

show at a glance that the power and the effort of alternate strokes are not equal. A combined card for the three cylinders, with adiabatic and isothermal lines drawn, shows a very large gain over single-stage adiabatic compression.

Fig. 29 shows the usual design for three-stage duplex compressors. There are two double-acting steam cylinders, two double-acting low-pressure air cylinders, a single-acting intermediate air cylinder and a single-acting high pressure air cylinder. Considering one-half of this compressor by itself, it will be evident that the work and the resistance of alternate strokes are very unequal. On the forward stroke the pressure of the air in the single-acting cylinder assists the steam, on the return stroke it opposes it, hence there must, in any case, be considerable energy transmitted through the crankshaft, either to and from the fly-wheel or from one side of the compressor to the other. Taking the compressor as a whole, the work of alternate strokes would be most nearly equalized when the cranks were set at 180° , but then of course there would be a possibility of the compressor getting on the dead centre.

In the *American Machinist* of April 23, 1896, and in the *Journal of Electricity* (San Francisco) for December, 1895, there were descriptions of two compressors of this type which were designed and built in San Francisco for the pneumatic gun battery at Fort Winfield Scott. These compressors, from the excellence of their design and construction and from the unusual conditions of the service, present many features of interest.

There are two exactly similar compressors in the plant, and the description applies to either one of them. The cranks are set at 145° in order that the machine may be as nearly balanced as possible and yet be able to start from any position. The steam cylinders are high-pressure, non-condensing. They are twenty inches in diameter by twenty-four inches stroke, and are fitted with Meyer hand-regulation cut-off. The steam pressure usually carried in the boilers is 100 pounds, and the engines ran under full load when cutting off at $\frac{3}{8}$ stroke. "The low-pressure air cylinders are placed next the steam cylinders. They are double-acting, with pistons packed in the usual manner, by cast-iron rings sprung into place. The intermediate and high-pressure air cylinders are single-acting, with plungers. The intermediate plunger is packed with soft packing in the ordinary form of stuffing box. The high-pressure plunger is packed with sectional babbitt and brass rings. This has proved a

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