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3.5 FUNCTIONAL SYSTEMS

3.5.1 Introduction

The machinery of a movable bridge may be classified as span drive machinery and span stabilizing machinery. Span drive machinery comprises those mechanisms which move the span. It also serves to stabilize the span when the span is not in the fully-closed position. Stabilizing machinery supports and restrains the span when it is at rest and when in motion, but it does not accelerate the span. Span drive machinery is sometimes called operating machinery but this terminology can be ambiguous because some stabilizing machinery also operates, in the strict sense. These classifications are mainly for convenience of reference in machinery descriptions.

The span drive machinery varies little with movable bridge type because the objective is the same for all types, to convert the low-torque rotation of a motor (electric or internal combustion) to the high torque or force required to move the span. In electro-mechanical drives, gearing is used to convert the low-torque, high-speed, rotation of the motor to high-torque low-speed rotation for moving the span. In hydraulic/mechanical systems the high-speed low-torque output shaft of the motor rotates a pump which pressurizes a suitable hydraulic fluid. Modern hydraulic systems utilize mineral, vegetable, or synthetic fluids – the older systems used water. The pressurized fluid is transmitted to hydraulic cylinders, which move the span directly, or to hydraulic piston motors, which move the span by rotating a rack pinion, sometimes using intermediate gearing.

Stabilizing machinery comprises electro-mechanical and hydraulic components that support the span when it is in motion and when it is at rest. Some stabilizing components do not support the moving span – they may be used to decelerate it under certain conditions.

In this chapter common span drive and stabilizing machinery arrangements are described. The emphasis will be on layouts found on movable bridges in Wisconsin.

3.5.2 Span Drive Machinery

Many combinations of electrical, mechanical, and hydraulic components may be assembled to form span drives. There is no “right way” to move a span. However, some machinery arrangements have become common because they were part of the original bridge patentee’s designs and, after the patents expired, were regarded as traditional. In this section, we shall consider electro-mechanical and electro-hydraulic-mechanical drives.

3.5.2.1 Type 1 Span Drives

A common arrangement of electrical and mechanical components to form a span drive with two low-speed, high-torque final outputs is shown in Figure 3.5.2.1-1. Span drives in which all the outputs are connected mechanically are denoted as Type 1, and the three subtypes are differentiated by using the suffixes ND, AD, and LD, as explained later. In Type 1 arrangements, a motor is connected to the primary speed reduction gearing, usually by a flexible coupling. This gearing is enclosed in a welded steel housing on most contemporary designs, but cast steel and various kinds of cast iron were and are used in manufacturing these speed reducers. Power is distributed from the primary reduction gearing to two (or more) sets of secondary reduction gearing located at the sides or ends of the movable span. The secondary speed reductions are often made with enclosed speed reducers as depicted in Figure 3.5.2.1-1, however, open gearing is also very common. On some newer bridges the primary and secondary reduction may be made in one larger speed reducer. Three different variations of Type 1 span drives have been installed on bridges – based on the capability of the drive to equalize the output torques.

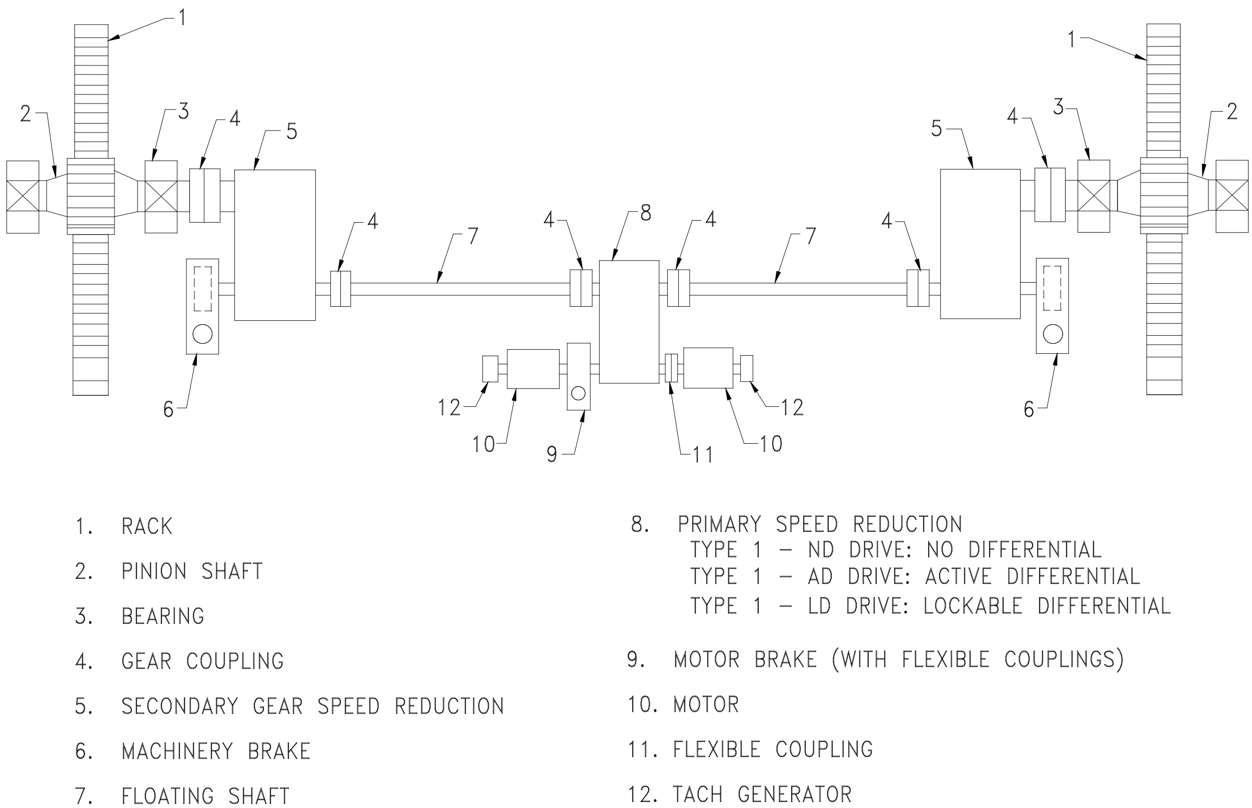


Figure 3.5.2.1-1: Type 1 Span Drive.

Type 1-ND Span Drive (No Differential)

In Type 1-ND span drives, the motor is connected to the input shafts of the primary speed reducer, which may have two or more parallel shafts. The number of speed reductions is one less than the number of shafts, except when the reducer contains idler gearing. The output shaft is continuous through the gear box and hence both shaft extensions rotate at the same speed. However, the torques delivered to each extension are not necessarily equal, in fact they usually are not. The distribution of torque between the two extensions is a function of the stiffnesses of the drives outboard of the primary reducer and the rigidity of the structure being driven. Much depends on the simultaneous engagement of both sets of pinion and rack teeth.

Type 1-AD Span Drive (Active Differential)

Under some circumstances, designers consider it important that the primary speed reducer has two output shafts rather than a common output shaft, thus permitting the output shafts to rotate at slightly different speeds, but transmit equal torques. This distribution of speed and torque is accomplished by including a differential in the primary speed reduction gear train. The principle and function of this differential is the same as that on a rear-wheel drive automobile. If the differential is always active (it is said to be free), we designate the span drive as a Type 1-AD.

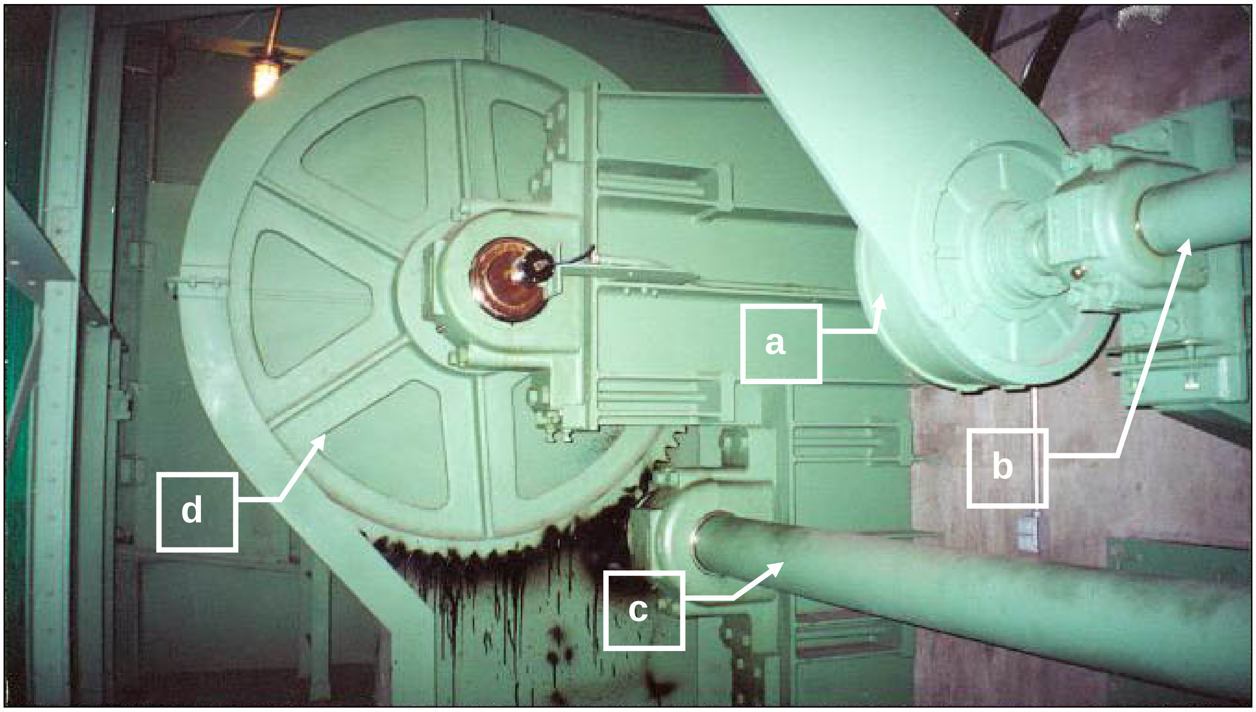
Type 1-LD Span Drive (Lockable Differential)

There are situations for which the designer wants the output shaft extensions of the primary reducer to normally rotate at the same speed but, under special conditions, wants to permit differential action. In order to enable this dual action a primary gear box is provided which incorporates a differential mechanism that can be "locked out", i.e., both output shaft extensions can be forced to rotate at the same speed. When the differential is unlocked, i.e., the differential is "free", it behaves as a normal differential gear box. A drive with a lockable differential in the primary train is denoted as a Type 1-LD Span Drive.

3.5.2.2 Secondary Speed Reductions for Type 1 Span Drives

From the primary reduction gearing, power is transmitted to the secondary reduction gearing by shafting, which is arranged to be "floating" in contemporary designs in order to minimize the effect of superstructure distortion on the action of mechanical components. The floating action is achieved with the aid of flexible shaft couplings that permit only minimal amounts of axial, transverse, and angular motion at the joint while transmitting torque.

If the output shaft of the secondary gearing is connected to only one rack, as shown in Figure 3.5.2.1-1, the secondary gearing does not contain a differential. Such is the case for trunnion and rolling lift bascules and for vertical lift bridges with only one counterweight sheave per corner of the span. If the secondary reducer drives two racks, it is usually equipped with an active differential so that the rack tooth forces are equalized. Figure 3.5.2.2-1 shows a portion of the drive machinery for a typical bridge.



a Hydraulic motor with torque arm
b Input shaft to primary gear reduction
c Input shaft to secondary gear reduction
d Gear

Figure 3.5.2.2-1: Secondary Gear Reduction – 8th Street Bridge, Manitowoc.

3.5.2.3 Span Drive Type Relative to Movable Bridge Type

The Type 1 span drives described in the foregoing have been installed on the following types of movable bridges:

1. Type 1-ND
   - Trunnion bascules
   - Rolling lift bascules
   - Swing bridges (mostly early). Not desirable, in general.
   - Vertical lift bridges [span drive, connected tower drive, tower drive, and pit drive].
2. Type 1-AD
   - Trunnion bascules
   - Rolling lift bascules
   - Swing bridges
3. Type 1-LD
   - Trunnion bascules (differential normally locked)
   - Swing bridges (differential normally unlocked)

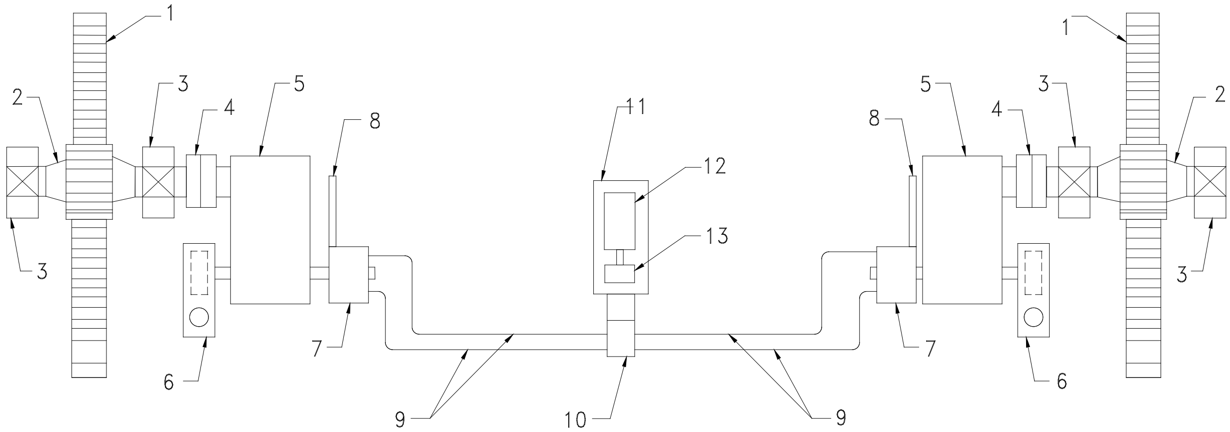
Vertical lift bridges (differential normally locked), [span drive, connected tower drive, and tower drive].

3.5.2.4 Type 2 Span Drives

In the Type 1-ND and Type 1-LD (when locked) mechanical drives, as described previously, the two output pinions rotate at the same velocity. Unless the structure to which the machinery is fastened is very flexible, or the machinery is well aligned, or the machinery is very “springy”, the teeth of both racks will not simultaneously be subjected to equal force. In other words, the racks will not “share the load” equally. The early rolling lift bascules had Type 1-ND span drives which were torsionally soft (springy) and hence tended to distribute the torque to the two racks nearly uniformly if the gearing was properly installed. However, in later bridges stiffer shafting was utilized and hence differentials were installed (Type 1-AD) to make load sharing more reliable.

Not all bridge designers are convinced of the need for differentials to ensure load-sharing between multiple racks. They are willing to forgo uniform loading of racks for the safety advantage of the Type 1-ND or Type 1-LD (locked) drives due to their redundancy outboard of the primary reducer. The two philosophies will not be discussed further here because the emphasis of the Manual is on inspection, not design.

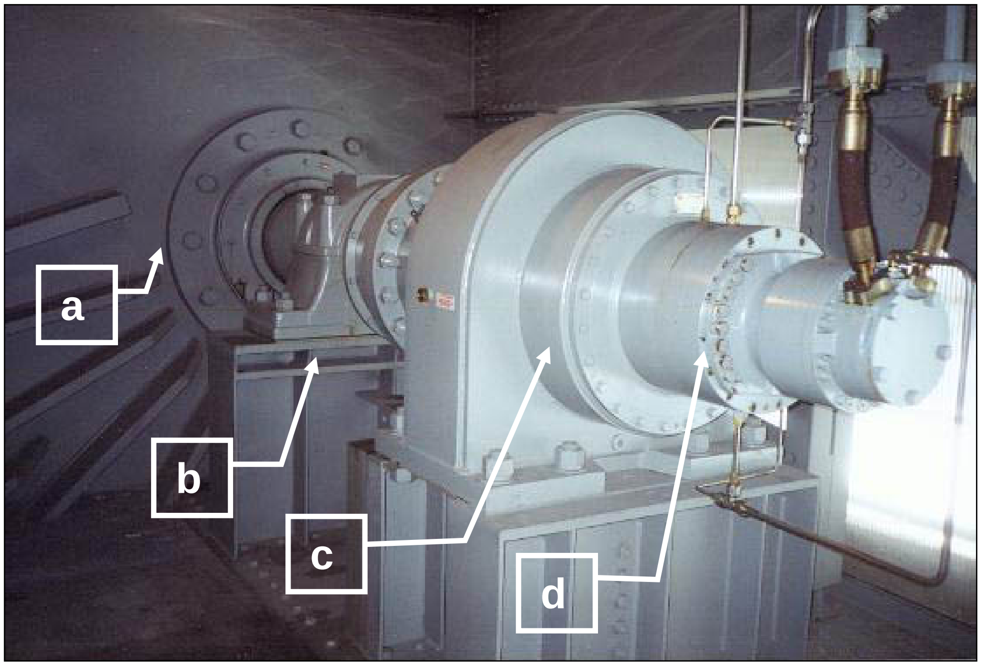
Another approach to load sharing has been adopted by designers of large and stiff simple trunnion bascules and swing bridges. One or more pinions, each separately powered, engage a common rack in the case of swing bridges. For bascules with two racks, each pinion is separately powered. The reasoning is that if all of the drive machinery packages are alike, then the pinion tooth loads should be alike. In practice, this simplistic approach has not proved valid during driving when electric motors are prime movers, especially with modern feed-back controls. The pinion tooth loads are also not alike during retarding if each drive package is equipped with thrustor-released, spring set, friction brakes.



1. RACK
2. PINION SHAFT
3. BEARING
4. GEAR COUPLING
5. SECONDARY GEAR SPEED REDUCTION
6. MACHINERY BRAKE
7. HYDRAULIC MOTOR
8. TORQUE ARM
9. HYDRAULIC LINES
10. MANIFOLD & VALVES
11. TANK
12. MOTOR
13. PUMP

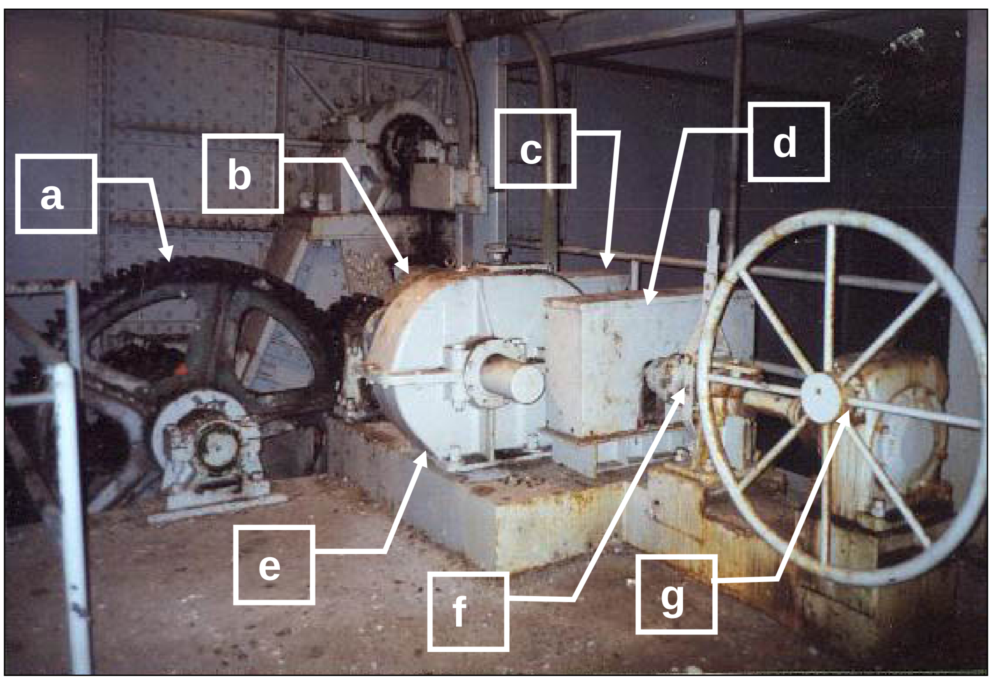
Figure 3.5.2.4-1: Type 2 Span Drive.

Figure 3.5.2.4-1 depicts a Type 2 span drive with two pinions, each powered by a separate hydraulic motor through a geared speed reduction. The fluid input to the two motors comes from a common source; hence the torques applied by the pinions should be nearly equal, assuming that both sets of motors and gearing, and piping, etc., are alike. Parallel shaft gear reducers are shown in Figure 3.5.2.4-1, but planetary gear reducers may be used as well, as were installed at Main Street in Green Bay (see Figure 3.5.2.4-2). Open gear trains are also common.



a Pinion Shaft
b Planetary Speed Reducer
c Hydraulically released spring disk brake
d Hydraulic Motor

Figure 3.5.2.4-2: Type 2 Span Drive – Main Street Bridge, Green Bay.



a Secondary gear reduction train
b Motor (behind speed reducer)
c Motor Brake
d Machinery Brake
e Primary Speed Reduce
f Clutch (behind manual drive wheel)
g Manual Drive (with right angle reducer)

Figure 3.5.2.4-3: Type 2 Span Drive – Oneida Street Bridge, Appleton.

The Oneida Street Bridge in Appleton has a Type 2 span drive with completely independent electro-mechanical drives. Figure 3.5.2.4-3 depicts one of the two units on this simple trunnion bascule bridge. One of the two drive units is fitted with a means for manual operation.

3.5.2.5 Type 3 Span Drives

Span drives whose output is transmitted to the moving span by linear action, as depicted in Figure 3.5.2.5-1, are designated as Type 3 Span Drives. Such drives have been installed on simple trunnion bascules, rolling lift bascules, swing bridges, and vertical lift bridges. The linear action is usually produced by hydraulic cylinders, but chain, wire rope, and screw drives have also been used. The cylinder mountings shown are for a simple trunnion bascule or a pit vertical lift bridge.

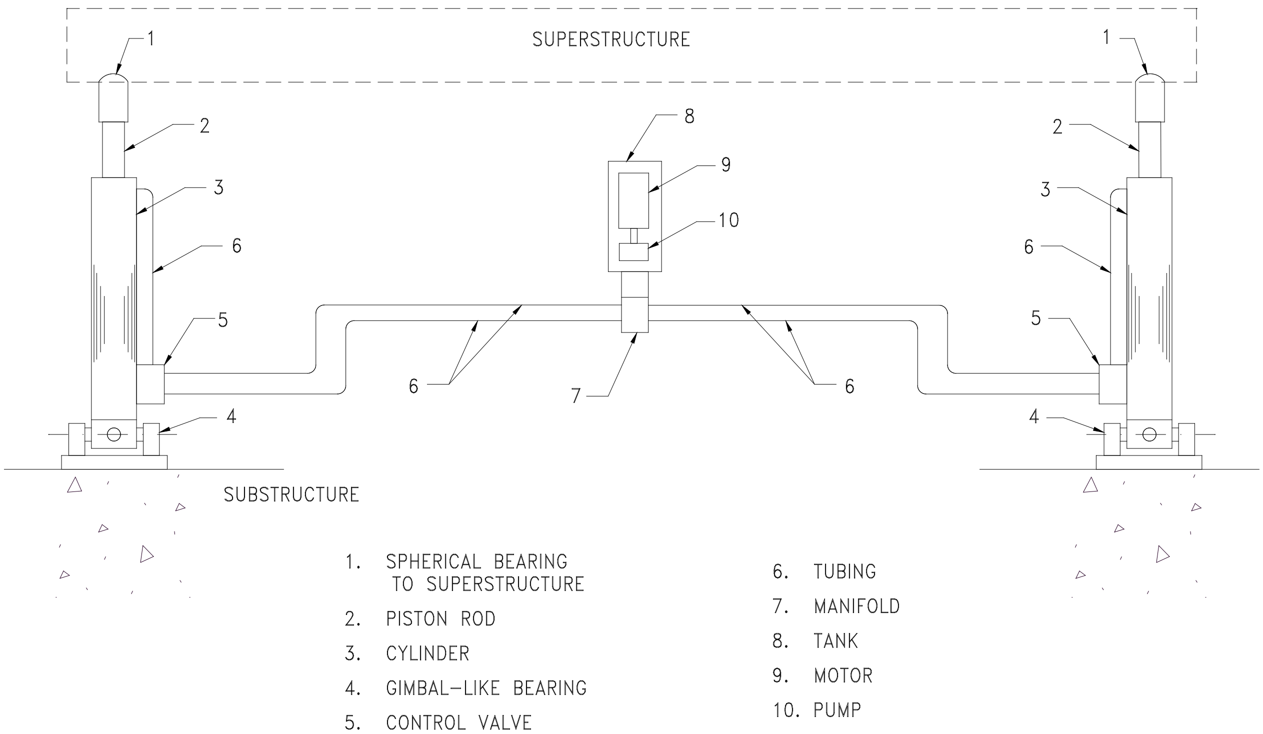
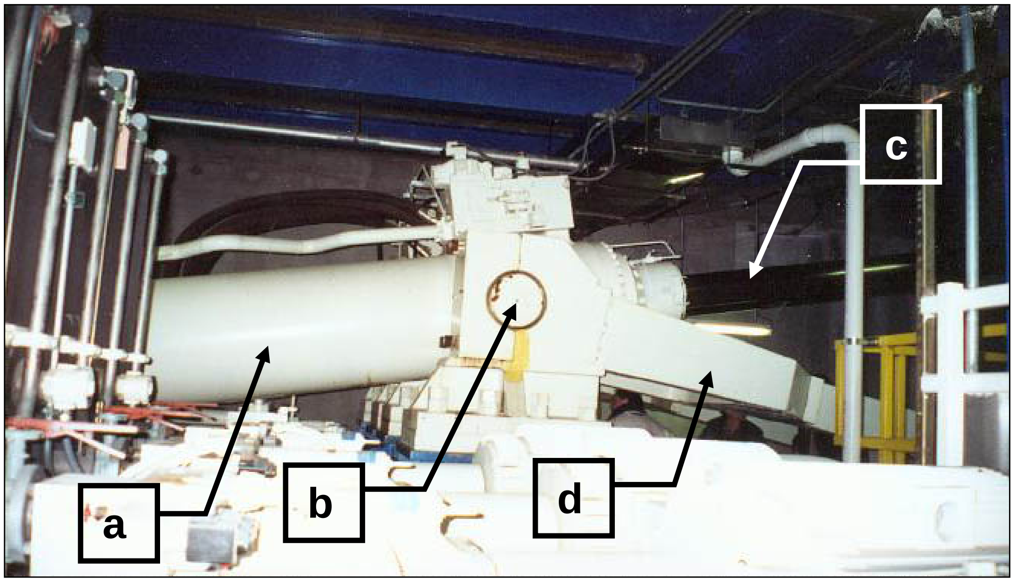


Figure 3.5.2.5-1: Type 3 Span Drive.

Rather than mount the cylinders in an inclined position in the bascule pit, simple trunnion bascules have also been rotated by fastening levers (crank arms) to the ends of the bascule girders and pivot mounting the cylinders in a near horizontal position. The linear action of the cylinders acting on the crank arm produces a torque that rotates the end of the bascule girder. Figure 3.5.2.5-2 shows one of the cylinders driving the Eighth Street Bridge in Sheboygan.



a Cylinder
b Pivot mountings
c Piston rod
d Strut

Figure 3.5.2.5-2: Cylinder of Type 3 Drive, Eighth Street Bridge, Sheboygan.

For rolling lift bascules the cylinder is usually horizontal with the piston rod end usually connected to the bascule girder at the center-of-roll and the cylinder foot fastened to the fixed structure. Extension or retraction of the piston causes the leaf to travel and thus rotate closed or open.

For vertical lift bridges, the cylinders are vertically mounted in pits with the rod end fastened to the lift span.

3.5.2.6 Types of Span Drives on Selected Wisconsin Bridges

Examples of movable bridges in Wisconsin having the types of span drives previously described are listed below.

Type 1-ND Span Drive

1. Wisconsin Avenue, Kaukauna. Connected tower vertical lift.
2. US-10, Prescott. Rolling lift bascule.

Type 1-AD Span Drive

1. Mason Street, Green Bay. Simple trunnion bascule.
2. Walnut Street, Green Bay. Rolling lift bascule.

Type 1-LD Span Drive

1. Unknown

Type 2 Span Drive

1. South Kinnickinic Avenue, Milwaukee. Simple trunnion bascule.
2. Main Street, Green Bay. Rolling lift bascule.

Type 3 Span Drive

1. Highland Avenue, Milwaukee. Unbalanced pit vertical lift.
2. Eight Street, Sheboygan. Unbalanced single-leaf bascule.
3. Main Street, Oshkosh. Rolling lift bascule.

3.5.3 Stabilizing Machinery

Stabilizing machinery supports the span when it is in motion and at rest. The machinery components and assemblies are usually mechanical but fluid power (air and liquid) components are also utilized. General examples of stabilizing components for various types of movable bridges are:

1. **Trunnion Bascule Bridges:** Trunnion shafts and trunnion bearings; live load reactions; toe, mid-span, and tail locks; centering devices; and buffers.
2. **Rolling Lift Bascule Bridges:** Treads mounted on segmental girders; tracks; tail locks; midspan joints or locks; live load reactions; centering devices; and buffers.
3. **Vertical Lift Bridges:** Counterweight sheaves with trunnions and bearings; main counterweight and auxiliary counterweight ropes; live load supports; centering devices; span locks; span guides and guide wheels or shoes; and buffers. Hydraulic cylinders for vertical lift bridges without counterweights.
4. **Swing Bridges:** Center pivot bearings and balance wheels; rim girders, rollers, and spider assemblies; center wedges; end lifts; centering latches or centering mechanisms; buffers; bumpers; and rigid stops.
5. **Retractile Bridges:** Tracks; wheeled bogies; wheel stops and bumpers; and span locks.

The locations of most usual stabilizing machinery components on bascule, vertical lift, and swing bridges are shown in Figures 3.2.2-1, 3.2.3-2, 3.3.1-1, 3.4.2-1, 3.5.3.1-1, and 3.5.3.3-1. The functions of many components are obvious, but the actions and needs for others may not be so obvious. Subsequently, the components usually installed on common bridge types will be briefly explained. Additional details will be found in Chapter 6, Electrical Systems and Chapter 8, Mechanical Systems.

3.5.3.1 Simple Trunnion Bascules

Single Leaf

Figure 3.2.2-1 is a simplified diagram of a single leaf simple trunnion bascule showing stabilizing machinery including:

1. Trunnion Shafts and Bearings**:** They support the full dead load (balanced leaf) and usually support live load when the leaf is closed. In the leaf open position they support the full dead load, wind, and ice.

2. Toe Locks: A toe lock is usually comprised of a lock bar in an operator (electro-mechanical or hydraulic), lock bar guides, and a receiving socket. The arrangement shown in Figure 3.2.2-1 is common but on some bridges the operator is located on the rest pier and the socket on the leaf. Much depends on availability of space and the availability of the submarine cable or other means to transmit power and control signals across the channel. The function of a toe lock is to prevent upward movement of the toe of the leaf due to: live load rearward of trunnion, a counterweight-heavy imbalance condition, or vibration due to moving live load.

3. Live Load Bearing: Besides the obvious live load, the live load bearing supports a positive dead load (from a desired span-heavy imbalance), and the force due to residual torque in the span drive machinery (wind-up on seating).

4. Bumper: Bumpers are installed to stop the moving leaf in the event that the leaf travels beyond the fully open position. Bumpers may be constructed of timber or synthetic rubber.

5. Centering Device: The function of this device is to align the toe of the leaf laterally so that finger joints in the roadway and sidewalk will mate properly during lowering of the leaf. Not all bascules are equipped with centering devices. They are usually installed on highway bridges having long, narrow, leaves and on all bridges having railway tracks.

Double Leaf

Double leaf simple trunnion bascules require a different arrangement of stabilizing machinery because there is no pier at the toe of the leaf.

1. Midspan Lock or Center Lock: Its function is to maintain the adjacent toes of the leaves at the same elevation (or nearly so). In order to accomplish this, the lock bar must be able to transfer live load shear across the open joint between the leaves. They may also be designed to align the leaves laterally.

2. Live Load Bearings: Their function is the same as on the single leaf bascule, but they are not located at the toe of the span. Three possible arrangements are:

    a. **Live load Bearings at Front Wall:** The advantage of the front wall location for a balanced bascule is that the cantilevered length of the bascule girder is shortened; see Figure 3.5.3.1-1 (a). However, an extreme live load applied near the toe of the leaf when the midspan lock is ineffective can create uplift against the trunnion bearing cap if the ratio B/L is small.

b. **Primary Live Load Bearings at Front Wall, Secondary at Rear of Bascule Girder:** In order to prevent uplift against the trunnion bearing caps, some bridges have primary live load bearings on the front wall and secondary live load bearings at the tails of the bascule girders. There is a small gap above each secondary bearing so that it will only act when the forward part of the leaf is subjected a large live load. There is also a gap or spring arrangement under the bearing cap to preclude loading the cap by uplift.

   If the rear roadway break is located rearward of the trunnions, a secondary live load bearing, or tail lock, may be necessary to stabilize the leaf when live loads are located between the trunnions and the roadway break.

c. **Live Load Bearings at Rear of Bascule Girder:** Locating the live load bearings at the tails of the bascule girders has the advantage that the elevation of the midspan is not as sensitive to live load bearing adjustments as the dimension C in Figure 3.5.3.1-1 is usually larger than B. However, the bascule cantilever span is longer than for the front wall live load bearing arrangement. Shim packs are usually provided for adjustment, but screw adjustments such as on South Kinnickinnic Avenue Bridge in Milwaukee are not uncommon. These simple rear live load bearings are provided on bridges with floor breaks forward of the trunnions. If the breaks are to be behind the trunnions an upward bearing (tail lock) may be provided at the rear end of the bascule girder.

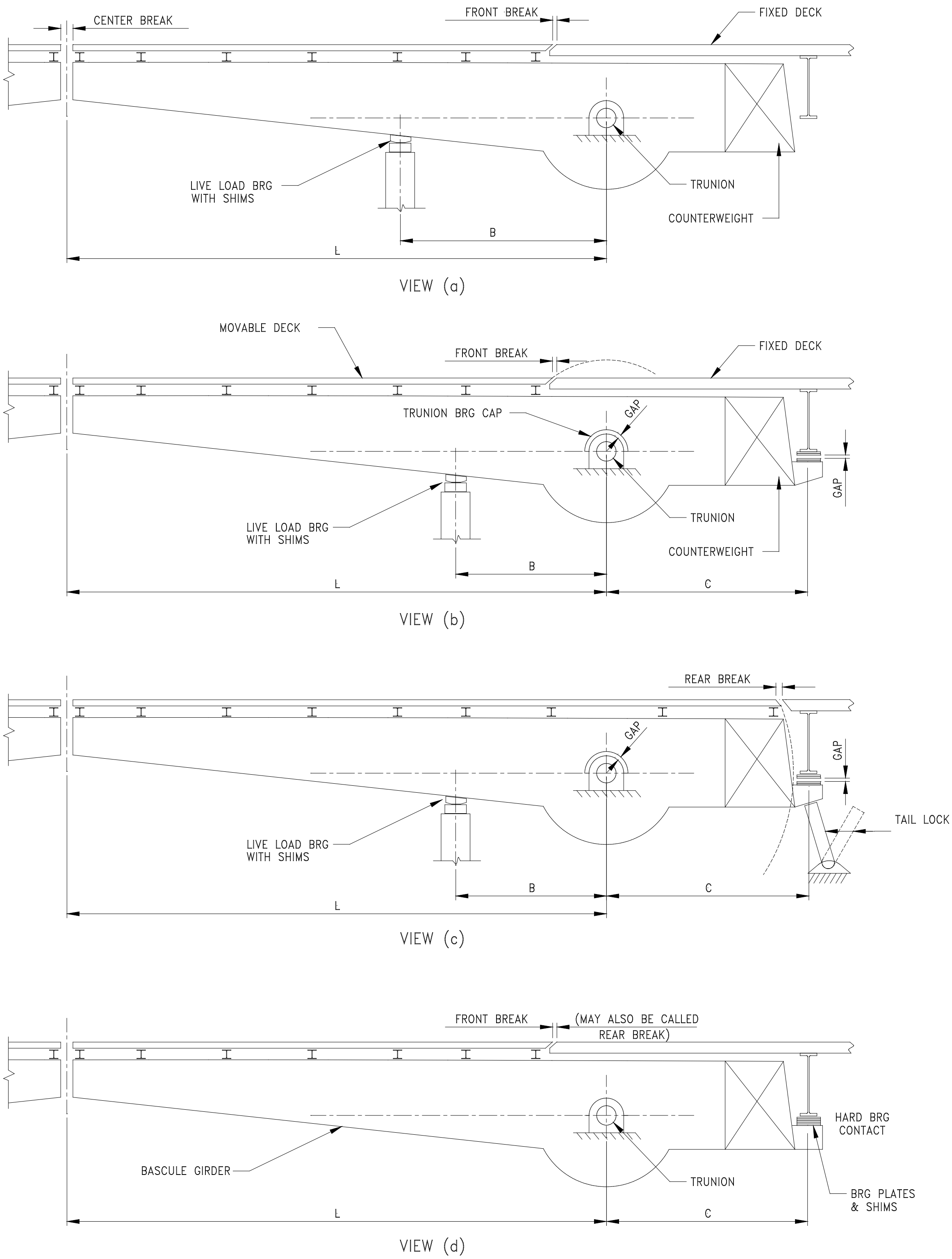


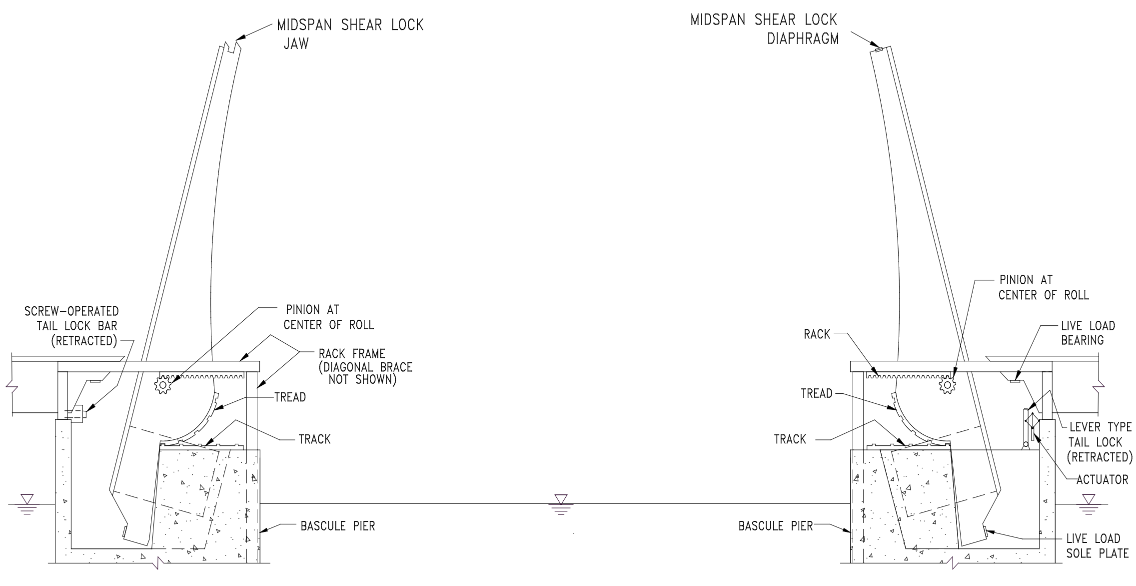
Figure 3.5.3.1-1: Live Load Bearings for Various Types of Double-Leaf Simple Trunnion Bascules

3.5.3.2 Articulated Counterweight Bascules

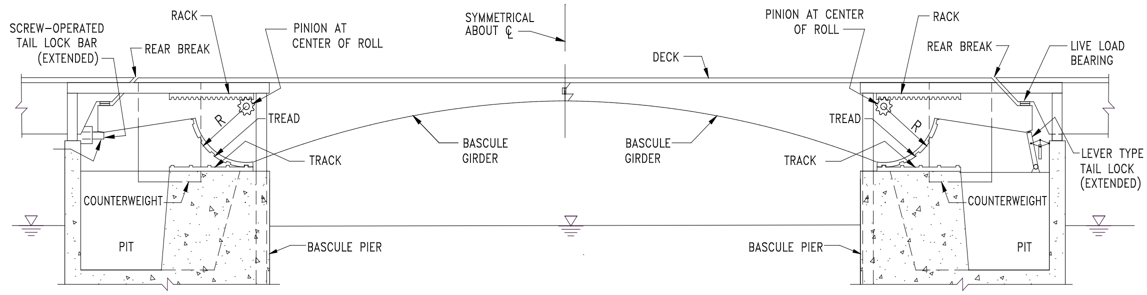
Bascule bridges with articulated counterweights may be single-leaf or double-leaf. All ABT (named after the inventor of the bridge style, Hugo Abt) style bridges are single-leaf. Strauss style bascules may be either single-leaf or double-leaf. The stabilizing machinery is very similar in function to that of the single-leaf or double-leaf simple trunnion bascules. The only additional devices, on some older bridges without automatic deceleration control, are air buffers. Their function is to reduce impact on the structure if the bridge is closed at excessive speed.

3.5.3.3 Rolling Lift Bascules

Stabilizing machinery on rolling lift bascules is illustrated schematically in Figure 3.2.3-2 for a single-leaf and in Figure 3.5.3.3-1 for a double-leaf bascule. The figures are composites; they show features from a number of bridges.



LEAVES FULLY OPEN



LEAVES FULLY CLOSED

Figure 3.5.3.3-1: Double-Leaf Rolling Lift Bascule.

Single-Leaf Rolling Lift Bascule

Some of the essential stabilizing machinery for any rolling lift bascule is depicted in Figure 3.2.3-2 and includes:

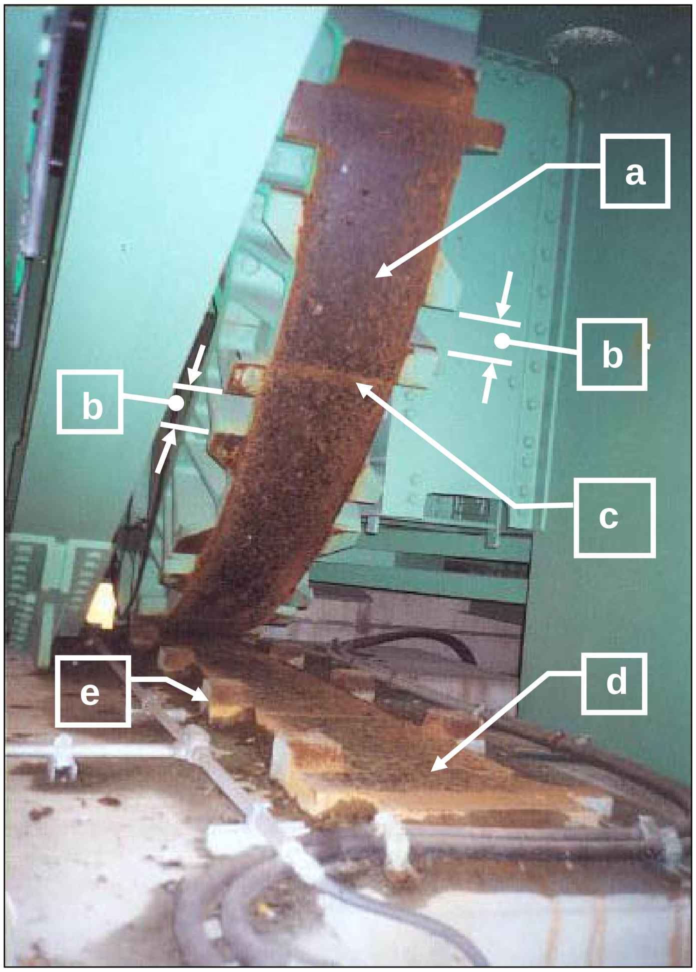
1. Tracks and Treads: Each bascule girder rolls on a track which has upward projecting lugs (they are equivalent to gear teeth). As the bridge may have a multiplicity of bascule girders (from 2 to more than 4) there is a multiplicity of tracks. In the United States, it is typical for all tracks to have lugs; elsewhere it is typical for only the outer two of a leaf to have lugs. The lugs of early rolling lift bridges were protrusions (rectangular in plan) of the steel casting which were spaced from about 10 to 25 inches apart, depending on the radius of roll. Lugs may be found in one line centered on the track, or staggered in two lines along the edges of the track. Figure 3.5.3.3-2 depicts the lugs on the edges of a track of the rolling lift bridge at 8th Street Manitowoc.

   Many tracks were manufactured with lugs made by inserting pins (of circular or rectangular cross section) into vertical holes in the track.

   Another approach to engaging the tracks and treads is to bolt racks to the vertical sides of the track and bolt gear segments to the sides of the tread, as shown in Figure 3.5.3.3-3.

2. Live Load Bearings: Their function is the same as for simple trunnion bascule.

3. Toe Locks: Their function is the same as for simple trunnion bascule. Because the rear floor breaks of rolling lift bascules tend to be proportionately further rearward of the center-of-roll in the closed position than for simple trunnion bascules, greater uplift has to be resisted at the toe. To avoid this situation some single-leaf rolling lift bascules have lever tail locks, as described subsequently for double leaf rolling lift bascules.



a: Tread

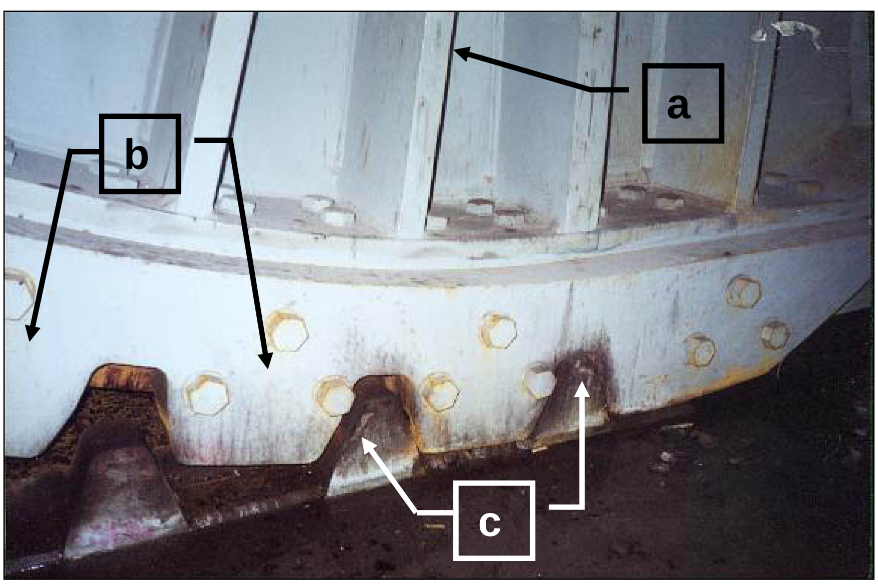
b: Socket

c: Joint Between Segmental Tread Castings

d: Track

e: Lug

Figure 3.5.3.3-2: Track And Tread Castings On Rolling Lift Bascule - Eighth Street Bridge, Manitowoc.



a: Segmental Girder

b: Segmental Tooth Casting (pinion) bolted to Tread

c: Track Tooth Casting (rack) bolted to Track Casting

Figure 3.5.3.3-3: Track And Segmental Girder Tread – Main Street Bridge, Green Bay.

Double Leaf Rolling Lift Bascule

Figure 3.5.3.3-1 shows a double-leaf rolling lift bascule in the open and closed positions with stabilizing machinery noted. It must be emphasized that the design shown supports live load only by bending of the bascule girder. There is no arch action of this double leaf rolling lift bascule because the midspan joint shown cannot resist thrust (horizontal force). The stabilizing machinery includes:

1. Tracks and Treads: Function is same as for single-leaf rolling lift bascule.

2. Midspan Shear Lock (Center Lock): This lock is intended to maintain the toes of both leaves at the same elevation and in proper lateral alignment when the bridge is in the closed position and subjected to live load. In order to accomplish this, it must transfer live load shear between the leaves. The joint shown is known as a Jaw and Diaphragm Detail. On most bridges, a diaphragm casting is bolted to the two side plates at the end of the Diaphragm Leaf. Figure 3.5.3.3-4 depicts a diaphragm casting on the 8th Street Bridge in Manitowoc. As the bridge closes, the jaw shown in Figure 3.5.3.3-5 enters between the diaphragm side plates and the diaphragm casting is engaged between the upper and lower jaws.

   With time, the top and bottom edges of the diaphragm casting and the sliding surfaces of the jaw strike plates wear. The rate of wear depends on the number of bridge openings and the amount of heavy truck traffic passing over the bridge. On the newer rolling lift bascules, shims are provided under the jaw plates in order to permit adjustment. Figure 3.5.3.3-6 is a detail drawing of the mid-span lock parts shown in Figure 5.3.3-4 and Figure 3.5.3.3-5.

   For mid-span locks without provision for adjustment with shims, worn areas may have been built-up by welding, followed by grinding, to achieve the desired reduction in clearance between the diaphragm casting and the strike-plates on the jaw. Regardless of the manner of adjustment, the adjustment should be made so that the roadway joint plates (usually finger-jointed) of both leaves present a flush surface. As a cautionary note, readjustment of rear live load bearings and tail locks may be required in connection with adjustment at mid-span.

3. Tail Locks: Live load on the leaf forward (channel-ward) of the center-of-roll causes uplift at the rear end of the bascule girder, and therefore, structural framing is required to provide a downward reaction. However, when live load is located between the center-of-roll and the rear floor break an upward reaction must be provided. Tail locks provide this function. Because of the motion of the leaf, the tail lock must be retractable.

   Two different tail locks, typical on Wisconsin bridges, are depicted in Figure 3.5.3.3-1. At the left is a retractable lockbar and at the right is a lever that is moved by a toggle. In this 2-dimensional sketch, both mechanisms are shown operating in the longitudinal direction. In reality, the motion of these units on most Wisconsin bridges is in the transverse direction. Figure 3.5.3.3-7 shows a lever tail lock in the extended position (the bridge leaf is fully closed).

4. Live Load Uplift supports: When the bridge is in the closed position each girder's heel top flange should be checked for being firmly seated against the live load uplift support.

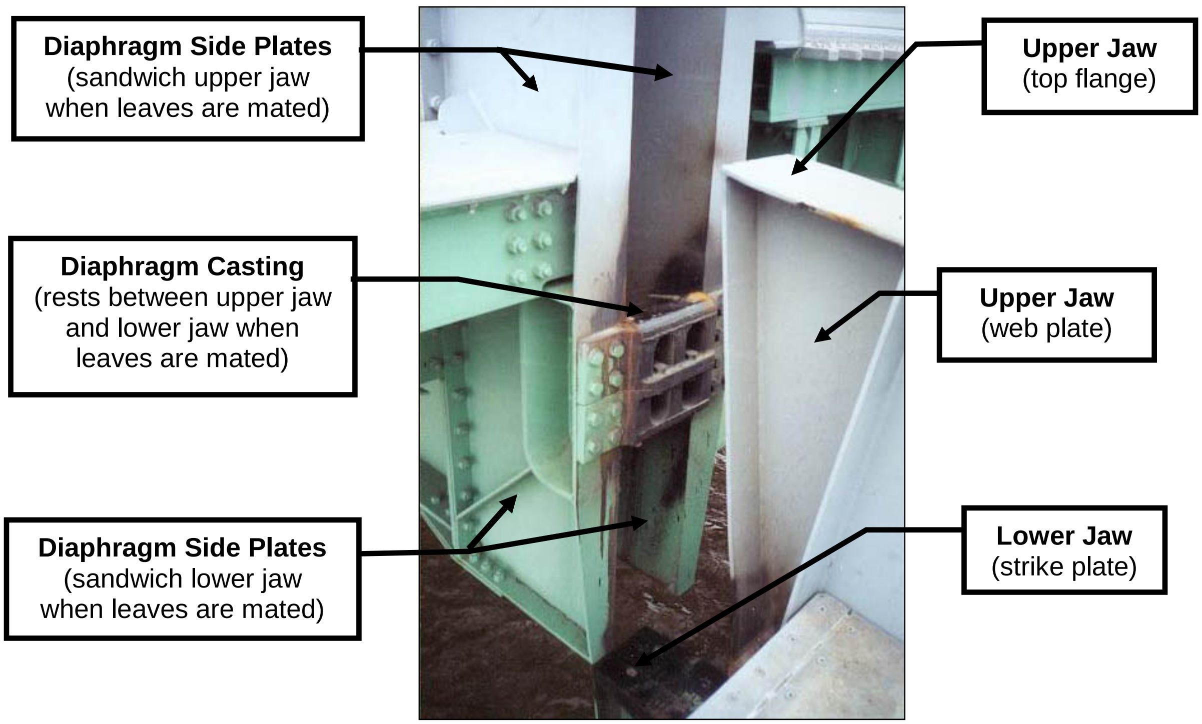


Figure 3.5.3.3-4: Center Lock on Double-Leaf Rolling Lift Bascule, Eighth St. Bridge, Manitowoc.

Note: When leaves begin to mate, diaphragm casting will come to rest on lower jaw strike plate

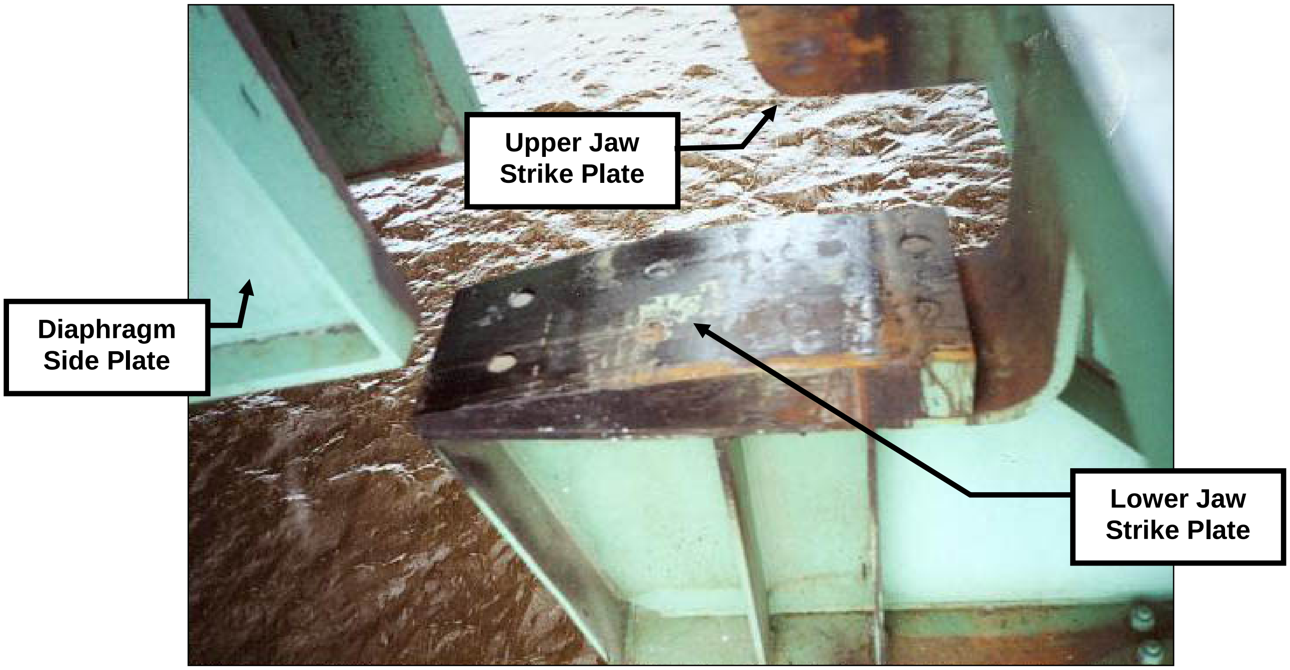


Figure 3.5.3.3-5: Center Lock Jaw on Double-Leaf Rolling Lift Bascule, Eighth St. Bridge, Manitowoc.

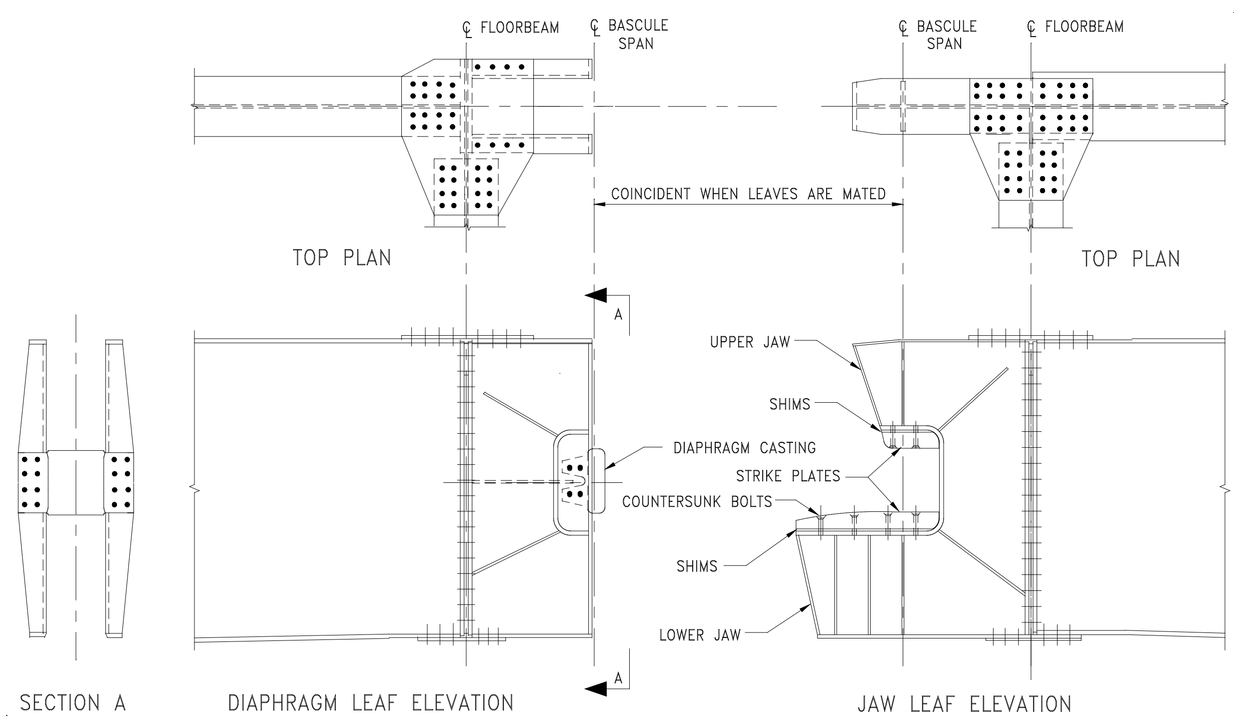
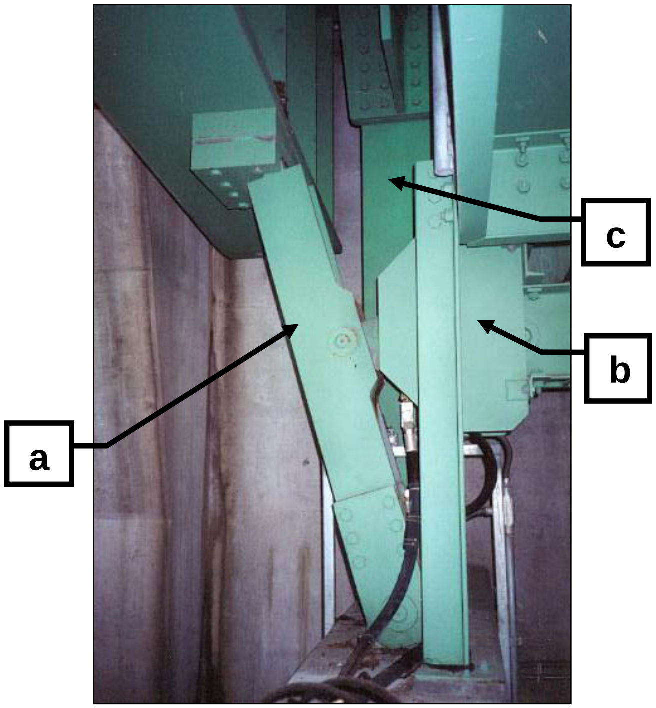
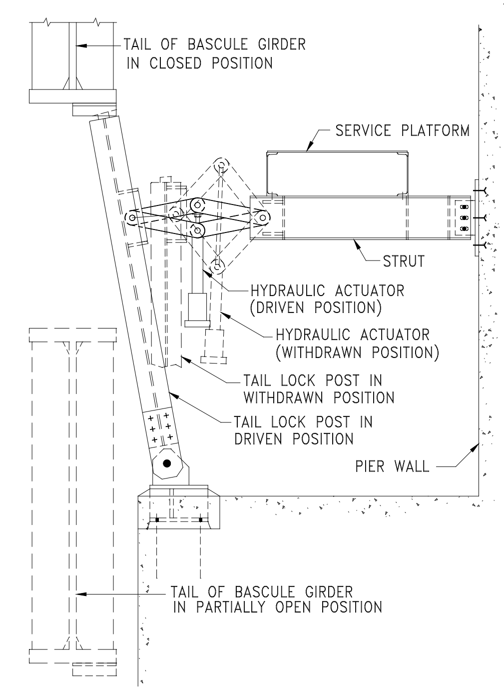


Figure 3.5.3.3-6: Detail of Mid-Span Shear Lock.

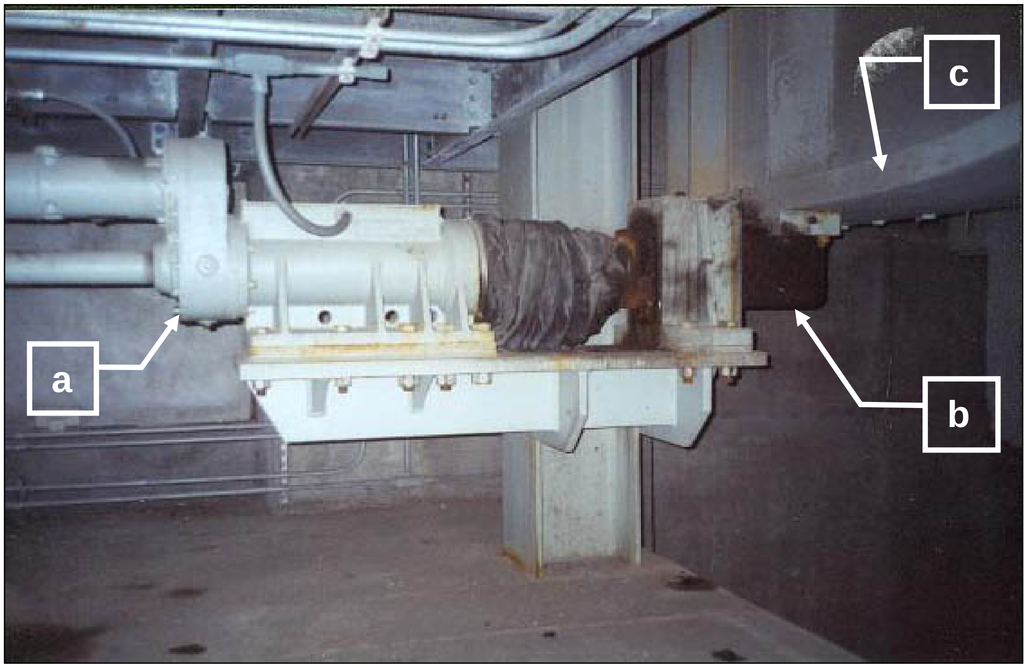




a Tail Lock Post in Driven Position
b Actuator (hidden by enclosure)
c Live Load (Uplift) Anchor Column

Figure 3.5.3.3-7: Lever Tail Lock - Eighth Street Bridge, Manitowoc.

Horizontal lockbars act as tail locks for the Main Street Bridge in Green Bay. Figure 3.5.3.3-8 depicts the installation with the leaf closed. Note that the bar is oriented normal to the bascule girder web.



a Screw-type Operator
b Tail Lock Lockbar
c Bottom Flange of Bascule Girder (closed position)

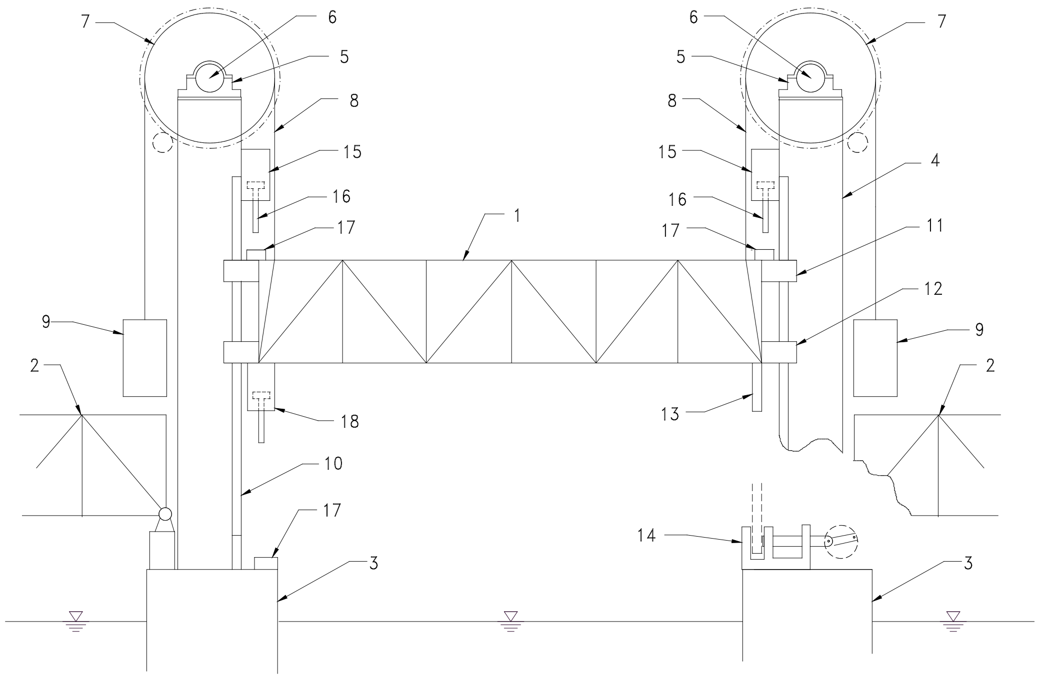
Figure 3.5.3.3-8: Horizontal Lockbar Tail Lock – Main Street Bridge, Green Bay.

3.5.3.4 Vertical Lift Bridges

Various types of vertical lift bridges are described in Chapter 3 and shown in Figure 3.3.1-1. Except for the pit drive type, the stabilizing machinery for vertical lift bridges is quite similar. Figure 3.5.3.4-1 depicts the stabilizing machinery for a tower drive that does not have auxiliary counterweights. The stabilizing machinery components include:

1. **Main Counterweight Ropes:** Although the lift span and the main counterweights are usually considered structural components, the wire ropes connecting them are classified as stabilizing machinery. They are typically 6 x 19 Class (6 x 25 filler wire construction) helical wire rope with a fiber core. Current specifications require right regular lay, but other lays were formerly used. The rope is normally prestretched to about 40 percent of the catalog strength in order to remove some of the internal wire looseness which is a result of the manufacturing process. Rope terminations are made with forged or cast steel sockets using molten zinc to form the wedges.

2. **Counterweight Sheaves and Trunnions:** The counterweight ropes are looped over grooved sheaves of cast steel or welded rolled steel. A trunnion shaft is fitted through the sheave. Because of the rotation of the shaft and sheave, while supporting full dead load, stress reversals occur and these can lead to cracking of the sheave and the shaft. Cracking usually occurs at the step in the shaft nearest the sheave if the fillet radius is not large enough to reduce the stress concentration sufficiently. Such fatigue cracking can be a serious safety concern.



1. LIFT SPAN TRUSS
2. FLANKING SPAN TRUSS
3. PIER
4. TOWER
5. CWT TRUNION BEARING
6. CWT TRUNION
7. CWT SHEAVE
8. MAIN CWT ROPES
9. MAIN CWT
10. GUIDE BAR
11. UPPER SPAN GUIDE
12. LOWER SPAN GUIDE
13. CENTERING BAR & SPAN LOCK SOCKET
14. SPAN LOCK ACTUATOR & LOCKBAR (RETRACTED)
15. UPPER BUFFER
16. PISTON ROD
17. STRIKE PLATE
18. LOWER BUFFER

NOTE: LIVE LOAD REACTIONS FOR LIFT SPAN AND AUXILARY COUNTER WEIGHTS NOT SHOWN

Figure 3.5.3.4-1: Vertical Lift Bridge – Typical Components of Stabilizing Machinery.

3. **Span Guides:** As the lift span is moved vertically by the span drive it is horizontally guided at all four corners. The guides transfer the wind loads to the towers. In order to minimize frictional resistance when the lift span is moving vertically, the guides are equipped with rollers or bronze wear plates. The rollers must be arranged such that longitudinal and lateral thermal expansion of the lift span framing is not restricted.

4. **Guide Bars:** The guide shoes or guide wheels rub or roll on machined plates attached to the tower columns. The contact surfaces should be smooth and the rubbing surfaces lubricated.

5. **Centering Devices:** The purpose of the centering devices, which are usually located along the longitudinal centerline of the lift span, is to laterally center the span as it descends to the seated position. This action is important to ensure that finger joints on highway bridges mate and especially on bridges with railway tracks where the cantilevered extensions of the running rails must be lowered into joint castings having

little lateral clearance. Sometimes, the centering device bar is designed to also serve as the socket for the span lock.

6. **Span Locks:** Span locks are often provided on vertical lift bridges to ensure that the lift span does not rise inadvertently while traffic is permitted on the structure. Such an event can occur due to control malfunction or brake release on an improperly balanced lift span.

7. **Buffers:** Buffers were installed on bridges without automatic deceleration controls in order to reduce impact of the moving mass, if the operator should lower the lift span too fast. Most buffers cushion by compressing air and discharging it slowly.

Stabilizing machinery of other types of lift bridges are similar to that for the tower lift bridge just described. Recall from Part 3 Chapter 3 that Wisconsin does have lift bridges that do not rely on mechanical equalizing systems. The Wisconsin Avenue Bridge in the City of Milwaukee is an example of a structure that uses internal sensors within the hydraulic system to stabilize the hydraulic cylinders during operation. While this reduces the number of mechanical components an inspector needs to be aware of during an inspection, it is important to operate the structure under normal conditions to verify the bridge is operating and functioning as designed.

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