company. In 1900, a modern hyro-electric power plant, on the same site, was completed and commenced operations; while in 1902 this plant was extended to its present capacity, viz., a minimum of 12,000 H.P. In addition to this, the company still operates two steam plants at Rome having 5,000 H.P. By the present autumn, the same company will have in operation a second hydro-electric plant at Subiaco, about 35 miles east of Rome, generating 5,000 H.P. under 225 ft. head, with three-phase generators of novel pattern, wound to 30,000 volts, thus not requiring transformation for transmission.

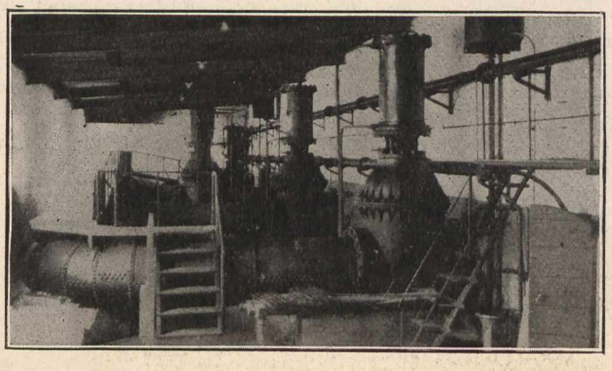

Fig. 2.—Tivoli Station: Hydraulic, Penstock Gate Valves.

The falls of Tivoli are at the base of the Sabine Hills, and are formed by the Anio which here passes through a romantic ravine, having a fall of 360 ft., and an aggregate of some 530 ft. within two miles. Great engineering works were constructed at and around these falls by the ancients, also in the beginning of the last century; when, owing to destructive floods, at and above the town, new relieving spill tunnels were driven. For centuries, a considerable manufacturing community has existed at these falls, operating its mills by water-power, with wheels of all descriptions. The town itself has still several paper mills, but its manufacturing interests are small.

The hydro-electric plant is situated in the gorge where it debouches into the wide valley. It is situated beneath the famous Villa d' Este, 300 years old, one of the most beautiful gardens of Italy, and is within a few minutes of Hadrian's Villa, the greatest of ancient royal homes.

Water is brought to the forebays on both sides of the river, high up on the cliffs. The older waterway is by means of ancient canals on the town side; the new one on the opposite side consisting of a canal a mile long. Water obtained by the older canals, provides two heads of 530 and 346 ft., from different points, while the newer system gives only 165 ft., being obtained by a dam built in the gorge above the lower cascades of the falls. The dam is of masonry, built on rock foundation, arched up stream in plan to a radius of 280 ft., and has a crest length of 240 ft. It is 50 ft. high, of overfall ogee type, having a width of 12 ft. on top, and 45 ft. on the base. The new canal has a capacity of 350 cubic feet per second, and terminates in a forebay 120 x 110 ft. and 19 ft. deep, divided into two parts by a wall with submerged arches, to assist in obstructing debris.

Penstocks built at different times under the various heads are 3'-0", 5'-0", and 4'-4" diameter, respectively. Of these the first serves two units, the second, three; and the third set (three in number) serve one unit each—see Fig. 1. They are built of steel plate, with inside and outside lap rings. The three new penstocks are made of 5/16" plates at the top, and 7/16" at the lower end; while for the 80 ft. spans across the river, they are ¾" plates, and double riveted. In addition to gates at the forebay, each penstock has a gate valve before connection to the turbine, operated hydraulically. (See Fig. 2.)

The substantial construction of these works is indicated in the method of carrying the penstocks down the river bank, a most generous expenditure of heavy masonry, ornamental bridges, stairways and portals, which would appal American investors. The bridging of the river, however, by the penstocks, without auxiliary support is an example of the utilitarian side of European engineering, instances of which one meets every day alongside the aesthetic features. This leads one to consider whether in newer America, where all is utility we do not too often entirely forget the aesthetic. Are we not also sometimes inclined to reduce our substantiability in design to a minimum, in our desire to be economical, and in our effort to rush through what might be termed semi-temporary construction in order to secure quicker financial returns?

In the generating station, which is of stone masonry, are seven power units on horizontal shafts, four of which were installed in the first construction, under the higher heads, using Girard turbines, and three in the extension installation using Francis type turbines. These are arranged in a long central hall (see Fig. 3) having the penstocks and tail race on one side and the switchboards and offices, etc., on the other.

All the turbines are built by Gang & Co., of Buda-Pesth, and are nominally of about 3,500 H.P. each. The Francis type installed in 1902, are examples of a system frequently built by this company, and, while generally similar to most turbines of this class now manufactured in European shops, have the distinction of being regulated by gates in the draft tube, on the lower side of the runner. This type is not a novelty, there being several similar installations both in Europe and America, but the arrangement is sufficiently out of the ordinary to merit special description. Referring to Fig. 4, which shows a vertical section of the turbine through the shaft, the following are explanatory notes:—

K—The cast iron wheel case "Snail Shell" type for incoming water, connected to penstock.
S—Distributor between case and runner, fixed vanes.
R—Runner, Francis vanes, attached on end of main shaft Y.
O—Draft tube.
A—Governor centrifugal regulating fly-wheel, "Hartung" type.
B—Dash pot with glycerine, to regulate oscillations.
C—Connections to governing valves, servo-motor, and hydraulic governing relay.
N—Adjustable fulcrum for controlling lever Z.
U—Cylinder connected to Servo-motor for actuating piston of gate stem X.
X—Gate stem attached to cylindrical gate.
Q.—Cylindrical gate piston, reciprocating horizontally, to open or close outlet from runner R. Diagram shows gate wide open.

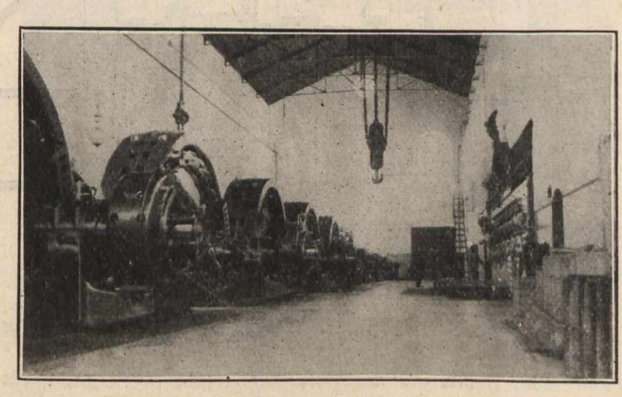

Fig. 3.—Tivoli Station: Interior.

The same general principle is used on the Girard units, but, owing to the nature of the turbines, which are outward discharge, the gate operating mechanism is differently applied. All these units are connected in parallel with conspicuous success; results, all the more remarkable, because of two types of turbine operating under three different heads, and having a transmission line with mixed and extremely varying load.

The generators are 3,300 K.W. rated capacity at 10,000 volts, three phase revolving field type, each having its exciter carried on the outboard end of the main shaft. The internal diameter of the armature is 13 ft. and the inductor weighs 24 tons. While the units are three phase, they are operated about half the time as mono-phase; on account of a large single phase distribution system, which had existed