Heavy Movable Structures, Inc.

SIXTH BIENNIAL SYMPOSIUM

October 30 - November 1, 1996

Doubletree Resort Surfside
Clearwater Beach, Florida

E.D. Sawyer's Legacy: Barrier Gate Rehabilitation

by

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E.D. SAWYER'S LEGACY: BARRIER GATE REHABILITATION

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INTRODUCTION

This paper tracks the development of the historic Sawyer yielding barrier gates and describes problems encountered and solutions implemented during the rehabilitation of similar gates on the Pulaski Bridge in New York City.

Although AASHTO's Standard Specifications for Movable Highway Bridges - 1988, Section 2.1.6 gives designers the option in specifying energy absorbing barrier systems for resistance gates on movable bridges, Sawyer barrier gates are installed on several bridges around the country. The attachment of the gate support structures to vertical lift structures and their designation as part of historical landmark structures makes rehabilitation a viable option.

In July 1992, the New York City Department of Transportation's (NYCDOT) Bridge Design Section, as part of its bridge rehabilitation program, decided to rehabilitate all Sawyer gates on movable bridges under its jurisdiction. Initially, two bridges were selected for rehabilitation: the Pulaski Bridge, a four-leaf bascule bridge connecting the boroughs of Brooklyn and Queens, and the Roosevelt Island Bridge, a vertical lift bridge between Queens and Roosevelt Island, providing the only vehicular access to the island.

Since the bridge's barrier gate system was a proprietary development whose inventor, Emerson D. Sawyer, had died and whose last known manufacturer, the Mollenberg-Betz Company, stopped production in 1985, available design information was extremely limited. The decision to rehabilitate the gate system also stemmed from a lack of interest by prospective manufacturers, likely due to issues such as product liability or limited market potential.

HISTORY

Emerson D. Sawyer was from Chicago, Illinois, and for a time served as chief engineer of Pennsylvania's Link-Belt Corporation. Sawyer's first patent filing, No. 1,653,670, dates back to December 27, 1921, and was granted on October 9, 1928. This first patent filing was followed by 19 additional applications between 1927 and 1961. All, except two, were improvements for "yieldable barriers" to be positioned at either train crossings or bridges.

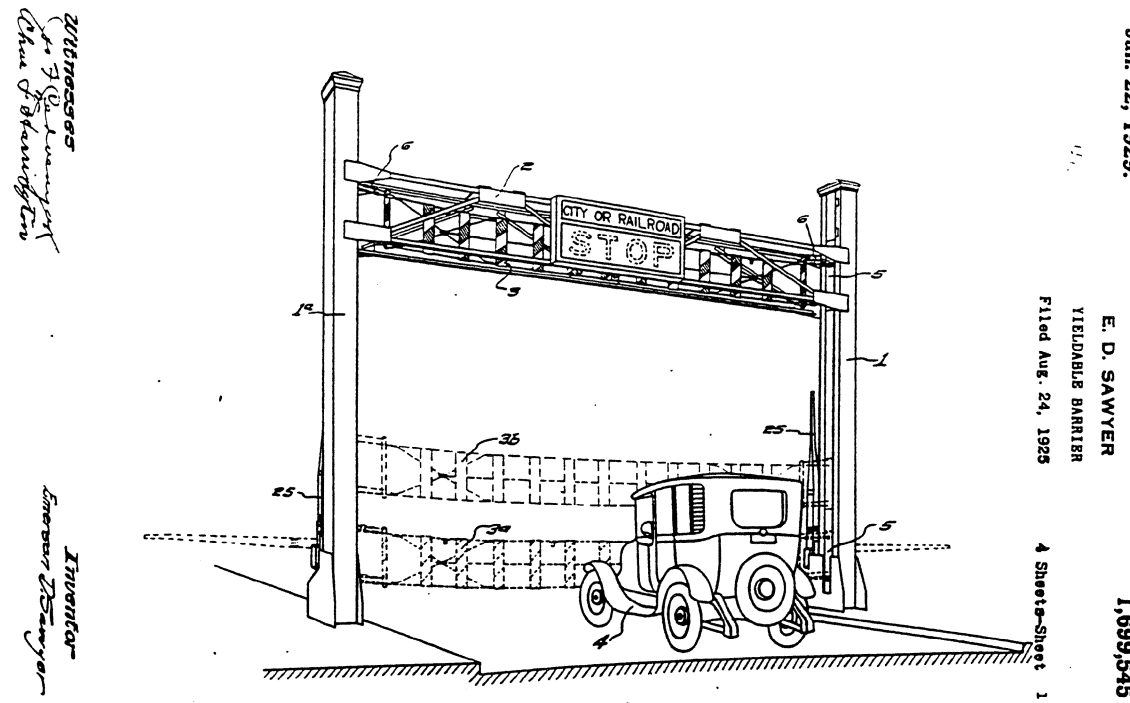


Figure 1

An interesting patent (No. 1,699,545), granted on January 22, 1929, shows a Model T sitting on a ramp approach (Figure 1). Sawyer claimed that this improved design allowed the net to be readily torn loose at both ends if it was struck by a vehicle when it was being lowered.

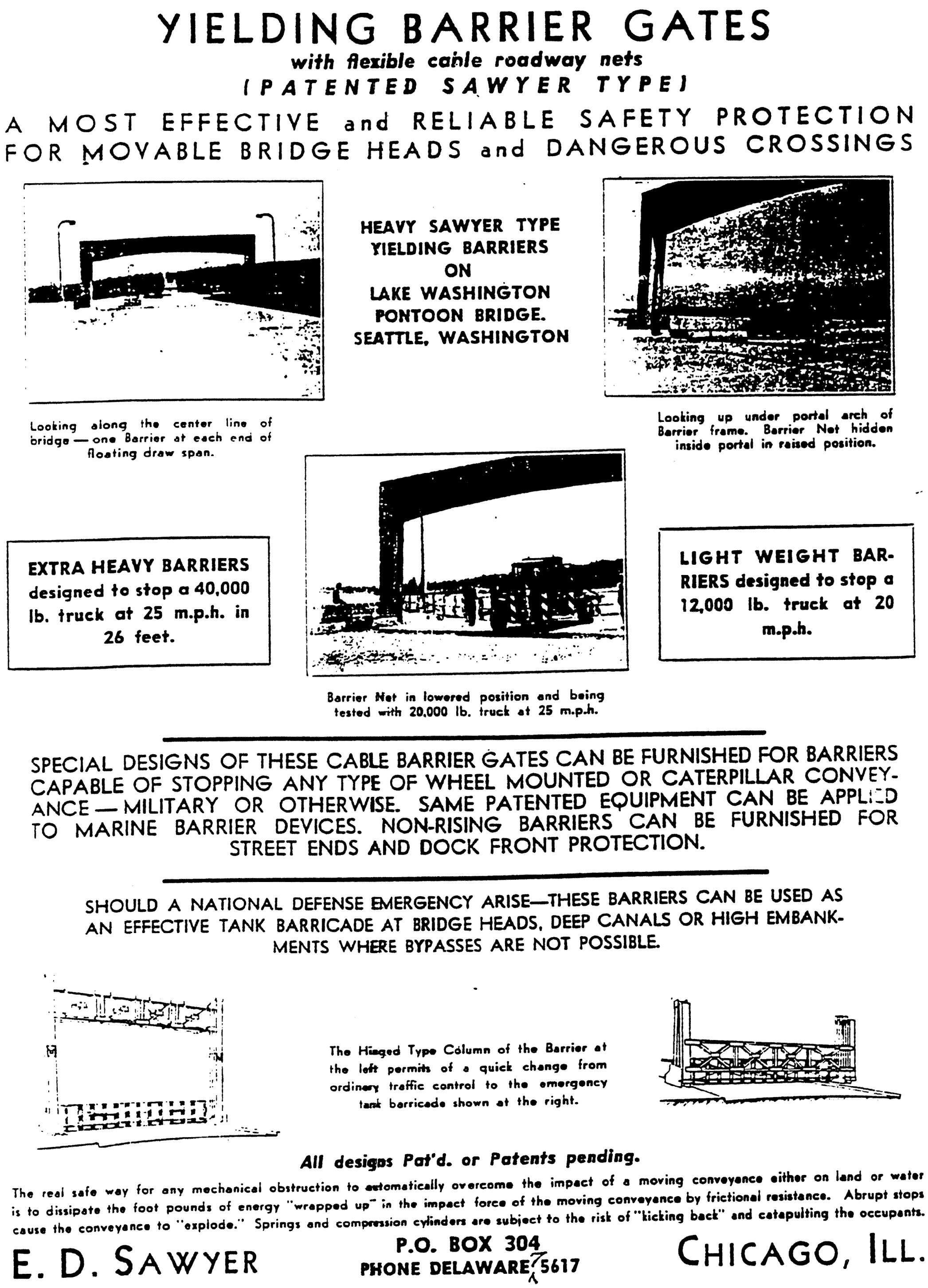


Figure 2

The advertisement in Figure 2 highlighted barrier installations on Seattle's Lake Washington Pontoon Bridge. Note the ad's claim that during a national emergency, the barriers could be used as "an effective tank barricade at bridge heads, deep canals or high embankments where bypasses are not possible."

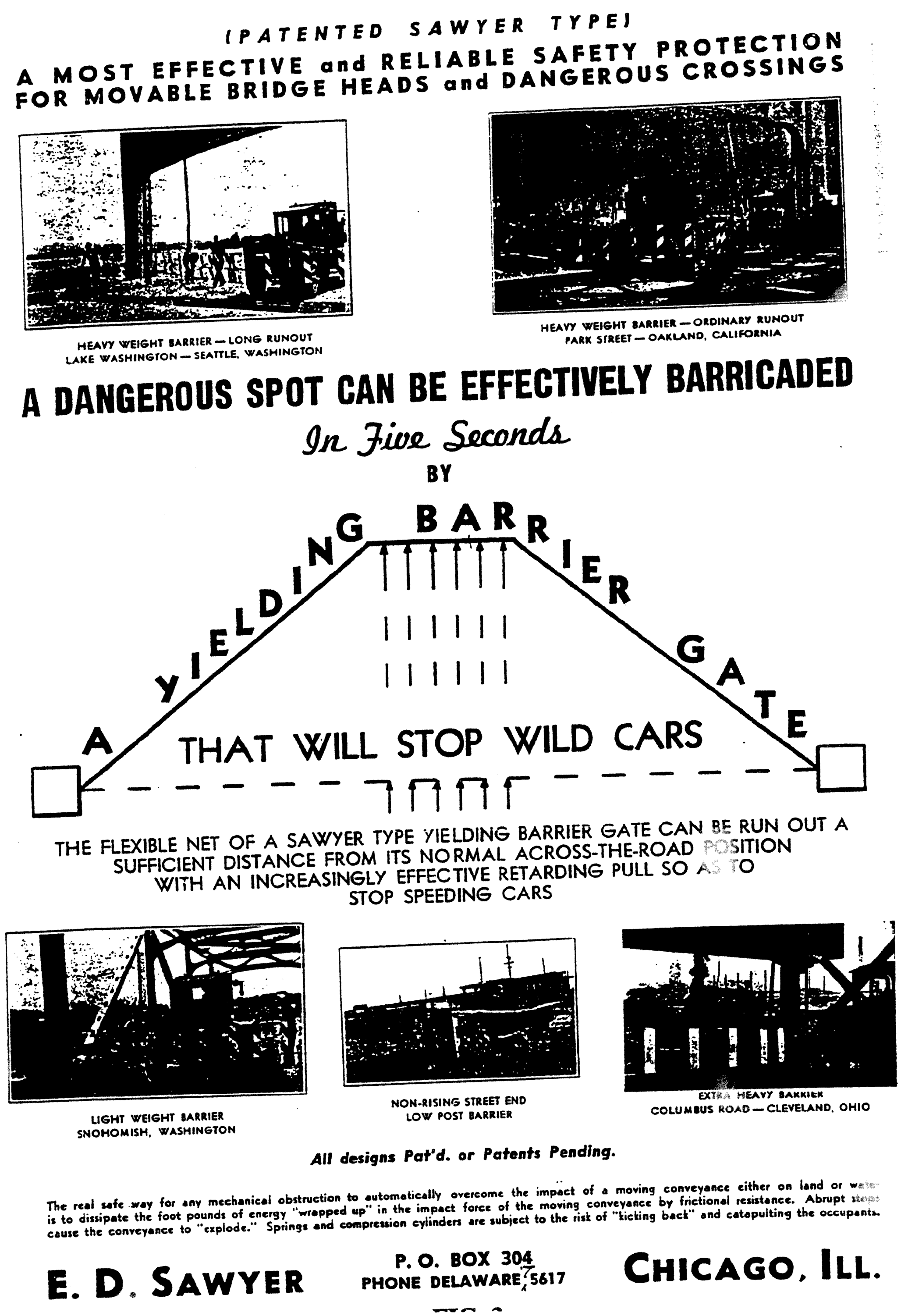


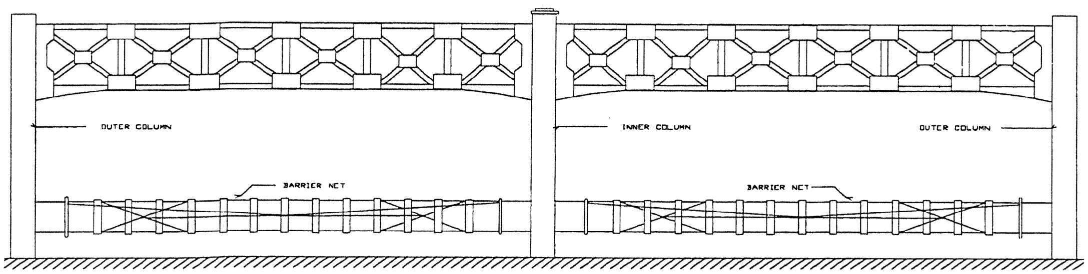
Figure 3

Another advertisement (Figure 3), highlighted similar installations in Oakland, California; Columbus Road in Cleveland, Ohio; and Snohomish, Washington. While ignoring potential military uses, this ad did focus on the need to restrain speeding or uncontrolled cars.

Mohr and Sons Company of Chicago and Link-Belt Corporation were two of the original firms under license to manufacture these gates. Later, between 1959 and 1985, the Mollenberg-Betz Company of Buffalo, New York, manufactured and installed similar gates around the country. Their claimed design improvement over Sawyer's models reputedly eliminated "catapulting and counteraction."

GATE DESCRIPTION

Yielding gates were generally built in pairs, one at each end of a bridge. Each barrier consists of two steel columns, one on each side of the roadway, with a shaft extending from one column to the other (Figure 4). A barrier net stretches between the two columns and is capable of vertically moving from its up position above traffic level, down to its operative position to intercept cars or trucks.



TYPICAL BARRIER GATE

Figure 4

The drive system for moving the net up and down is attached to the base of the right hand column. The motor is normally geared to a speed reducer by silent drive chains and sprockets (Figure 5). The slow shaft, in turn, is connected with a belt chain attached to the top and bottom of a brake drum. Any movement in one operating chain induces a like movement in a similar operating chain located in the idler column. The retarding force is achieved by developing frictional resistance on the brake drum. The drum turns within a brake band that is tightly applied each time the box is in its lowest position. Balancing the drum boxes are counterweights that provide additional resistance to the payout cables attached to the net. This resistance is a very small fraction of that generated by the friction of the brake drum.

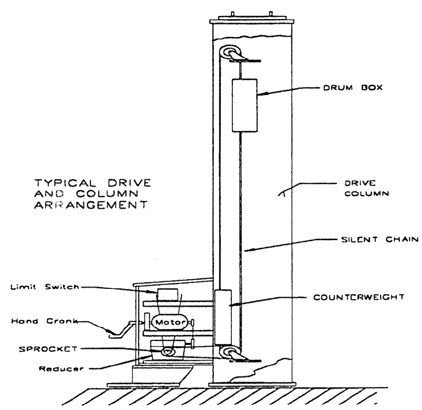
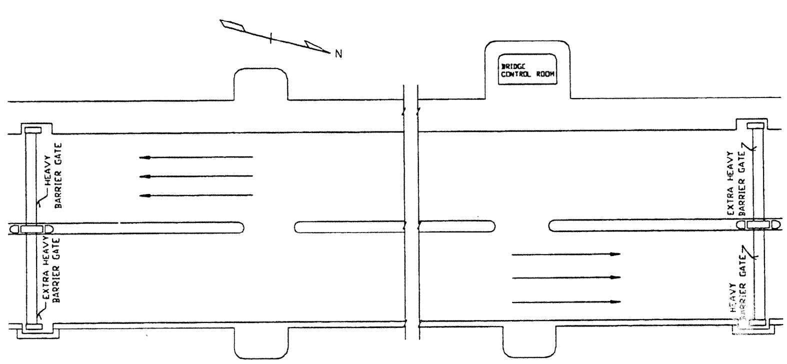


Figure 5

There were two types of Sawyer gates on m[illegible] bridges: the "ex[illegible]-heavy type" that had an advertised capacity to stop a 40,000-pound vehicle at 25 mph within 26 feet, and a "heavy type," designed to stop a 12,000-pound vehicle at 20 mph.

PULASKI BRIDGE

The Pulaski Bridge, a four-leaf bascule structure, was built in 1954. Each double-leaf bridge carries three lanes in each direction as shown in Figure 6. In 1991, a $37 million, 42-month bridge rehabilitation contract was awarded to Perini Construction Corporation. Rehabilitation of the Sawyer yielding barrier gates was subcontracted to S.N. Tannor, the electrical subcontractor, and Hardesty & Hanover Consulting Engineers served as the resident engineer.



PLAN OF PULASKI BRIDGE

Figure 6

Since the drive machinery was still operational, the rehabilitation approach was to identify, by visual inspection, all worn parts and to subsequently replace and test them using available design criteria. This approach allowed NYCDOT to gain some insight into the workings of the gate mechanisms as well as to generate test data for future rehabilitation projects.

REHABILITATION PROBLEMS

The information available to NYCDOT's design staff were the original shop drawings as well as descriptions of the operating mechanisms and the energy absorption capabilities of similar gates on two other city bridges. The project was complicated by the fact that:

1) The yielding barrier gates were a proprietary system whose original designer and manufacturer no longer existed.
2) The original design calculations and safety factors were not available.
3) There was no comprehensive research conducted or national standards in effect at the time of construction.

Copies of original specifications for two identical systems were available for the Roosevelt Island and Hamilton Avenue Bridges. These specified that "the extra-heavy type barriers shall be capable of stopping a 36,000-pound vehicle traveling at 20 mph without disabling damage to the barrier or its support columns. The payout distance measured parallel to the roadway and from the cable barrier in its normal position to a fully extended position shall not exceed 20 feet." The heavy type specification indicates that this type of barrier was designed to stop a 20,000-pound load at 25 mph in a distance of 22 to 26 feet.

COMPONENTS IDENTIFIED FOR REPLACEMENT

1) Drive System:

   The enclosed drive system was functional and in good condition. Most of the drive systems on yielding barrier gates are located directly behind the columns and are shielded from damage in the event of a net impact.

2) Barrier Nets:

The barrier nets and thimbles consisted of 3/4-inch extra-heavy plow steel wire ropes, lug nuts, and cotton belts with stiffener plates. The nets and all accessories were replaced due to wear and accident damage. The surface of the cotton belts were painted red and white to conform to Manual of Uniform Traffic Control Devices (MUTCD) regulations.

3) Drive Shaft Assembly:

The drive shaft which transmits torque from the drive column to the idler column, as well as associated shaft accessories, were in good condition. These parts were subsequently identified for replacement on the Roosevelt Island, Broadway and Hamilton Avenue Bridges.

4) Counterweight:

The counterweight and counterweight ropes are essential parts of the yielding mechanism. The gate mechanism requires that the counterweight be twice the weight of the drum box. Most of the drum boxes that were removed did not meet this criteria. The total weight of the extra-heavy type drum box, net, and miscellaneous hardware was 1,465 pounds, while the associated counterweight was 2,930 pounds. Therefore, an additional 530 pounds was added to satisfy this design criteria.

5) Drum Boxes:

The main retardation forces to the moving vehicle are generated from the drum boxes, therefore particular attention had to be paid to these parts of the gates. The critical components of the drum boxes are the payout system and the braking mechanism.

The main parts of the payout mechanism are the top and bottom cables, recoil stopper assembly, and the wire rope sheave. The cables were replaced with 7/8-inch-diameter and 5/8-inch-diameter 8x19 extra strength plow steel wire rope, for the extra-heavy and heavy types respectively. Additionally, the cable drum or rope sheave that was cast together with the brake drum and the drum box casing, were all sandblasted and checked for cracks.

The ability of the brake band to firmly engage the brake drum when the net was lowered had to be examined. The retardation force is generated by developing frictional resistance applied on a brake drum which turns within an external contracting brake band that is tightly applied each time the drum box is in its lowest operating position. The tightening of the brake band is accomplished by means of the movement in a brake tightening lever that swings through an angle. This angular movement of the brake-tightening lever is accomplished as the drum box is lowered into its down position by means of a curved cam track attached to the face of the column.

During this project, the brake band and all attached springs were replaced. Also, the roller bearings that help drive the boxes up and down the columns were found to be worn and were all replaced. The drum box shaft bushings were also replaced due to excessive shaft clearances. All other components were carefully cleaned and examined, and the extent of wear on each part was carefully documented and compared to the original shop drawings. A complete listing of replacement parts is included in Appendix A.

BARRIER GATE TESTING

The southbound roadway was completed in July 1993 and preliminary testing performed during the first two weeks of August.

Design Criteria and Approach

The approach to the testing of the extra-heavy type gates was based on design criteria that a 36,000-pound truck traveling at 20 mph be stopped in less than 20 feet without damaging the gate (calculated kinetic energy approximately 500,000-foot-pounds). The energy is absorbed by brake action to decelerate the truck. Since a dynamic test involving an actual vehicle was not within the budget or scope of the project the following methodology was selected for a pull test.

1) Calculate and set retardation or resistance forces provided by the braking system within the drum boxes.

2) Calculate the force applied to the net over each foot of distance for a total of 20 locations. For an extra-heavy type gate, this should add up to a total resistance of 500,000-foot-pounds. These criteria assumed brake settings of 27 kips and 18 kips for the extra-heavy and heavy-type gates, respectively.

Test Set Up

The net suspension spring assembly was temporarily detached from both drum boxes. As shown below, four-pieces of 2 1/2-inch-diameter Schedule 40 pipe pieces were welded together and attached to the barrier net with 1-inch-diameter eye bolts. A four-way sling was then attached to a primary pulley, and a wire rope from a winch mounted on a truck was attached to three other pulleys with a dynamometer in a four-way arrangement (Figure 7). Incremental distances a foot apart were then marked from the centerline of the net in the direction of the pull for instant readings of the net payout.

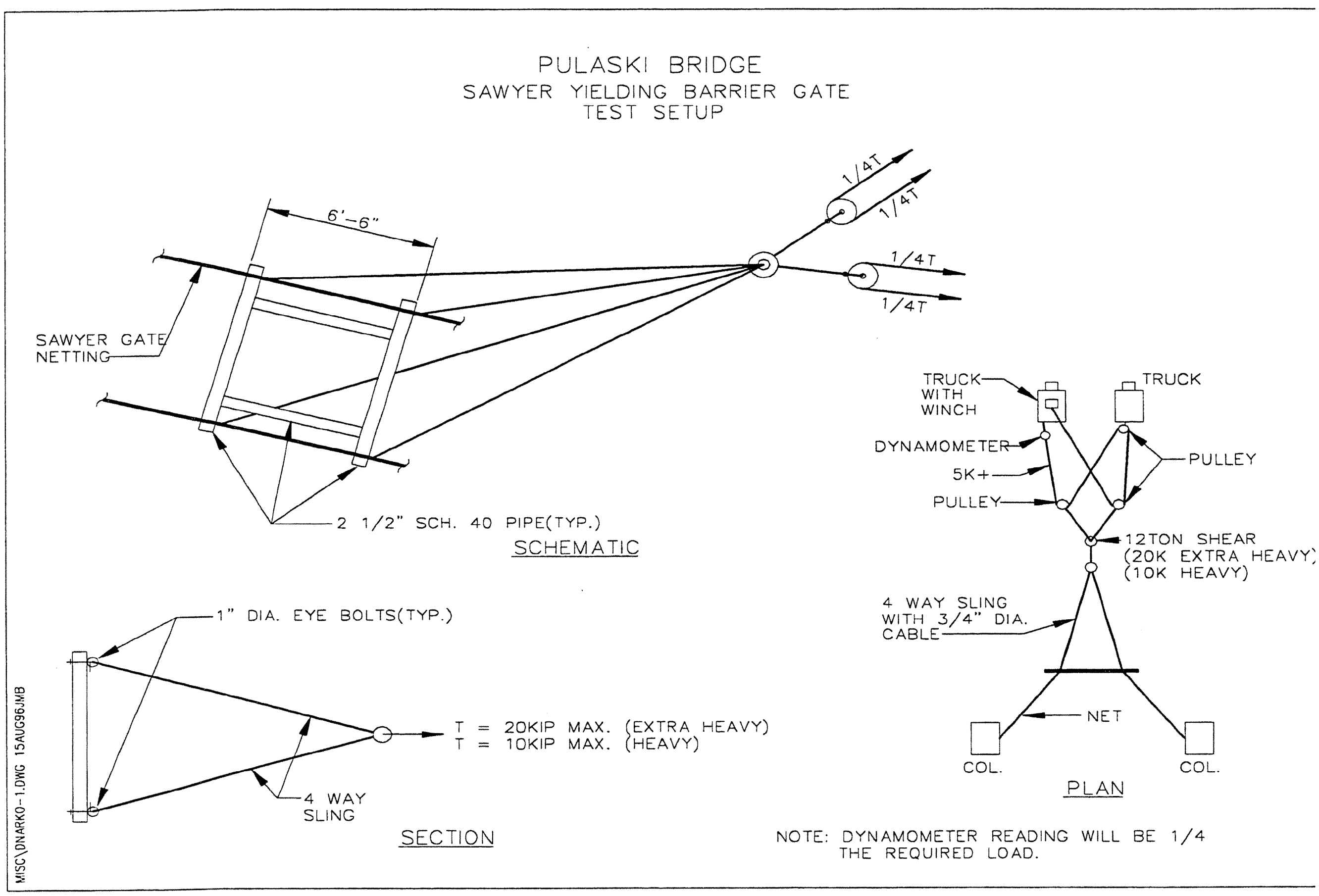


Figure 7

Test Objectives

There were two main parts to the tests:

1) The pull force from the dynamometer readings relative to the length of payout distance was recorded. The test force was gradually increased using the dynamometer to avoid damage to the barrier components.
2) The net had to smoothly payout and retract when the brakes and the dog assembly were released. This was to ascertain that the barrier net worked as described in the original design specification.

OBSERVATIONS

The final testing was successfully completed on August 13, 1993. After several trials, the desired tension was achieved at acceptable incremental distances from the center line. Testing revealed that:

1) The theoretical brake force was not readily achievable. The brake tightener assembly had to be modified by modifying the washers on the brake lever to change the compression of the springs.
2) During testing, the barrier net did not retract immediately into the drum boxes as was expected on the release of the brake lever and the dog assembly. The net had to be pulled back to its original position with a boom truck. From this observation, it is possible to conclude that in the event of a real crash, a light vehicle will not catapult back to its original position.
3) The pin at the end of the brake band was initially adjusted and left in a preset position. Clearances for different brake lever angles were checked with feeler gauges.
4) It was quite difficult to get the cables in both columns to payout equally due to the challenge encountered in setting equal braking resistance in both columns.

MODERN YIELDING GATES

Available records indicate that the last patent filed by Emerson Sawyer was granted on May 16, 1961. The company that manufactured many of the gates stemming from his concepts was Mollenberg-Betz of Buffalo, New York (which stopped manufacturing gates of this variety in 1985). In recent years, Lockran Industries, Inc., of Ashtabula, Ohio, has designed and marketed barrier gates based on Sawyer's inventions. Lockran's version claims additional improvements over Sawyer's inventions and the Mollenberg-Betz version. Improvements include controls located directly on top of the column, and various safety improvements. The energy absorption capacity of this modified version ranges from 334,000 to 500,000-foot-pounds.

CONCLUSION

Although testing was not dynamic, it did offer some insight into the workings of the gates. The testing proved to be labor intensive, but provided useful data that was recorded for subsequent rehabilitation work. This allowed testing to be simplified during other NYCDOT rehabilitation projects involving the Roosevelt Island, Broadway and Hamilton Avenue Bridges.

Some basic guidelines should be followed when deciding to either replace or rehabilitate gates:

1) Construction date of existing yielding gates: some gates built during the early 1900s require much maintenance and do not meet modern safety standards.
2) Layout of gate columns: gate columns attached to vertical lift bridges are difficult to replace when the bridge lift tower structure is not being replaced.
3) Historic landmark designations: some bridges are designated historic landmarks and overall layouts cannot be changed during rehabilitation.
4) Budget available for rehabilitation or replacement: rehabilitation can be labor intensive due to the number of components that need to be inspected and the labor-hours involved in testing.

N.E. Sawyer Barrier Gate Test Data

Load vs. payout distance at various times

Time	6:17PM	6:22 PM	6:45 PM	7:18 PM	7:37: PM	7:44PM	7:56PM	8:08:PM	8:12PM
Load (Kips)			**Distance** (Ft)						
1	2.00	2.50	2.00	3.00	3.00	2.50	2.50	3.25	3.00
2	2.50	2.75	2.00	3.50	3.00	2.75	2.50	3.50	3.00
3	2.75	2.75	2.50	3.75	4.00	3.00	3.00	3.50	3.25
4	3.00	3.00	2.75	3.75	5.50	3.00	4.00	3.75	3.25
5	3.75	3.50	3.50	4.00	6.50	4.00	4.00	4.00	4.00
6	4.50	4.00	4.00	5.00	7.00	4.50	4.50	4.50	4.50
7	5.50	5.00	4.75	6.25	8.00	5.25	5.00	5.00	5.00
8	6.75	5.75	5.00	7.00	8.50	6.50	6.00	6.00	5.75
9	7.25	6.25	6.00	7.50	9.75	7.00	6.50	6.75	6.25
10	8.00	7.00	7.00	8.00	10.00	7.50	6.75	7.50	6.75
11	8.50	8.00	7.50	8.50	10.50	8.00	7.50	8.00	7.50
12	9.00	8.75	8.50	9.25	10.75	8.75	8.50	9.00	8.25
Column			**Cable Payout Distance** (In)						
East	11.00	38.00	18.00	0.50	0.50	4.50	23.50	20.50	24.00
Center	51.00	18.00	35.00	57.00	84.00	50.00	22.00	42.00	25.00

Heavy type

PULASKI BRIDGE

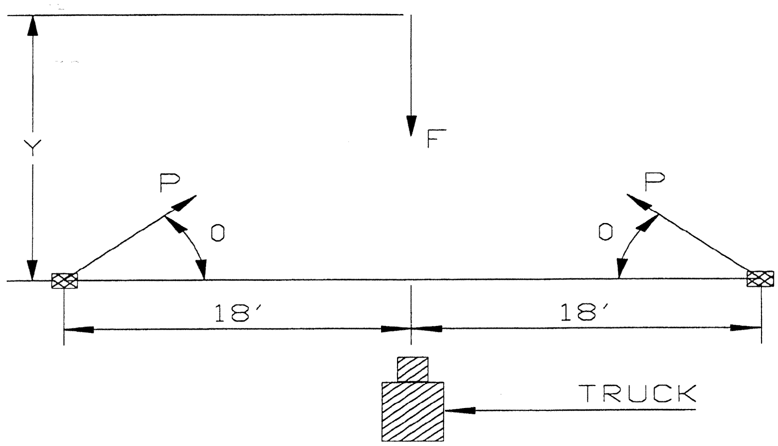
S.E. Sawyer Barrier Gate Test Data

Load vs. payout distance at various times

Time	11:08AM	11:25AM	11:40AM	11:55AM	12:55PM	1:27PM	1:50PM	2:40PM	2:40PM
Load (Kips)			**Distance** (Ft)						
1				3.00					
2				3.50	3.25				3.75
3				4.00	3.50	3.00		3.75	4.00
4				4.00	3.75	3.50	3.00	4.00	4.00
5				4.25	4.00	3.50	3.50	4.00	4.00
6			4.00	4.25	4.00	3.75	3.50	4.00	4.00
7	5.50		4.25	4.50	4.00	3.75	3.75	4.00	4.25
8	6.50		4.50	4.50	4.00	3.75	4.00	4.00	4.25
9	7.50		5.00	5.00	4.50	4.00	4.75	4.25	4.50
10	8.50		5.50	5.50	5.00	5.25	5.00	4.25	4.50
11	9.33	5.75	6.00	5.75	5.25	6.00	5.50	4.50	4.50
12	10.00	7.00	6.67	6.25	5.75	6.75	5.75	6.00	4.67
13	11.50	8.00	7.00	6.75	6.17	7.25	6.25	6.75	5.00
14	12.50	9.00	7.33	7.00	6.50	7.67	6.50	7.00	5.17
15	13.00	9.25	7.83	7.50	6.83	8.00	6.75	7.50	5.50
16	14.25	10.00	8.33	9.75	7.17	8.50	7.17	8.00	5.75
17		10.75	8.75	10.33	7.25	9.08	6.50	8.50	6.67
18		11.50				9.33			
19									
20									
Column			**Cable Payout Distance** (In)						
East	59.00	34.00	51.00	32.00	30.00	0.00	41.00	3.00	15.00
Center	83.00	63.00	9.00	47.00	17.00	63.00	0.00	44.00	8.00

Extra-Heavy type

Pulaski Bridge
Barrier Gate Energy Calculations



F= Stopping Force

P= Resisting Force P is fixed by brake adjustment.

$P := 27 \qquad \theta := 90$

$y := 20 \qquad x := y$

$F := 2 \cdot P \cdot \sin(\theta)$

$$F := 2 \cdot P \cdot \frac{y}{\left(\sqrt{y^2 + 18^2}\right)}$$

I. The kinetic energy of the 36,000 lb vehicle @ 20 mph

$$KE = \frac{36000}{2 \cdot 32.2} \cdot \left(\frac{20 \cdot 5280}{3600}\right)^2 = 4.81 \cdot 10^5 \text{ Ft-lb}$$

This must be resisted and absorbed in the snubbing action of the barrier gate.
The total energy absorbed is

$$F := 481000 \quad \text{lb-ft}$$

$$KE = F \cdot \int_0^y 1\, dy := 2 \cdot P \cdot \int_0^{20} \frac{y}{\sqrt{y^2 + 18^2}}\, dy$$

$$KE := 2 \cdot P \cdot \sqrt{y^2 + 18^2}\,\Big]_0^{20}$$

$$KE := 2 \cdot P \cdot \sqrt{18^2 + x^2}\,\Big]_0^{20}$$

Pulaski Bridge
Barrier Gate Energy Calculations

at 20' $\quad KE := 2 \cdot P \cdot \left(\sqrt{18^2 + 20^2} - \sqrt{18^2}\right)$

at 20' and 481,000 ft-lbs

$$P = \frac{481000}{17.8} = 2.702 \cdot 10^4 \quad \text{KIPS}$$

and $\quad F_{20ft} = 2 \cdot 27 \cdot \frac{20}{\sqrt{724}} = 40.138$ KIPS at 20'

Note that P @ 27 Kips is assumed constant. This is the brake setting.
F varies as the barrier is played out.

At other payout lengths F is as follows.

y	F	y	F	y	F
1	3	8	21.9	15	34.6
2	6	9	24.2	16	36.0
3	8.9	10	26.2	17	37.0
4	11.7	11	28.2	18	28.1
5	14.4	12	30.0	19	39.2
6	17.1	13	31.6	20	40.2
7	19.6	14	33.2	KE	502.1 ft-lb

S.E. Sawyer Barrier Gate-Extra Heavy Type

Theoretical Resistance

ASSUMPTIONS : P = 27 KIPS (BRAKE RESISTANCE SETTING)

TEST INCREMENT(FT)	PAYOUT DISTANCE Y(FT)	BRAKE RESISTANCE P(KIPS)	LONGITUDINAL FORCE F(KIPS)	ENERGY EXPENDED IN 1FT. INCREMENTS (K-FT)
1	3.00	27.00	8.88	8.88
2	4.00	27.00	11.71	11.71
3	5.00	27.00	14.45	14.45
4	6.00	27.00	17.08	17.08
5	7.00	27.00	19.57	19.57
6	8.00	27.00	21.93	21.93
7	9.00	27.00	24.15	24.15
8	10.00	27.00	26.22	26.22
9	11.00	27.00	28.16	28.16
10	12.00	27.00	29.95	29.95
11	13.00	27.00	31.62	31.62
12	14.00	27.00	33.15	33.15
13	15.00	27.00	34.57	34.57
14	16.00	27.00	35.88	35.88
15	17.00	27.00	37.08	37.08
16	18.00	27.00	38.18	38.18
17	19.00	27.00	39.20	39.20
18	20.00	27.00	40.14	40.14

TOTAL ENERGY NEEDED TO STOP A 36,000# VEHICLE AT 20MPH IN 20FT. = <u>**491.92**</u>

INITIAL RESISTANCE IS ENCOUNTERED AT A PAYOUT DISTANCE OF 3FT.

N.E. Sawyer Barrier Gate-Heavy Type

Theoretical Resistance

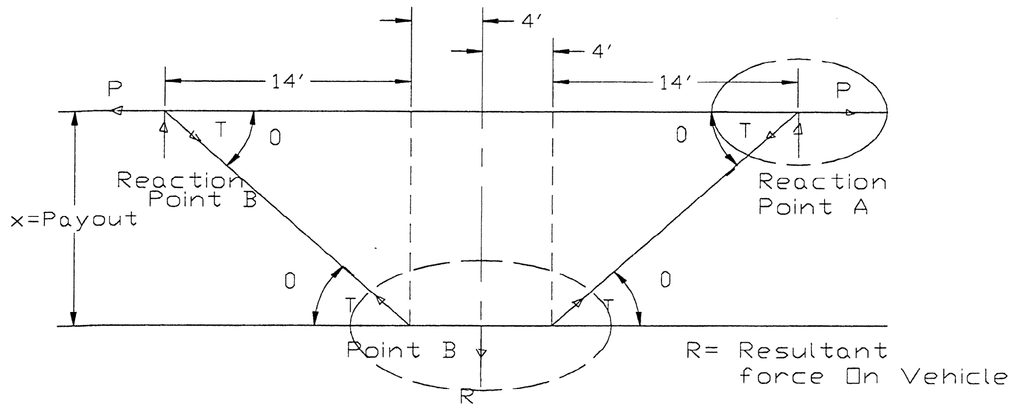
ASSUMPTIONS : P = 18 KIPS (BRAKE RESISTANCE SETTING)

TEST INCREMENT(FT)	PAYOUT DISTANCE Y(FT)	BRAKE RESISTANCE P(KIPS)	LONGITUDINAL FORCE F(KIPS)	ENERGY EXPENDED IN 1FT. INCREMENTS (K-FT)
1	3.00	18.00	5.92	5.92
2	4.00	18.00	7.81	7.81
3	5.00	18.00	9.64	9.64
4	6.00	18.00	11.38	11.38
5	7.00	18.00	13.05	13.05
6	8.00	18.00	14.62	14.62
7	9.00	18.00	16.10	16.10
8	10.00	18.00	17.48	17.48
9	11.00	18.00	18.77	18.77
10	12.00	18.00	19.97	19.97
11	13.00	18.00	21.08	21.08
12	14.00	18.00	22.10	22.10
13	15.00	18.00	23.05	23.05
14	16.00	18.00	23.92	23.92
15	17.00	18.00	24.72	24.72
16	18.00	18.00	25.46	25.46
17	19.00	18.00	26.13	26.13
18	20.00	18.00	26.76	26.76
19	21.00	18.00	27.33	27.33
20	22.00	18.00	27.86	27.86
21	23.00	18.00	28.35	28.35
22	24.00	18.00	28.80	28.80

TOTAL ENERGY NEEDED TO STOP A 36,000# VEHICLE AT 20MPH IN 20FT. = **440.30**

INITIAL RESISTANCE IS ENCOUNTERED AT A PAYOUT DISTANCE OF 3FT.

Pulaski Bridge
Barrier Gate Brake Setting Calculations



Plan of Barrier Gate Geometry

Point A:

Point B:

$T := 2$ $\quad\cos(\theta) := \frac{P}{T}$ $\qquad \sin(\theta) := \frac{\frac{R}{2}}{T}$

$\theta := 45$ $\quad T := \frac{P}{\cos(\theta)}$ $\qquad T := \frac{R}{2\cdot\sin(\theta)}$

$\frac{P}{\cos(\theta)} = \frac{R}{2\cdot\sin(\theta)}$ $\qquad R := 2\cdot P\cdot\tan(\theta)$

$\tan(\theta) := \frac{x}{14}$ $\qquad R := \frac{P\cdot x}{7}$

$x := 20$ Ft $\qquad F(x) := \frac{P\cdot x}{7}$

$\text{Work} := \int_0^x F(x)\,dx$ $\qquad \text{Work}_{net} := \int_0^x \frac{P\cdot x}{7}\,dx$

$\text{Work}_{net} := \frac{P\cdot x^2}{14}$ $\qquad \text{Work}_{net} = 28.6\ P$

Pulaski Bridge
Barrier Gate Brake Setting Calculations

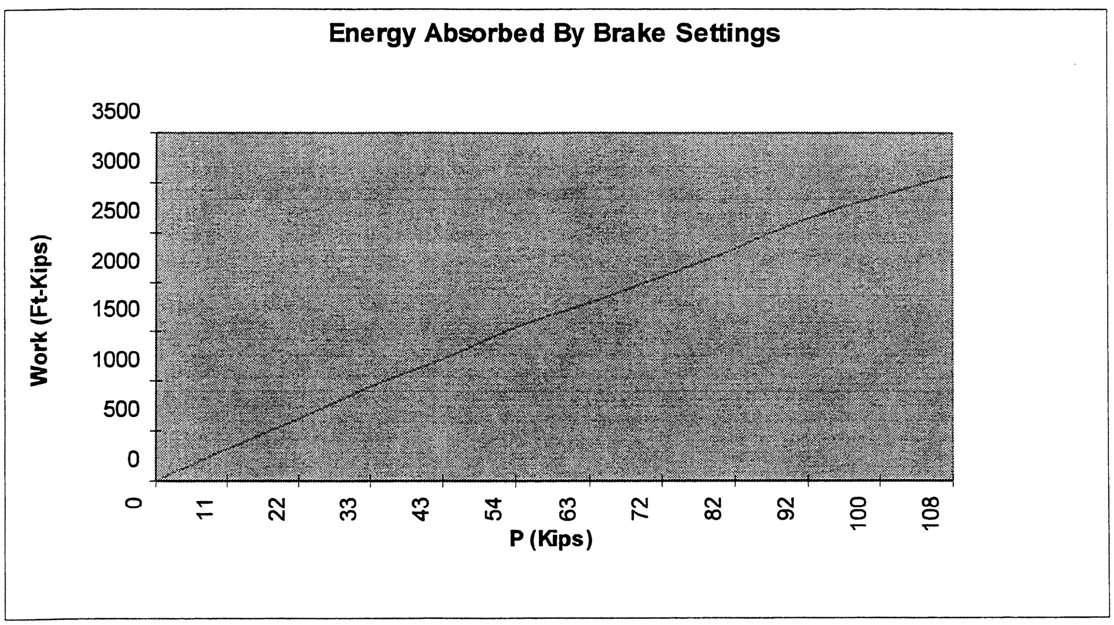
Energy Absorbed By Brake Settings:

P=Brake Load Setting Per Drum Box

$P := 18$ Kips $\quad W := 515$ Ft-Kips

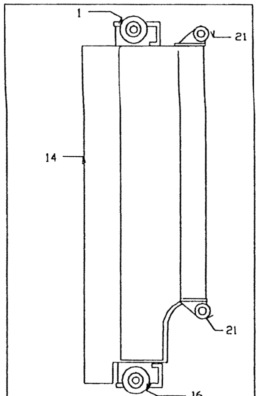
$P := 17$ Kips $\quad W := 486$ Ft-Kips

P (Kips)	Energy (Ft-Kips) = 28.6 P
11	314
22	629
43	1,230
54	1,544
72	2,059
108	3,089

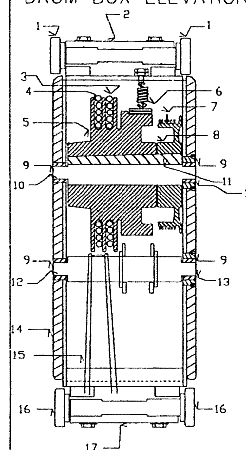


Drumbox parts and recommended repairs

LOCATION	MARK	QUAN.	DESCRIPTION	WORK TO BE PERFORMED
SOUTHEAST OUTER	1	2	TOP ROLLERS	REPLACE
SOUTHEAST OUTER	2	1	TOP ROLLER FRAME	DYE PENET. INSP., REPAIR SHAFTS, BLAST & PAINT
SOUTHEAST OUTER	3	1	TOP WIRE ROPE	REPLACE
SOUTHEAST OUTER	4	1	BOTTOM WIRE ROPE	REPLACE
SOUTHEAST OUTER	5	1	MAIN CABLE DRUM	POLISH BRAKE SURFACE, BLAST & PAINT SHEAVE
SOUTHEAST OUTER	6	1	BRAKE ASSEMBLY	REPLACE LINING & RECOIL STOPPER, BLAST & PAINT
SOUTHEAST OUTER	7	1	RECOIL STOPPER DOG ASSEMBLY	REPLACE WORN PARTS, BLAST & PAINT
SOUTHEAST OUTER	8	1	RECOIL STOPPER DRUM	DYE PENET. INSP., REPAIR WORN TEETH, BLAST & PAINT
SOUTHEAST OUTER	9	4	OILITE BUSHING	REPLACE
SOUTHEAST OUTER	10	1	DRUM SHAFT	CLEAN, CHECK FOR STRAIGHTNESS & KEYWAY CONDITION
SOUTHEAST OUTER	11	1	TAPERED KEY	CLEAN, CHECK FOR TIGHT FIT WITH KEYWAY
SOUTHEAST OUTER	12	1	BRAKE ANCHOR SHAFT	CLEAN, CHECK FOR STRAIGHTNESS
SOUTHEAST OUTER	13	2	STEEL BUSHING	VERIFY PROPER ID. AND OD. FIT
SOUTHEAST OUTER	14	1	DRUM BOX CASING	BLAST AND PAINT, BUILD UP ANY WORN AREAS
SOUTHEAST OUTER	15	1	FUNNEL	BLAST AND PAINT, DYE PENETRANT INSPECTION
SOUTHEAST OUTER	16	2	BOTTOM ROLLERS	REPLACE
SOUTHEAST OUTER	17	1	BOTTOM ROLLER FRAME	DYE PENET. INSP., REPAIR SHAFTS, BLAST & PAINT
SOUTHEAST OUTER	21	4	BACK DRUM ROLLERS	REPLACE
SOUTHEAST OUTER	22	4	TOP & BOTTOM GUIDES	BLAST AND PAINT, DYE PENETRANT INSPECTION
SOUTHEAST INNER	1	2	TOP ROLLERS	REPLACE
SOUTHEAST INNER	2	1	TOP ROLLER FRAME	DYE PENET. INSP., REPAIR SHAFTS, BLAST & PAINT
SOUTHEAST INNER	3	1	TOP WIRE ROPE	REPLACE
SOUTHEAST INNER	4	1	BOTTOM WIRE ROPE	REPLACE
SOUTHEAST INNER	5	1	MAIN CABLE DRUM	POLISH BRAKE SURFACE, BLAST & PAINT SHEAVE
SOUTHEAST INNER	6	1	BRAKE ASSEMBLY	REPLACE LINING & RECOIL STOPPER, BLAST & PAINT
SOUTHEAST INNER	7	1	RECOIL STOPPER DOG ASSEMBLY	REPLACE WORN PARTS, BLAST & PAINT
SOUTHEAST INNER	8	1	RECOIL STOPPER DRUM	DYE PENET. INSP., REPAIR WORN TEETH, BLAST & PAINT
SOUTHEAST INNER	9	4	OILITE BUSHING	REPLACE
SOUTHEAST INNER	10	1	DRUM SHAFT	CLEAN, CHECK FOR STRAIGHTNESS & KEYWAY CONDITION
SOUTHEAST INNER	11	1	TAPERED KEY	CLEAN, CHECK FOR TIGHT FIT WITH KEYWAY
SOUTHEAST INNER	12	1	BRAKE ASSEMBLY SHAFT	CLEAN, CHECK FOR STRAIGHTNESS
SOUTHEAST INNER	13	2	STEEL BUSHING	VERIFY PROPER ID. AND OD. FIT
SOUTHEAST INNER	14	1	DRUM BOX CASING	BLAST AND PAINT, BUILD UP ANY WORN AREAS
SOUTHEAST INNER	15	1	FUNNEL	BLAST AND PAINT, DYE PENETRANT INSPECTION
SOUTHEAST INNER	16	2	BOTTOM ROLLER	REPLACE
SOUTHEAST INNER	17	1	BOTTOM ROLLER FRAME	DYE PENET. INSP., REPAIR SHAFTS, BLAST & PAINT
SOUTHEAST INNER	21	4	BACK DRUM ROLLERS	REPLACE
SOUTHEAST INNER	22	2	TOP & BOTTOM GUIDE ROLLERS	BLAST AND PAINT, DYE PENETRANT INSPECTION



TYPICAL EXTRA HEAVY DRUM BOX ELEVATION



TYPICAL EXTRA HEAVY DRUM BOX SECTION

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to the following individuals:

Joe Lock of Lockran Industries for copies of Emerson Sawyer's expired patents and Sawyer's advertisement pamphlets; Balram Chandiramani of NYCDOT's Bridge Design Section who granted me permission to publish this paper; George Foerster, resident mechanical engineer of Hardesty & Hanover, who collected most of the data; John Tampakis at Tamco Machine Shop, who compiled the listing for the drum box rehabilitation; Rob Tannor of S.N. Tannor, who came up with ideas for test fabrications; and Michael Abrahams, my supervisor at Parsons Brinckerhoff, for his encouragement.