BASCULE BRIDGE LOCKING DEVICES

by

JAMES M. PHILLIPS, III

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I. INTRODUCTION

Bascule bridges are utilized to provide large vertical clearances where fixed bridges of greater magnitude and height would be impractical or impossible to construct. In the open position a portion of the superstructure is displaced from the path of marine traffic, thereby removing the obstruction which limits the passage of vessels with vertical dimensions exceeding the clearance of the closed bridge. In this position the bridge is not continuous across it's surface and must be closed to traffic which wishes to cross it. In the closed position the bridge will be open to traffic crossing it and must function as though it where a fixed bridge with a continuous surface.

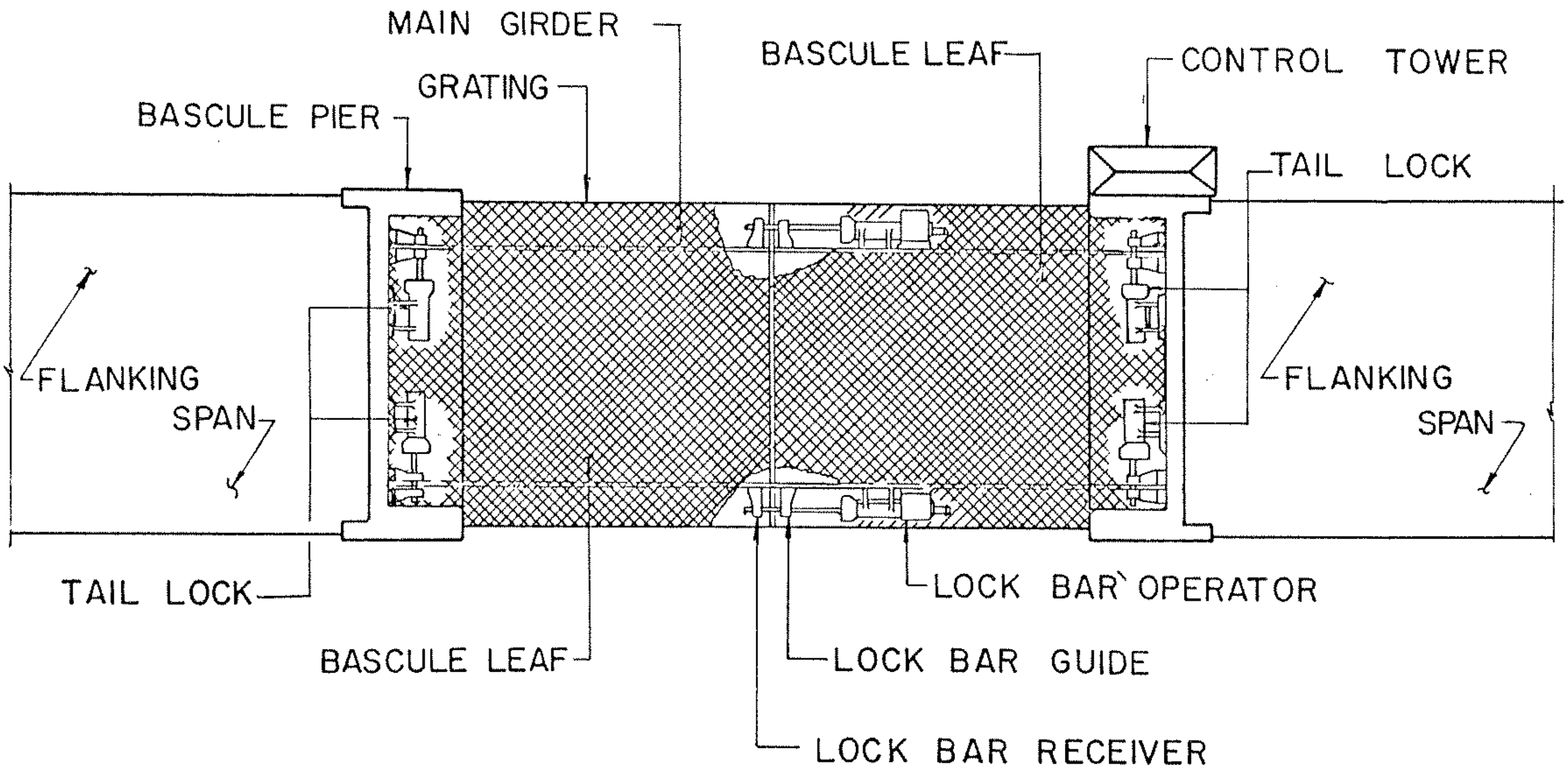
This paper deals with span locks which, along with tail locks, are used to insure the continuity of bascule bridge surfaces in the closed position. Tail locks secure the counterweight end of the leaf to the bascule pier while end locks secure the opposite end of the leaf to the rest pier or adjacent leaf. End locks on double leaf bascule bridges are called span locks.

Improper alignment of the locking system is commonplace. This problem, combined with improper span balancing and live load shoe adjustment, is responsible for many of the difficiencies found in bridge structures and drive systems. It is the intent of this paper to familiarize bascule bridge designers, owners, and maintenance personnel with span lock concepts and requirements and emphasize the importance of span locks as an integral part of the bridge.

This paper is limited to bascule bridge lock systems and will not consider locking machanisms for vertical lift or swing bridges. Various types of span locks will be discribed, but only driven bar type locks will be discussed in detail. The discussion of drive systems in this report will point out some basic requirements and configurations but will not attempt to provide detailed design data for motors, reducers, or other system components. Such detailed information can be obtained from the component manufacturers. Several recommendations will be made reguarding the selection and design of a new lock system and the renovation of existing bascule bridge locks. Finally, some new ideas for improved locks will be introduced and discussed.

II. LOCK FUNCTIONS ON BASCULE BRIDGES.

While the need for locking devices is clear, criteria for designing and maintaining them is not. This is evidenced by the great diversity of lock types seen in use throughout the United States. It is apparent that the function of locks should be examined and various types of lock systems scrutinized.



TYPICAL LOCK LOCATIONS

FIG. 1

One reason for lack of standardization in lock design may be the inadequate direction given by familiar institutions providing design standards. The current edition of the American Association of State Highway and Transportation Officials (A.A.S.H.T.O.) Standard Specifications for Movable Highway Bridges (1978) gives designers the following limited guidelines for span locks in section 2.1.4-Aligning and Locking:

> "Movable bridges shall be equiped with suitable mechanisms to surface and align the bridge and roadway accurately and to fasten them securely in position so that they cannot be displaced either horizontally or vertically under the action of traffic. Effective end lifting devices shall be used for swing bridges, and span locks for bascule bridges.'...'Span locks on movable bridges shall be designed so that they cannot be locked unless the movable parts are within 1/2 inch (0.013 m) of proper position."

End locks maintain the alignment of adjacent deck sufaces on movable bridges when the bridges are in the closed position. On single leaf bascule bridges end locks, tail locks, or both are used to insure the continuity of the deck surface along the joint between the flanking span and the counterweight end of the leaf and between the rest pier and the far end of the leaf. Similarly, tail locks and/or span locks maintain the alignment of the deck surface along the joint between the opposing leaves of double leaf bascule bridges as well as between the flanking spans and the tail end of both leaves.

On double leaf bascule bridges, span locks also transfer shear forces between oposing leaves. This causes the spans to deflect together when loaded, holding the ends of the leaves in relative alignment. Another result of this shear transfer is the reduction of negative moments in the loaded leaf's main girders due to the distribution of the load to the opposing leaf.

Properly operating lock mechanisms reduce vibrational effects of live loads on the structure and machinery. Locks which are poorly designed or maintained will often lead to excessive impact loads and vibration as vehicles bounce across the joint and the leaves bang against each other or the rest pier. These increased vibrations are transmitted throughout the leaves' structure and machinery causing accelerated deterioration and wear of both.

There are several general features of span locks necessary for proper performance and reliability. Of primary concern is the operation of the locking system. Lock systems must function within the operational system whether the bridge is operated by mechanical or hydraulic power or the control system is manual or by programmable controller. The lock system should be monitored by position sensors indicating engaged and disengaged lock conditions. Locks which are not fully engaged will not hold adjacent surfaces in line when heavy loads move across the joint. The only way for operators to be informed of the lock's status, other than visual inspection, is for a sensor to signal the status to the operator.

Lock systems must also be durable enough to withstand vibrations and forces to which they are subjected. Lock replacement is expensive so locks should be designed for durability.

Also of primary importance in lock design is maintainability. Locks should be accessable and adjustable. The designer should be familiar with maintenance procedures so the design does not hinder normal maintenance proceedures.

In addition to the requirements mentioned above, there are other factors, which while not of primary importance, should be considered when design, repair, or renovation of locks is undertaken. A good example of this is the use of independently driven locks as opposed to locks which share a common drive. The use of independ drives is inherently superior because falure of one component does not prevent operation of the other lock. This system also is more suited to the use of "shelf components" such as self contained operators. Shelf items, as well as factory assembled components are advantageous because they are readily available during construction or replacement and are manufactured under conditions favorable to those encountered in the field.

III. END LOCK SYSTEMS

A quick review of various bascule bridges will reveal the great variety of lock systems in use. A brief description of the most common lock types will provide the background required to analyse each type's advantages and drawbacks.

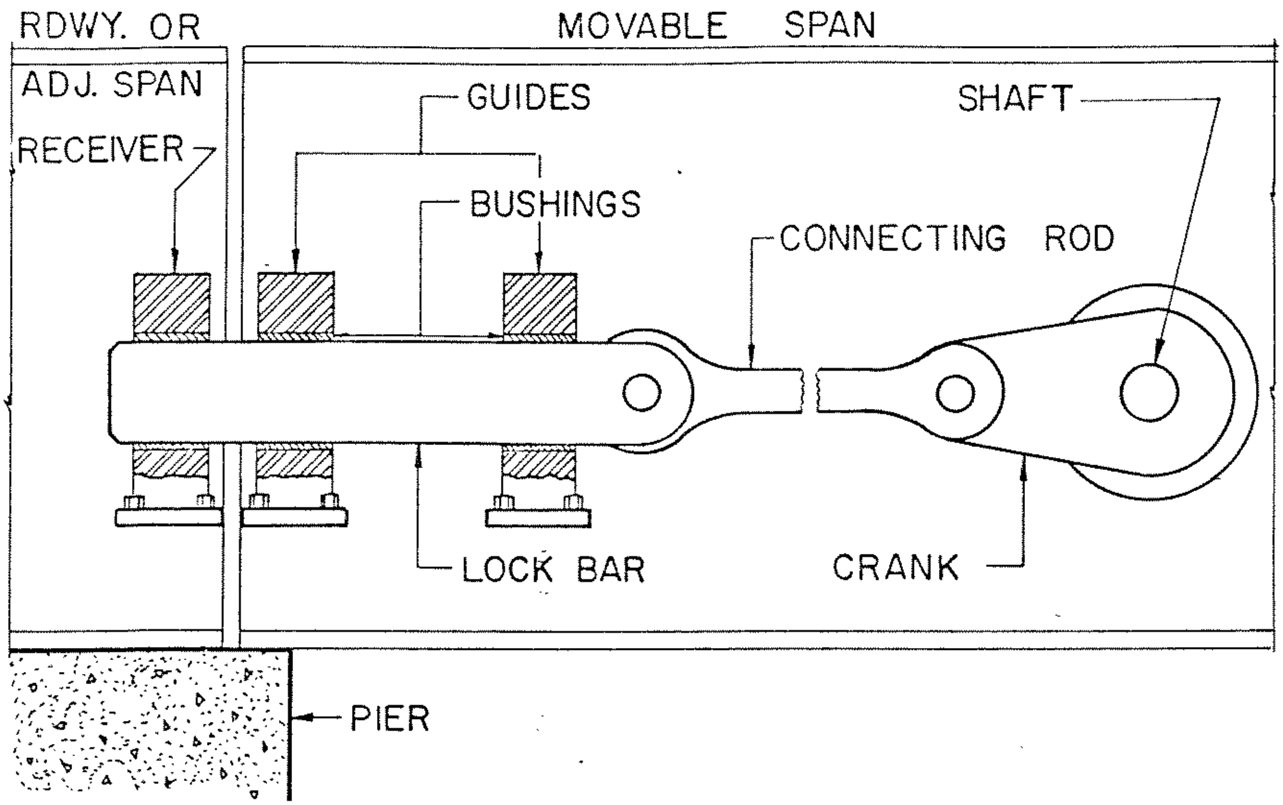
Driven Lock Bars: The most common and probably the most effective locking systems are of the driven lock bar type. Driven lock bar systems incorporate several methods to drive a rectangular or cylindrical shaft across the joint between opposing bascule leaves for double leaf spans or between the leaf and the rest pier of single leaf spans. One or two guides on the drive side of the joint and a receiver on the other side hold the bar in position and transfer the load from the bar to the main girder or rest pier. In general, driven lock bar systems are superior to other systems presently in use, because adjustment and monitoring is less complicated than for most other systems. However, use of cylindrical shafts is not recommended because alignment adjustments are difficult. There a three basic methods of powering driven lock bars.

a. Crankshaft: Crankshaft driven lock bar systems sometimes referred to as conventional systems, drive and pull the lock bar by turning a shaft which in turn actuates a crank and rod connected to the end of the lock bar (see figure 2). For these systems, the lock bar is usually contained within two guides on one side of the joint and one receiver on the opposite side. The motor may be located on the bascule pier or out on the bascule leaf. There may be one motor for each lock bar or, more commonly, one motor for each pair of lock bars. In either case, a reducer and set of gears or combination of shafts and links, or both reduce the rotational speed and transfer the force to the lock bar(s). Because the rod which is connected to the lock bar is free to rotate at the crank end, the lock bar must be fixed against rotation. For this reason crank shaft systems should include two guides for each lock bar.

b. Self-contained lock bar operators: Self contained lock bar operators incorporate the motor, gear reduction, lock bar, and limit switch within one unit (see figure 3). Forces are transmitted to the lock bar through a gear and acme screw or set of helical gears. There are several advantages to these systems including reliability, ease of adjustment, and simplicity of operation. These systems usually have only one guide and one receiver because the operating unit provides stability of one end of the lock bar. These units have the advantages previously mentioned for independently driven shafts. Reliability of these systems may be improved over other systems because they are assembled under factory conditions rather than field conditions.

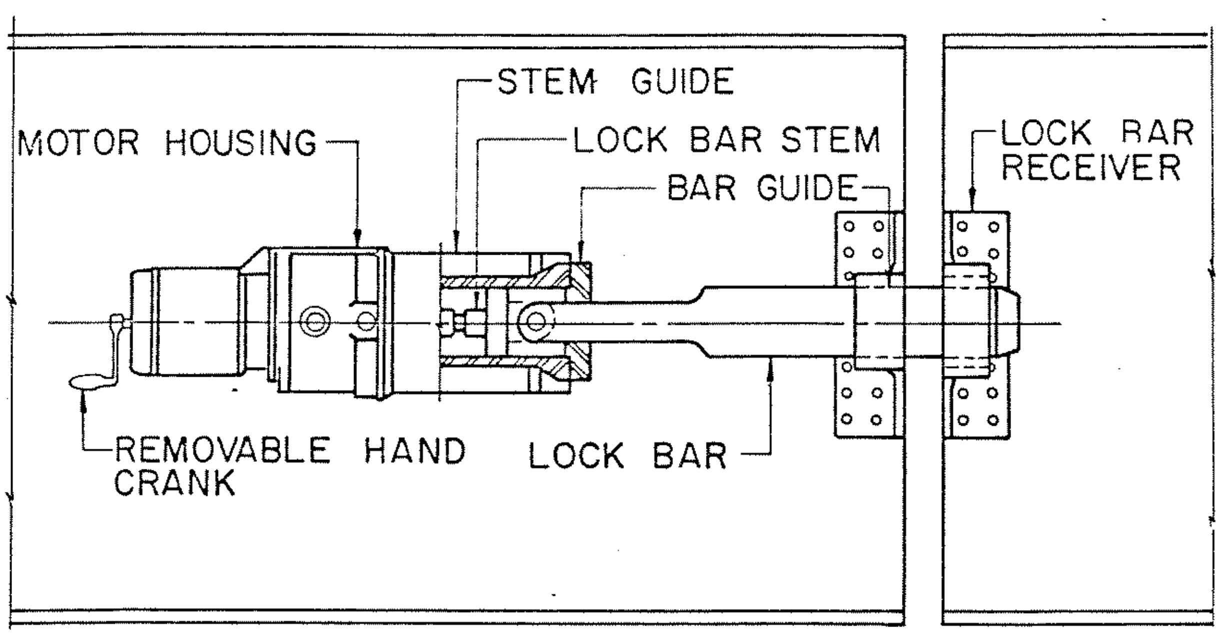
c. Hydraulic cylinder: Hydraulic cylinder driven shafts are similar in configuration to self-contained units except the gear reduction and motor are replaced by a small medium pressure hydraulic cylinder usually about 3 inches in diameter. Also, the position sensors are separate external items. While this system does not have the advantage of factory construction, it does provide for longer travel changes without adjustment and pressure sensing capabilities. Pressure sensing, which can be utilized in self adjusting lock bars will be discussed later. Hydraulic systems have the advantages of shelf item components as well as those previously mentioned for independently driven locks.

Interlocking Leaves: Some older bridges interlock the ends of the main girders as they close providing continuity and locking. One main girder is equipped with a key or tongue while the opposing leaf's main girder has a keyway formed by two jaws placed one above the other. This system requires the leaves to be closed in a particular order, either simultaniously (typical for rolling type bascules) or one side prior to the other (typical for trunnion type bascules). Normally, the procedure for closing double leaf bascule



CONVENTIONAL LOCK BAR ASSEMBLY

FIG 2



SELF CONTAINED LOCK BAR OPERATOR

FIG 3

bridges equipped with interlocking leaves involves lowering one leaf to within a few feet of the closed position and then lowering the other leaf until its tongue rests on the lower jaw of the first leaf. The two leaves are then closed simultaniously, incerting the tounge between the upper and lower jaws. The lock is broken by opening of the leaves. Such procedures require more time and effort on the operators behalf than most other lock systems. Not only does this extend the total time required to operate the bridge but the operators extensive braking to align the key and keyway may reduce machinery life by imparting additional forces on the operating machinery.

Interlocking leaves require greater tolerances between sliding parts and therefore tight fits are difficult to obtain and maintain. In addition to other shortcommings, the major drawback for this system is the inability to operate one leaf without the other. This may become necessary when one leaf's drive system is out of order and the bridge must be opened to maintain marine traffic.

Spring Loaded: Spring loaded lock systems are similar to driven lock systems in that they drive a bar across the joint. The major difference being that these systems derive the driving force from a spring and do not pull the lock back before the bridge opens. The lock is broken by the opening of the leaves. When the leaves approach the closed position a striker plate forces the bar toward the spring until it clears the plate. As the bar passes the striker plate the spring forces it out into the guide. These systems may be shimmed and are easy to maintain. However, breaking of the lock tends to wear down the bar and receiver shoes rapidly, causing alignment problems. Spring loaded systems are also difficult to monitor which may result in machinery damage if the leaves are opened when the lock is jammed.

Miscellaneous (mechanical clamps, leavers): There are several other systems which lock the leaves together by mechanical means. Some of these resemble scissors or clamps, and others wedges. Almost all of these devices are difficult to shim or adjust and are prone to failure due to the complexity of the drive mechanisms.

IV. DESIGN OF DRIVEN LOCK BAR SPAN LOCKS

Design Loads: Lock bars must be designed to transfer shear forces across the joint without excessive stress or wear. The shear force should be calculated based on A.A.S.H.T.O. loadings and the bascule span geometry. For the purposes of analysis the closed lock should be considered to act as a hinge, transferring shear but no movement. No attempt should be made to design lock bars to transfer moment across the joint. The relatively small depth of penetration of the bar into the receiver combined with the sliding fit of the bar and receiver does not fix the bar to form a moment connection. The total shear force on the span should be evenly divided between the lock bars on the span.

Lock location: Locks transfer forces across the joint from one main girder to the other and should therefore be located on the main girders. Each main girder should have a span lock and the locks should be symmetrically located so as not to induce torsion on the span. By locating the locks on the outside of the main girders it may be possible to provide access to the locks through the sidewalk rather than the roadway. This will limit traffic disruptions during maintenance and reduce the amount of roadway grit and debris which falls on the lock bar and drive system. Where possible locks should be enclosed in a cage and maintenance platform. When locks must be located between the main girders they should be well protected from roadway debris and accessable through a hatch in the roadway surface. One side of the cage should be designed for easy removal to provide access to locks for installation or service from below.

Tail locks are not recommended because they do not provide positive alignment of the far ends of the span. The length of a bascule leaf is much greater on the span side than the counterweight side, so locating locks on the counterweight end does little to limit deflections at the other end. Conversely, the joint between the flanking span and bascule leaf is very close to the main girder supports and the depth of the main girder is greater behind the supports than over the channel so the deflections at this joint are minimal. Redundant tail locks, those used in conjunction with end locks, are not recommended because they complicate structural analysis of the leaves and increase the number of mechanisms to be monitored and actuated during bridge operation.

Lock servicability and adjustment: The importance of span locks is such that service and maintenance of their components cannot be overemphasized. The fit of the lock bar and receiver must be maintained at acceptable tolerances for locks to function properly. This dictates a locking system which is accessable and adjustable. The lubrication fittings for the lock drive, guides, and receivers should be mounted on the deck or in a location accessable from the deck without difficulty. Maintenance personnel should be able to service or adjust the lock bar, drive system, and position sensors by way of a secured hatch on the deck or from the oposing span with the leaf partially open.

Alignment of the leaves should be possible with the application or removal of shims between the lock bar guide or receiver and the wear plates or shoes. These shims and shoes should be installed with cap screws or some other method which allows for shoe adjustment or replacement.

Lock system materials: Selection of materials for use in span lock system components is beyond the scope of this paper, however, the following design considerations are given. The designer must accept the inevitability of wear and respond by controlling the location of it. Replaceable shoes are an effective means of maintaining alignment only if the wear is concentrated on them. The following combination of lock bar and shoe materials has been used successfully in the past: lock bars of forged steel ASTM A668 class D and shoes of ASTM B22 Alloy C.

Fits and finishes: As previously noted, A.A.S.H.T.O. requires the bar-receiver fit to be such that the locks cannot be engaged if the leaves are not within 1/2 inch of proper position. This is a minimum requirement which can easily be met, however, it does not insure proper alignment of the leaves. With 1/2 inch of play the leaves will be free to bounce against each other as traffic passes across the joint. Earle Industries recommends a vertical clearance between the bar and shoes of 0.01 inches, preferably 0.005 inches top and bottom. This fit allows the bar to move freely when actuated while limiting relative motion between the leaves. Horizontal clearances are not nearly as critical, in fact the locks should not pull the girders into alignment horizontally. If the lock bar has 1/4 to 1/2 inch of clearance on either side, it should operate properly. *If the horizontal alignment is out more than 1/2* inch, the lock bar should not fit and the position sensors should inform the operator of the problem. For bascule bridges, such mis-alignment indicates excessive wear of the trunnion bearings or the flat tracks which should be repaired immediately.

Protection from the environment: Since most bascule bridges are located over water, locks are usually in a corrosive environment. In addition, roadway grit and debris can damage drive equipment and accelerate wear of the bars, guides, and receivers. Proper lubrication, materials, location, and protective covers will extend lock life and reduce repairs. Protective covers may include housings to enclose the mechanism or flexible boots to cover the lock bar which are available from some manufacturers of self-contained operators. Protective covers are especially useful where locks must be located below open roadway grating.

Emergency operation: All lock systems should have provisions for emergency operation during loss of power or other breakdowns. Self-contained units are normally equipped with hand cranks for emergency operation. Hydraulic systems should include a relief valve and an auxilliary power pack.

Electrical Requirements: There are two basic elements of a span lock system which require electical service, the drive system and the monitoring system. The drive system usually requires power and control to operate a motor or hydraulic pump. The control of the drive must be interfaced with the monitoring system and the operators switches or programmable controler.

Electrical sensors serve three puposes in span lock systems. First, they control the movement of the locks, stopping travel at the fully driven and fully pulled positions. Secondly, sensors provide interlocking to prevent bridge operation when the locks are not in the proper position for a given operation. Finally, they provide the bridge operator with an indication of the completion of the operation.

Sensors used in bridge span lock monitoring consist of two main types, limit switches and proximity switches. Limit switches are trip actuated by a cam or dog on a moving portion of the lock mechanism. Conversly, proximity switches have no moving parts but detect the precence of targets within a specified distance. Both types of sensors must be mounted in a maner which provides a means of vertical and horizontal adjustment to compensate for lock wear and alignment during installation.

Electrical power should be supplied to the span lock drive mechanism and electrical sensors in accordance with manufacturer's specific recommendations.

V. LOCK OPERATION

The sequence of lock operation is mostly clear cut. Locks must be pulled before the bridge is opened and driven after the bridge is closed. Opening presents no operational dilemmas, the leaf drive system should not be activated until the sensors indicate all locks are completely pulled. Closing, however, does present a problem worthy of discussion which has designers divided over two concepts. Some engineers believe the leaves should be driven down to the live load shoes and the locks driven before the leaf motors are turned off. Others prefer to shut off the motors before the leaves contact the live load shoes and allow the leaf to drift into final position before the locks are driven.

Theoretically, the second concept is recommended by the author. Leaf alignment should be such that under dead load only conditions no forces are applied to the locks. Such forces may jamb the lock in the closed position and damage the lock drive system. Driving the locks into position may produce deflections which result in lock bar forces when the motors are shut off and the spans try to return to their unloaded position. The drawback to this concept, which promotes the opposing concept, is that it requires the leaves to be properly balanced. Proper balancing results in an unbalanced load favoring the span side of the leaf. Under this ideal condition the leaf will settle on the live load shoe under its own weight. If the leaves are not end heavy enough to overcome frictional forces and buffer resistance they will stop before reaching the load shoe unless power is supplied to drive it down.

The author believes the locks should be set up to operate under the ideal design conditions. If field conditions dictate additional power is required to seat the leaf, the bridge should be driven into position only until the span can be properly balanced.

VI. NEW SELF-ADJUSTING DESIGN

In an effort to eliminate many of the bascule bridge defficiencies which have been found during inspection of existing bridges which can be linked to lack of spanlock maintenance, Pat Yaskin, P.E., vice president of Kunde, Sprecher, Yaskin and Associates, Inc and the author have developed a hydraulic span lock system which is self-adjusting. Self-adjusting in this case means that the lock continues to fit tightly (within tolerance) in the receiver as the shoes wear.

The system will first be tested early in 1985 in a replacement for the existing spring loaded lock system on the Treasure Island Causeway linking the City of Treasure Island, Florida with St. Petersburg, Florida. It should be noted that the span drive machinery on this bridge has already been replaced with a hydraulic system and programmable controller, both of which are desirable conditions for the application of the new design.

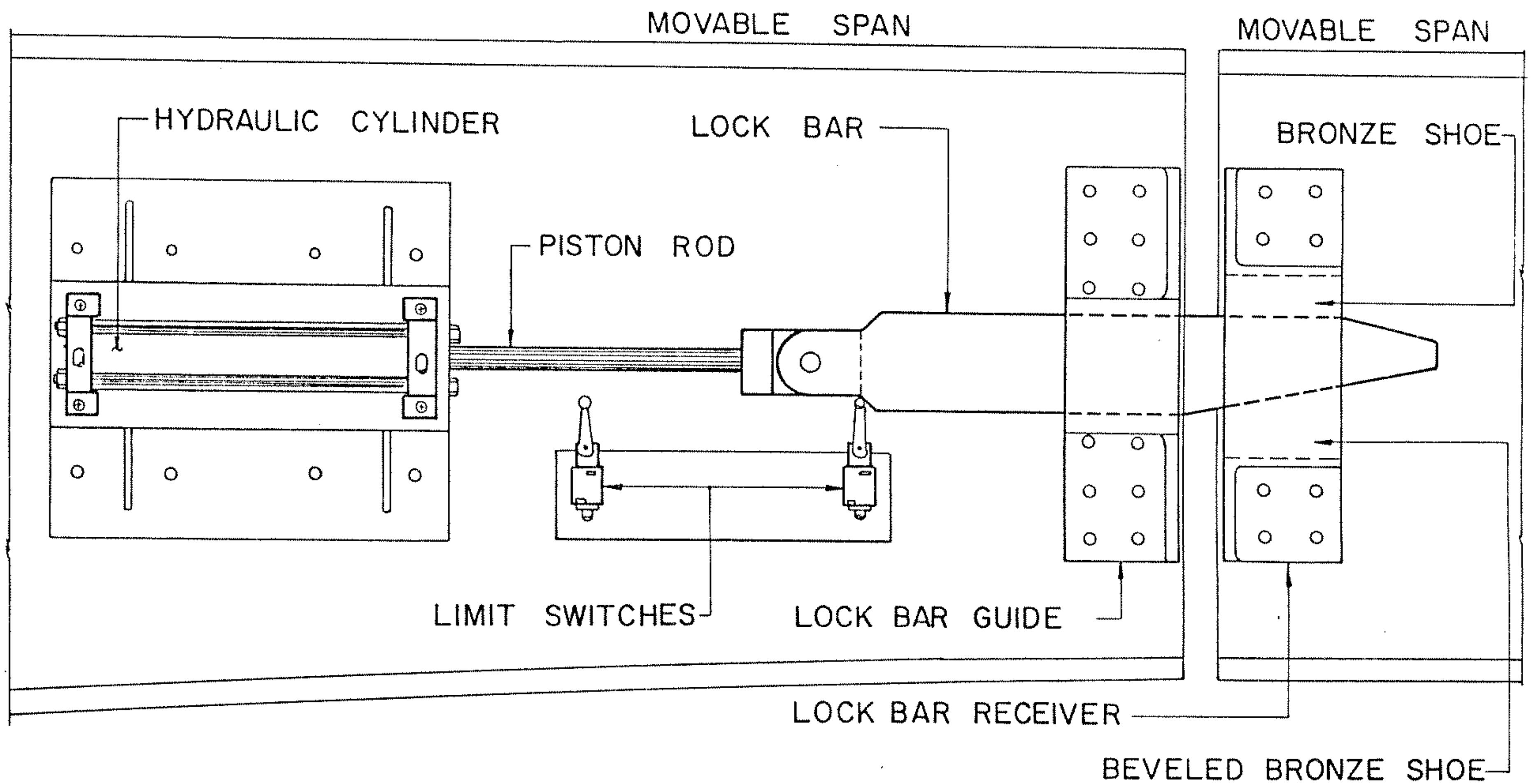
The outstanding difference between this system and other modern systems is the use of a beveled or wedge shaped lock bar and receiver shoe. As the softer shoe wears, the hydraulic cylinder will drive the bar farther into the receiver until proper fit is obtained. The bevel is located on the bottom of the bar so that final positioning of the leaves is controled by the flat surface on the top of the bar which is not subjected to excessive wear (see Figure 4).

In order to maintain full monitoring, this system incorporates three sensors for each lock bar. In addition to the limit switches used to indicate fully drawn and fully driven positions, a pressure sensing guage in the pressure line to the hydraulic cylinder will be included. This guage will generate a signal to stop driving the lock when the lock is fully seated in the receiver as indicated by the build up of pressure in the cylinder. The limit switch on the receiver side of the lock must also sense that the lock is fully driven for the driving to stop normally. This double signal is necessary to prevent the pressure sensor from being tripped if the lock were to jam against the exterior of the receiver without being locked. Similarly, the programmable controller used to operate this system will be able to warn the operator of aligment problems if the clyinder pressure continues to increase but the limit switch on the receiver side is not actuated.

Power to drive the locks will be supplied from hydraulic pumps which drive the leaves. As a backup, an emergency power pack will be installed so that the locks can be operated if the main power supply fails.

VII. LOCK MAINTENANCE AND INSPECTION

Inspection: Span lock systems should be periodically inspected for the following:



SELF-ADJUSTING HYDRAULIC SPAN LOCK

FIG. 4

1.) Proper lubrication of motors, guides, and receivers
2.) Functioning limit switches
3.) Span alignment, shoe and bar wear, especially uneven wear.
4.) Lubrication system should be supplying the shoes with clean grease, all lines should be intact.

Lubrication: Bar guides and receivers should be checked and lubricated weekly. Exxon Lidok EP-0 or equal is suggested by Earle Industries. For self-contained operating units and other factory equipment, refer to manufacturer's lubrication recommendation.

VIII. REHABILITATION AND REPLACEMENT

Rehabilitation of Existing Locks: Existing locks which utilize acceptable lock mechanisms should be maintained or repaired unless they are beyond economic repair. Cylindrical shaft lock bars should be updated to rectangular shafts and associated guides and receivers to enable shimming for proper alignment. All locks should be shimmed to proper alignment. Locks which do not have proper lubrication fittings or protection from roadway grit should be provided with such. Limit or proximity switches should be installed on all lock systems which are not so equipped. It may be advantageous to add service platforms to systems which are difficult to access. In all renovation projects the addtion of extra weight must be considered by the designer as it may result in span balancing problems. Replacement of operating systems may evoke a need for renovation or replacement of the lock system to provide compatability. For example, the installation of a fully automatic programmable controller to operate the leaves must be accompanied by the replacement of spring loaded lock systems which cannot be controlled by the operating system.

Tail lock systems found on bascule bridges may be removed if the designer determines them to be redundant. This is advantageous because it reduces the number of mechanisms to be operated and monitored and simplifies the analysis of forces on the end locks.

Replacement of Existing Locks: Lock systems which are damaged beyond repair or are deemed insufficient because they are prone to breakdowns, non-adjustable, or non-fuctional, should be replaced with new locks utilizing independently driven, fully monitored, rectangular shafts. Where bridges are to be equipped with programmable controllers the lock system installed must be compatable with their operation.

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