall consider all factors necessary to provide a safe and efficient operation. The signal block length should be a nominal 4500 feet in length where possible. Such spacing allows passenger trains to operate with optimum headways and utilization of "fourth aspect" (i.e. flashing yellow) signaling provides "safe braking distance" for freight trains. Also, block spacing of this length can easily be incorporated in cab signal systems.

Braking criteria for 100 TPOB (Tons per Operative Brake) freight trains, operating at a maximum speed of 50 MPH, and Passenger Train braking based on Amtrak's Braking Standards (CE-205 Standards) shall be used in calculating safe braking distance. The Caltrain Signal Standard Drawings contain braking and deceleration tables for both types of consist. When manual calculations are used, the "average grade" shall be computed for each block for freight train braking, and Equivalent Level Track distances shall be computed for Passenger trains to ensure safe braking distance is provided. Where short blocks are unavoidable and safe braking distance cannot be achieved by utilizing the flashing yellow aspect, the designer shall repeat the "yellow" aspect to a point where the flashing yellow aspect is applicable.

Computerized train performance programs are acceptable for calculating braking distances.

EXAMPLE:

RED--------YELLOW--------YELLOW---------FL. YELLOW--------GREEN
+------------UNSAFE DISTANCE-------------+
+--------------------------SAFE DISTANCE------------------------------+

The signal system while allowing for freight train braking will also be designed for the greatest possible passenger train efficiency. In some cases, an Approach Medium or an Approach Limited may provide a more efficient operation than Advance Approach. Advance Approach should not be used where the approach block is less than 2500 feet, or where the distance from the advance approach to the stop signal provides stopping distance for less than timetable speed. Care should be exercised when the approach block is short.

With speed signals, the designer must assure that the approach to a limited, medium or slow speed signal provides sufficient stopping distance for both the passenger and freight train to attain the target speed at the point where a speed reduction or Stop is required. In other words, an Approach Limited Signal up to a Limited Clear must provide sufficient braking for the train to be at Limited Speed at the Point of Switch. It is not necessary for the Approach Limited to provide braking distance to the Limited Clear Signal.

2.0 SIGNAL SYSTEM HEADWAYS

The present signal system will generally support headways for local trains of six (6) minutes and for express trains at five (5) minutes. Signal spacing must maintain or improve on these headways. The express train for the purposes of calculating headways makes no stops between San Jose and San Francisco and is followed by another express making no stops running on Green signal aspects. The headway for locals is calculated based on a local train making all stops followed by a second local making all stops running on Flashing Yellow or better. Train Performance, station dwell and signal system response and propagation times are part of the calculations. Refer to "**Systra Signal System Capacity Study**" performed for Caltrain in the **APPENDIX** which explains the methodology.

D. SIGNAL PLACEMENT

Where possible, block signals shall be placed to the right of the track governed, except back-to-back ground signals shall be placed where practical to minimize the construction costs. Left-hand signals shall be placed where track centers do not accommodate right-hand placement. Bridge or cantilever signal structures shall be placed where more than two tracks must be signaled and where right-of-way constraints will not permit placement of ground signals. The use of dwarf signals is restricted to areas where trains operate at slow speeds or where high mast ground signals are not practical. Where practical, signals shall be placed in full view of station platforms so that the aspect displayed can be seen by the locomotive engineer when leaving the station.

Signals shall be placed and aligned to allow optimum viewing by the locomotive engineer. Where possible, signals shall be placed adjacent to tangent track. Where practical, the locomotive engineer shall be provided an unrestricted view of the signal for a minimum of 2,000 feet in approach to the signal. Where conditions require placement in advance of, or within a curve, spread lenses shall be installed on the signal units to maximize the viewing area.

Each signal unit consists of three (3) lamp units. The signal units shall be color-light, stacked type, equipped with removable lamp units for ease of maintenance. Signal housing shall be designed to allow easy removal of lamp units from the rear of the housing. Each lamp unit shall be equipped with a LED assembly as described in AREMA C&S Manual Part 7.5.1. Unused Lamps shall be provided with Blank Cover Plates.

The designer shall make a thorough review of proposed signal locations to ensure signals placed in accordance with Caltrain standards will not be obstructed by vegetation, buildings, highway overpasses, or other structures. Each location shall provide adequate space for each signal, signal house, and other apparatus and be of sufficient size to provide ample walkways. Where signals are located on curves and adjacent tracks are present, signal height should be sufficient to ensure signals can be viewed above standing rail cars. The designer should ensure that upper and lower signal units are visible.

Ground signals shall be approximately 22 feet high measured from the base on the ground to the top of signal top. This height will accommodate the placement of an upper and lower unit. Masts of this length will also provide adequate space for the addition of a lower unit to a single headed signal. Signals are Top Justified.

In general, Absolute Signals at Control Points will have three heads, Approach Signals to Control Points will have two heads, and intermediate signals which do not serve as Approach Signals to Absolute Signals will have one head.

Signal cantilever and signal bridge structures shall be installed with a clearance of 28 feet above top of rail, unless an exception is granted by the Caltrain Deputy Director of Engineering. This placement will accommodate future track elevation increases and electrification.

No portion of a dwarf signal shall be placed closer than six (6) feet from centerline of any track. No portion of the dwarf signal shall be located higher than 34 inches above top of rail. (Note: Although the CPUC regulation allows placement of signal apparatus up to 36 inches above top of rail, the two (2) inches variation should accommodate settling of the track, thus ensuring compliance with the regulation.)

Care shall be taken to ensure signal lenses do not reflect light from adjacent structures creating “phantom aspects”. Signal houses and cases shall be placed at a location where light cannot be reflected from the top or side of the housing. Where such placement cannot be avoided, the top of the housing shall be painted “flat black”. The use of “lens” screens or guards also help reduce such reflections.

Signals shall be placed so that a train leaving a station can see the signal before reaching 40 MPH, so that no "delay in the block" will occur. In some cases it will be desirable to locate a signal at a grade crossing to eliminate additional insulated joints, and economize on equipment.

E. SIGNAL SYSTEMS

Control points shall utilize solid-state interlocking systems configured for use with color-light signal units. Solid-state interlocking systems shall be the GETS Global Signaling Vital Logic Controller, or equivalent systems. Intermediate color-light signals shall utilize electronic coded track circuit systems such as Electrocode 4 Plus or equivalent systems which will emulate the Electrocode 4 Plus rates and communicate through the rail with existing equipment. In order to enhance system response time, transit rates will be used if possible. The utilization of “vital relays” shall be minimized where possible. All signal systems shall be equipped with electronic data recorders that will record information useful in maintenance and repair of the system. Data recorders should be capable of storing a minimum of 72 hours of information.

Electronic coded track circuits shall be utilized wherever practical to transmit and receive vital block signal data. Electrocode 4 Plus code rates shall be used. New application logic software must be approved by the Caltrain Deputy Director of Engineering. The following Code Rates and Aspects in **TABLE 5-1** shall be used.

TABLE 5-1 CODE RATE AND ASPECT

CODE RATE	ASPECT
7	Clear
4	Advance Approach
3	Approach Limited
8	Approach Medium
2	Approach
9	Approach Slow
6	Accelerated Tumble Down
5	Non-Vital code indicating track occupancy, or a hand-throw switch in the block out of normal correspondence
M	Non-Vital code indicating power off in the block, or a lamp out condition in the block. Power Off will indicate from the east end CP, lamp out from the west end CP

"Light out" application logic shall incorporate aspect downgrades that minimize train delay. Under normal conditions the upper and lower units of two and three unit signals shall be illuminated. The principle can be summarized as follows: a Top Green will downgrade to a Flashing Yellow, all other Lamp Outs will downgrade to a Restricting Aspect unless the Dark Aspect does not affect safety. The principle is that the lamp out condition will be acted upon more quickly when a Restricting Aspect is displayed. When elaborate lampout downgrade schemes are used, signals may not be reported until there are multiple lamps out.

The following typical downgrade logic shall be incorporated: Lampout schemes should be shown on the circuit plans for each location. Refer to the following **TABLE 5-2** through **TABLE 5-7**.

TABLE 5-2 ONE UNIT SIGNAL
ONE LAMP OUT

GREEN lamp out	**FLASHING YELLOW**
FLASHING YELLOW lamp out	**FLASHING RED**
YELLOW lamp out	**FLASHING RED**
RED lamp out	**DARK**

TABLE 5-3 TWO UNIT SIGNAL
TOP UNIT LAMP OUT

GREEN over **RED**	**FLASHING YELLOW** over **RED**
YELLOW over **FLASHING GREEN** (for a Number Plated Signal)	**DARK** over **YELLOW**
YELLOW over **FLASHING GREEN** (for an Absolute Signal)	**FLASHING RED** over **RED**
YELLOW over **GREEN** (for a Number Plated Signal)	**DARK** over **YELLOW**
YELLOW over **GREEN** (for an Absolute Signal)	**FLASHING RED** over **RED**
YELLOW over **YELLOW** (for a Number Plated Signal)	**DARK** over **YELLOW**
YELLOW over **YELLOW** (for an Absolute Signal)	**FLASHING RED** over **RED**
FLASHING YELLOW over **RED**	**FLASHING RED** over **RED**
YELLOW over **RED**	**FLASHING RED** over **RED**
FLASHING RED over **RED**	**DARK** over **FLASHING RED**
RED over **GREEN**	**DARK** over **FLASHING RED**
RED over **FLASHING YELLOW**	**DARK** over **FLASHING RED**
RED over **YELLOW**	**DARK** over **FLASHING RED**
RED over **FLASHING RED**	**DARK** over **FLASHING RED**
RED over **RED**	**DARK** over **RED**

TABLE 5-4 TWO UNIT SIGNAL
BOTTOM UNIT LAMP OUT

GREEN over **RED**	**GREEN** over **DARK**
YELLOW over **FLASHING GREEN**	**YELLOW** over **RED**
YELLOW over **GREEN**	**YELLOW** over **RED**
YELLOW over **YELLOW**	**YELLOW** over **RED**
FLASHING YELLOW over **RED**	**FLASHING YELLOW** over **DARK**
YELLOW over **RED**	**YELLOW** over **DARK**
FLASHING RED over **RED**	**FLASHING RED** over **DARK**
RED over **GREEN**	**RED** over **FLASHING RED**
RED over **FLASHING YELLOW**	**RED** over **FLASHING RED**
RED over **YELLOW**	**RED** over **FLASHING RED**
RED over **FLASHING RED**	**FLASHING RED** over **DARK**
RED over **RED**	**RED** over **DARK**

TABLE 5- 5 THREE UNIT SIGNAL TOP UNIT LAMP OUT

GREEN over **RED** over **RED**	**FLASHING YELLOW** over **RED** over **RED**
YELLOW over **FLASHING GREEN** over **RED**	**FLASHING RED** over **RED** over **RED**
YELLOW over **GREEN** over **RED**	**FLASHING RED** over **RED** over **RED**
YELLOW over **YELLOW** over **RED**	**FLASHING RED** over **RED** over **RED**
FLASHING YELLOW over **RED** over **RED**	**FLASHING RED** over **RED** over **RED**
YELLOW over **RED** over **RED**	**FLASHING RED** over **RED** over **RED**
FLASHING RED over **RED** over **RED**	**DARK** over **FLASHING RED** over **RED**
RED over **FLASHING GREEN** over **RED**	**DARK** over **FLASHING RED** over **RED**
RED over **GREEN** over **RED**	**DARK** over **FLASHING RED** over **RED**
RED over **FLASHING YELLOW** over **RED**	**DARK** over **FLASHING RED** over **RED**
RED over **YELLOW** over **GREEN**	**DARK** over **FLASHING RED** over **RED**
RED over **YELLOW** over **YELLOW**	**DARK** over **FLASHING RED** over **RED**
RED over **YELLOW** over **RED**	**DARK** over **FLASHING RED** over **RED**
RED over **FLASHING RED** over **RED**	**DARK** over **FLASHING RED** over **RED**
RED over **RED** over **RED**	**DARK** over **RED** over **RED**

TABLE 5-6 THREE UNIT SIGNAL SECOND UNIT LAMP OUT

GREEN over **RED** over **RED**	**GREEN** over **DARK** over **RED**
YELLOW over **FLASHING GREEN** over **RED**	**YELLOW** over **RED** over **RED**
YELLOW over **GREEN** over **RED**	**YELLOW** over **RED** over **RED**
YELLOW over **YELLOW** over **RED**	**YELLOW** over **RED** over **RED**
FLASHING YELLOW over **RED** over **RED**	**FLASHING YELLOW** over **DARK** over **RED**
YELLOW over **RED** over **RED**	**YELLOW** over **DARK** over **RED**
FLASHING RED over **RED** over **RED**	**FLASHING RED** over **DARK** over **RED**
RED over **FLASHING GREEN** over **RED**	**RED** over **FLASHING RED** over **RED**
RED over **GREEN** over **RED**	**RED** over **FLASHING RED** over **RED**
RED over **FLASHING YELLOW** over **RED**	**RED** over **FLASHING RED** over **RED**
RED over **YELLOW** over **GREEN**	**RED** over **FLASHING RED** over **RED**
RED over **YELLOW** over **YELLOW**	**RED** over **FLASHING RED** over **RED**
RED over **YELLOW** over **RED**	**RED** over **FLASHING RED** over **RED**
RED over **RED** over **GREEN**	**FLASHING RED** over **DARK** over **RED**
RED over **RED** over **FLASHING YELLOW**	**FLASHING RED** over **DARK** over **RED**
RED over **RED** over **YELLOW**	**FLASHING RED** over **DARK** over **RED**
RED over **FLASHING RED** over **RED**	**FLASHING RED** over **DARK** over **RED**
RED over **RED** over **RED**	**RED** over **DARK** over **RED**

**TABLE 5-7 THREE UNIT SIGNAL
THIRD UNIT LAMP OUT**

GREEN over **RED** over **RED**	**GREEN** over **RED** over **DARK**
YELLOW over **FLASHING GREEN** over **RED**	**YELLOW** over **FLASHING GREEN** over **DARK**
YELLOW over **GREEN** over **RED**	**YELLOW** over **GREEN** over **DARK**
YELLOW over **YELLOW** over **RED**	**YELLOW** over **YELLOW** over **DARK**
FLASHING YELLOW over **RED** over **RED**	**FLASHING YELLOW** over **RED** over **DARK**
YELLOW over **RED** over **RED**	**YELLOW** over **RED** over **DARK**
FLASHING RED over **RED** over **RED**	**FLASHING RED** over **RED** over **DARK**
RED over **FLASHING GREEN** over **RED**	**RED** over **FLASHING GREEN** over **DARK**
RED over **GREEN** over **RED**	**RED** over **GREEN** over **DARK**
RED over **FLASHING YELLOW** over **RED**	**RED** over **FLASHING YELLOW** over **DARK**
RED over **YELLOW** over **GREEN**	**RED** over **YELLOW** over **RED**
RED over **YELLOW** over **YELLOW**	**RED** over **YELLOW** over **RED**
RED over **YELLOW** over **RED**	**RED** over **YELLOW** over **DARK**
RED over **RED** over **GREEN**	**RED** over **RED** over **FLASHING RED**
RED over **RED** over **FLASHING YELLOW**	**RED** over **RED** over **FLASHING RED**
RED over **RED** over **YELLOW**	**RED** over **RED** over **FLASHING RED**
RED over **FLASHING RED** over **RED**	**RED** over **FLASHING RED** over **DARK**
RED over **RED** over **RED**	**RED** over **DARK** over **RED**

The applicable code transmitted from signals displaying the lamp out condition indicated above shall also downgrade. Application logic shall be configured to provide “approach lighting” of signals. Approach lighting may be accomplished by lighting the signal upon loss of a vital code on the approach to the signal, in the same fashion Approach Locking is accomplished. Controlled signals shall light on approach, when a “signal control” bit is received from control station, and when a test clip or switch is “closed” (i.e. lamp test). Where multiple track operations are present, all signals on adjacent tracks governing movements in the same direction shall be illuminated where practical. Where a signal on one track is dark, the signal on the adjacent track(s) will be put to stop or Restricting, and approaches downgraded. Special lighting circuits should be incorporated to illuminate a signal displaying a STOP aspect where an approach lighting circuit is effective less than 2,500 feet in advance of the signal.

Although each design will provide for utilizing “approach lighting” Caltrain Operations will make the final determination if the feature will be applied. The designer shall evaluate each location to determine if special circuits should be applied to ensure aspects can be readily observed and acted upon by the train engineer.

F. APPLICATION LOGIC

Application logic software shall conform to all regulatory requirements. Applicable Route Locking, Indication Locking, Time Locking, and Approach Locking shall be used. Route Locking shall be released utilizing the first two consecutive track circuits. Sectional releasing shall be used wherever possible. New Installations will use Approach Locking. Separate Timers will be used on each signal in a pair where Microprocessor systems are used. Program nomenclature is to follow Caltrain naming conventions. Program Logic is to follow the Typical Caltrain Program Logic. Any relay installations are to follow the same principles of application logic as microprocessor based systems

Companies providing Application Logic Programs must have a documented process of checking, computer simulating and rack testing all programs. All programs, upon being placed in service are to be stored on a secure web site as directed by Caltrain's Manager Engineering Signals and Communications.

Application logic shall follow the following sequence of activities for clearing a signal.

a. Request the signal and switch (Composite Delivery will be used)

b. Check the Route – Switches in position, opposing signals at stop and not in time, good codes received, detector tracks up, and any other applicable conditions.

c. Apply the Locking (Lock terms go false)

d. Tumble down to the adjoining Control Point

e. Upon verification of locking (Lock terms false, Switch Motor Control Relays de-energized) Clear the Signal

f. Upon confirmation of signal aspects, upgrade the codes to the Approach Signal to display the proper signal aspect.

With no signals cleared, vital codes are transmitted in both directions on each track, as in a four wire HD model. There will be a tumble down timer in the non-standard direction of travel, that is south on Main Track 1 (MT-1), North on MT-2.

Where Sectional Releasing is used, the switch will be allowed to change position as soon as the locking is released and applicable Loss of Shunt time runs. If a new route can be created which is protected from fouling by switch position, then a signal can be cleared even though the first train is still in the CP.

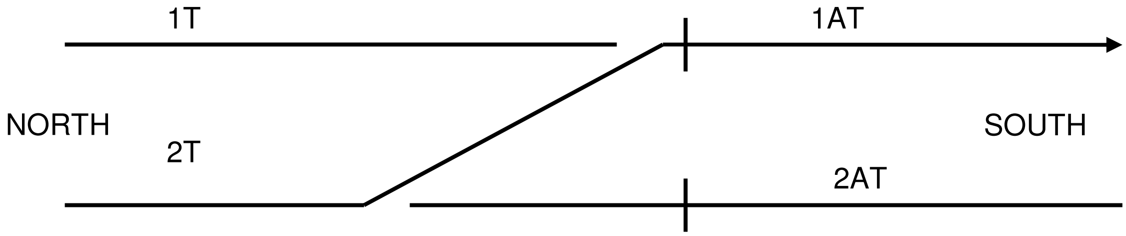

FIGURE 5-1 INTERLOCKING RELEASE (SWITCH LOCKING RELEASED)

When the southbound train has crossed over and is occupying 1AT, as shown in **FIGURE 5-1**, the locking will be released as soon as 1T completes Loss of Shunt Time. At this moment, the crossover can be returned to the normal position, and a new route can be created as shown in **FIGURE 5-2**. Signals can be cleared on track two in either direction while the first train occupies the 1AT.

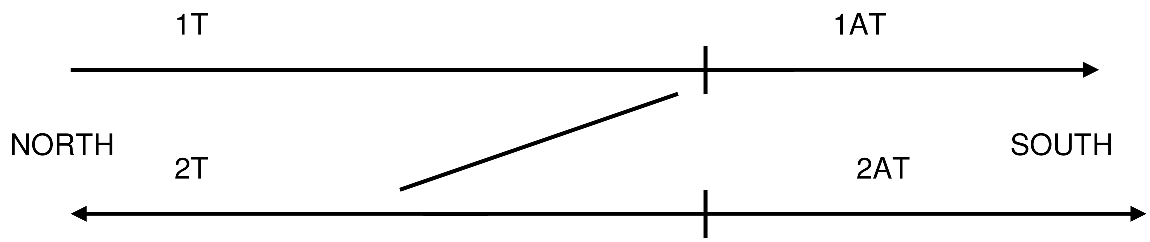

FIGURE 5-2 INTERLOCKING RELEASE (NEW ROUTE CREATED)

In **FIGURE 5-2** above, if the southbound train was occupying the 2AT, the locking on the switch would release, and the switch could be reversed as shown in **FIGURE 5-1**, however a new route would not be allowed since the train in the 2AT could roll back and foul the 2T.

G. SWITCH MACHINE

110 Vdc Switch machines are to be used. Backup Battery shall be provided by a separate 110 Vdc supply as manufactured by C-Can or National Railway Supply Model ERB-C Overload Timers in the Vital Program will be used. The M23A is the preferred switch machine since the points are locked in hand operation. South of CP Bowers only M23A machines should be installed. North of CP Bowers, in existing plants with Alstom Model 5F machines, Model 5F machines should be installed.

If In-Tie Switch Machines are installed, they should be of a type that locks the points when in hand operation.

Turnouts #20 and greater require Push - Pull Helper Rod Assemblies. Where clearance is a concern, the Rotary Helper Assembly is acceptable.

Relays named NWR (Normal Switch Control Relay) and RWR (Reverse Switch Control Relay) will be used for Switch Control. The last called for relay will be held in the energized position until such time as locking is applied. The switch contact will be back-checked in the microprocessor program.

H. REQUISITES FOR CTC

The following is the requisites for the CTC.

a. "Approach or Time Locking" shall be applied to all approaches. Approach Locking is preferred but Time Locking may be used where directed.

b. "Indication Locking" is required in connection with all electrically locked switches, movable-point frogs, or power derails at control points and inter-lockings.

c. "Route Locking" is required. Sectional route locking (Sectional Release) shall be used to facilitate the movement of trains.

d. Detector Loss of Shunt time is to be five (5) Seconds in terminal areas and lower speed areas. It will be considered at Control Points in higher speed territories, however the designer must carefully evaluate the time of OS occupancy of short fast trains in conjunction with the timing parameters of the Wayside signal system, communications system, control office processing and system loading, to ensure there is no degradation to train tracking in the Control Office. The 10 second Detector Loss of Shunt time should be used where train tracking is a concern, or potential loss of shunt is possible due to rail conditions.

I. TIME AND APPROACH LOCKING

Time Locking is provided in connection with existing signals. Approach locking is to be provided in connection with signals on routes where greater facility is required than is possible with Time Locking.

Time Locking is used to ensure that after a signal has been cleared, a conflicting or opposing signal cannot be cleared or the position of a switch or derail in the established route cannot be changed until expiration of a predetermined time interval after the signal has been placed at STOP, except when the locking is released by occupancy of two successive tracks in advance of the signal.

Approach Locking provides that the time locking will not be effective if the track is unoccupied from a point at least 1500 feet in approach to the approach signal to the controlled signal, or, in four-aspect signal territory, from a point at least 1500 feet in approach of the first normally restrictive signal approaching the control signal. In most cases, checking that the same direction controlled signal at the Control point in the rear is at Stop and not in time, and no intervening track circuits are occupied satisfies the requirement for Approach Locking.

EXAMPLES:

!----------(adequate braking distance)--------!-------------1500'---------------!
RED---YELLOW-----------------------------GREEN
!---------------------------(Approach Locking limits)-------------------------------!

!--------------(adequate braking distance)-----------!----------1500'------------!
RED-----------------YELLOW--------------FLASHING YELLOW-------------GREEN
!-----------------------------(Approach Locking limits)----------------- ------------!

Time or approach locking should be released by a train occupying two consecutive track circuits beyond the control signal. On low-speed routes, where a second track circuit is not available, one track circuit may be used to release time and/or approach locking; however, two-track circuit releasing is preferred. It should also be released by a time element relay, or electronic timer, with automatic control.

Signal control circuits shall be so arranged that they cannot display proceed when the timing device is not normal.

Where the back contact of a detector section track relay, or track relay repeater, is used to release approach, or time locking, the control circuit for either the electric locking of the interlocked switches, or the control circuits for the interlocked signals, must be cut through the front contacts of the same relay whose back contact is used for releasing, or a repeater of that relay. Preferably, the control circuits for both the electric locking of the interlocked switches and the interlocked signals should be through front contacts of the same relay whose back contact is used for releasing, or a repeater of that relay.

J. INDICATION LOCKING

Indication locking shall be provided in connection with all interlocking signals. Approach signals of the light-type, controlled by independent two-wire circuits or by electronic track circuits, need not be checked in the interlocking signal indication circuits. Indication locking does not apply to colorlight signals. The principle of Indication Locking applies to mechanical devices such as searchlight signals and power switch machines.

K. ROUTE LOCKING

Route locking shall be provided in connection with all mechanical, or power switches. It maintains the switch locking in front of the train after the signal has been passed, and the train is still in the route. It must be accomplished by a system of track circuits extending throughout the interlocking which control normal and reverse locks switches, derails, and movable point frogs.

Where there is more than one track circuit, a more complicated scheme of route locking may be necessary. In some cases, where there are a number of track sections in a route, it will be found convenient to use route locking relays to secure continuous switch protection throughout the route.

On interlocking plants where traffic is so heavy that maximum facility is needed, a system of sectional route locking shall be installed to provide for the release of switches behind a train as soon as the rear end of a train has reached a point sufficiently beyond clearance to ensure safety from conflicting moves. Sectional route locking will be used in new design to facilitate train operations.

When parallel routes are proposed, there must be sufficient distance between the points of switch on the common track so that neither train will foul the route of the other. In general, this is 100 ft from Point of Switch to Point of Switch, and minimum 13 foot track centers through the parallel portion of the route. Design of signaling for a parallel route must be closely coordinated with the track design

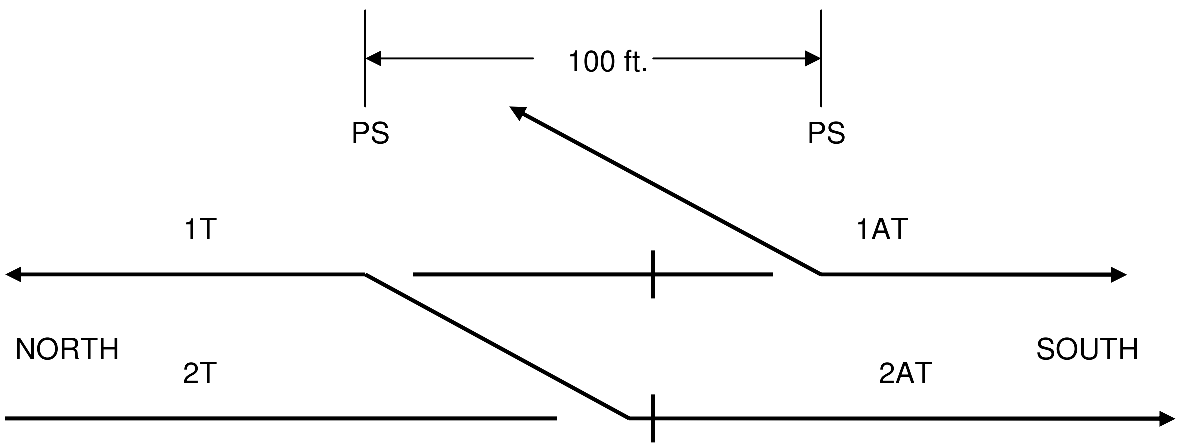

FIGURE 5-3 PARALLEL ROUTES

L. POWER SYSTEMS FOR OTHER THAN VEHICULAR CROSSING LOCATIONS

Power to each location shall be provided from a commercial power system. Each location shall be evaluated and the appropriate service connection provided. At a minimum, a 120/240 Vac single phase 100-Amp service shall be provided at new locations. Where power is not readily available, an express cable shall be installed to the nearest power source. The size of the express cable conductor required shall be determined by utilizing National Electrical Code Standards. Each Control Point shall have an external plug connection for a generator to provide power to the house in the event of an extended outage

Standby battery shall be provided at all locations. Battery chargers shall be of the programmable type equipped with temperature monitoring sensors. All storage cells shall be Ni Cad (Nickel-Cadmium). Batteries shall be of sufficient capacity to provide

48 hours of standby time under "normal operating conditions". "Normal operating conditions" is defined as "the signal system operating with all signals normally dark and power switches at rest and properly lined". Battery capacity for highway crossings shall be as specified in the **CHAPTER 7 – GRADE CROSSINGS**.

M. SIGNAL BLOCKS

Electrocode codes will be transmitted simultaneously in both directions throughout signal blocks. "Turn of Traffic" signaling shall not be used. Tumbledown will take place after a signal has been requested into a block with vital codes being received. A timer should be installed allowing four (4) seconds per block for the signal being cleared into the Non-Standard direction of traffic.

As soon as the lead train enters the OS track, a Code 2 will be sent into the block so the Approach Signal displays Yellow up to the Red Absolute. At an intermediate signal, once the approach track is occupied, a Code 2 will be transmitted into the axle of the approaching train. This will prevent the potential "flash of green" behind the lead train.

Code 6 is used to accelerate the tumbledown. Code 6 will be used when a signal is cleared into a block. When a train is flagging past a signal, or a switch point pumps, vital codes will be removed, but Code 6 will not be transmitted. This is to prevent unintentional accelerated tumbledown. Code 6 will also be used as a Stick-Breaker at intermediate signals.

When a train is to enter a signal block between Control Points over a hand operated switch, a comeout signal is preferred over an Electric Lock. In the case of a comeout signal or an Electric Lock, a short tumbledown timer shall run and Code 6 shall be transmitted in both directions, then if vital codes are received in both directions, the Lock will release, and in the case of a comeout signal, after the hand operated switch is full reverse, the signal will clear.

N. THE AVERAGE GRADE

The following procedure or steps should be followed for calculating the average grade of the block.

a. Using the engineer's scale measure the distance between all grade change points in the block. The sum of the distances is equal to the total block length.

b. Multiply each distance recorded by the grade indicated between each point. This is known as the "Distance Grade" (DG).

c. Sum the "distance grades" and divide by the total block distance. This is the Average Grade (AG) of the block.

$$AG = \frac{DG + DG + DG + DG + \ldots}{\text{TOTAL BLOCK LENGTH}}$$

For Freight train braking, 6,000 feet in approach of the block must be used in averaging, unless the 6000 foot approach grade is positive, in which case it shall not be factored..

For passenger train braking calculations, 1000 feet in approach of the block must be used in averaging, unless the 1000 foot approach grade is positive, in which case it shall not be factored. Braking distance may be calculated either by using the average grade and using the charts, or converting the distance of the block to the equivalent distance of level track. Equivalent Distance may be calculated for ascending grades by the following:

$$\frac{(\text{Actual Distance}) \times (6 + G)}{6}$$

For descending grades it is :

$$\frac{(\text{Actual Distance}) \times (4 - G)}{4}$$

G is the average grade of the block being equated, plus the approach specified above. The Amtrak's Braking Curve CE-205 with a 25% safety factor, and eight (8) seconds free running will be used for the F40PH trains in use on the corridor.

A commercially available train performance simulation program for calculating safe braking may be used. Any such program must be accepted for use on at least two (2) Class 1 Railroads or Passenger Railroads subject to FRA regulation.

O. QUALIFICATIONS OF DESIGNERS AND CHECKERS

Signal designers who perform signal design or programs for Caltrain must be approved by the Caltrain Deputy Director of Engineering. Similarly, signal checkers who perform review of Caltrain signal circuitry design or programs must be approved by the Caltrain Deputy Director of Engineering.

1.0 SIGNAL DESIGNERS

The classification Signal Designer is generic and refers to the responsible individual who produces signal circuitry design or programs. A company or third party agency may classify this position as a Signal Engineer or other title. In general, a signal designer should have a minimum of five (5) years experience designing for a Class 1 or Commuter Railroad which operates under Sections 234, 235, and 236 of the FRA regulations.

The experience requirements for signal designers also apply to programmers of Vital logic programs.

Designers may be called upon to demonstrate their familiarity with applicable regulations, both state and Federal, and their familiarity with traditional relay logic, ladder logic, and Boolean Equations. Principles of railroad signaling, including automatic block signals, centralized traffic control, and interlocking must be demonstrated to the satisfaction of the Caltrain Deputy Director of Engineering. An understanding of train operations and the interaction with the signal system is required, as well as the ability to analyze braking distances, and calculate locking release times. In addition to this, knowledge of Highway Grade Crossing Warning systems must be demonstrated.

At the discretion of the Caltrain Deputy Director of Engineering, the designers may be interviewed. The interview may require a demonstration of circuit and program analysis.

2.0 SIGNAL CHECKERS

In general, a signal checker should have a minimum of five (5) years experience designing for a Class 1 or Commuter Railroad which operates under Sections 234, 235, and 236 of the FRA regulations, and an additional five (5) years of experience checking signal designs and vital signal programs.

Signal checkers may be called upon to demonstrate their familiarity with applicable regulations, both state and Federal, and their familiarity with traditional relay logic, ladder logic, and Boolean Equations. Principles of railroad signaling, including automatic block signals, centralized traffic control, and interlocking must be demonstrated to the satisfaction of the Caltrain Deputy Director of Engineering. An understanding of train operations and the interaction with the signal system is required, as well as the ability to analyze braking distances, and calculate locking release times. In addition to this, knowledge of Highway Grade Crossing Warning systems must be demonstrated.

The signal checker may be interviewed, at the discretion of the Caltrain Deputy Director of Engineering. The interview may require a demonstration of circuitry design and program analysis.

P. FINAL CHECK INSTRUCTIONS

In an effort to ensure the quality and integrity of the Caltrain signal and highway grade crossing warning system design, all designs shall receive a “final check”. The final check shall ensure that all designs meet the minimum requirements of the Code of Federal Regulations Title 49, Parts 234, 235, and 236. Designs shall also conform to Caltrain Communications and Signal Design Standards and applicable federal, state, and local regulations. All design applications shall adhere to the manufacturer’s minimum recommendations.

Signal designs shall be completed by a signal design firm authorized by Caltrain to provide such services. Upon completion of the design, two (2) complete drawing sets shall be distributed to an outside firm authorized by Caltrain to perform “final checks”. Included with the drawing sets shall be any pertinent information that may aid the final checker in performing this work. Pertinent information shall include field surveys, service contracts, CPUC application documents, project correspondence, calculations, etc. Pertinent information shall include circuit design drawings of adjoining locations sufficient to check all circuits and controls in the affected case to both point of origination and termination.

The “final checker” shall review the drawings for adherence to the Caltrain standards, field survey requirements, service contracts agreements, CPUC application drawings, and circuit integrity. On one (1) drawing set the final checker shall indicate any corrections that are needed. Once completed the “marked-up” drawing set shall be returned to the originating design firm for correction. Upon completing the revision, a corrected or revised copy shall be sent to the final checker for approval. Once approved, the design firm shall place the final checker’s initials in the appropriate field in the “JBNOTE” cell and distribute the drawings for construction.

In instances where construction must immediately begin and sufficient time is not available to complete the final check procedure prior to distribution, the drawings shall be clearly marked **PRELIMINARY** and the checker’s field in the JBNOTE cell shall be left blank. At the time of this preliminary distribution, two (2) drawing sets shall be sent to a final checker. **Prior to placing the modifications in operation a final check shall be completed.** Once the final check of the preliminary drawing set is completed and corrections have been made, a final drawing set shall be distributed. Prior to distribution a new date shall be entered in the date field of the JBNOTE. The original date shall be displayed “yellowed out”. The transmittal letter shall reference the new drawing date and a statement will be incorporated instructing construction forces to destroy the preliminary plan set in lieu of the final drawing set.

In an emergency situation, and only in such situations, modifications to the signal system may be made by field forces with concurrence of the Caltrain Deputy Director of Engineering. In such instances, the modifications shall be clearly marked on a drawing set and the modified drawing set delivered to a final checker as soon as possible. All field modifications shall be thoroughly tested to ensure the integrity of the system.

Q. FILE MANAGEMENT

Part 236 Section 1 and Part 234 Section 201 of CFR 49 require that up to date and accurate signal drawings are kept at each location. Part 236 Section 18 requires a Software Management Control Plan for Vital Signal Application programs

Signal Drawings and Signal Programs are living documents that must be properly maintained to ensure the integrity of the signal system. Duplicate file copies increases the possibility of misleading or inaccurate drawings and programs being distributed to construction or maintenance forces. Files shall not be duplicated without the authority of the Caltrain Deputy Director of Engineering.

In order to maintain control of Caltrain Signal Drawings and Programs and be compliant with Federal Regulations, the following checkout procedure shall be followed by all Signal Design Firms.

A general description of the project(s) shall be submitted to the Caltrain Deputy Director of Engineering along with specific milepost limits. The designer should first request paper or PDF files of any locations within the project limits. Only files which the designer will need to modify for the project will be checked out to the design firm.

Upon completion of the design or program, the designer shall return the CADD files, application program files and an 11 x 17 hard copy of each drawing and 8 1/2 x 11 copy of the program to the Caltrain Deputy Director of Engineering. The designer shall include an itemized list of the files returned. The list shall categorize files by NEW FILES, MODIFIED FILES, and DELETED FILES.

If the designer is required to furnish AS-BUILT files, the designer shall provide the Caltrain Deputy Director of Engineering with CADD files of drawings that are distributed for construction and then provide corrected CADD files upon completion of the project. Program files will be furnished after the location is placed in service.

R. SUPERVISORY CONTROL SYSTEM AND OFFICE TO FIELD COMMUNICATIONS

When a project requires the addition of a new control point(s), it is the responsibility of the designer to determine whether the additional control point(s) will require the addition of new codelines or additional regions to the Supervisory Control Office.

Empirical evidence suggests that no more than 12 control points should be on a radio codeline. Composite delivery may be used and stop bits are used in the message structure. The office sends only the bit which has changed.

The designer should make an analysis of the impact of increased radio traffic and office system capacity as a part of the 35% design submittal. This will allow Caltrain to make any necessary arrangements for capacity improvements.

S. SIGNAL AND TRAIN CONTROL SYSTEM MIGRATION

The migration path has been defined as moving the Caltrain signal and train control system from bi-directional CTC to a system of PTC. The base safety system of wayside signals is in place. The Caltrain signal system uses Electrode 4 Plus Code Rates. While this is a system manufactured by GETS, the code rate structure is an open architecture and can be emulated by competitive vendors. The microprocessors at Control Points in most cases are the GETS VHLC’s. This equipment is able to communicate from controller to controller and from controller to radio.

1.0 MIGRATION FORM CTC TO PTC

The type of PTC system being implemented is an overlay system. This system builds on the underlying safety critical signal system to first enforce compliance with signal aspects, then to provide a greater level of on track safety for roadway workers and high rail equipment. The PTC system will rely on radio communication of wayside signal information to the locomotive, and a separate path of train to office communications for civil enforcements, mandatory directives, and track occupancy permission. The new dispatch system must be able to communicate with the PTC office system at the CEMOF Dispatch Center.

It is important to understand that communications must be established with other operators on the Caltrain corridor, namely Amtrak trains, UPRR trains, ACE trains, and Capitol Corridor trains. The system must be interoperable to be truly effective, however it is possible to initially install equipment on Caltrain trains and in Caltrain wayside locations. Wayside interfaces on Caltrain shall use “vital” signal equipment.

Since PTC is still under development and interoperability is a critical component, the following strategy of implementation should be regarded as a guideline to incremental implementation of PTC.

a. Provide enforcement of wayside signals.

b. Provide train to office communications for enforcement of track restrictions, mandatory directives and track occupancy by roadway workers and on track equipment including hi-rails.

c. Apply enhancements to train handling, schedule adherence, real time train performance information and other desired features.

d. Provide enhancements to grade crossing activation such as advanced activation for higher speed trains and crossing inhibits for near side station stops.

T. SIGNAL DESIGN STAGES

The design cycle is an iterative process which may involve Railroad Operations, Finance, Contracts, and the other Railroad Engineering Disciplines:

1.0 CONCEPTUAL DESIGN LEVEL

The conceptual design level document may be produced by Caltrain or by the Signal Engineering design firm on behalf of Caltrain. It is a very basic document intending to capture the rationale for the project. It may consist of the following:

a. A conceptual overview. This is a single line drawing identifying track configuration, signals and switches.

b. A conceptual overview of any alternate configurations, if any.

c. A rough Order of Magnitude Budget estimate.

2.0 35% DESIGN LEVEL

The 35% design level submittal builds on the 5% design level. This document is suitable for review by all of the stakeholders. Upon completion of the 35% design level submittal and of Caltrain acceptance, the track configuration should be locked in. At this time Operations may decide whether an additional crossover or turnout is required. The document generally consists of the following:

a. A preliminary scaled layout of the preferred alternative.

b. Preliminary aspect charts.

c. A Design Basis Report, when required describing the reason for the project and operational benefits. A discussion of alternatives may be necessary.

d. A preliminary Order of Magnitude Estimate.

e. The preliminary materials list containing long lead time items may be required at this time, particularly with a grade crossing project where an agreement is required with the public agency.

3.0 65% DESIGN LEVEL

The 65% design level submittal is the evolving work in progress. It is essentially the final design that is not yet fully detailed. It should consist of the following.

a. Final scaled layouts and aspect charts.

b. Preliminary materials list (long lead time items accurately depicted). It may include the final design for prewired signal houses. At this time, if deemed appropriate, a procurement package for the long lead items should proceed.

c. Signal drawings that have signal house layouts and most equipment shown. The circuitry design is still in progress, but detailing is not complete.

d. Preliminary Engineer's Estimate. This estimate is developed to the same level of detail that of the design.

e. The technical specifications.

4.0 95% DESIGN LEVEL

The 95% design level submittal should be the last review opportunity in the design cycle. It should consist of all of the following.

a. The final plans are transmitted to checking firm for review.

b. The final materials list.

c. The final Engineers Estimate.

d. The final technical specifications.

5.0 FINAL DESIGN

The final design submittal is the “Issued for Construction” or Issued for Bid” package. The design is complete, and the construction package is ready for distribution. The package consists of the following.

a. Final design for distribution. It incorporates any changes to the 95% document which may come out of the final check.

b. The IFB package includes Plans, Specifications and Engineering Estimate if it is a Contract for third party work.

c. Software will be furnished for outside check after construction has begun, after the Issued for Construction drawings, and after or during initial construction.

The design stages above are guidelines for the design cycle on Caltrain Signal projects. Caltrain may choose to combine stages, or introduce additional review cycles. For instance if there are significant changes during the 35% review cycle, Caltrain may require a 40% iteration which reflects those changes. On a rehabilitation project, Caltrain may elect to go directly to the 95% design.

END OF CHAPTER