HEAVY MOVABLE STRUCTURES, INC.

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"CUSHIONLOKS - an Overview after Five Years Successful Service"

by James F. Alison, P.E.
Steward Machine Co., Inc.
And
Robert L. Cragg, P.E.
Consulting Engineer

CUSHIONLOKS® – An Overview After Five Years Of Successful Service

At the Heavy Movable Structures meeting in Fort Lauderdale, Florida, November 1992, Steward Machine Co. introduced the concept of improved, zero clearance, energy-absorbing span locks for bascule bridges. The heart of that system included assurance of firm lock bar contact with the wear shoes in the guides and receivers at all times, provision for automatically compensating for wear of the shoes and lock bars, and means for cushioning the shock loads during passage of heavy traffic.

These three goals were achieved by supporting the wear shoes on stiff disc springs contained in a heavy-duty steel housing secured to either the end floor beam or the bascule girder at the tip of the leaf. Steward manufactured and tested prototype units, made and was granted a patent application and Cushionloks® are now manufactured and marketed under U.S. Patent No. 5327605. Figure 1 shows a section through typical Cushionloks® guides and receivers and illustrates the manner in which the wear shoes are supported by stacks of Belleville Washers, or disc springs.

Originally we had several concerns about the serviceability of Cushionloks®, including:

- Accelerated wear of the bronze shoes against the steel lock bar due to the built-in preload
- Excessive wear of the Acme drive nut (on mechanically actuated installations) due to the increased force required to push the bar through the preloaded shoes
- Stresses and deflections in the housings during the passage of heavy traffic
- The ability of the system to perform as envisioned and actually absorb the shock loads, maintain a uniform leaf tip deflection, and reduce the routine maintenance and frequent adjustments required on existing bar lock installations

In-shop testing of the system throughout more than 36,000 continuous, full insert/withdraw cycles revealed that the high-strength bronze material selected for the wear shoes and Acme nut in the actuator was ideal for the application. No measurable amount of wear was observed on the lock bar and wear shoes or the Acme screw and nut at the completion of the tests, which represented about 10 years service for a bridge opening 300 times a month.

The guide and socket housings were investigated by an independent consultant using a finite element computer software package developed by Algor, Inc., Pittsburgh, Pennsylvania. This analysis disclosed that no excessive stresses, from either a loading or fatigue standpoint, were present under even the most adverse conditions and confirmed the serviceability of the housings.

Because it was not practical to duplicate field conditions, confirmation of the ability of the system to perform as intended had to wait until Cushionloks® were actually installed and had been in service for at least a year. The first installation was completed in February 1995, on the Bellaire Bridge, Pinellas County Florida. The application has been distinctly successful. Performance of the Cushionloks® exceeded even our most optimistic expectations--no maintenance, adjustments, or servicing has been required or conducted in more than five years, and they continue daily, trouble-free operation.

At this time we have furnished Cushionloks® for more than 20 double leaf bascule bridges in bar sizes from 4 x 6 to 6 x 9 inches with shear load transfer requirements from 30,000 to 120,000 pounds. Additionally they have been successfully installed on trunnion and rolling lift bascules as shear connectors at the leaf tips as well as tail locks located in the vicinity of the counterweights.

The purpose of this presentation, then, is to update movable bridge designers and users with our experiences in the design, installation, maintenance, successes, and limitations of these span lock systems since that time.

SYSTEM DESIGN

Design of the system is relatively straightforward. Steward must know the required shear load transfer together with details of the leaf tips to determine if sufficient room is available to install a workable system.

From this data Steward will select the bar size and material, determine the number and arrangement of the disc springs, propose the guide and receiver housing configurations, fix the required actuator stroke, and prepare a layout defining the locations of the actuator--mechanical or hydraulic--as well as the guides and receivers on the leaf tips.

Determination of a suitable bar size is dependent upon the shear load transfer, the relationship of the locations of the bar guides and receiver, the resulting stresses due to bending and shear, and the allowable stresses of the material selected. Figure 2 illustrates a typical calculation.

Disc spring sizes and stack arrangements are selected to limit the total vertical misalignment of the leaf tips as well as provide for infinite fatigue life of the springs. These calculations are in accord with the methods developed by Almen and Laszlo [1]. Figure 3 shows a sample calculation relating the applied load to the spring deflection and resulting stresses at the corners.

The configurations of the housing are flexible, and they may be either foot or flange mounted, and in some installations they are securely mounted between two structural supports. Obviously housing design is extremely important and we work closely with the engineer and owner to achieve the best arrangement for the job at hand.

After locating the guide and receiver, it is simple to determine the required stroke in order to fully insert and withdraw the bar to permit operation of the leafs.

[1] Almen, I.O. and Laszlo, A. "The Uniform-Section Disc Spring," ASME 58(1936), p 305-314

Functionally it makes no difference whether a mechanical or hydraulic actuator is used--we have many installations with both types in successful service. However, when a hydraulic actuator is used, an additional guide is required to resist the moment introduced by the shear load. With a unitized operator such as an Earle EG-3, the reaction is taken by the guide at the forward end of the operator assembly.

INSTALLATIONS

Figure 4 lists current Cushionloks® installations. The majority of installations are retrofits on existing bridges. These usually involve removing the existing lock system and installing Cushionloks® and new operators, either mechanical or hydraulic. The major differences from an installation standpoint between Cushionloks® and conventional locks are their size and weight. Due to the spring stacks over the shoes, Cushionloks® guides and receivers are taller and longer than conventional lock systems. In only one instance was this size difference problematic. In cases where the locks are being replaced with the same size bar, we have been 100% successful at working the Cushionloks® into the existing structures. On one bridge where the bar size was increased from 4 x 6 to 5 x 8 inches, the owner was not satisfied with proposed installation and the Cushionloks® were not installed. The concern was not that the guides and receivers would not fit, but that access for maintenance was extremely limited.

The good news is that our original installation at Bellaire Causeway in Pinellas County was recently inspected and found to be still operating satisfactorily without any adjustments or failures. Pinellas County maintenance personnel lubricates the guides and receivers via the lube station on the roadway every three weeks. No other maintenance has been performed or required in over five years. The Bellaire Causeway Bridge is scheduled to be replaced in the next three to five years. Steward plans to disassemble and inspect the guides and receivers for a complete evaluation and perhaps install them on another bridge to continue their useful life.

Minimal maintenance and no adjustments have been Steward's goal from the beginning, and we have been successful with all installations to date. Cushionloks® have reduced noise associated with traffic crossing the bridge and reduced impact damage to its structure, lock operator, and drive machinery.

In the process of working through the installations, Steward has developed a general sequence of steps to ensure a successful application. The first step is the design stage, when bar sizes, materials, and approximate locations for the guides and receivers are determined. Although the spring housings and bronze shoes are fairly standard for a particular bar size, the mounting arrangement for the guides and receivers can be quite different. To date Steward has designed foot mounts, flange mounts, combination wing mounts, floor beam mounts, mounts over existing rivets, mounts in gusset plates on truss girders, mounts with sidewalk supports built in, even circular flange mounts (Figures 5-11). This work is done in coordination with the owner's design engineering consultants or directly with the owner. If needed, proposal drawings are produced by

Steward for incorporation into design plans. Once a contract has been awarded, the next step is detail shop drawings. If it is a retrofit into an existing bridge, Steward visits the site to verify existing dimensions. Calculations are rechecked with the final guide and receiver locations. The completed assembly drawings are submitted to the customer for approval of the mounting arrangement. Production begins once the drawings are approved. Steward batch produces and stocks some standard parts, such as bronze shoes. However, the guide and receiver weldments are produced from scratch for each job. This allows flexibility with mounting arrangements.

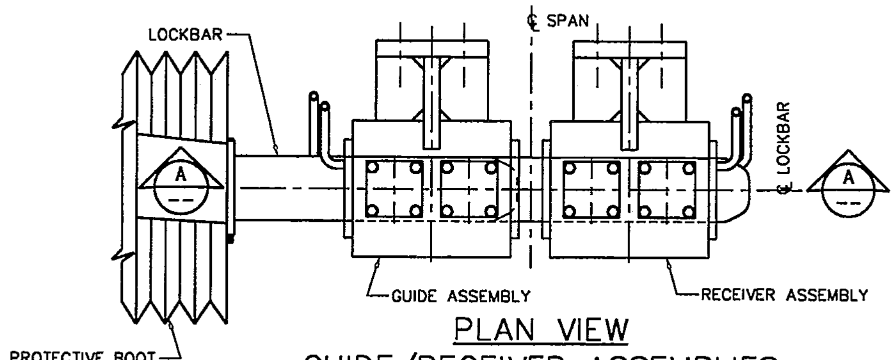
The completed guides and receivers are shop assembled with the lock bars and tested before shipment. In most cases the guides and receivers are shipped with the lock bars inserted into them. A pair of wedge tools for separating the shoes is shipped with each job to ease removal and installation of the lock bar at field assembly. As with any bar lock system, alignment of the lock bar, guides, and receivers is important. With Cushionloks®, the guide and operator can be mounted and then the receiver clamped onto the extended lock bar to allow shimming of the receiver before mounting. Steward will provide field assistance with the mounting and alignment of all Cushionloks® installations. For a typical installation Steward recommends at least one day of on-site support at the start of mounting the first unit.

Once installed, Cushionloks® do not require any maintenance or adjustments. Lubrication of the shoes and lock bar is through remote deck level lube fittings, similar to conventional lock systems. The lube lines will have to incorporate flexible hoses at the shoe connection due to the movement of the shoes in operation. All of the moving parts inside the Cushionloks® guides and receivers are packed with grease and sealed at shop assembly and do not require further lubrication.

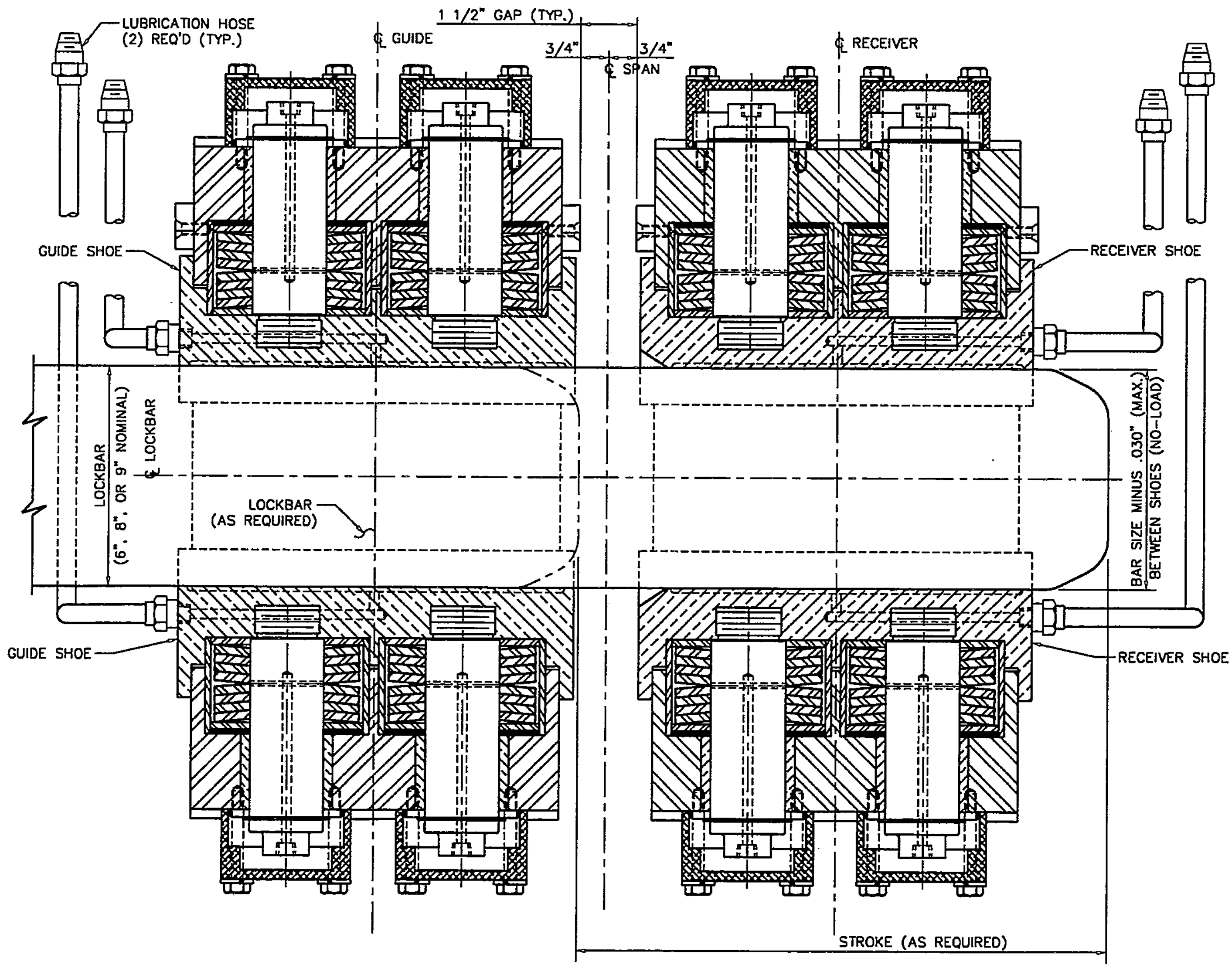
The benefits of Cushionloks® have been demonstrated with each installation. The three original goals of keeping the bar in firm contact with the shoes, self-adjusting for wear, and reducing shock loading have been achieved with all installations to date. In addition we've seen a couple of unexpected benefits. The most noticeable benefit has been a significant reduction in noise. With the passing of traffic, the leafs deflect and move normally but do not slam down on the lock bars. The other benefit has been that the components do not seem to wear nearly as fast as conventional systems. By eliminating the shock loading (pounding) on the shoes and bars, these components don't seem to wear as rapidly as with standard systems. A recent field measure of lock bars on the Bellaire Causeway Bridge found no measurable wear after five years service. The other major benefit is the complete elimination of periodic maintenance for shimming the guides and receiver shoes. Not a single installation has required any adjustment since put into service.

The proposed advantages of the Earle Cushionloks® span lock system have proved to be real in the five years that they have been in service. The measured lack of wear on the bars, the total elimination of periodic adjustments, the quieter, softer, more controlled leaf tip movement are all noticeable, documented advantages. The concerns of operator wear or installation difficulties have not been significant. The increased weight has been accommodated in all installations on existing bridges without overloading the drive systems.

With numerous projects in the works, Steward continues to refine the systems. Goals for the future include reducing weight and cost and further documenting the progress of the existing systems as time and traffic passes.

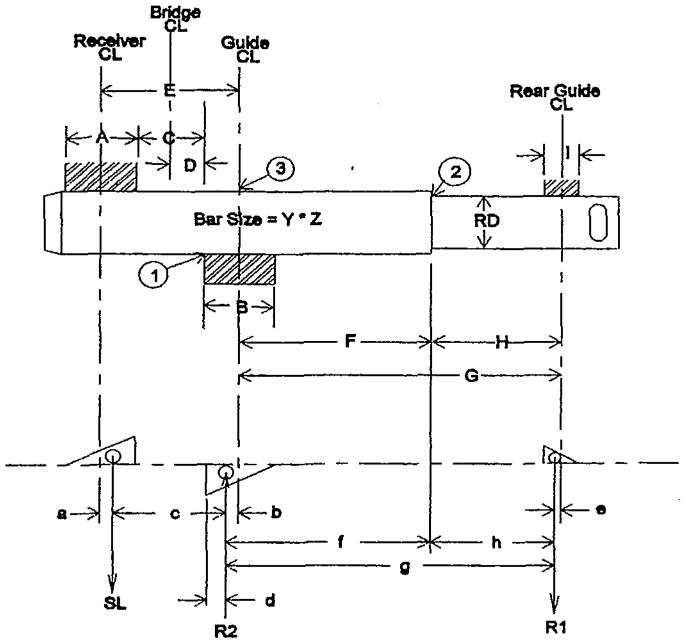


PLAN VIEW
GUIDE/RECEIVER ASSEMBLIES



SECTION A

FIGURE (1)



Job Name: HMS - 11/2000

INPUT: Lock Bar: Size - Width, Y 5 Material: A 668 Cl G
Height, Z 8 Allowable Stress.PSI 16000

Max. Shear Load Transfer, SL, lbs : 64295

Note: For bars with no round section insert "NA" for dimensions F and H and "0" (zero) for RD.

Dimensions:

A	9.875	G	32.5
B	10.625	H	18.5
E	13	I	3
F	14	RD, dia.	6.5

CALCULATED RELATIONSHIPS:

Dimensions, in: Reactions. lb :

a	1.645833	e	0.5	R1	18245
b	1.770833	f	12.22917	R2	82540
c	9.583333	g	33.77083		
d	3.541667	h	18		

Bending Moment at "1", lb.-in: 388449
Section Mod, s = y*z^2/6 in^3 : 53.33
Stress at "1", PSI - M/Sec Mod 7283

Bending Moment at "2", lb.-in : 328416
RD. Sec. Mod, = Pi*d^3/32 in^3: 26.96
Stress at "2", PSI - M/Sec Mod 12181

Check shear stress at "1". Allowable stress, PSI = 8000
Shear stress -3*SL/(2*Area) PS 2411

Check bending stress on bar at centerline of guide, "3" :
Moment at "3": 547310
Stress @ "3", PSI -M/Sec Mod: 10262

Check bending stress along line of action of R2:
Moment along "R2: 616160
Stress @ "R2", PSI-M/Sec Mod: 11553

Figure 2

Cushionlok Belleville Spring Analysis

This program will calculate the stresses at the critical points on Belleville Springs.
Use correct values for Modulus of Elasticity and Poisson's Ratio for the material selected.

	Steel	17-7 PH	Phos. Br.
Modulus of Elasticity	3.00E+07	2.90E+07	1.86E+07
Poisson's Ratio	0.30	0.34	0.33

Spring Data :		*Material Data :*	
Outside dia, in. :	7.87	Material :	Steel
Inside dia., in. :	3.62	Modulus of Elas. :	3.00E+07
Thickness, in. :	0.5520	Poisson's Ratio :	0.30
Dish height, in. :	0.1614		

Load Data:	Deflection, in. :	0.050
	Load, lb. :	25951

The stresses in PSI are :

Q0 = -77,465 Q1 = -142,341 Q2 = 91,881
Q3 = 68,885 Q4 = -38,851

Figure 3

Cushionloks Installations

Name	Location	BridgeType	Bar Size, (in)	Shear Load, lb. per bar	Operator
Bellaire Causeway	Pinellas County, FL	Trunnion	4 x 6	28,000	EG-2B
Woolbright Avenue	Palm Beach Co., FL	Trunnion	4 x 6	41,600	EG-3
Ocean Avenue	Palm Beach Co., FL	Trunnion	4 x 6	41,600	EG-3
Palmetto Park Blvd.	Palm Beach Co., FL	Trunnion	4 x 6	41,600	EG-3
*Donald Ross Road	Palm Beach Co., FL	Rolling Lift	5 x 8	75,000	EG-3
Co. Rd. 707	Palm Beach Co., FL	Trunnion	4 x 6	41,600	EG-3
*Kinnickinnic Avenue	Milwaukee, WI	Trunnion	5 x 8	75,000	EG-3
Kilbourn Avenue	Milwaukee, WI	Trunnion	5 x 8	48,000	EG-3
*N. Emmber Lane	Milwaukee, WI	Trunnion	5 x 8	75,000	EG-3
*Roosevelt Bridge	Stuart, FL	Trunnion	4 x 6	50,000	Hyd.
Las Olas Blvd	Ft. Lauderdale, FL	Trunnion	4 x 6	50,000	Hyd.
Hillsboro Blvd	Ft. Lauderdale, FL	Trunnion	5 x 8	59,000	Hyd.
*Hallendale BeachBlvd.+	Ft. Lauderdale, FL	Trunnion	5 x 10	85,000	Hyd.
*Boynton Beach Blvd.+	Ft. Lauderdale, FL	Trunnion	5 x 8	75,000	Hyd.
B.B. McCormick Bridge	Jacksonville, FL	Trunnion	4 x 6	56,400	EG-3
Cermack Rd.	Chicago, IL	Rolling Lift	6 x 9	120,000	EG-3

* New Bridges + Construction in process Aug. '00

Figure 4

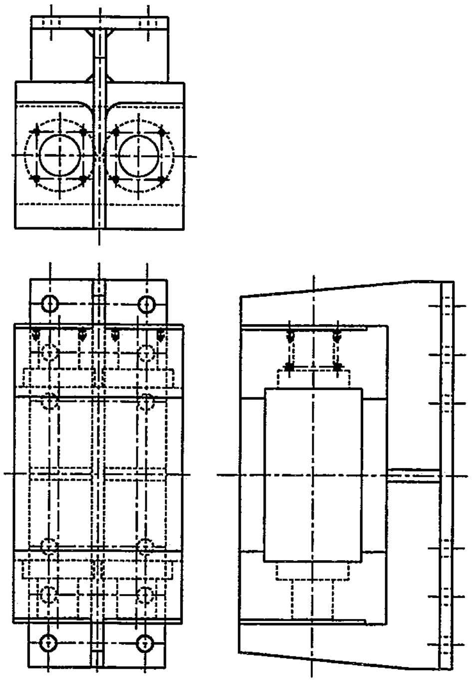


FIGURE (5)
STANDARD FOOT MOUNT

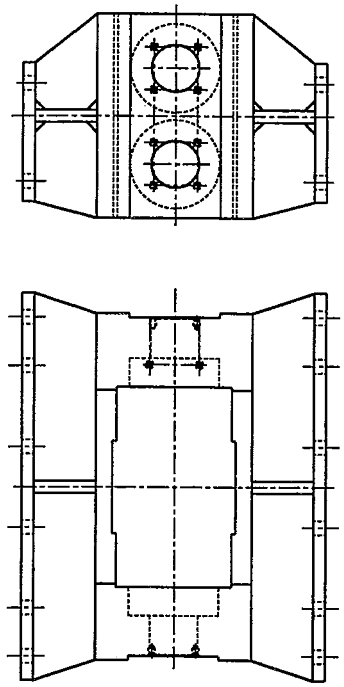


FIGURE (6)
WING MOUNT

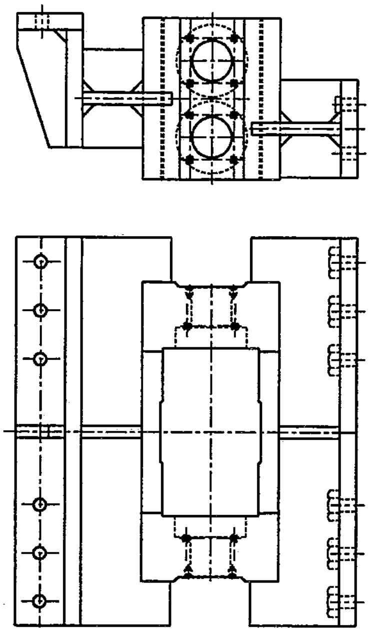


FIGURE (7)
COMBINATION FOOT/SIDE MOUNT

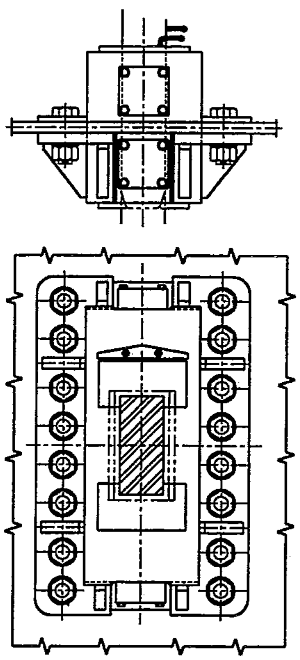


FIGURE (8)
FLANGE MOUNT

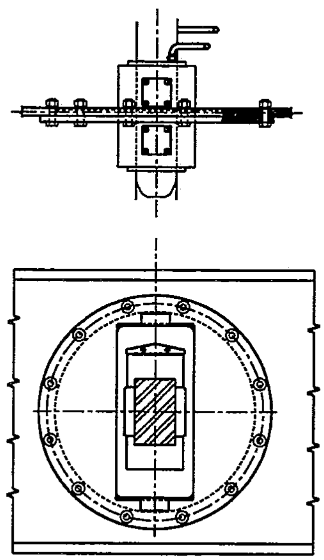


FIGURE (9)
ROUND FLANGE MOUNT

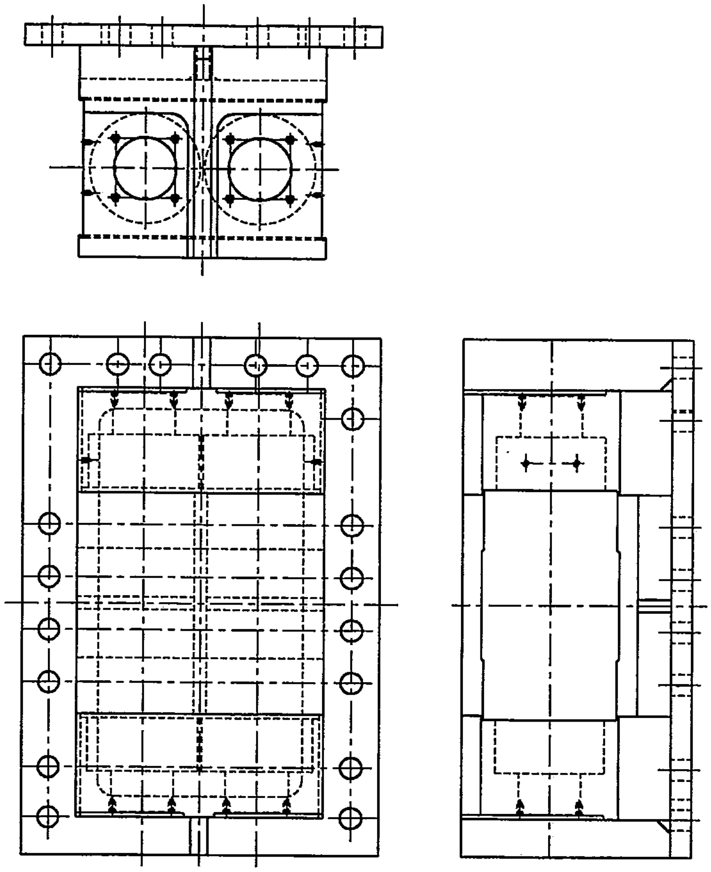


FIGURE (10)
MODIFIED FOOT MOUNT FOR 6"X9" BAR

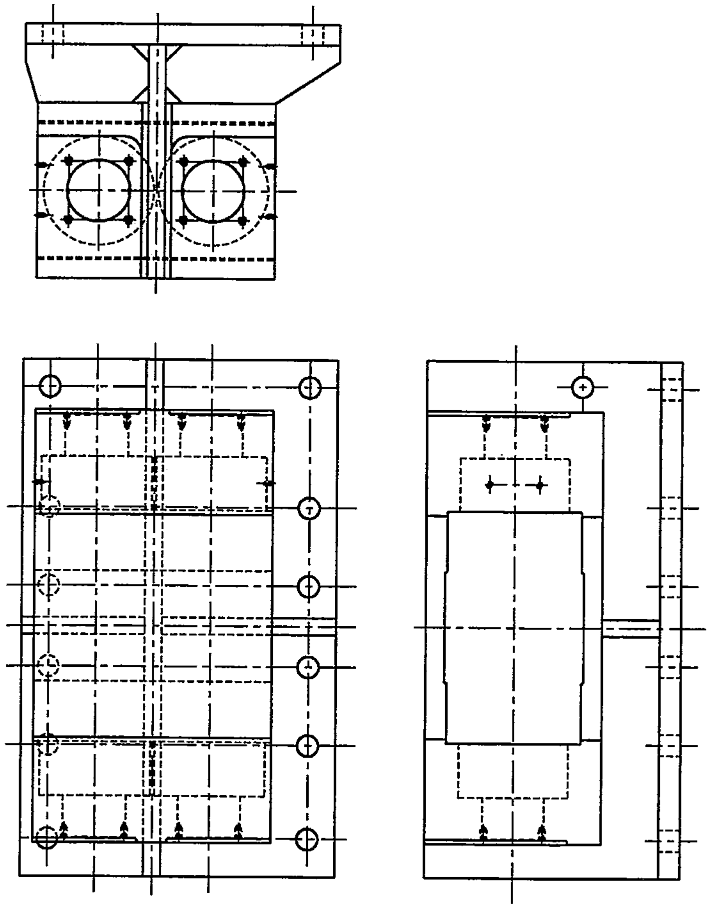


FIGURE (11)
MODIFIED FOOT MOUNT (OFFSET)