found a 1% reduction in voltage in general is followed by a 1% cut in load. Generally speaking, voltage may be reduced as much as 7½% with satisfactory results. Authors outline a procedure for reducing voltage and frequency under emergency conditions.

Tests conducted by the Kansas City Light and Power Co, serving the metropolitan area of Kansas City, Mo., show it is possible to lower system primary voltage up to 5%. decreasing frequency 1½% at the same time.

AIEE technical paper 48-267, presented at the AIEE Midwest general meeting, Milwaukee, Wis., Oct 18-22, 1948.

STEAM STATION COSTS, *by A E Knowlton, Electrical World.* Energy generated in a representative USA central-station power plant shows production costs ranging from as low as 1.5 to as high as 14 mills with an average value of 4.5 mills per net kwhr. Nine years ago this average was about 3 mills.

Average cost of net kwhr at the busbar for plants from 5000 up to 300,000 kw rating in 1947 ran 7.5 mills. With this figure plus the average 4.5 mills, production-cost fixed charges can be set around 3.0 mills on a broad average basis.

One point of considerable interest advanced by the author was the fact that the 1947 load proved so great only one in six plants had a peak below rated capacity. In fact, peaks commonly reached 120 to 130% rated capacity. Plant factor (ratio of actual net output to that obtainable over 8760 hours of full-rated capacity) showed up even more favorably, except for the largest plants, the national, sampled average ran about 70% in 1947.

Survey, with 102 generating stations reporting, indicates a kilowatt of installed capacity has cost as much as $200 and, at one time, as little as $46. This phenomenally low figure comes about from (1) an outdoor installation (2) a highly simplified design built specifically for a very low-cost fuel. General average runs about $90 to $130 for plants operating in 1947, regardless of age of the oldest operating unit.

Progressively larger plants carried at lower costs per unit of rating than smaller ones. Largest plants, even if quite ancient, represent lower costs than middle-sized ones. The latter show up advantageously in over-all costs per net generated kwhr.

Plants of under 60 megawatts, built in 1920-1929 and not since expanded, cost on the average about $150 per kw. Those built in 1930-1934 average about $107, while those in 1935-1939 cost as low as $76. By 1940-1944, unit cost soared to $110, and by 1945-1947 to $135. According to the author this figure of $135 still does not touch the unit cost experienced in the inflation and boom after World War I.

Investment costs for plants of 60-149 megawatt rating, built within the 1920-1929 decade, average about $100 per kw of rated capacity. By 1940-1944 this average fell to $83, but by 1945-1950 came back to about $118. Investment cost regardless of plant vintage indicates that spread in dollar per kw runs much higher for small plants than for large. The largest represent $85 per kw, and the smallest about $120.

Boiler plants constitute the largest component of over-all costs. Structure and improvements for a $100 plant amount to $28, boilers and associated thermal equipment to $36, and turbine-generator to an added $26. All office space, shop, electrical galleries, etc. account for another $10.

Higher boiler pressures and steam temperatures afford better thermal performance. The 1200- to 1600-psi hit below 11,500 Btu per net kwhr; 800- to 1000-psi plants hover near 12,000. The 600- to 700-psi plants reflect about 13,000. Finally, the 200- to 400-psi plants range from about 14,000 to 26,500. July 3, 1948, *Electrical World,* 330 W 42nd St, *New York City.*

To Obtain Complete Text

Material in these briefs comes from one of two sources unless specifically identified after review of paper.

American Institute of Electrical Engineers, Midwest general meeting, Oct 18-22, 1948, Milwaukee, Wis. Available at AIEE, 29 W 39th St, New York.

American Society of Mechanical Engineers, spring meeting, March 1-4, 1948, New Orleans, La.; fall meeting, Sept. 7-9, 1948, Portland, Ore. Available at ASME, 29 W 39th St, New York.

STEAM EQUIPMENT

SUPERHEATER TUBE FAILURES, *by H B Snider and F H Ward, Humble Oil and Refining Co.* Continued failures of end superheater tubes in a 275,000-lb-per-hr 650-psi boiler kept causing unscheduled shutdowns and interruptions to steaming capacity. Upon examination of the ruptured tubes excessive deposits showed up.

A checkup of *normal* causes for carryover, excess boiler-water alkalinity, high total solids, high water level revealed no abnormal conditions. For this reason decision was made to carry out a fairly comprehensive test of steam leaving the boiler drum and entering the superheater. Standard sampling apparatus and sampling connections were set up to draw from the drum, twelve of the connector tubes between drum and saturated header, saturated superheater header, saturated header drain, and eight end superheater tubes.

Saturated header construction is such that the space through which steam enters the header from the drum connector tubes is less than that in which steam leaves the saturated header through the superheater tubes. This construction forces a lateral flow of steam at the ends of the *saturated* header. The resulting 90-deg turn precipitates solids to the end of the saturated header where they concentrate. The end superheater tube obtains its steam from this section and overheating of the tube *results.*

Steam samples indicated a steam quality of 0.60-ppm total solids average produced in the drum. This quality held for the steam entering the saturated header. Since *superheater-tube* failures from carryover are rare with steam of a quality less than 1 ppm for solids, steam from the drum and the saturated superheater header were felt not to cause these tube failures.

Saturated header steam showed 1.4 ppm, and at this header drain it was 13.35-ppm total solids. All evidence indicated the solid concentration as developing at this end of the saturated header.

Steam samples from the superheater tube ends confirmed this evidence. The end superheater tube contained 3.15-ppm total solids, while samples from the adjacent superheater tubes indicated much less.

To correct this feeding of heavily concentrated solids to the end superheater tube it was decided to add an additional connector tube between saturated header and drum, just opposite the superheater tube next to the end superheater tube. In addition, new drum internals of the same design as the old ones were put in.

When the boiler returned to service data from sampling points showed a decided improvement in steam quality. From the drum it was 0.30 ppm, and from the saturated superheater header

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