

4 Turbine floor plan of the powerhouse. Pelton turbines have two nozzles, one connected to each of two penstocks along opposite sides of the powerhouse. Pump discharge comes up between the two groups of vertical-shaft water

PUMPED STORAGE continued

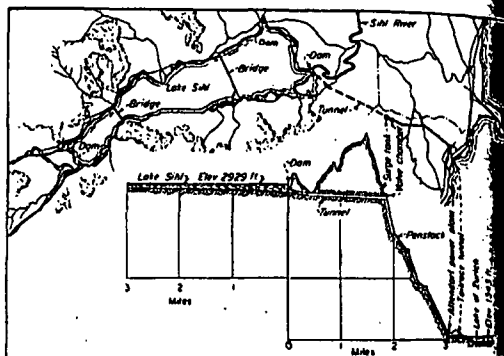
because of the pumps' thrust bearings. This could have been done by different valve schemes but, again, the turbines control shutting down the pumps. This is probably the first time this method has been used.

With this system, when electric power to a pump fails and it starts to slow down, the governor opens the turbine's nozzles. The turbine then brings the unit to speed ready to synchronize the generator for connection to the power system.

To adapt the turbine governors to this type of control they are supplemented by a safety governor driven by the exciter shaft. This governor has switches that trip the generator-motor off the power system if speed drops 5% below normal and that start closing the isolating valve in the discharge line if pump speed drops to 60% normal.

Pumping-Plant Benefits. Only during dry summers, when natural drainage fails to fill Lake Sihl are the pumps needed to help fill the lake. Normally they serve principally to balance the power supply over short periods, generally a few weeks each year. Nevertheless, the storage pumps have substantially improved performance of the power station.

Government regulations are quite rigid as to the date when Lake Sihl must be filled in summer. The pumps make it possible to meet these requirements always. If surplus night and weekend power is available from base-load stations, pumping during these periods may be valuable to improve load factor of the power system. This is true in spring, summer and autumn, and also in winter when water is lowest in the rivers sup-



5 Plan and profile of the Etzel hydroelectric development. It has 120,000 installed capacity in six 20,000-hp units operating under a 1500-foot

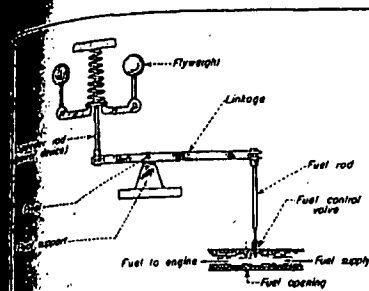
plying other plants on the power system.

Low-Water Operation. Because of extremely low water during the winter of 1949-50, Switzerland was threatened with a power shortage. Every available means was needed to meet these conditions without seriously restricting power use, including importing power from systems outside the country.

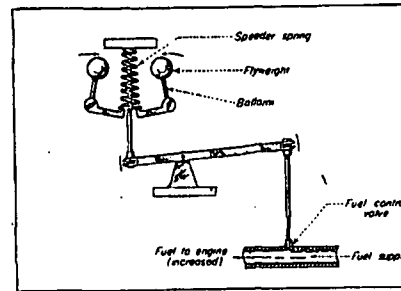
Much of the imported power was available during nights and weekends only. For example, Holland furnished power from 10 pm to 6:30 am, and on Sundays. Part of this power was used in the Waggital and Etzel stations to drive pumps to store water for peak-load generation during week days. Water was also stored in the reservoir of the Oberhaali power station of the Bernische Kraftwerke for week days.

During week-day nights part of the power generated in the Bernische plant pumped water into storage this way the Etzel pumped-storage and others like it have given excellent service, not only during power shortages but also in normal times, the system can easily carry the peak and peak loads.

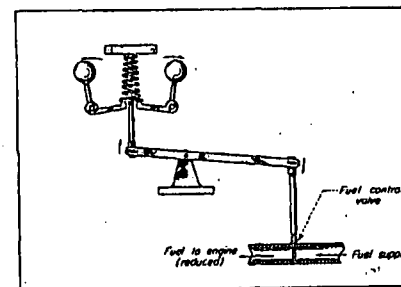
Conclusions. Hydroelectric pumped-storage plants have an advantage over most large power systems. They increase the output of many hydro plants, and use power surpluses that otherwise go to waste. The Etzel plant is an interesting example of a high-head plant where storage pumps improve performance and economy despite of natural runoff that fills the reservoir during normal years.



1 Schematic arrangement of the fuel-control mechanism for diesel and dual-fuel engines. Valve shown is simplified



2 The combined action of speed-measuring and fuel-changing mechanism during load increase in a mechanical governor



3 Action in a simple mechanical governor during decrease in engine load. Governor reduces fuel supply to engine

DIESEL GOVERNORS—II

What Does Speed Regulation Mean?

It's the job of your governor to keep engine speed within desired limits for load carried.

This second article of our series shows you how mechanical governors are applied today

By EDOAR J. KATES, Consulting Engineer, New York

LAST MONTH we discussed the various types of governors available for diesel and other high-compression engines. We're now ready to take a closer look at what happens when a governor regulates engine speed.

Speed regulation is the change in an engine's "steady" speed (its final or sustained speed) when load is changed from the full-rated value to zero, or vice versa, without governor adjustment. Change in steady speed is expressed as a percent of full-load speed by:

Speed regulation, % = $\frac{\text{no-load rpm} - \text{full-load rpm}}{\text{rated full-load rpm}}$

Note that speed regulation refers to a change in steady speed. This means that

governor and engine are given enough time to reach a stable position and speed, respectively, for the given load. For partial changes in load, steady-speed change is proportional to the speed regulation.

Example. Suppose our engine runs at 600 rpm at full load, and at 624 rpm steady speed when all load is removed. Since speed increase is 24 rpm between full and no load, speed regulation is $(100) (24) \div 600 = 4\%$.

Knowing the speed regulation we can easily compute speed change for any partial load change. With a load change of one-quarter rated load, say from 4/4 to 3/4, or 3/4 to 1/2 load, resulting speed change is one quarter that from full to

no load. For this engine it is 1/4 (24) = 6 rpm. Table below summarizes change of speed with load, for this engine.

Load	Speed, rpm	Speed change, %
Full (4/4)	600	0
3/4	606	1
1/2	612	2
1/4	618	3
0	624	4

Speed regulation is important for many reasons. One is that it determines how two or more engines driving the same load will share any load change. An engine's speed regulation is directly related to the governor speed droop. Speed droop is the change in rotating