Signal Timing

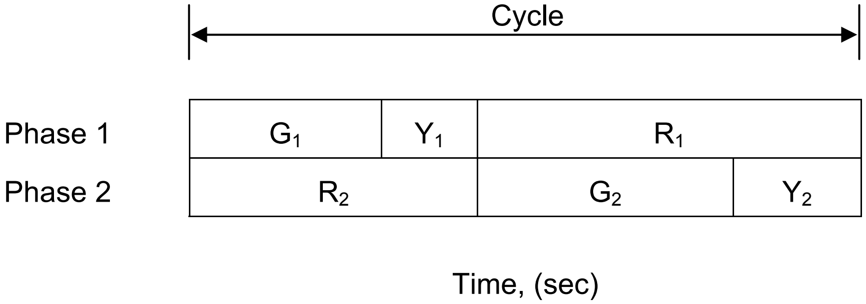
Intersections are bottlenecks within the street/highway system. They cause;

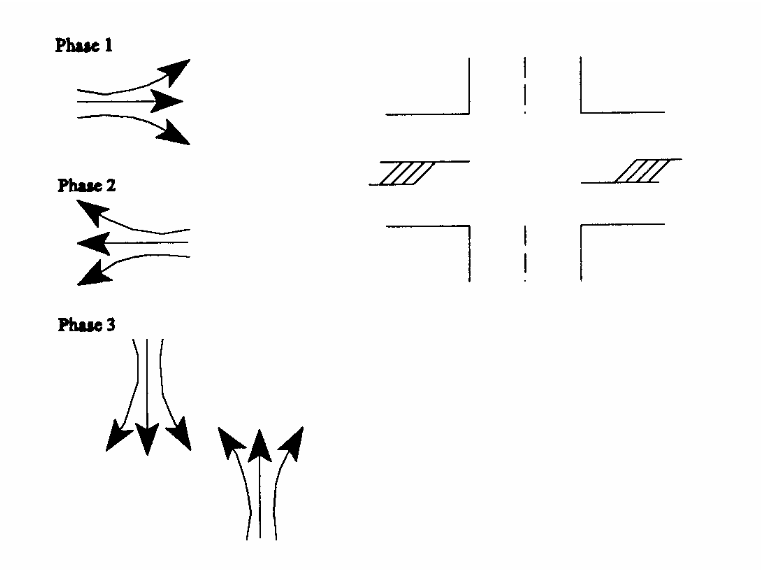
- Increased conflicts in operations
- Reduced capacity or increased delays since all approaches use a common area
- Increased hazard due to numerous conflicts with crossing, merging and diverging movements
- Increased fuel consumption due to inefficient deceleration and acceleration
- Increased air pollutant emissions due to slowing, idling, and acceleration

Definitions

Cycle time - time required to complete the sequence of signal directions

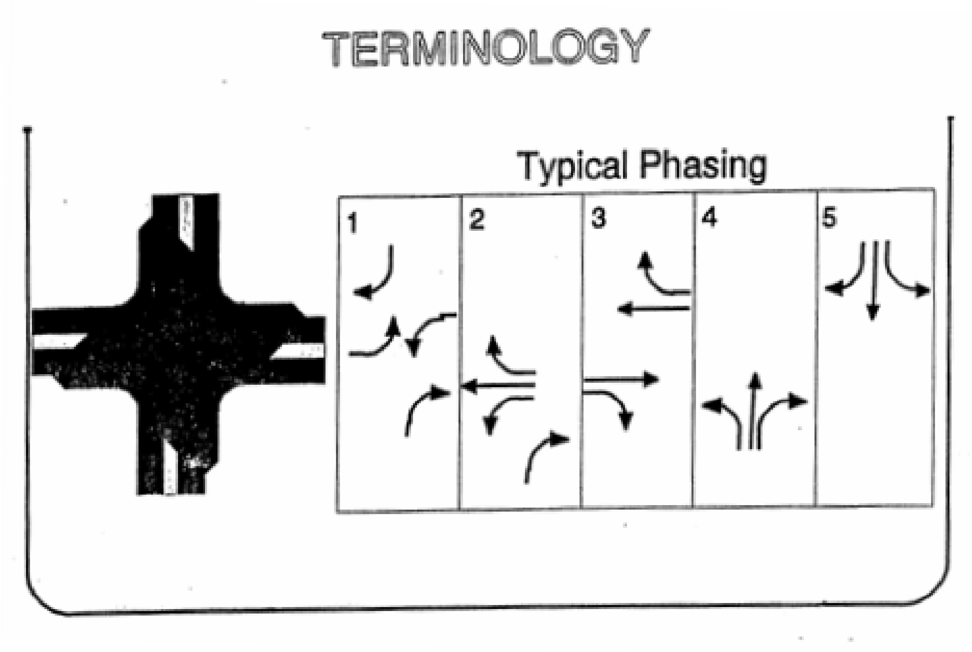
Phase - the part of a cycle allocated to any combination of traffic movements receiving right-of-way simultaneously





Saturation Flow - the average maximum flow rate, in vehicles per hour of green, on an approach, 1800 to 1900 passenger cars/hour of green. Saturation flow measured in the field begins when the rear axle of the fourth vehicle in queue crosses the stop line and ends when rear axle of the last queued vehicle crosses the stop line (see figure).

Effective Green - the green time per cycle that the traffic can flow at smooth, maximum flow rate, that is, saturation flow.



Traffic Signal Controllers

- Pre-timed: Phases and cycles are pre-set according to a predetermined schedule, based on historic traffic patterns. The controller often has three dials or drums on shafts that are mounted with changeable gears. The size of the gear determines the cycle length. Keys placed on the dials or drums, operate cams that turn off and on lights in the signal head.
- Semi-actuated: Detectors are placed only on the main street approaches. Main street has “green” until actuation of a side street detector. Side street receives “green” phase:
  - Until all vehicles served (gap out)
  - Until preset maximum “green” (max out)
- Fully-actuated: All approaches have detectors. All signal phases controlled by detector actuations. Minimum greens and maximum greens specified for each phase. Certain phases may be optional.
- NEMA and 170 controllers: These controllers are micro-processors with built-in algorithms that will optimize the operations of the signal. They can provide timing for 2-8 phase operation.

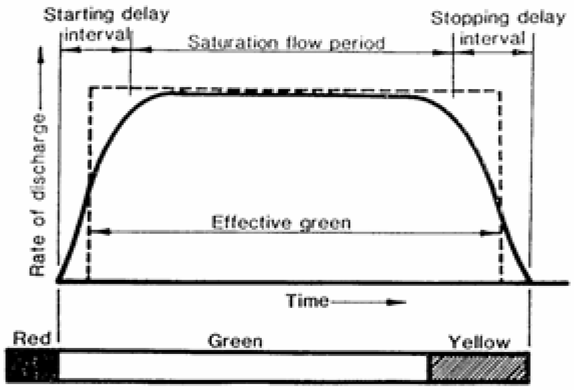


Figure 3.10. Queue discharge across the stop line

Table 3.1. Vehicle headway data

Position in Line	Observed Time Spacing (Sec)	Time Spacing at Constant Flow (Sec)	Added Startup Time (Sec)	
1	3.8	2.1	1.7	
2	3.1	2.1	1.0	
3	2.7	2.1	0.6	Total
4	2.4	2.1	0.3	3.7
5	2.2	2.1	0.1	
6 and over	2.1	2.1	0.0	

Source: Reference (*10*)

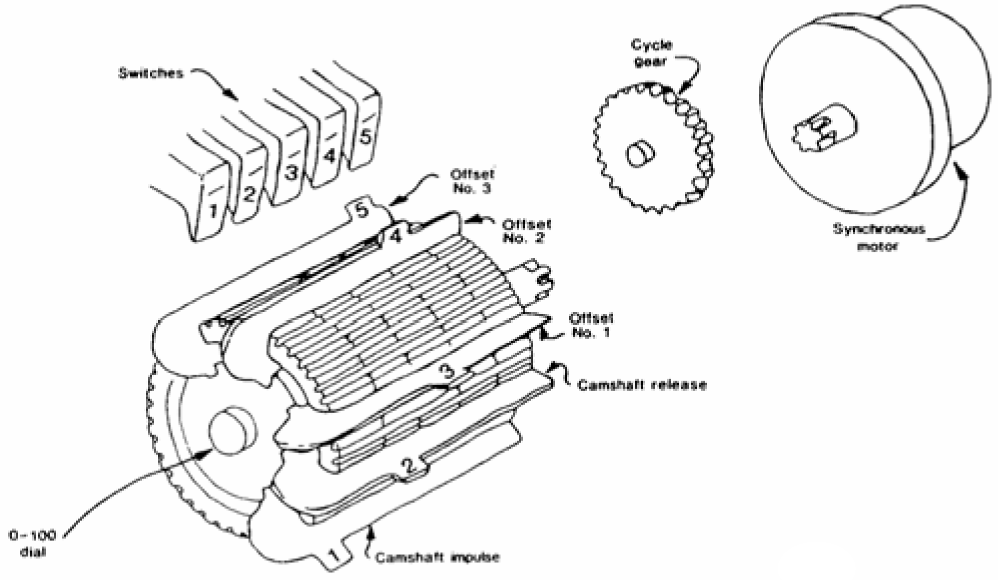


Figure 6.1. Typical dial unit

Detectors for Actuated Signals

These devices register the presence or passage of a vehicle at the approach to an intersection or a pedestrian activating a push-button.

- Inductive loop detector: A wire loop embedded in the pavement carrying a predetermined frequency signal. A vehicle passing over the loop changes the inductance and, hence, the frequency or phasing of the signal. This change is detected and converted to a relay actuation. The detection is maintained as long as the vehicle is over the loop, thereby acting as a presence detector. Because of reliability and low cost, this detector has become the most commonly used for traffic signal applications.

- Magnetometer detector: A detector installed in the roadway that measures the differences in the level of the earth's magnetic forces caused by the passage or presence of a vehicle.

- Magnetic detector: A probe with a coil of wire and a highly permeable core placed below the pavement. The constant lines of flux from the earth's magnetic field are deflected by the passage of a vehicle causing a voltage to be developed.

- Video imaging detection: A video image is taken and pixels, that are different shades, are detected as vehicles. At times, the movement is tracked to assure it is a vehicle and not a shadow.

- Other infrequently used detectors include: radar detectors, sonic detectors, pressure-sensitive detectors, light-sensitive detectors, and pedestrian detectors.

Cycle Times

The selection of the best cycle time considers the volume, intersection configuration, approach speeds and coordination with nearby intersections.

- Typical cycle times - 30s to 120s.

- Cycle time should be as short as possible in off-peak periods 40s - 60s.

- Cycle times of 120s - 150s are often required on major arterials in urban areas.

- Capacity of intersection increases with increased cycle time.

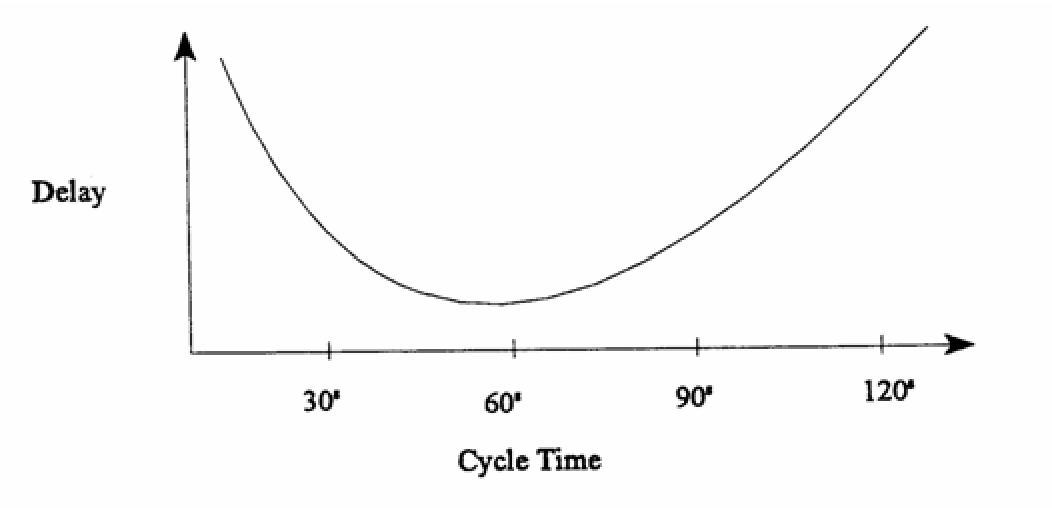
$$Cy = G_1 + Y_1 + G_2 + Y_2$$

- Increased green time per hour for an intersection increases capacity. Assuming that yellow times of three seconds, note the increase in percent of green time per hour with increased cycle in Table 1.

Table 1. Decreased Total Green Time per Cycle with Increased Cycle Time

Cycle	$G_1 + G_2$	$Y_1 + Y_2$	% Green
20	14	3 + 3	70%
30	24	3 + 3	80%
40	34	3 + 3	85%
50	44	3 + 3	88%
60	54	3 + 3	90%
70	64	3 + 3	91.4%
80	74	3 + 3	92.5%

- Delays increase with increased cycle time



(double cycle time ≅ double delay)

Yellow Times

Yellow times (or yellow change interval) are selected based on approach speed. These are provided to eliminate the potential for a dilemma zone, that is, the vehicle can neither stop safely nor clear the intersection before the cross street green begins.

Table 2. Yellow Change Intervals

Approach Speed	Yellow
<35 mph	3.0 sec.
35-40 mph	3.5 sec.
40-45 mph	4.0 sec.
45-50 mph	4.5 sec.
>50 mph	5.0 sec.

Note: At wide intersections or where approach speeds are very high, the yellow time may need to be increased.

Isolated Intersections Signal Timing

- Signal timing may be based on:
  - o Relative volumes
  - o Volumes and saturation flow
- Signal phasing based on relative volumes within constraints of:
  - o Minimum green time for pedestrians

Min. G = ped. clearance time - yellow + initial interval

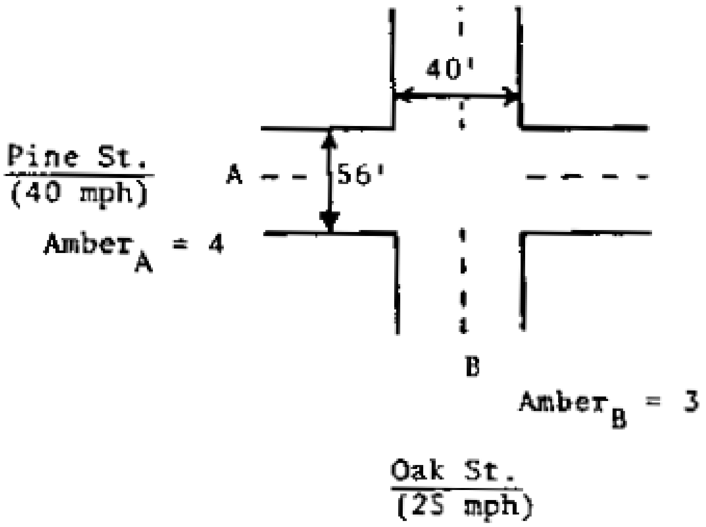
$$\frac{\text{Street Width}}{4\text{ fps}} - Y + 7 \text{ with 'WALK' signals}$$

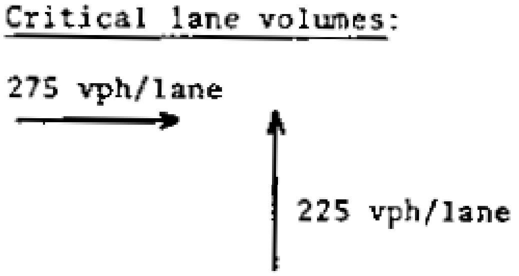
(clearance time) - yellow + (initial interval)

$$\frac{\text{Opposing Street Width}}{4\text{ fps}} - Y + 5 \text{ without 'WALK' signals}$$

- Minimum 15 seconds green typically provided for through movements at pretimed intersections

Examples:





Pedestrian Clearance Times:

A: 40/4 = 10 sec B: 56/4 = 14

Minimum Green Times:

A: $10 - 4 + 7 = 13 \text{ sec} \leq 15^s \therefore$ use 15^s

B: $14 - 3 + 7 = 18$ sec

Compute Green Times - (use Oak as critical)

$$\frac{Vol_A}{Vol_B} = \frac{G_A}{G_B}$$

$$G_B = \frac{275}{225}(18^s) = 22 \text{ sec - 'Pine' St Green}$$

Cycle Length:

$c = 22 + 4 + 18 + 3 = \underline{\underline{47 \text{ sec}}}$ cycle length

Note: Prorate difference when cycle length is rounded up to an even 5 sec cycle

Therefore, for a 50 second cycle,

$$\text{Increase } G_A = \left(\frac{225}{225+275}\right)^{(3)} = 1.4^s \text{ and } \text{Increase } G_B = \left(\frac{275}{225+275}\right)^{(3)} = 1.6^s$$

G_A = 18 + 1.4 = 19.4 seconds; G_B = 22 = 1.6 = 23.6 seconds

<table>
<tr><td>$G_A = 19.4^s$
39%</td><td>$y_A = 4^s$
8%</td><td colspan="2">$R_A = 26.6^s$
53%</td></tr>
<tr><td colspan="2">$R_B = 23.4^s$
47%</td><td>$G_B = 23.6$
47%</td><td>$y_B = 3$
6%</td></tr>
</table>

Cycle lengths:

30-120 seconds - typical range for pretimed

40-90 seconds - desirable range for pretimed

Long cycles used with:

1. High volumes
2. Multiphase signals
3. Long pedestrian walk times