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The BETHLEHEM TORQUE AMPLIFIER

A Recent Mechanical Development

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

THE BETHLEHEM TORQUE AMPLIFIER

THE Torque Amplifier is a mechanical unit recently developed by Bethlehem Steel Company under the direction of H. W. Nieman and covered by pending patents. Its purpose is to step up or increase weak forces. The unit is driven by a motor or other source of continuous power. Entering at one end is a small control shaft, while at the other end there is provided a heavy work-delivery shaft. Action of the internal mechanism is such that any rotational movement imparted to the control shaft is reproduced by an identical movement of the work-delivery shaft. It is as though the two shafts were positively connected and moved as one, with the important difference that while the force needed to turn the control shaft may be very weak, the work-delivery shaft is caused to rotate with a great deal of power.

To illustrate this action. In an installation on anti-aircraft guns—for turning and aiming—where the work-delivery shaft of the amplifier is attached to the handwheel of the gun, which normally requires the full strength of a man, the control shaft could be turned by a knob the size of a watch-stem. In this case, although the power of the operator is multiplied about 5,000 times, his control of the gun's movements, through this little watch-stem, would be just as perfect as though he grasped the handwheel itself. Every slightest movement of the knob produces an exactly corresponding movement of the gun, the response being instantaneous and without lag or lost motion.

There are many types of amplifiers, designed for different purposes, but all operating on the same principle and all having the characteristic of scaling up the weak force of the control shaft into the powerful force delivered by the work shaft; in every case the control and work shafts maintaining perfect synchronism, no matter how rapidly or slowly the control shaft is revolved (within the scope of the device) or how sudden its reversals. Through the operation of the mechanism the power of the driving motor is supplied automatically to the work shaft, to whatever extent the external load requires; in other words, the difference between the power input at the

control shaft and the power output at the work-delivery shaft is supplied by the continuously running motor. Ratio between the power of the control shaft and that of the work-delivery shaft is called amplification. In the gun-turning amplifier the amplification is 5,000 to one; other amplifiers run from 10 to one to 50,000 to one, depending upon the purpose for which designed.

PRINCIPLE OF OPERATION

Friction is the basis of mechanical torque amplification. To take a familiar example of how friction may be used for this purpose, consider the ship's capstan or "niggerhead." The capstan is a cylindrical shaft rotated by steam power; around it are passed two or three turns of rope, one end of the rope attached to the anchor and the other end held by a sailor, as shown by diagram Fig. 1. As the capstan revolves the sailor pulls in his end of the rope, and the wrapping friction between rope and capstan exerts a great force on the anchor.

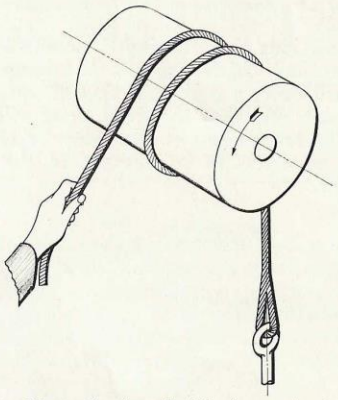

Fig. 1.—*Illustrating the principle of wrapping friction.*

Although the capstan is rotating at a constant speed, the sailor can, by pulling in his rope fast or slow, cause more or less relative slip between rope and drum and, as both ends of the rope must move with the same speed, he can control the speed of the anchor as he wishes. He can stop altogether, or let the anchor descend. It is not the sailor's strength that moves the anchor: the actual work is done by the engine which turns

the capstan. In the Torque Amplifier the same elements enter—a continuous drive, a light force on the control end, a varying amount of relative slip, and amplified force on the work end.

For adaptation to mechanics a rotary movement is preferable to the straight pull of the rope. The method of accomplishing this is shown below, where a single turn of friction band replaces the rope.

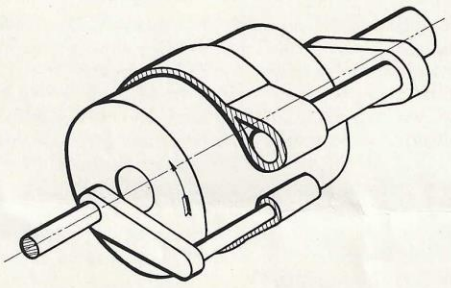

Fig. 2.—*Adapting the principle of the Torque Amplifier to mechanics. A friction band replaces the rope shown in Fig. 1.*

It is obvious that turning the control shaft in the direction which tightens the band on the drum will exert a multiplication of force on the work shaft, and that the work shaft will exactly follow the movements of the control shaft. This perfect synchronism is inherent in the Torque Amplifier.

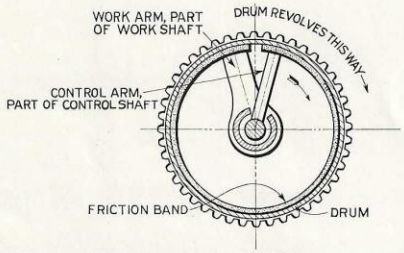

Fig. 3.—*Drum with friction band applied internally. Drive is by gears on drum.*

To make the amplifier operate positively in both directions, two drums are employed, driven so as to rotate in opposite directions. Each drum is provided with its friction band, one end of each band being connected to an arm on the control shaft, and the other end of each band connected to an arm on the work shaft. One band loosens when the other tightens. Operation of such an arrangement is quite obvious, but its actual application was not found mechanically feasible, because of the difficulty of insuring that one band eases into frictional engagement as the other eases out, a condition necessary for successful operation. This problem was met in the Torque Amplifier by the invention of the Lashlock, an automatic adjusting device. In appearance this is merely a small pivoted member, but as its operation requires considerable discussion, it will be omitted here. The effect of the Lashlock, however, is to prevent both bands from frictioning at the same time, while automatically removing all backlash and compensating for differences in initial length and subsequent wear of the bands.

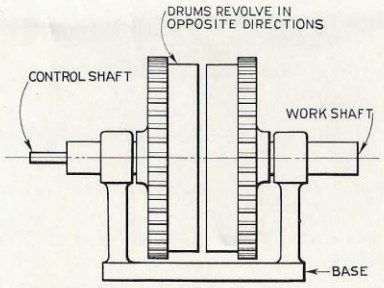

Fig. 4.—*Two-Directional Torque Amplifier.*

To obtain high amplifications the amplifier is arranged in stages, which is equivalent to coupling two or more amplifiers together in series, the work-delivery shaft of number one actuating the control shaft of number two, and so on. If each amplifier in the series has an amplification of ten to one, a series of two would have 100 to one, a series of three 1,000 to one, etc.

USES

Many developments are now in progress by Bethlehem Steel Company, and by other organizations, applying the Torque Amplifier to their existing problems and producing new devices in a number of different lines. Some of the applications already developed or in which development is possible are listed on the following page.

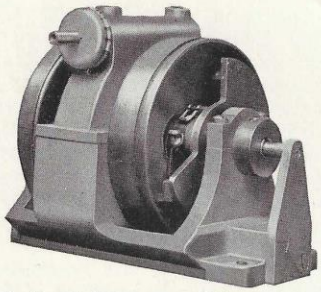

Fig. 5.—*Light duty type of Torque Amplifier.*

USES (*Cont'd*)

Bethlehem Steering Control, for automobiles, trucks and buses.

Amplifying any form of manual control, such as lever, treadle, handwheel, key.

Revolving doors and sliding doors.

Automatic gun control.

Remote control of valves, dampers. gates, doors, etc.

Synchronizing rolls, etc., in machinery handling paper or textiles.

Speed control of mechanical drives or of driven parts.

Control through governors, thermostats, clockwork, pressure gauges, or weak electrical forces.

Ship steering.

As a mechanical power relay, in computing and recording instruments, fire controls, regulators, governors.

Governing any heavy force, or actuating machinery under heavy load, by a weak force.

Train control, elevator control.

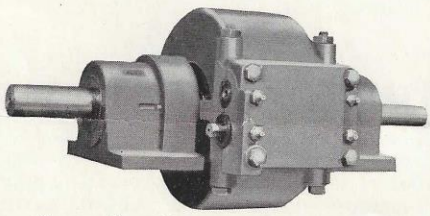

Fig. 6.—*Heavy duty type of Torque Amplifier.*

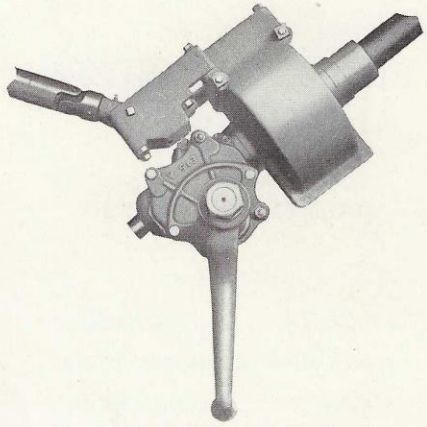

Fig. 7.—*The Bethlehem Steering Control.*
A Torque Amplifier on the steering column of an automobile. Engine connection is shown at upper left.

Bethlehem Steel Company will be glad to render engineering advice on any contemplated application of the Torque Amplifier. Data necessary for the understanding of a problem include:

Strength of control element; that is, amount of torque which can be taken from it without seriously disturbing its accuracy.

Maximum speed at which control element will revolve.

Maximum power to be delivered by work shaft.

Speed of drive—whether motor, line-shaft, etc.

Drawing or sketch of either the whole machine or the part where amplifier is to be applied.

Address inquiries to

BETHLEHEM STEEL COMPANY

Development and Research Department

BETHLEHEM, PA.

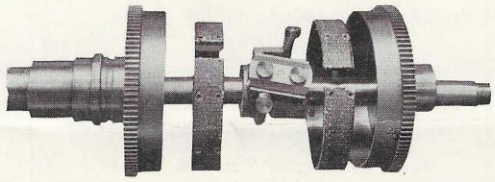

Fig. 8.—*Bethlehem Steering Control, with housing removed, showing friction bands, control arms and Lashlock for eliminating backlash.*