PENNSYLVANIA RAILROAD
PLATE FULCRUM MASTER SCALE
INSTALLED AT ALTOONA, PA.

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IN CONNECTION with the past and present interest taken in the use in scale construction of the plate fulcrum or, as termed by some, the flexure plate, attention is invited to the most recent application of this principle in the just completed master track scale of the Pennsylvania Railroad at its Altoona Works. This master scale is the outgrowth of a gradual development during the past twelve years, during which time the application of the plate fulcrum principle to track scale construction has been studied in minute detail on the Pennsylvania, and its completion marks another forward step in the efforts of the Pennsylvania Railroad to provide itself with the best obtainable weighing equipment. Some of the considerations which led up to the present installation are as follows:—

THE FIRST PLATE FULCRUM TRACK SCALE.

Approximately 260 track scales are owned and used currently by the Pennsylvania Railroad for weighing both loaded and empty cars. Prior to 1915, all of these scales were of the knife-edge type, with continuous weigh-bridges, and almost entirely of the four-section type. During the
year 1915, the first plate fulcrum track scale was installed at East Tyrone, Pa. This experimental installation was of the four-section type with articulated weigh-bridge (Fig. 1, page 18), but the complicated construction and the expense incident to its manufacture suggested the wisdom of developing a two-section design. This was done, and the two-section design proved so successful in every way that it was adopted as standard for all new construction on the Pennsylvania, and some 28 track scales of this type (Fig. 2, page 20), in lengths of 52, 62 and 75 feet, are now in regular service.

**Test Weight Cars.**

The advantages of the plate fulcrum over the knife-edge type of track scale are too numerous to mention in detail, but they include such important factors as economy in maintenance, absolute freedom from friction, definite control of sensitivity, uniformly correct indications, and continuity of satisfactory service under practically any or all operating conditions.

To permit of ready calibration of all track scales, and to prove the continued correctness of such scales at the required frequency with reasonable certainty and without undue expense, it is necessary to provide test weight cars. Such cars are, in reality, portable test weights which may be handled in train service. Since the most impor-
tant requirement for this class of equipment is, obviously, constancy in the actual weight, these cars, as designed and built by the Pennsylvania Railroad for its own use, are of the most approved type (Fig. 3, page 21). They are self-contained, and so constructed as to shed quickly all rain and snow, and are of the roller bearing type. This last feature is especially valuable in that, first, repacking of the journal boxes while the cars are enroute, with the attendant erratic changes in weight, is eliminated and, second, the power required to move a car from point to point along a scale during a test is greatly reduced.

**The Master Scale at Altoona.**

Test weight cars are operated in pairs, each consisting of one 40,000-pound car and one 80,000-pound car, and each pair is scheduled over a definite route at approximately three-month intervals. Each route starts and ends at a master scale, at which point the cars are thoroughly cleaned, inspected and reconditioned, the weight of each car being recorded as it arrives at the master scale and again when necessary reconditioning has been completed and the car is ready to be sent out again.

The Pennsylvania Railroad has for some years maintained three master scales, the most important of which, from the standpoint of the number
of its test weight cars calibrated, being that located in the system Scale Shop at Altoona. Shortly after completion of the first plate fulcrum track scale at East Tyrone, the need of a more satisfactory master scale at Altoona was apparent. As has already been indicated, the plate fulcrum track scales had been found to be more sensitive and to maintain their adjustment more closely than preceding types. Test weight cars had been developed which were more constant in weight under service conditions. It therefore remained to provide a facility for checking the weights of test cars, which would be at all times beyond question.

**Accuracy in Weighing Test Weight Cars.**

The importance of unquestionable accuracy in the weight of test cars cannot be overestimated. As an indication of the situation, in 1926 the Pennsylvania Railroad handled 230,000,000 tons of freight. The revenue derived from transporting this enormous tonnage was based directly on the weight thereof, and as an exceedingly large proportion of such weights must be determined on track scales, it is obvious, for both the Railroad and the Shipper, that the facilities for determining the correctness of the track scales must be adequate and of the greatest obtainable accuracy.
When the Scale Shop was recently moved to its new and larger building (Fig. 4, page 22), it became necessary to either move or replace the old master scale, and the decision was finally reached to install in the new shop building a new plate fulcrum master scale, the first of its kind in the United States, in fact, in the world, as far as we can find record.

In the design of this scale, the following general principles were agreed to:

1. It should conform to the general specifications of the American Railway Association for master scales of the knife-edge type, as far as those specifications were applicable.
2. It should be installed under cover in a location as free as possible from vibrations due to machinery, train or other causes, and where it would not be run over by cars or material not to be weighed.
3. It should be used primarily for calibrating test weight cars or for other special weighing where extreme accuracy might be required. It should not be used for general weighing.
4. It should be of the two-section type, with multiple of 100:1 at the butt of the beam.
5. The scale rail should be twelve feet long, and should be located centrally over and entirely inside the span of the scale bridge. The approach tracks should be on a tangent for at least twenty-five feet in each direction from the scale.
6. The capacity of the scale should be 150,000 pounds.

7. It should be capable of adjustment, and the maintenance of such adjustment should be possible within the limits shown in the following tabulation, respectively:

<table>
<thead>
<tr>
<th>Test Load in Pounds</th>
<th>Tolerance in Pounds For Adjustment</th>
<th>For Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,000</td>
<td>3.00</td>
<td>6.00</td>
</tr>
<tr>
<td>30,000</td>
<td>3.68</td>
<td>7.36</td>
</tr>
<tr>
<td>40,000</td>
<td>4.24</td>
<td>8.48</td>
</tr>
<tr>
<td>50,000</td>
<td>4.75</td>
<td>9.49</td>
</tr>
<tr>
<td>60,000</td>
<td>5.20</td>
<td>10.40</td>
</tr>
<tr>
<td>70,000</td>
<td>5.62</td>
<td>11.22</td>
</tr>
<tr>
<td>80,000</td>
<td>6.00</td>
<td>12.00</td>
</tr>
<tr>
<td>90,000</td>
<td>6.37</td>
<td>12.74</td>
</tr>
</tbody>
</table>

(Note:—The figures shown in the above tabulation are those adopted by the U. S. Bureau of Standards and by the Scale Committee of the American Railway Engineering Association.)

8. The design and installation of the scale should be such as to enable the above tolerance requirements to be consistently met and the adjustment of the scale to be held constant.

In addition to the foregoing general principles, the further requirement was laid down by the Management of the Pennsylvania Railroad that, regardless of the Bureau of Standards' tolerances, the proposed scale was to be consistently accurate to the irreducible minimum limit.

With these specifications and requirements as guides, the manufacture of the scale was completed and the installation was accomplished in
due time to the apparent satisfaction of all concerned, at a total cost of approximately $32,000.00.

**Details of Construction.**

Some of the details of the scale are described as follows:—

The inside dimensions of the pit which is of monolithic reinforced concrete, are 24' 0" x 11' 0" x 10' 2\(\frac{7}{8}\)" deep. The inside dimensions of the neck are 6' 8" x 8' 0". The neck is covered with a concrete ceiling supporting the beam cabinet, reinforced to sustain within the permissible limits of deflection the weight of the cabinet and the load transmitted thereto by the beam rod. All piers supporting any part of the lever system were bush hammered and carefully rubbed down to exact level. Walls or piers, part of the foundation, support the approach tracks rigidly. Access to the interior of the pit is by means of a stairway leading to the neck.

The lever system is of the two-section type (Fig. 6, page 24), and the multiples of the various levers are as follows:—

Main levers, 3\(\frac{1}{2}\):1;
Longitudinal extension levers, 6 6/7:1;
Transverse extension lever, 4 1/6:1;
Total multiplication to butt of beam, 100:1.

The arrangement of the lever system as installed in the pit is shown in Figs. 5 and 6, pages 23 and 24.
In the design of this scale every effort was made to incorporate parts which were already standard in the existing 52, 62 and 75 foot track scales. Therefore, the main base-plates, fulcrum stands, main levers, connections between main and longitudinal levers, heel castings, nose irons and connections between longitudinal and transverse extension levers are standard parts. The main base-plates are of cast iron, the top and bottom surfaces of which are machined, and are secured to the foundation by means of eincnch anchor bolts, placed after the base-plates were accurately spotted. The fulcrum stands are bolted to the upper surfaces of the main base castings, and are accurately doweled to exact location.

The Fulcrum Plates.

The fulcrum plates throughout the lever system correspond in form to the standard design used in connection with track scales, and are made of Special Chrome Vanadium Steel furnished by the Crucible Steel Company of America, under the trade name of "Cruco Fulcrum Steel." The physical properties of this steel are:

- Elastic Limit .................. 95,000
- Ultimate Strength .............. 125,000
- Elongation in 2" .................. 21%
- Reduction in Area .............. 61%

These plates receive a special heat treatment, after which they are machined and ground to
exact dimensions as shown by the drawings, and are jig-drilled to permit interchangeability of like parts. To absolutely insure this interchangeability, all surfaces against or on which the fulcrums bear are accurately scraped to exact planes. This provides perfect contact and freedom from initial strain in the plates when they are secured in place. No plates are used in direct tension.

**General Specifications.**

Both the longitudinal and transverse extension levers are of composite construction. The lever itself consists, in each case, of a 20-inch, 140-pound "H" beam, to the ends of which special castings are securely fastened by means of taper-fit alloy steel bolts. The casting at the butt end of the lever is designed to receive the butt fulcrum plate and load plate, while the casting at the tip end of the lever is designed to receive, in full machined ways, the nose iron, the movement of which is controlled by an adjusting screw. The selection of the section used as the main part of these levers was based on a deflection limit of 1/64 inch.

The connection between the longitudinal extension levers and transverse extension lever is made through a platen which is suspended from the transverse lever, and to which the load is applied by compression through vertical connections with the longitudinal levers. These con-
Connections are provided with fulcrum plates at both top and bottom, and screw adjustment is provided at the bottom in order to permit vertical alignment at normal temperature. The primary purpose of the compression connection is to compensate for changes in length of the longitudinal levers, caused by temperature variations, which, without this arrangement, would affect the accuracy of the scale. The load platen is stayed to the foundation in order to maintain accurately its position, and a stay-rod is also applied between the tip end of the transverse extension lever and the pit wall, for the same reason. These stays permit free vertical movement, within the necessary limits, of the scale parts to which they are bolted.

**The Weigh-Bridge.**

The weigh-bridge consists of one 30-inch, 180-pound rolled section under each of the scale rails. These beams, which are heavily cross-braced, are supported on the main bearing plates of the lever system, through suitable cross girders. On the bridges are mounted combination crossties and rail columns of cast iron, and accurate alignment of these castings is obtained by means of machined steel pads which were welded to the upper surface of the girders at proper points. The weigh-bridge is stayed by a plate applied at one end to prevent both longitudinal and trans-
verse motion (Figs. 7 and 8, pages 25 and 26), and by a stay-rod applied at the other end to prevent traverse motion.

**The Weigh-Beam and Indicating Mechanism.**

The entire pit is covered with a steel deck supported by channel sections and at such elevation with respect to the scale mechanism that the tops of the scale rails fall below the top surface of the deck. The openings which are necessary on account of this condition are covered, when the scale is not in use, by hinged steel plates which present no obstacle to walking across the deck. When the scale is in use, these plates are turned back (Fig. 9, page 27). Some difficulty having been experienced on account of air currents through these comparatively large openings, a series of baffle plates was later introduced to break up the air currents. Arrangements were also made to maintain more uniform temperatures in both the pit and the beam cabinet with thermostatic control. The surface of the steel deck is coated with mastic, 1\(\frac{3}{8}\) inches thick.

The weigh-beam mechanism is entirely enclosed in a cast metal frame cabinet provided with hinged hinged plate glass windows (Figs. 10, 11 & 12, pages 28, 29 and 30). A glass partition is provided between the operating handles referred to below and the rest of the cabinet, so that, even
when the scale is in use, no air currents can strike the beam. The interior of the cabinet is illuminated by a series of incandescent lamps similar in type and location to those usually seen in show cases.

**Sensitivity of Scale.**

The connection from the tip end of the transverse extension lever to the weigh-beam which is located in the upper section of the beam cabinet, is through a twin steelyard rod which passes through an oil seal at the base of the beam cabinet. The load thus applied to the butt of the beam 4 inches from the main fulcrum is counterbalanced by three groups of telescopic counterpoise weights. The first group of nine 100-pound weights is located 8 inches from the beam fulcrum; the second group of nine 1,000-pound weights is located 20 inches from the main fulcrum, and the third group of fourteen 10,000-pound weights is located 40 inches from the main fulcrum. The fractional bar is graduated at 1-pound intervals up to 100 pounds, and the use of a vernier poise on this bar permits accurate readings to be taken to the nearest 1/10 pound. The beam is sensitive to this amount under a load of 100,000 pounds and by means of adjustment provided can be made much more sensitive than this without the usual tendency to become unstable.
The manipulation of both the telescopic weights and the vernier poise is controlled by operating levers in the middle section of the beam cabinet. This operating mechanism is interlocked mechanically with the beam locking device in such a way that no telescopic weight can be applied or removed at any time unless the beam is locked. The amount represented by the telescopic weights when applied to the beam is indicated to the weigher by vertical bars connected with the operating mechanism on the face of which are numerals that correspond to the weight.

**Accuracy of Counterpoise Weights.**

The equilibrium of the beam is shown by the position of the indicator or pointer which is connected to tip of the main beam to magnify its motions. The tip of this pointer moves across a graduated arc the middle graduation of which corresponds to a horizontal position of the main beam. Zero load balance of the weigh-beam is obtained by two balancing weights which have screw adjustment. The sensitivity and frequency of the beam are controlled by vertically adjustable weights supported on spindles and located respectively over the main fulcrum of the weigh-beam and the fulcrum of the indicator pointer. The tendency of the beam to respond to outside influences is controlled by means of an oil
dashpot in which vertical oscillation of the beam causes horizontal displacement of the oil in the dashpot which is connected with and operated by the indicator referred to above.

**INTERNAL OPERATING MECHANISM.**

The telescopic counterpoise weights, and also the vernier poise used on the fractional bar, are gold-plated to prevent tarnishing or change in mass due to oxidation. Before being applied to the scale these weights were submitted to the Bureau of Standards, where they were tested, as a result of which the Bureau furnished a certificate to the effect that the weights had been found to be correct within the limits of tolerances for class “A” weights and to remain constant within 1/5 of these tolerances during a period of three months. The following tabulation shows the tolerance values referred to in the Bureau of Standards certificate:

<table>
<thead>
<tr>
<th>Weight</th>
<th>Weight Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fractional poise</td>
<td>4 Ounces</td>
<td>0.1 Gr.</td>
</tr>
<tr>
<td>100 pounds telescopic weight</td>
<td>0.5 Pounds</td>
<td>0.1 &quot;</td>
</tr>
<tr>
<td>1,000 pounds telescopic weight</td>
<td>2.0 Pounds</td>
<td>0.3 &quot;</td>
</tr>
<tr>
<td>10,000 pounds telescopic weight</td>
<td>10.0 Pounds</td>
<td>0.8 &quot;</td>
</tr>
</tbody>
</table>

The spindles supporting the telescopic weights are also gold-plated.

The lower section of the beam cabinet is devoted entirely to the weight operating and interlocking mechanisms. The manipulation of the telescopic
weights is accomplished by means of rack and quadrant mechanism suitably counterbalanced to obtain uniform resistance when raising or lowering the spindles which control the telescopic weights. When the sealed and tested counterpoise weights and the fractional poise were received at Altoona from the Bureau of Standards, the weigh-beam was set up and the beam was sealed to the weights on the basis of the established multiple at the butt of the beam of 100:1. After this had been done, the beam was connected to the scale proper and the scale was carefully tested up to 100,000 pounds with carefully calibrated weights (Fig. 13, page 31). The weights used in this test had previously been sealed by the Bureau of Standards, and the probable error of the entire nest of weights has been determined to be 0.24 pounds. This value is materially less than the tolerance adopted by the Bureau of Standards for this class and quantity of test weights.

**Calibration of Scale.**

The weights were applied at each end and at the center of the scale. While it is realized that this condition of loading does not correspond to either actual weighing or to the load used by the Bureau of Standards in their routine master scale tests, it is believed that the method of concentration used constitutes a more severe test than with the load
applied on four wheels. In view of this, it is also believed that when the official Bureau of Standards test is made the performance of the scale will be even better than that determined by the tests made up to this time, in which a maximum error of five-tenths (5/10) pound under a load of 100,000 pounds has been developed.

A MASTERPIECE IN DESIGN AND CONSTRUCTION.

The completion of this scale has thus far been received by members of the Engineering Mechanical and Scale professions in a most gratifying manner. It is generally conceded by all who have seen it that it is a master-piece in both design and construction, especially for a scale of its capacity.

The original design was worked up under the direction of Mr. A. H. Emery (deceased), former Civil and Mechanical Engineer, Glenbrook, Conn.; while the work of redesigning the scale was done in the Engineering Department of the Pennsylvania Railroad at Altoona, and was participated in by Mr. A. S. Vogt (deceased), former Mechanical Engineer; who should be given great credit for his many valuable and helpful suggestions; also Mr. R. N. Miller, Assistant Engineer; Mr. A. W. Epright, Supervisor of Scales and Weighing, and others.
That the scale has finally been completed and installed, is due to the persistent efforts and personal interest taken in the matter by Mr. J. T. Wallis, Assistant Vice-President in Charge of Operation, Pennsylvania Railroad, whose foresight and ability made this achievement possible.

Figures 1 to 13, referred to in the text, appear on the following pages.
FIG. 1.—FOUR SECTION PLATE FULCRUM TRACK SCALE—FIRST OF ITS TYPE TO BE BUILT AND INSTALLED FOR WEIGHING CARLOAD FREIGHT.

(See page 8).
Fig. 2.—Two Section Plate Fulcrum Track Scale of the Most Recent Design.
(See page 2).
FIG. 3.—P. R. R. Standard Test Car Used As Portable Test Weight. (See page 9).
Fig. 4.—P. R. R. Scale Shop, Altoona, Where Master Scale is Located and Where All Scales Used on the System Are Manufactured. (See page 6).
FIG. 5.—LEVER SYSTEM. TWO SECTION PLATE FULCRUM MASTER SCALE. (See page 7.)
Fig. 6.—Lever System Two Section Plate Fulcrum Master Scale with Bearing Plates Attached. (See page 7).
FIG. 7.—SECTION OF SCALE BRIDGE SHOWING LONGITUDINAL STAY PLATE CONNECTED. (See page 11).
FIG. 8—ARRANGEMENT OF SPACER BRIDGE AND STAY PLATE WITH RAIL COLUMN INSTALLED. (See page 11.)
FIG. 9.—SURFACE VIEW OF PLATE FULCRUM MASTER SCALE SHOWING BEAM CABINET AND SCALE RAILS WITH HINGED COVERS. (See page 11).
Fig. 10.—Front View of Beam Cabinet Showing Beam Indicating and Beam Control Mechanism—Also Gold Plated Telescopic Counterpoise Weights.

(See page 11).
Fig. 11.—End View of Beam Cabinet Showing Beam Arresting Device and Nest of 10,000 Lb. Telescopic Weights. (See page 11)
FIG. 12.—END VIEW OF BEAM CABINET SHOWING THE THREE SETS OF TELESCOPIC WEIGHTS AND MECHANICAL MEANS FOR APPLYING THESE WEIGHTS TO THE WEIGHT BEAM.
(See page 11).
FIG. 13.—NEST OF LARGE WEIGHTS USED IN CALIBRATING MASTER SCALE—PROBABLE ERROR IN 100,000 LBS. .24 LBS. (½ Lb.).
(See page 18).