DEVELOPMENT OF POSITIVELY STEERED RADIAL TRUCK

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Investigation of derailments revealed two short-comings of existing three-piece trucks, namely poor tracking on curves and hunting on tangent track. Design and installation requirements developed for innovative primary suspension radial truck. Initial design incorporated Ackermann linkage for positive steering of wheelsets. Prototype trucks later modified to simple geometric positive steering system, also used in trucks tested at Calgary by CP Rail, in TDOP and in FAST. Production design developed using standard bolster and pair of special side frames. Conversion kit for three-piece trucks available to give benefits of positive wheelset steering for existing cars at minimum cost. Concluded that positively-steered radial truck incorporating primary suspension meets requirements for ideal freight car truck.

INTRODUCTION

The investigation of freight train derailments showed that the majority of 'unexplained derailments' occurred on curved track. In consequence, the behavior of freight car trucks on curves was studied.[1] The poor tracking of three-piece trucks on curves was shown to be the probable cause of otherwise unexplained derailment, as well as the cause of severe wheel flange wear and side wear of curved rails.

Measurement of wheel-rail forces demonstrated clearly the high lateral forces produced by three-piece trucks when running on curved track of $1\frac{1}{2}^{\circ}$ or more curvature.[2] The need became evident for a radial truck which would maintain the wheelsets at right angles to the rails at all times and conditions.

In addition to poor tracking on curved track, three-piece trucks are subject to dynamic instability on tangent track, particularly under empty cars and with worn profile wheels. This phenomenon is generally known as 'hunting', and occurs at speeds of 45 m.p.h. or more in practice. 'Hunting' results in excessive wear of the truck components and has been blamed for a number of derailments.

The unsprung weight of three-piece trucks is comparatively high, because the side frames and brakegear are not sprung. In consequence, vertical shock loads on the track are intensified at joints, points and crossings, resulting in track damage.

Thus there appeared to be a need for an innovative truck which would overcome the three problems of the three-piece truck, namely poor tracking on curves, hunting on tangent track and high unsprung weight.

DESIGN REQUIREMENTS

Three essential design features for the innovative truck were determined as follows:-

1. Improved tracking on curves, equal to tangent track, in both empty and loaded conditions, with brakes applied as well as released, independent of wheel profile.
2. Stable (no hunting) at all normal running speeds, in both empty and loaded conditions, with new and worn profile wheels.
3. Reduced unsprung weight, to minimize vertical shock loads on the track.

INSTALLATION REQUIREMENTS

Three important installation specifications were also established as follows:-

1. Standard dimensions, for compatibility with existing cars and car designs.
2. Standard wheelsets, with 1 in 20 cone profile, for mechanical interchangeability.
3. Standard suspension components and brakegear, for simplified maintenance and inspection.

INITIAL DESIGN

The first design, shown in Figure 1., incorporated a transverse control bar, similar to the familiar Ackermann automobile steering system. The truck consisted of a one-piece fabricated H-frame, with primary suspension units in sub-frames which displaced longitudinally on low friction bearing pads as required by the control bar which was positioned at the bolster center line. The control bar was connected to the sub-frames on each side by tie bars and to the car body by bell cranks and anchor links. The control bar was moved outwards by the bell cranks and anchor links, as the truck swivelled under the car body on curved track, causing the sub-frames on the outside of the curve to move further apart and the sub-frames on the inside to move closer together. Thus the wheelsets took a position that was approximately radial. The arrangement was complicated and had the theoretical weakness of Ackermann automobile steering in that it was only exactly correct on tangent track and for one radius of curvature. A pair of trucks to this design were built and underwent preliminary testing.

Subsequently, the original steering system was replaced by a simple geometric one, shown in Figure 2., which gave precise steering for all main line curves. The geometric steering consisted of a steering arm on each side of the truck, pivoting on the transverse center line at the intersection with the side frame center line. Each steering arm was connected to the sub-frames by tie bars and to the body by an anchor link. The steering arms rotated as the truck swivelled under the car body on curved track, causing the sub-frames to move apart on the outside of the curve and together on the inside, to give an exact radial position for the wheelsets.

Test runs carried out on the Bessemer and Lake Erie Railroad with the trucks under a loaded 100 ton gondola car demonstrated the feasibility of the positive steering concept.

PROTOTYPE TRUCKS

Four pairs of positively steered radial trucks were built to the design shown in Figure 2. The first pair were used for static and fatigue tests. After stress relieving, they were sent to run in FAST at the Transportation Test Center at Pueblo, Colorado.[3] The second pair were tested by C.P. Rail at Calgary under a 'Bathtub' coal car.[4] The third pair were tested by Wyle Laboratories in the Truck Design Optimization Program (TDOP) sponsored by the Federal Railroad Administration at Las Vegas, Nevada.[5] The fourth pair were also sent to FAST.

Excellent results were obtained in all the tests, which are described in previous publications.[3,4,5,&6] Under the severe conditions of the FAST track at Pueblo, the positively steered truck is giving almost 3 to 1 improved wheel life while the self-steering trucks are showing about 2½ to 1 reduction in wheel wear compared with standard three-piece trucks. In TDOP, the positively steered truck recorded the lowest lateral forces and curving resistance of all the trucks tested, as shown in Figures 3,4,5, and 6. The positively steered truck was equal to or better than the self-steering trucks in the stability tests.

Thus the superiority of positive steering over self-steering systems for radial trucks is clearly demonstrated.

PRODUCTION DESIGN

A production design of the positively steered radial truck has been developed, shown in Figure 3. The production design consists of a standard cast steel bolster which rests on a pair of special side frames through curved saddle pieces to give full wheel load equalization. Sub-frames with primary suspension and positive steering linkage are incorporated.

CONVERSION DESIGN

A conversion kit has been designed to give positive wheelset steering for existing three-piece trucks, as shown in Figure 7. Modification of the pedestal area of the side frames is required to permit the addition of sub-frames, as shown. The vertical legs of the pedestal are cut back, which does not affect the strength of the side frame.

A kit for one truck consists of four sub-frames, four paired steering arms, two connecting links and two anchor links. The sub-frames bear against the side frames through low friction bearing pads attached to the pedestals. Extension arms from each sub-frame connect through a transverse bar with a pivot pin in the steering arm, which is pivotted on a bracket attached to the side frame. The bracket is retained by the same bolts that secure the wear plate for the bolster friction damper. The two steering arms for each side frame are joined at their outer ends by the connecting link. One end of the connecting link is coupled to the car body by the anchor link, fitted with ball joints at each end to allow for misalignment. The wheelsets of the converted truck steer on curves like the wheelsets of the radial trucks previously described.

This concept is also suitable for new trucks. It is comparatively simple to produce new side frames with the pedestal area changed to the shape shown in Figure 7. This positive steering system can provide the maximum benefits of the radial truck for freight cars at the minimum cost.

CONCLUSIONS

1. The positively steered radial truck incorporating primary suspension and positive wheelset steering meets the design requirements for an ideal freight car truck.
2. The addition of positive steering linkage to existing three-piece trucks permits their conversion to radial action at minimal cost.

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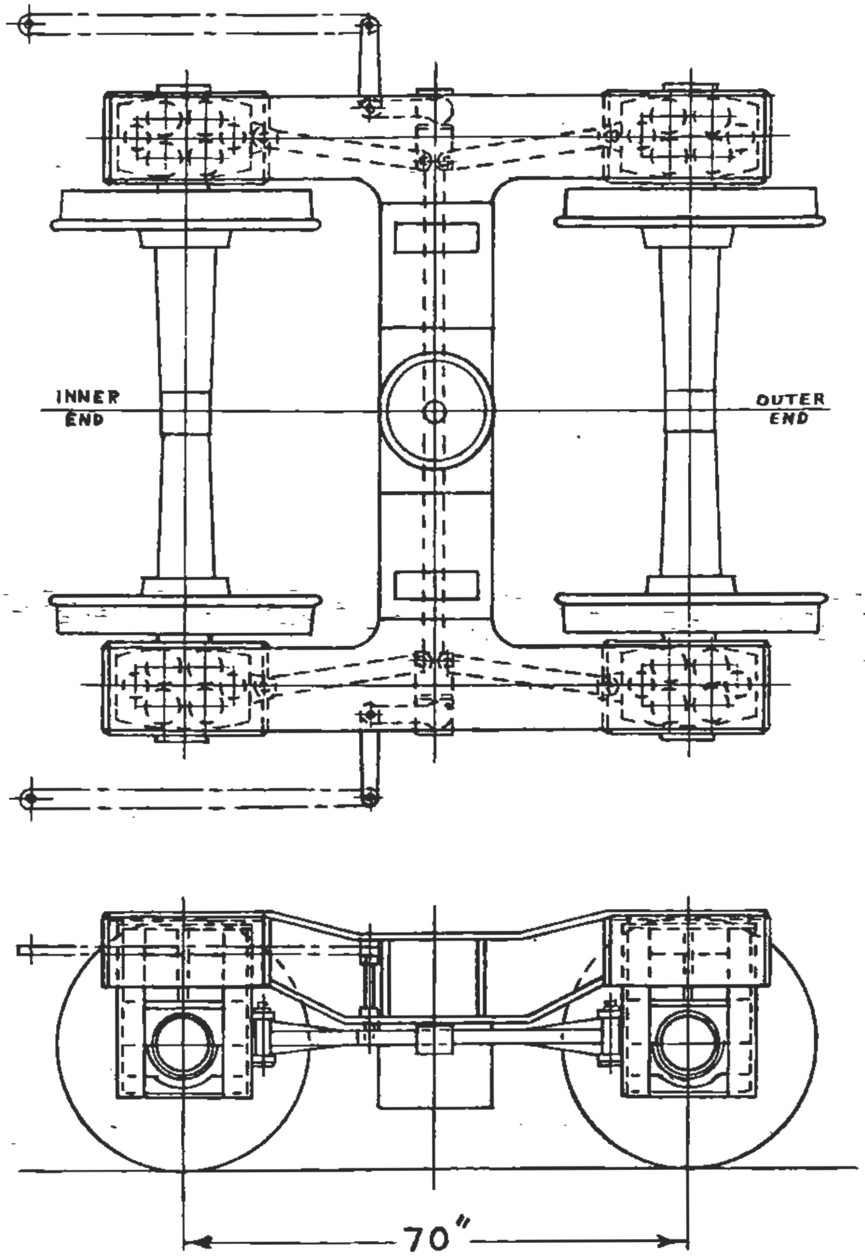

FIG. I. INITIAL DESIGN

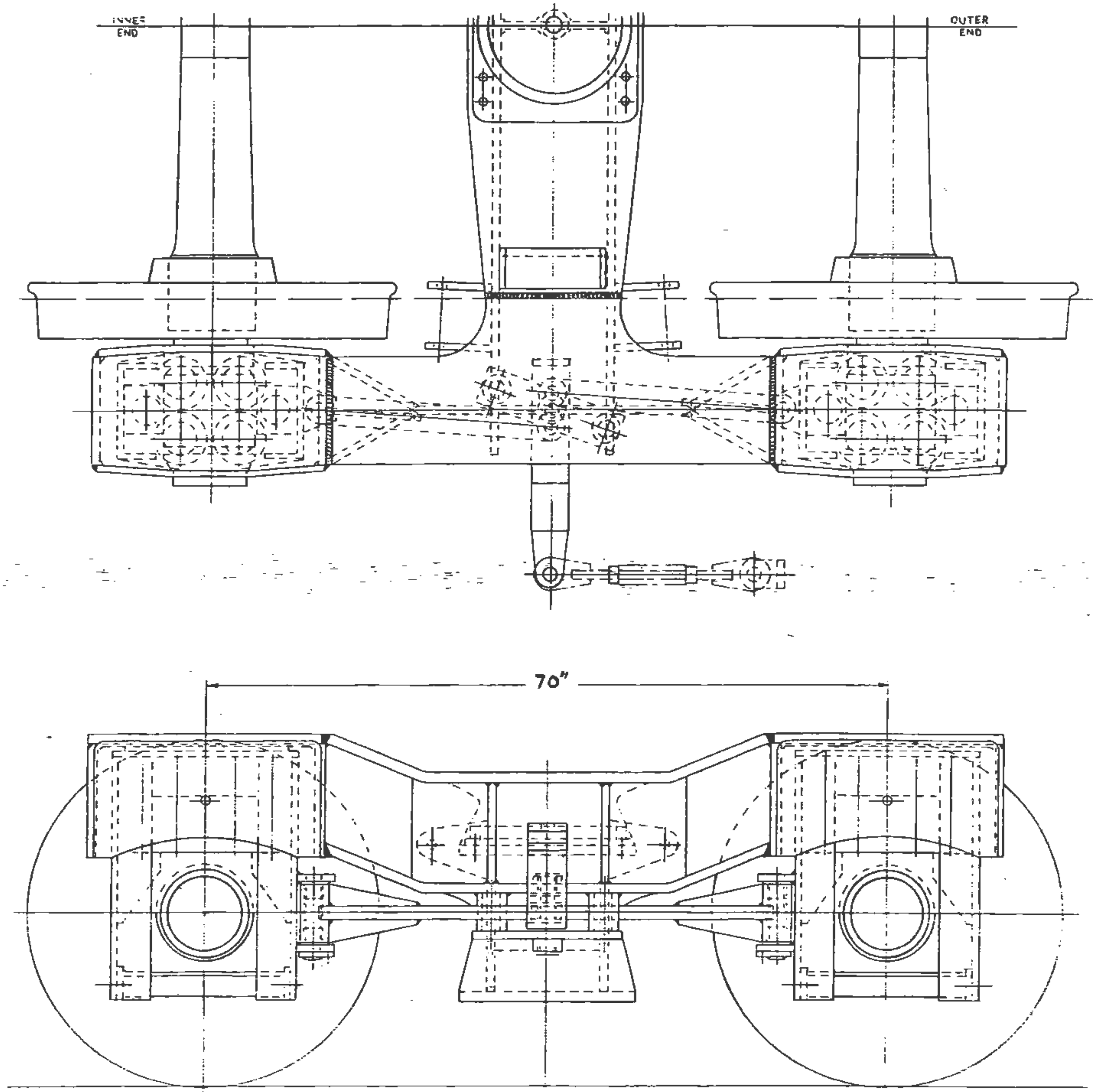

FIG. 2. PROTOTYPE DESIGN

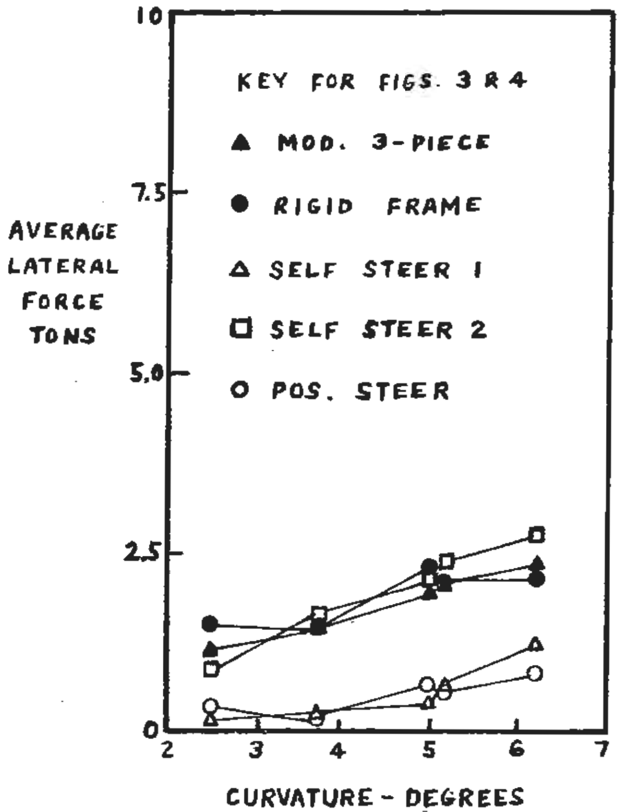

FIG. 3. LATERAL FORCE/CURVATURE FOR EMPTY HOPPER CARS

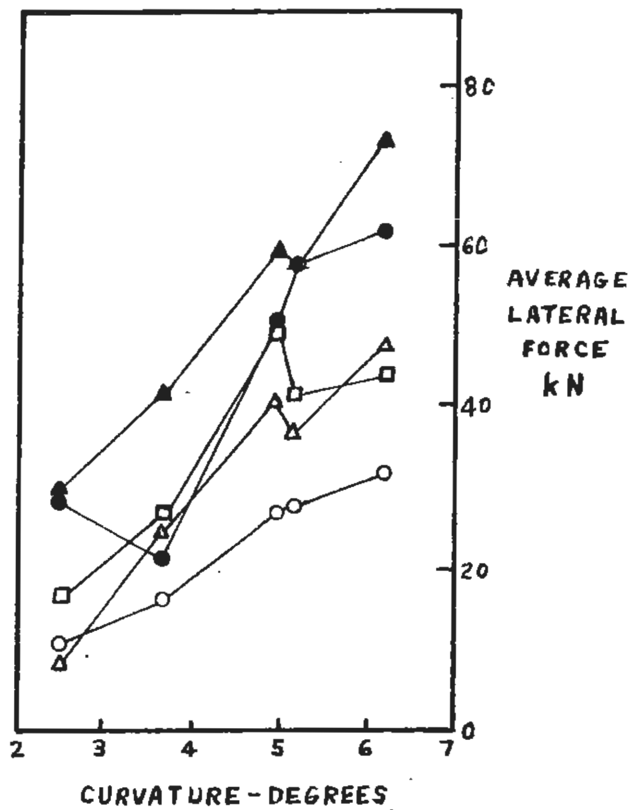

FIG. 4. LATERAL FORCE/CURVATURE FOR LOADED HOPPER CARS

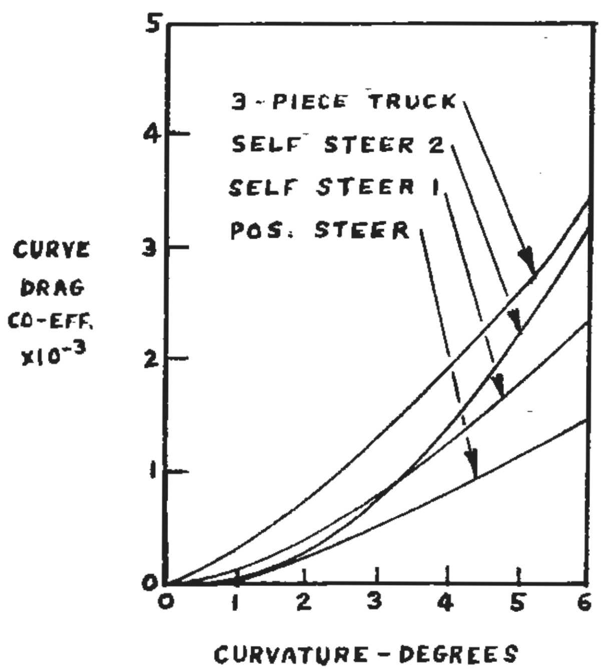

FIG. 5. CURVE DRAG/CURVATURE

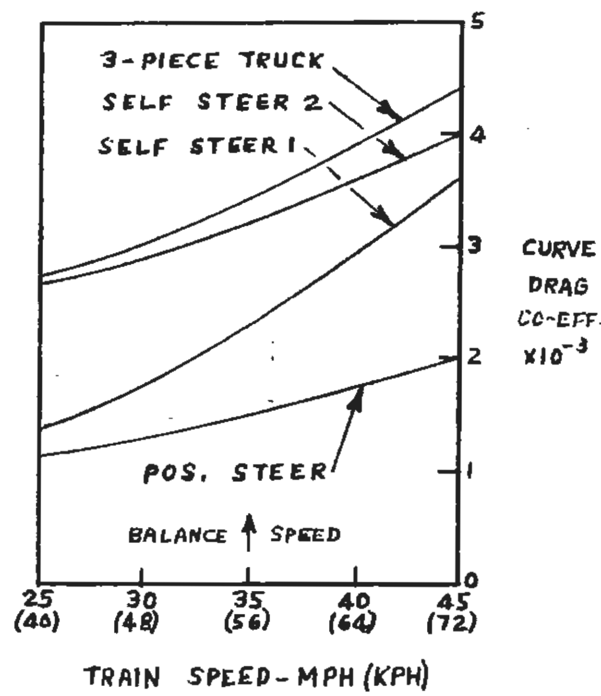

FIG. 6. CURVE DRAG/SPEED

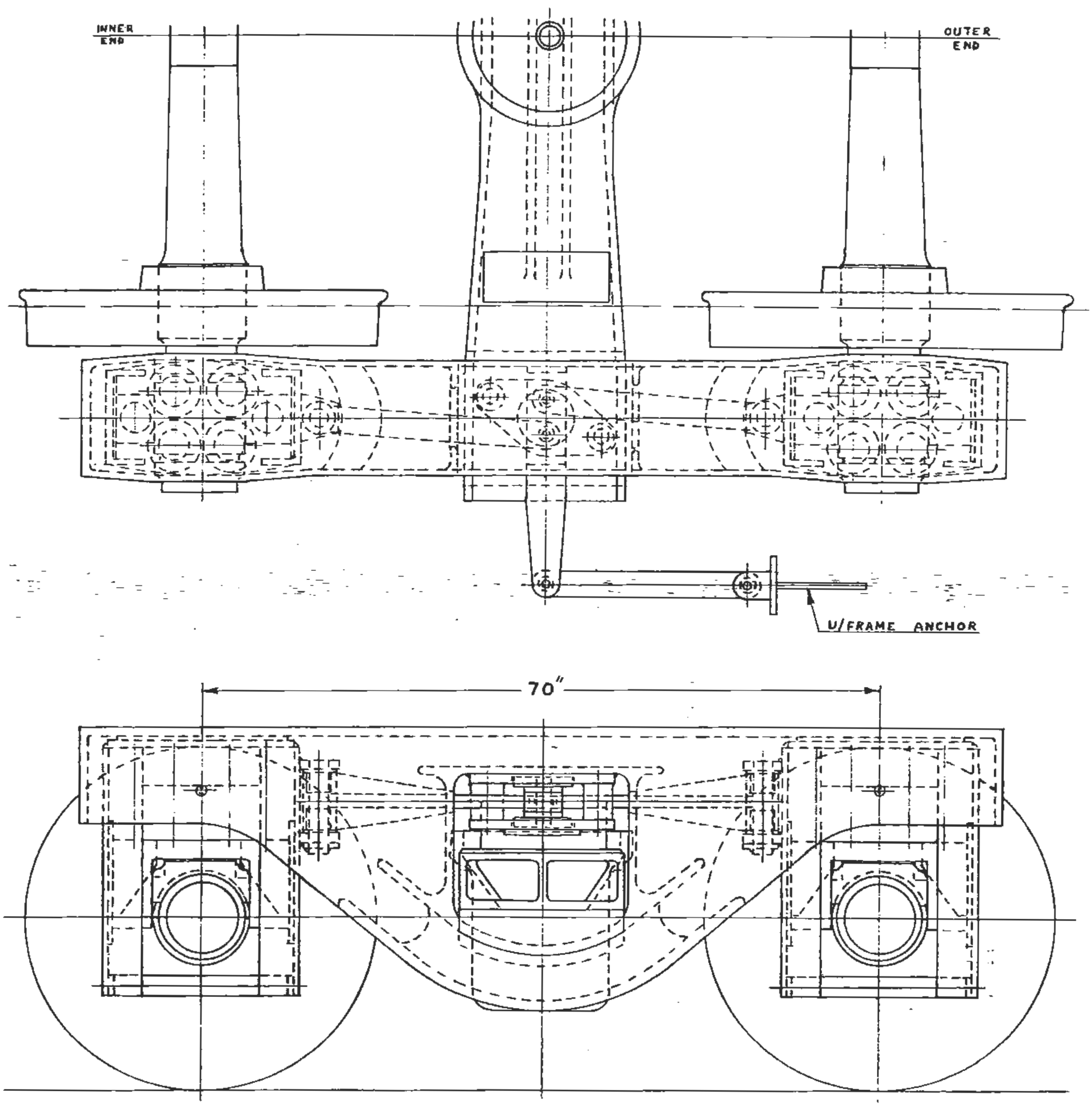

FIG. 7. PRODUCTION DESIGN

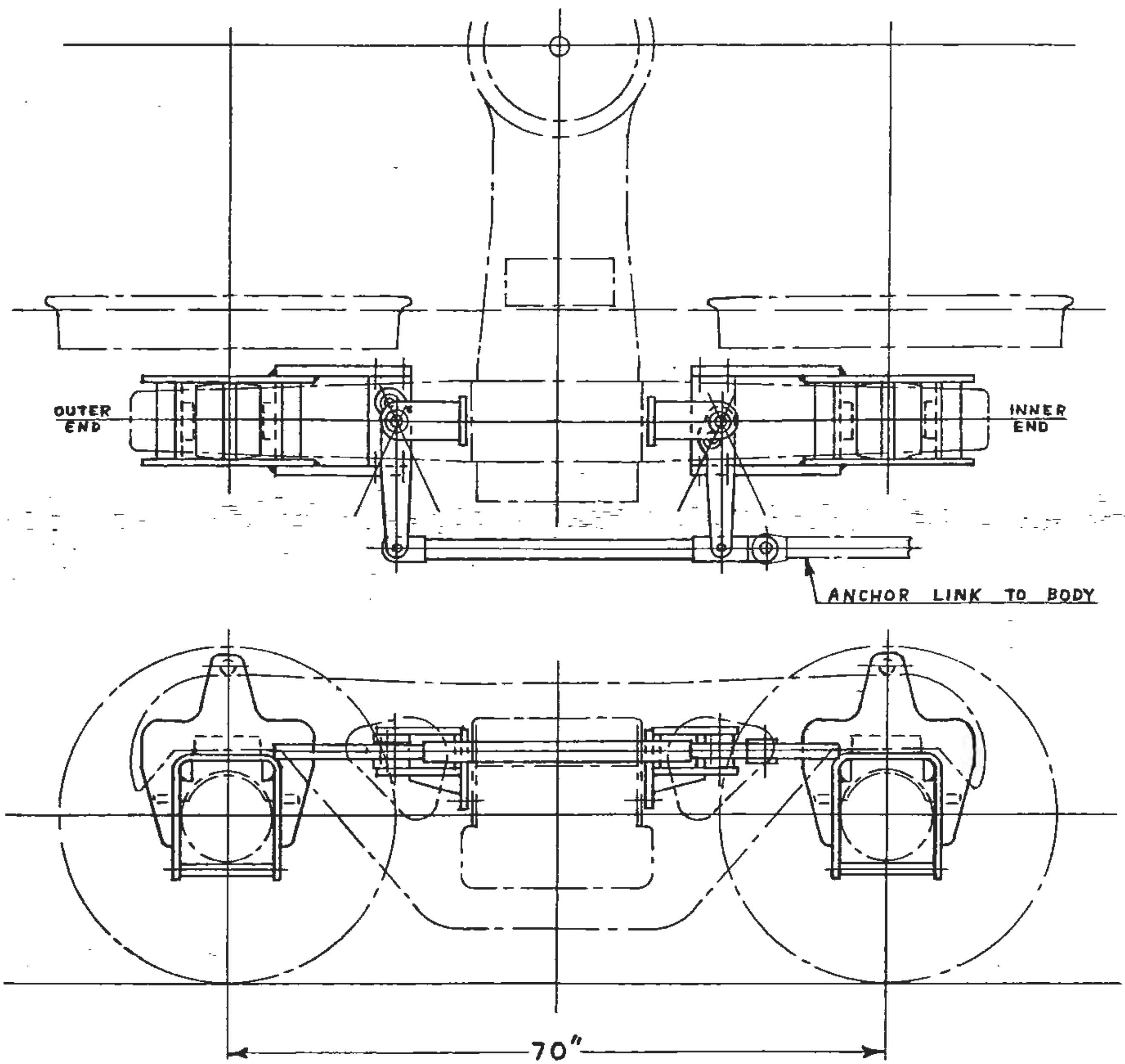

FIG. 8. CONVERSION KIT