

UNITED NATIONS  
ECONOMIC  
AND  
SOCIAL COUNCIL



LIMITED

ST/ECLA/CONF.7/L.5.2

30 November 1960

ORIGINAL: ENGLISH

LATIN AMERICAN ELECTRIC POWER SEMINAR

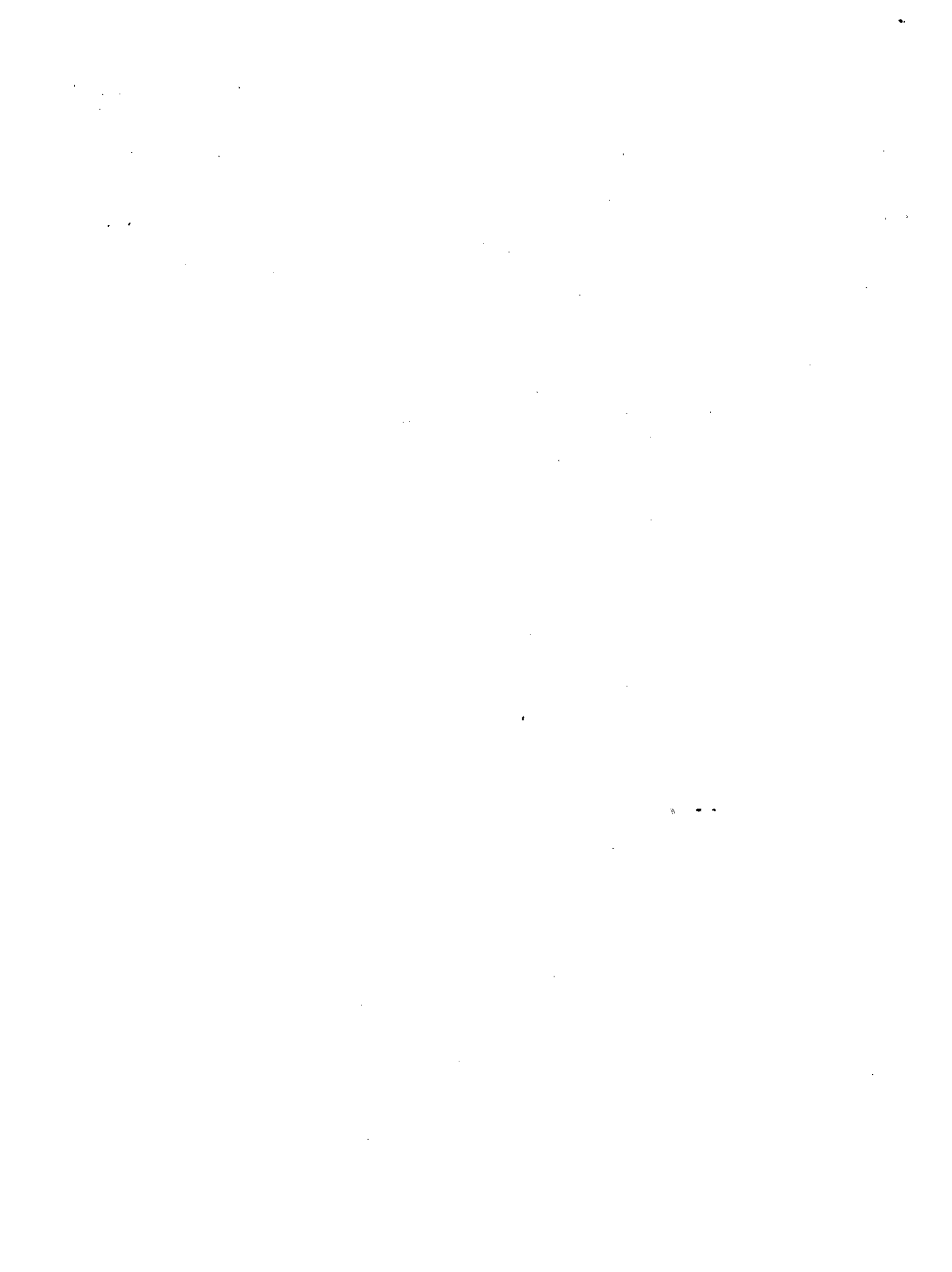
Held under the joint auspices of the Economic Commission for Latin America, the Bureau of Technical Assistance Operations and the Resources and Transport Economics Branch of the United Nations, with the collaboration of the Government of the United Mexican States

Mexico City, 31 July to 12 August 1961

ECONOMY OF COMBUSTION PROCESSES

by F.D. Wilson

NOTE: This text is subject to editorial revision.



What influences have resulted in the present-day economy of combustion processes, and how do these factors affect our utility plants? To bring us up to date on the economy of these plants, it might be well to review the history of the public utility business. By doing this, we can see what influence brought about these advances in economy.

The first public utility plant in the Americas was the Pearl Street Station in New York built by Thomas A. Edison in 1882.

The steam generating units of this plant were hand fired with bituminous coal on stationary grates and the only method of combustion control was the stack damper of the boiler. This resulted in poor combustion efficiency. There were no instruments for gauging the efficiency of the combustion. No effort was made to control the cleanliness of the internal surfaces by feedwater treatment, and there was very little or no cleaning of the outside heating surfaces. The result was a fuel consumption of about 10 pounds of coal per kilowatt hour.

During the next twenty years, some progress was made in combustion efficiency by the invention of the stoker. The stoker was of the overfeed variety and relied on a separate fan for providing forced draft, a method that increased the burning capacity of the steam generating unit with very little increase in burning efficiency. During this period, the turbine tube cleaner, a mechanical cutter for removing the scale which accumulated on the internal heating surfaces of the boiler, was invented and put into use. This increased the efficiency of the heat absorbing surfaces, and joined with the stoker resulted in a coal consumption per kilowatt hour of about 6.7 pounds.

From 1902 to 1922, many advances contributed to the economy of the steam cycle - the use of superheat, the treatment of the boiler feedwater by the use of chemical compounds, steam lances for cleaning the external heating surfaces, and the underfeed stoker.

With the underfeed stoker, the green coal was introduced beneath the burning fuel bed. The volatile gases from this coal, upon mixing with the air admitted under the fuel bed, were ignited as they rose

/through the

through the burning coals. Combustion air was proportioned to some extent by using a CO<sub>2</sub> meter. In addition, a crude form of automatic damper control, governed by the rise and fall of steam pressure in the boiler, was sometimes used in proportioning the fuel and air supply. These combined improvements resulted in an average fuel consumption of about 2-1/2 pounds of coal per kilowatt hour.

The decade between 1922 and 1932 brought numerous new devices to increase overall efficiency. Oil, which had been previously used in very crude burners, was for the first time burned in a circular burner. The oil was atomized by pressure and then was projected into a turbulent air stream so that there was an intimate mixing of fuel and air which resulted in a high combustion efficiency.

Based on their success with oil burners, engineers began to experiment with the pulverizing of coal to get a combustion process equivalent to that used with oil. Coal was first crushed and then placed in a pulverizer which consisted of a hollow drum filled with small steel balls or scrap iron. As the cylinder revolved horizontally, the intra-action of the coal and the iron charge pulverized the coal. A stream of air scavenged the mill and carried the pulverized coal to the burner, where a secondary stream of air was introduced around the coal and primary air stream. The resulting mixture burned with a much better combustion efficiency than had been attained by any method of burning coal previously used.

At the same time, there were increases in the steam pressure, and in superheat temperature; heat traps such as economizers and air heaters were also added to the boiler. By the end of this period, the capacity of units had expanded from the original 120 kilowatt units to units as large as 100 000 kilowatts. With the raising of pressure and temperature in the unit, the treating of feedwater became much more important and many good systems for purifying the feedwater were introduced, resulting in cleaner internal surfaces and the possibility of attaining higher rates of heat absorption. On the external side of the heating surface, the method of mechanically driven steam soot blowers /was introduced,

was introduced, which greatly improved the heat absorbing qualities of the boiler. All these improvements resulted in lowering the coal consumption per kilowatt hour to an average of 1.5 pounds.

The period 1932 to 1942 was one of consolidation and improvement of methods already in use. Fusion welding of boiler drums made possible much higher steam pressures. The development of alloy materials permitted higher steam superheat temperatures. Feedwater treatment had improved to such an extent that it was possible to incorporate water walls in all types of furnaces without unnecessary risk of high maintenance thereby eliminating maintenance of refractory walls. This allowed much higher furnace temperatures, which resulted in better combustion efficiency. It was then possible to go to much larger generating units so that, instead of a number of boilers for each turbine, there could be one boiler and one turbine per unit, which greatly simplified control and operation.

During this period, combustion meters and automatic control equipment were so improved that a large boiler unit could be controlled by instruments, and run with an efficiency equal to that which previously had been attained only during short test periods. By the end of these 10 years, the average efficiency increased so that 1 kilowatt could be generated with about 1.33 pounds of coal.

A new type of burning equipment was introduced in 1942 called the cyclone furnace. Coal that has been crushed but not pulverized is burned in a horizontally arranged cylindrical furnace 5 to 10 feet in diameter. Coal and air are introduced with a cyclonic motion at one end and spun around the inside periphery of the cyclone furnace. Secondary air tangentially introduced into the coal-air stream increases the whirling motion of the coal particles. Burning at high temperatures, the coal ash melts to a liquid slag which forms a layer on the walls of the cyclone. Particles of incoming coal are thrown to the walls and stick to the slag, and the secondary air scrubs the burning coal and slag at high velocity. The substantially slag-free gases are then discharged into the adjacent boiler furnace, and the molten slag drains to the lower portion of the

/cyclone furnace

cyclone furnace where it discharges through a tap hole to a slag tank under the boiler furnace. This method of burning coal not only attains a high combustion efficiency because of the smaller amount of excess air necessary, but further cuts down the unburned carbon loss and traps the flyash so that very little ash leaves the unit in the form of flyash through the stack. In fact, the stacks of coal-fired boilers utilizing a cyclone furnace are almost as free of atmospheric contaminants as those of oil-fired boilers. The progress made in combustion efficiency due to the cyclone furnace and the refinement of automatic control have resulted in optimum combustion efficiency; and, together with high pressure, high superheat temperatures and the reheat cycle, have resulted in very high cycle efficiency which, today, is equivalent to about .80 pounds of coal per kilowatt hour average in the public utility plants.

A summary of the average thermal efficiencies of this period is shown in table 1.

Table 1

## AVERAGE THERMAL EFFICIENCIES IN PUBLIC UTILITY PLANTS

<u>Year</u>	<u>BTU/kW</u>	<u>Cal/kW</u>	<u>THERMAL EFFICIENCY</u> <u>(Percentage)</u>
1882	138,000	35,000	2.48
1902	92,500	23,200	3.70
1922	34,500	8,550	9.90
1932	20,700	5,200	16.50
1942	18,400	4,640	18.50
1952	15,300	3,860	22.30
1960	11,200	2,800	30.70

In considering the combustion process over this period of time from the first utility plant to the present, we can judge the things which have influenced the increase in economy by three factors - time, turbulence and temperature. Time - the time that the particle of fuel stays in the burning zone before reaching the cooling influence of the /heat absorbing

heat absorbing surface. Turbulence - the amount of mixing of fuel and air during the combustion process. Temperature - the temperature of the combustion zone, governed to a large extent by the BTU release per cu ft of furnace volume and the BTU release per sq ft of furnace water wall absorbing surface.

If we look back to the hand fired boiler in the Pearl Street Station we see that these three factors were of relatively low grade. There was very little time, as the heating surfaces were close to the burning coal. There was little or no turbulence, as the air flowed in through the coal bed by very low natural draft. The temperature in the burning zone was relatively low due to the nearness of the heat absorbing surfaces and the low burning rate.

The underfeed stoker-fired installations had a larger furnace volume with the heating surfaces placed at a greater distance from the burning bed, which increased the time for particle burning. Air under pressure was introduced under the grate and in some cases through tuyeres above the grate so that there was some measure of turbulence and mixing of the air and fuel. Higher burning rates on the stoker accounted for higher BTU release and a higher temperature. The stoker reached the next higher point in combustion efficiency.

With pulverized coal burning, much larger furnaces were used and the time factor increased. The mixing of the air with the coal in the pulverizer and the introduction of secondary air at the burner caused a much higher degree of turbulence. Greater time for combustion and the higher BTU release in a burner with this method raised furnace temperatures to a point where refractories could no longer stand up and water walls made possible smaller furnaces with higher temperatures. The amount of excess air needed with pulverized coal was less than with the stoker due to the better turbulence and mixing of fuel and air in the burner. The result was greater combustion efficiency.

In the cyclone furnace the coal is caused to travel in a helical path through the furnace, thus increasing the retention time in the high temperature zone to promote complete combustion. The air sweeps over the burning coal at high velocity giving the maximum of turbulence  
/and mixing

