AMERICAN CONSULTING ENGINEERS COUNCIL'S

AFFILIATE

HEAVY MOVABLE STRUCTURES, INC.

4TH BIENNIAL SYMPOSIUM

NOVEMBER 10TH - 12TH, 1992

SHERATON DESIGN CENTER
FT. LAUDERDALE, FLORIDA

SESSION WORKSHOP NOTES

#28 Author: Robert L. Cragg
Steward Machine Co.
"Energy Absorbing Span Lock System - Bascule Bridges"

ENERGY ABSORBING SPAN LOCK SYSTEM FOR BASCULE BRIDGES

Presented by:

Robert L. Cragg, P.E.
Consultant

4th Biennial Symposium
Heavy Movable Structures/Movable Brdiges
Ft. Lauderdale, Florida
November 10 - 12, 1992

Energy Absorbing Span Lock System
For Bascule Bridges

Generally span locks on movable bridges are required for two purposes:

1. To hold the span securely down and in contact with the live load shoes.
2. To prevent the span from accidentally opening from the closed position.

In the case of a two-leaf bascule bridge the span locks have additional responsibilities:

1. To vertically align the leaf tips.
2. To transfer shear loads from one leaf to the other.
3. To provide for uniform deflection of the leaf tips under conditions of unsymmetrical loading.

Several types of locks have been used to accomplish these purposes. They include tension/compression type devices located on the bottom and top chords, such as the complicated mechanism patented by Mr. Cummings in 1901; spring loaded members that snap into place as the leafs close; interlocking members on each leaf tip; overlapping struts that bear on the deck; transverse bar locks like the system patented by Mr. Gilbert in 1952; and a variety of others. But the most popular and successful have been bar locks and jaw locks located on the bascule girders such as those illustrated in Figures 1 and 2.

It is the purpose of this paper to discuss common problems with span locks that relate to providing and maintaining suitable fits (vertical clearance) between the locking device and the receiver and the locking device and guide, if used. No discussion will be offered concerning the machinery system required to insert and withdraw the locking device.

Ideally the shear connector, or span lock, should accept vertical loading with no more deflection than that experienced by the other sections of the leaves. Unfortunately, as a practical consideration, this condition is not achievable. Yes, when first installed clearances between the mating parts may be held to a minimum but they quickly increase as the units are operated and subjected to the passage of live loads.

Several conditions contribute to the failure of locking devices to perform efficiently :

1. Improperly adjusted live load shoes that permit excessive vertical movement of the leaf tips.

2. Too much clearance between the locking device and receiver. On a bar lock this is between the bar and guide and bar and socket, while on a jaw lock the clearance is between the jaws and the receiving box.

3. Normal wear as a result of inserting and withdrawing the lock.

4. Pounding out of the bearing surfaces between the lock and the guides and receivers.

Usually means are provided to adjust the units, take up for wear and close down on the vertical clearances to avoid excessive vertical movement and resultant distress on the system. Unfortunately, the means of adjusting the vertical clearance is normally cumbersome and rarely, if ever, performed properly.

In Jaw Locks the throw of the jaws is adjusted by rotating eccentric pins, about which the jaws rotate, to set the vertical clearance between the jaws and receiver. Generally these pins are difficult to move after the locks have been subjected to dirt, rain, salt, snow and other adverse environmental conditions. Add to this the fact the pins are normally not in readily accessible locations together with a lack of familiarity with the adjustment procedure and its easy to understand why maintenance personnel avoid making adjustments.

Bar Locks, Fig. 3, are more easily adjusted, but it's still no easy job. While some guides and sockets are fitted with adjustable bronze wear plates, or shoes, others have the bar directly in contact with the guide or socket housing which is nearly always either a steel casting or weldment. If the bar bears directly on the steel housing wear can not be taken up except by reworking the bar, guide or socket or all three. An expensive and time consuming job.

Some guides and sockets have shims or other means of adjusting the position of the opening and controlling the clearance of the shoes over the bar. Even so it is necessary to have the correct shims and the available service interruption time to complete the adjustment. Other designs do not provide any shimming or other adjustment devices; accordingly, any adjustment requires major surgery in place or removal of the bar, guide and socket for rework in a shop.

The problem of excessive vertical clearance in span locking devices is common and of great importance. Engineers normally call for the vertical clearance to be in the 0.020 in. range; yet after being in service even a short time it is not unusual to have clearances increase greatly. In fact some span locks in service permit vertical movement of one leaf tip with respect to the other of 1-1/2 inches or more. This is a serious condition and one that can lead to severe consequences; a vehicular accident involving personal injury and/or damage to the bridge, for instance.

Certain facts are evident:

1. The greater the vertical clearance the more quickly the clearance will continue to increase.
2. With greater clearance the shock loads on the structures are increased and can result in insidious failure of those members.
3. Shock loads on the guides and sockets can contribute to their failure.
4. Increased clearances permit the leaves to "bounce" with resultant damage to the live load shoes and supports as well as probable harm to the operating machinery. The racks and pinions are particularly vulnerable to distress under these conditions.

Ideally no clearance should exist between the bar and shoes and the vertical opening be exactly equal to the height of the bar. Theoretically the bar would enter the receiver without interference and a line to line contact between the bar and shoes would transmit the shear loads smoothly from one member to the other. Also provision to take up for wear would be desireable. The idea is to control the vertical clearances and make it easy to compensate for any wear.

Designs have been developed that partially achieve both objectives. The first of these, Fig. 4, is a guide that is equipped with tapered spacers between the upper and lower shoes. As wear occurs the wedges are adjusted to position the shoes closer together and reduce the vertical clearance between bar and shoes. This is a step in the right direction but it does not represent much improvement over former designs that permitted adjustment of the shoes by means of shims. In both cases someone has to do the work; has to observe the condition and has to make the adjustments. This design also has certain aligning capabilities to accept initial misalignment between the guide and socket.

Another design, Fig. 5, using a tapered bar, considered a "New Self-Adjusting Design" was presented and discussed by Mr. James M. Phillips, III at the First Biennial Symposium and Exhibition on Movable Bridge Design and Technology, held in Tallahassee, Florida, November, 1985. Mr. Phillips pointed out this design is self-adjusting to the extent the lock continues to fit tightly and within tolerance in the receiver as the shoes wear. In this case the lock bar has a tapered end that enters the receiver and as the bronze shoe wears the tapered bar is merely inserted further, thus taking up for wear. The positioning of the bar in the receiver would be controlled by the force required to bring it to bearing and not by the length of some predetermined stroke. This is also a good approach, as far as it goes. But it may be seen that although it accommodates wear in the receiver on one leaf no correction is made for wear in the guide on the other leaf.

While both of these designs have advantages over prior concepts and, to some extent, facilitate adjustment of the clearances between bar and shoes neither has addressed the problem of repetitive shock loads applied to the shoes and bar during the passage of heavy traffic.

Steward Machine Co., Inc. has recently developed guides and sockets that provide intimate contact of the bar and shoes, continuous adjustment for wear and cushioning of the shock loads. In concept these energy absorbing guides and sockets are fitted with spring loaded shoes adjusted so the bar remains in contact with both shoes in each guide and socket. Continuous contact is assured because all shoes are slightly pre-loaded when the bar is inserted. Therefore as one shoe carries live load and compresses its supporting springs the other shoe maintains contact with the bar as its springs expand. Conceptually it is very simple as seen in Fig. 6.

This figure depicts a bar and the top shoe of a receiver. Keep in mind, although not shown, there is also another shoe at the bottom of the bar, identically spring loaded. 6(a) shows the receiver before the bar is inserted, the vertical distance between the shoes is less than the height of the bar. 6(b) illustrates the condition with the bar inserted, both shoes have compressed their supporting springs a predetermined amount. In 6(c) a load has been applied causing compression of the spring supporting the upper shoe; however, as that spring compresses the lower spring expands so that both shoes remain in contact with the bar. In addition it may be seen that the springs also cushion and buffer the shock load.

Of course as the spring compresses it permits the tip of the leaf to deflect. At the same time, though, the shear load is transferred by the bar to the companion leaf, having a similar guide which responds in a like manner and maintains a uniform relationship between the leaf tips, within the limits of the total spring deflection.

It is recognized the spring must be very stiff, having a high spring rate and sufficiently long to provide for pre-loading as well as additional compressive length.

The design as completed is shown in Fig. 7. This illustrates the bar inserted through the guide on one leaf and into the receiver on the other leaf.

Disc, or Belleville, springs were selected since they offered desireable spring rates as well as the convenience of stacking in order to obtain a manageable spring stack height. Notice that no matter how many discs are in the stack the load to flatten them does not change, it remains constant; the only thing that varies is the distance along which the load must be applied. For instance, if the dish height of one washer is 0.087 in. and it takes a load of 14,000 lbs. to flatten it, that load will travel 0.087 in. Then, a stack of 2 washers will also require a 14,000 lb. load to flatten them but the load will now have to be applied through 0.174 in. (2 x 0.087).

Selection of the disc springs must be done considering the anticipated applied loads. The units shown are typical for a two girder bascule bridge. Hool and Kinne in their book "Movable and Long Span Bridges" suggest the total shearing stress transmitted by the center locks of a two girder bridge to be 40,000 lb., or 20,000 lb. per lock as there would be one lock for each girder. This closely corresponds to an AASHTO HS-20-44 loading as defined in Section 1.2.12.

For this application we selected the springs just discussed. Each shoe is supported with two stacks of 2 washers. The vertical opening between the upper and lower shoes before inserting the bar is 5.950 in. so that when inserting a 6 in. high bar each shoe is pre-loaded 0.025 in. On the springs selected this equates to a pre-load of 2,000 lb. per stack, or 4000 lb on both the upper and lower shoes. The remaining compressive distance is 0.149 in. per stack, or a load of 12,250 lb. per stack or 24,500 lb. total in either direction, up or down. Since the anticipated shear loading is 20,000 lb. the disc springs will not completely flatten.

Now, if the loads exceed the design criteria the springs will continue to support them, until and beyond the load required to flatten the disc springs. The unit is designed so that a slight clearance (0.007 in.) exists between the housing and bronze shoe when the springs are deflected to a flat condition. Of course, when this occurs the impact has been substantially cushioned. Since disc springs are largely self-dampening no additional dampening devices are necessary. In this design the maximum vertical misalignment of the leaf tips is about 0.300 in.

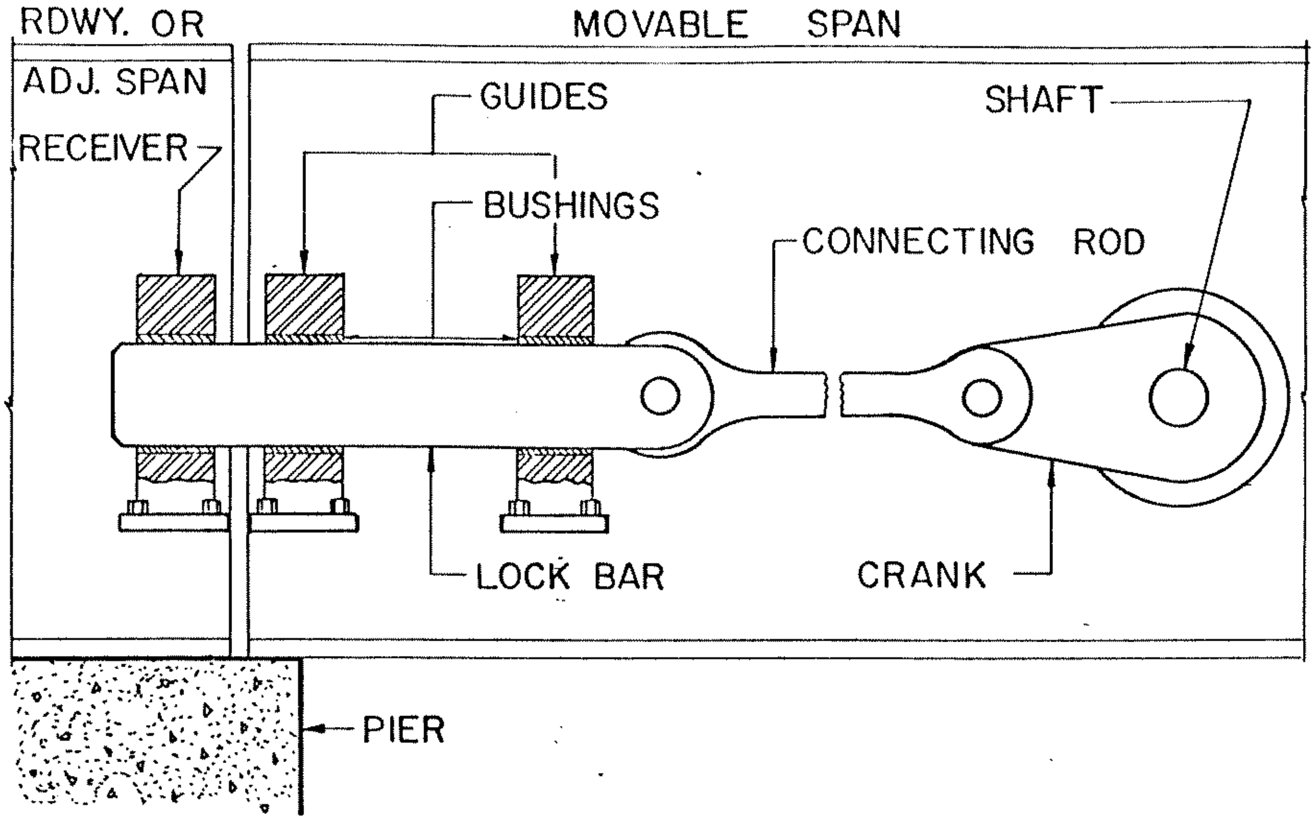
Although this paper did not intend to discuss the machinery required to operate the bar it is necessary to recognize that suitable power must be available to insert and withdraw the bar through the pre-loaded shoes. In the design discussed, using a linear bar speed of 1.5 in./sec. and a conservative Coefficient of Friction of 0.2, the Horsepower required is about 0.75.

As the springs deflect during passage of vehicular traffic the guide pins move vertically in a bronze bushing, lubrication to both the bushing and springs is introduced through drilled passages in the pin. A cylindrical, stainless steel sleeve around the outside circumference of the 17-7PH stainless steel disc springs retains the lubricant. Hardened washers, also stainless steel, are placed at the top and bottom of each stack of springs to prevent damage to the housing and shoes as the springs deflect. The shoes are, of course, a high quality machined bronze casting. Housings can be either steel castings or weldments.

Over a long period of operation the shoes and/or bar will wear until such time as the pre-load is reduced to an amount that permits vertical clearance between the bar and shoes. Replacement shoes are then necessary. They are relatively easily installed merely by withdrawing the bar, removing the covers over the pin ends, releasing the pins and shoes after removing the pin retaining rings ands installing new shoe and pin assemblies.

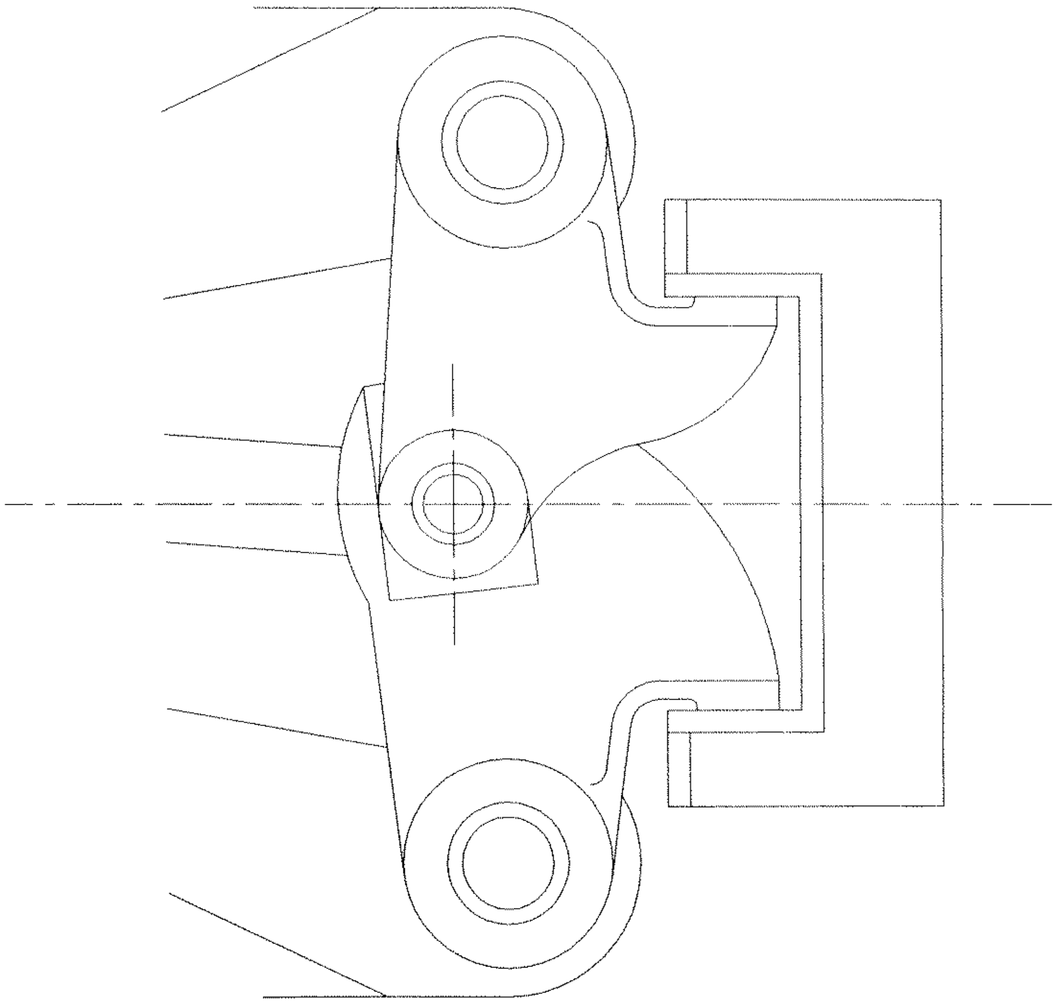
Another interesting feature is that the same concept can be applied to the receiver for jaw locks as shown in Fig. 8.

Steward Machine Co., Inc. is currently testing prototype units in their shop, they will subsequetly tested by an outside agency and then field tested on heavily travelled bridges. While the results look good so far our long experience in bridge machinery dictates that only after exhaustive testing will we know if theory is supported by fact.



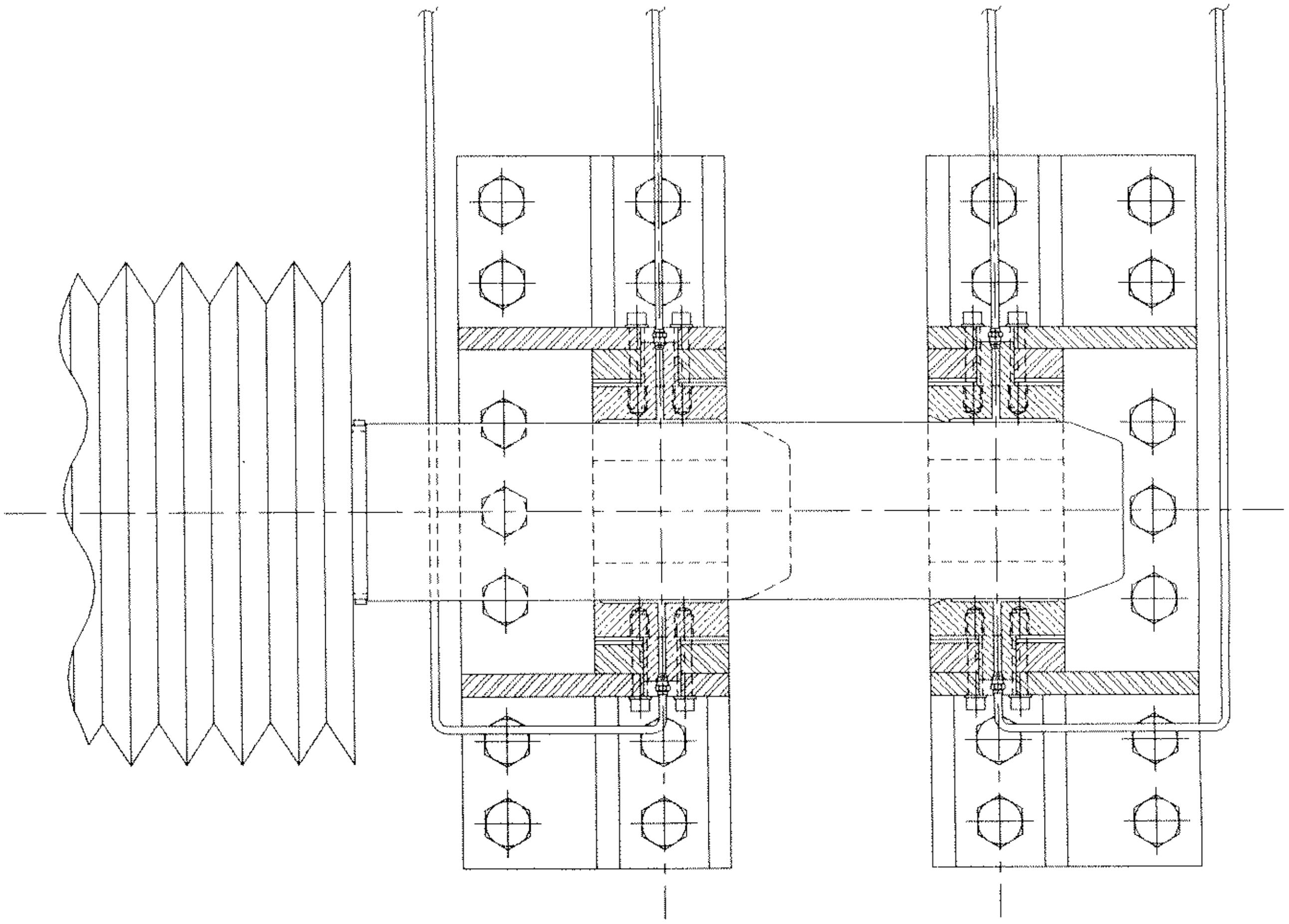
CONVENTIONAL LOCK BAR ASSEMBLY

Fig.1



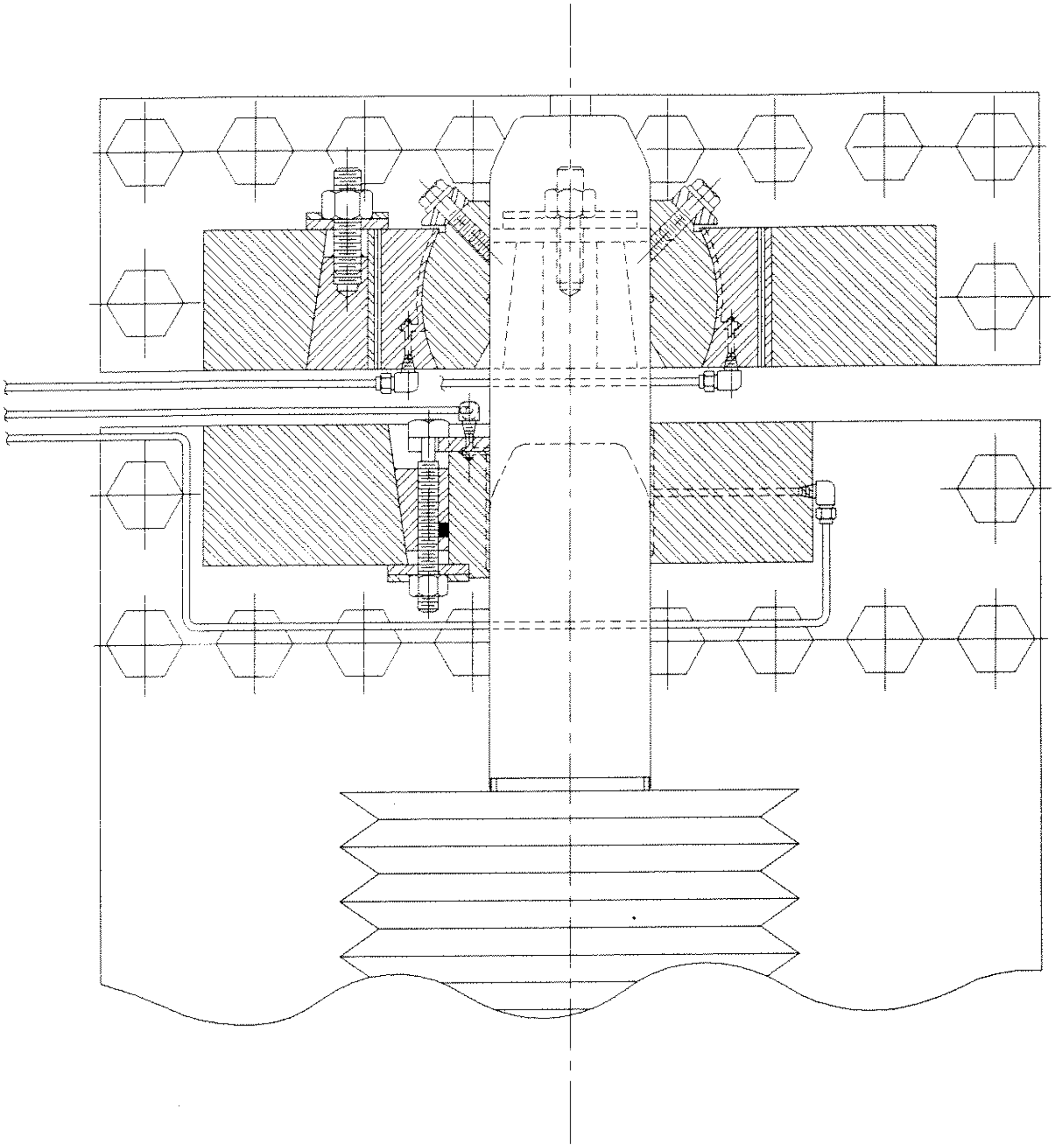
JAW TYPE SPAN LOCK SYSTEM

Fig.2



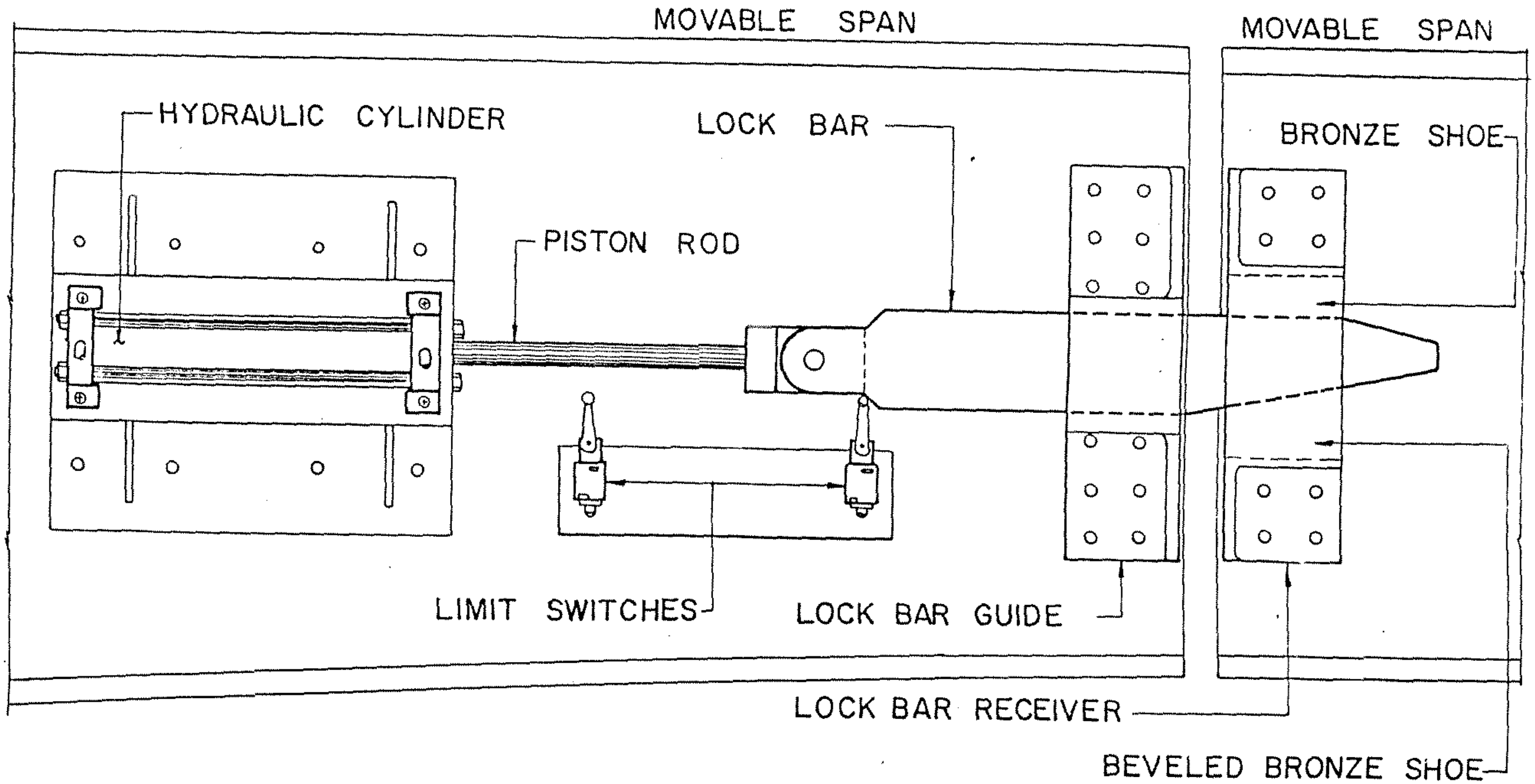
EARLE® SPAN LOCK SYSTEM

Fig. 3



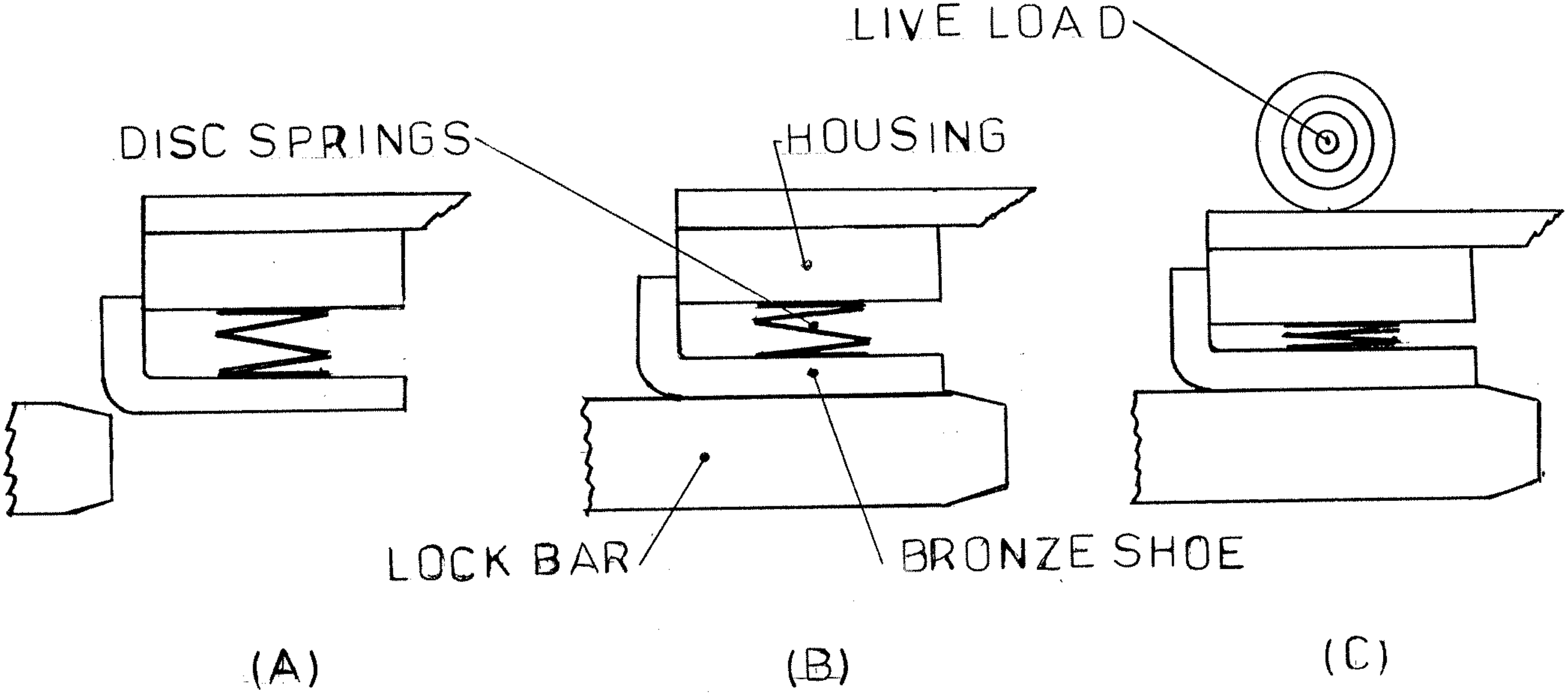
SELF-ALIGNING SPAN LOCK SYSTEM

Fig. 4



SELF-ADJUSTING HYDRAULIC SPAN LOCK

Fig. 5

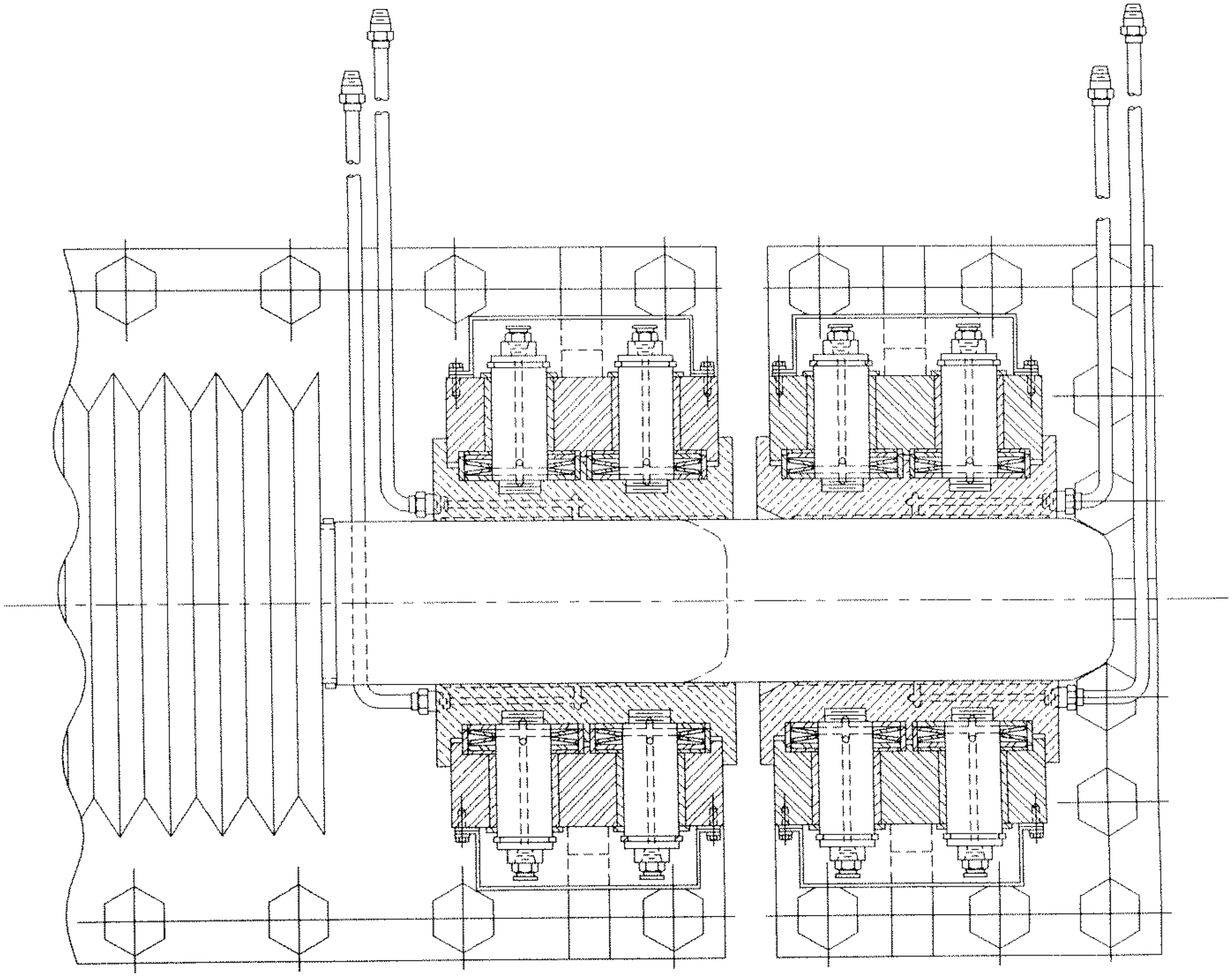


(A)

(B)

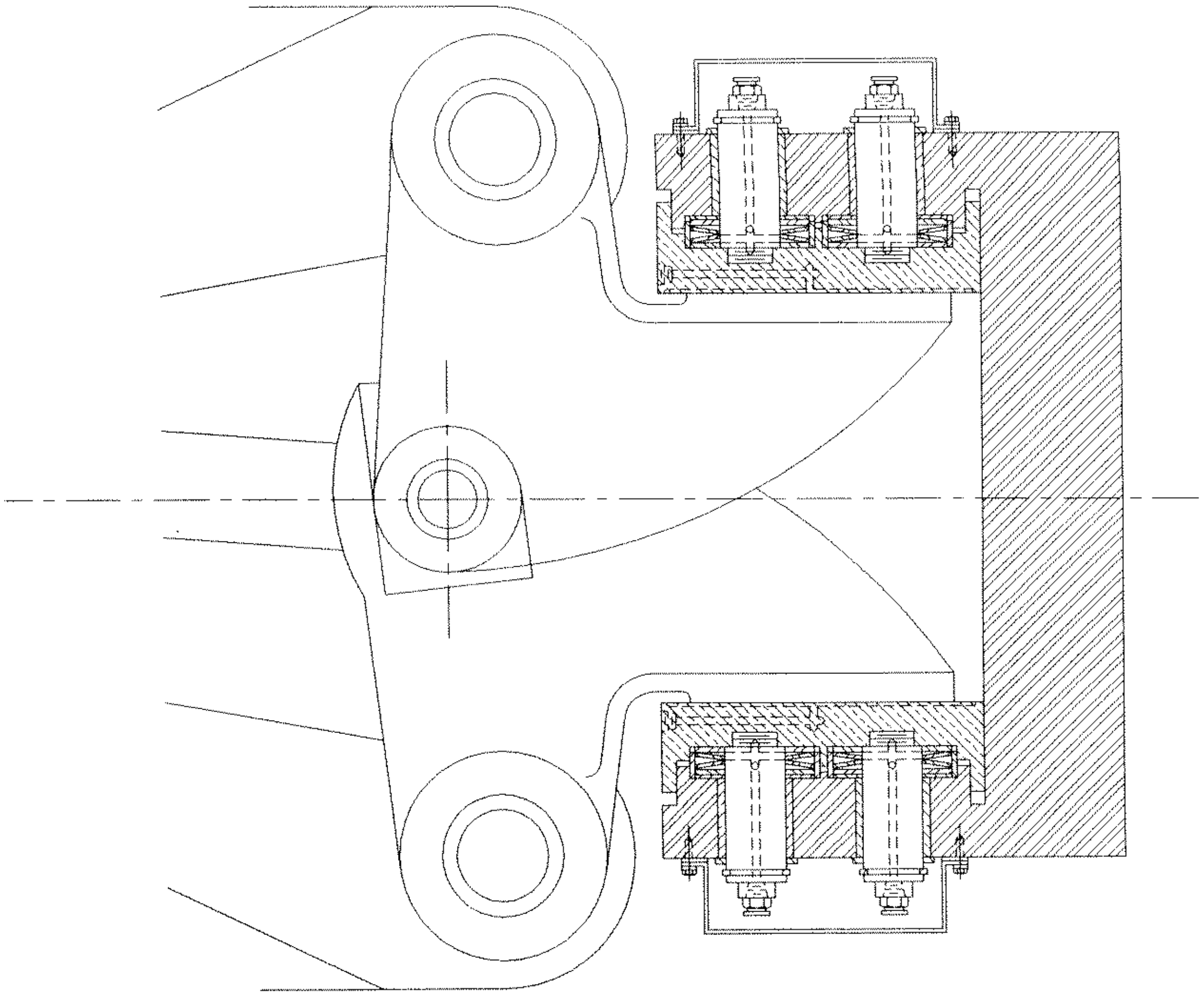
(C)

FIG. 6



ENERGY ABSORBING SPAN LOCK SYSTEM

Fig. 7



ENERGY ABSORBING JAW TYPE SPAN LOCK SYSTEM

Fig. 8