

1 During winter season condenser acts as heat exchanger to produce hot water for district heating. In summer it functions as condenser using circulating water

How We Cured Condenser Tube Corrosion

Sudden tube leakage on a special heater-condenser demanded quick solution to avert catastrophe. Here is an account of how some simple methods pinned down trouble and controlled it

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A NEW 3500-kw steam turbine started in January 1947 at the Odense Power Station. This plant supplies both electric energy and hot water to a district heating system. Turbine discharges to a special condenser with 5400 sq ft heating surface. Steel tube plates hold aluminum-brass tubes (77% Cu, 20.2% Zn, 2.7% Al) in metallic packings.

During the heating season the condenser cooling water circulates through the district heating system. Circulating water passes through the condenser at

the rate of 1,400,000 lb per hr under a pressure of 70 psig. Condensing steam raises water temperature from 122 to 175 F. The vacuum, naturally, is quite low.

During the summer, the turbine runs as an ordinary condensing unit, using river water for cooling in the condenser. This requires two sets of circulating-water connections, one for the river water and the other for the district heating system. At full condensing the turbine develops 4000 kw, but its steam rate is poorer than other units in the

station—hence during the summer it is used mostly for standby.

Trouble. In the summer of 1949, condenser tubes started leaking, and 113 had to be renewed. These were 5% of the total 2250 tubes. Chemical analyses and microscopic examination showed the material was good, Fig. 3.

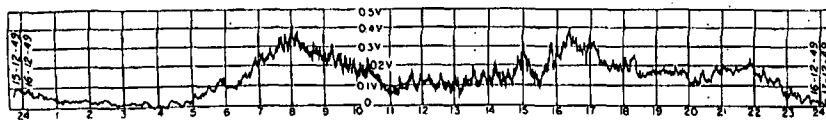
The corrosion involved zinc removal from the alloy. A thin scale coated the tube interiors, caused by sewage pollution of the river water. The zinc removal might have been caused by (1) the scale (2) district-heating water (3) stray-current electrolysis.

Electrolysis. A 2-wire 220-v dc system supplies the central part of Odense. In addition, a 500-v dc system feeds the tramway. Uninsulated copper cables serve as neutrals for the dc grid and feeders. In the station, the neutrals are grounded, while feeders to the tramway are insulated and not grounded. Fig. 1 shows, schematically, the 500-v system and the turbine installation.

The district-heating system consists of six miles of 16-in. mains. Feeder and return pipes tie side by side in a tunnel of reinforced concrete. "Cellular" concrete fills the space between pipe and tunnel walls. Since the tunnel is not quite waterproof, it is placed above ground-water level.

Measuring voltage drop between certain points in the power station started the search for possible electrolytic corrosion cause. Measuring points included outgoing and return heating pipes, cooling-water pipes, backpressure turbine, condenser, other turbines, boilers, steam and water pipes, water tanks. The portable millivoltmeter showed some of these points were negative and some positive, relative to the dc neutrals and tramway systems.

Readings were taken with (1) turbine-condenser heating circulating water for distribution (2) turbine-condenser using river water (3) turbine out of commission and district-heating pipes disconnected. These showed potential differences (pd) at all points, (1) and (2) in particular had the highest pd with one exception, a water pipe in the ash cellar. Apart from the latter, the pds were all less than 200 millivolts. On the district-heating pipes there



2 Electrical potential difference between condenser tube day exactly the same as the electrical load. Voltage drop plate and station dc neutral cable varied throughout the day reached a maximum during peak loads in morning and afternoon

was a noticeable pd in a direction toward the condenser. This was greatest when the condenser was disconnected from the district-heating pipes. It was found that the current in the dc neutrals was always into the station. A part of this current left the bare neutrals and strayed through the ground to the district-heating pipes and through these to the condenser tubes. This stray current also flowed into the river water, through the ground to the station grounding electrode.

Analysis. These data suggested the reason for the sudden tube corrosion during the fall of 1949. During the summer of 1949 the turbine ran for many hours, with river water flowing through the condenser aggravating the condition. The running hours exceeded those for the two preceding summers combined.

In Fig. 1, A, B and C are the pd measuring points. A is about 100 yards from C. The pds in millivolts for the three operating conditions were:

	A-B	A-C
(1) Heating operation	100	38
(2) Condensing operation	100	35
(3) Disconnected pipes	—	95

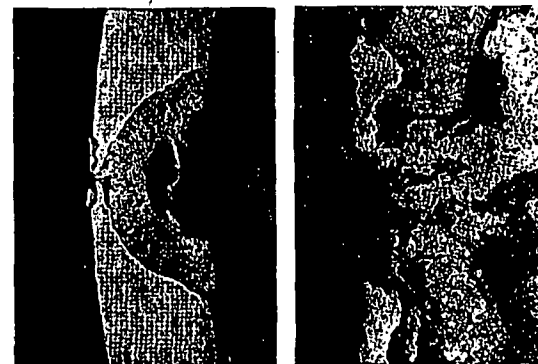
We measured the voltage variation for several days from A to B with a recording millivoltmeter. Records were made with the turbine in service for heating and condensing generation. In both cases the voltage drop varied in the same pattern. Fig. 2 shows that the pd varies almost proportionally with the dc load. It's a maximum of 0.4 volts at 8 am and 4 pm. The lowest values occur from midnight to 5 am.

Cure. The condenser tubes were constantly acting as an anode, hence, became badly corroded. The remedy was to provide a path for these currents around the condenser to the dc neutral. We did this in 1950 by connecting the condenser tube plate to the dc neutral with a copper bar 60 ft long, having a cross section 30x5 sq mm and a resistance of 0.002 ohm. A 0.0002-ohm shunt in the bar permitted taking ammeter readings of current flow. Ammeter readings have been taken at different hours of the day for the last couple years. Current in the bar has always been from the condenser plate to the neutral. The minimum current was zero and the maximum 85 amp. Normally it varies from 25 to 50 amp throughout a day.

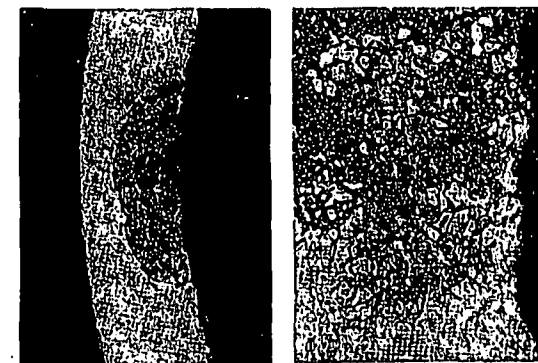
Since this connection was installed, there has not been a single failure in a condenser tube, even though the tubes were badly corroded at the time connection was made and the turbine running for a high number of hours during the summer.

Fig. 4 shows microphotographs of a

Microphotographs Gave Clue to Cause of Corrosion Trouble



3 Microphotographs of corroded tube at 24x and 180x enlargement showed the trouble was zinc removal from alloy. Tubes had thin scale coating an interior



4 Microphotographs of partly corroded tube at 24x and 180x enlargement after installation of electrical bypass showed the rate of wasting was greatly reduced

tube section installed in the condenser in the summer of 1949. It was examined in 1950. This tube had only 6 months' service before the copper bar connection was made. Although it had not failed at time of removal from condenser, the corrosion has penetrated about two-thirds of the wall thickness. Zinc removal is involved in this corrosion too.

We expect the tube corrosion will continue despite the electrical connection.

The deterioration rate, however, will be very much slower, and chemical in nature rather than electrical. Since no further tube failures have occurred, it would seem that condenser conditions are now under control to the maximum possible extent.

Without the electrical bus, it would have been necessary to replace all condenser tubes in a very short time. The prospective life of the replacement tubes would have been much too short.