STEAM CONSUMPTION IN AN ELECTRIFIED SUGAR MILL

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This paper is a brief abstract of a complete study made on the steam consumption of a sugar factory of this Island, with a quadruple effect evaporative installation, and on the expected steam consumption after the addition of a pre-evaporator which would supply also vapors to the juice heaters.

The scheme of adding a pre-evaporator to a quadruple effect forming a quintuple, and at the same time, supplying vapors at double effect to the juice heaters, is not new, as most of you may know. Noel Deerr in "Sugar" and Hausbrand in "Evaporating, Condensing, and Cooling Apparatus", treat that and similar schemes fully, and actual installations may be found in Cuba, Hawaii and other countries. So far as I know, though, this system has never been worked before in Porto Rico.

Before going into the discussion of the steam requirements, in the actual and in the system in project, a brief description of the factory apparatus and process is necessary.

Actually, the factory is almost wholly electrified. It has one 750 KW. Westinghouse Reaction type steam turbine and one 500 KW. Westinghouse Impulse type turbine. One Corliss engine of 120 HP. and one Corliss engine of 450 HP. drive most of the mill, and 100 HP. in small steam pumps are scattered in various works in the factory.

The juice is passed through three juice heaters, 1,250 square feet H. S. and heated to 212 degrees Fahr. After being clarified, it enters the quadruple effect at an average temperature of 180 degrees Fahr., and leaves as syrup of 27 degrees Beaume. Strikes of "Puras" and "first", massecuites are done in a calandria pan; "second", "third" and some "first" are done in two-coil pans.

The juice heaters and quadruple effect work with exhaust steam and the addition of live steam to mantain 6 lbs. ga. back pressure at the evaporator, or 11 lbs. ga. at the engines.

The calandria pan works with exhaust steam exclusively. The coil pans work mainly with live steam.

With the system in project, the juice heaters will work with vapors from the pre-evaporator; the pre-evaporator will work with the exhaust steam pressure same as previously; the calandria pan with exhaust exclusively, and the coil pans with live steam mainly, or if able, with exhaust steam exclusively. A new juice heater, 1,000 square feet H. S. will be installed also, for reheating the juice after clarification, and will work with vapors from the pre-evaporator.

Now, a word before submitting the results obtained. It would be foolish to claim exactness in the figures to be submitted. They represent the results from average conditions at the usual heavy rate of grinding and for maximum normal extraction of 83 per cent and 35 per cent dilution on cane. The calculations have been made mainly to show the relative proportions among the steam requirements of the different apparatus in the old and in the system in project. Please remember, therefore, that the tabulation of results given below must be considered as fairly approximate to the steam consumption of the apparatus.

TABULATION OF RESULTS FOR THE 750 KW. TURBINE UNIT IN SERVICE

	Live or exhaust steam consumption in lbs. of steam per lb. juice per hour.	Live or exhaust steam consumption in lbs. of steam per lb. juice per hour.	B. T. U. consumption per lb. juice per hour.	B. T. U. consumption per lb. juice per hour	B. T. U. consumption in per Cent of total B. T. U. consumption.	B. T. U. consumption in per Cent of total B. T. U. consumption.
	Quadruple	Quintuple	Quadruple	Quintuple	Quadruple	Quintuple
POWER:						
Turbine 750 K. W. unit.	0.2491	0.2491	25.24	25.24	4.97	6.01
Corliss Engines........	0.1054	0.1054	10.19	10.19	2.01	2.43
Steam Engines.........	0.0616	0.0616	1.57	1.57	0.31	0.37
EVAPORATION & BOILING:						
Heating of juice........	0.1370	....	118.80	....	23.38	....
Reheating of juice	0 0464	0.0052	40.14	4.50	7.88	1.07
Evaporation............	0.2230	0.3135	192.44	270.47	37.92	64.51
Boiling in Cal. Pan.....	0.0931	0.0809	80.66	70.04	15.85	16.71
Boiling in Coil Pans....	0.0068	0.0068	6.51	6.54	1.29	1.56
Evaporation of added water in pans.........	0.0212	0.0212	20.42	20.42	4.02	4.87
LOSSES:						
Steam pipe losses.......	0.0020	0.0020	2.00	2.00	0.39	0 47
Condensation losses....	0.0105	0.0087	10.05	8.40	1.98	2.00
			508.05	419.37	100.00	100.00

Comparative Heat Balance in Pounds Steam per Pound Juice per Hour, 750 KW. Turbine Unit in Service

WITHOUT PRE-EVAPORATOR SYSTEM:			
Exhaust produced by—			
Turbine	0.2491		
Corliss engines	0.1054		
Steam engines	0.0616		
		0.4161	
Exhaust required—			
First heating	0.1370		
Reheating	0.0464		
Evaporation	0.2230		
Boiling in calandria	0.0931		
			0.4995
Deficit in exhaust steam		0.0834	
		0.4995	0.4995
Deficit in exhaust steam			0.0834
Deficit in live steam equivalent			0.0746
USING PRE-EVAPORATOR SYSTEM:			
Exhaust produced by—			
Turbine	0.2491		
Corliss engines	0.1054		
Steam engines	0.0616		
		0.4161	
Exhaust required—			
First heating	0.0000		
Reheating	0.3135		
Evaporation	0.0052		
Boiling in calandria	0.0809		
			0.3996
Excess in exhaust steam			0.0165
		0.4161	0.4161
Excess in exhaust steam		0.0165	

TABULATION OF RESULTS FOR THE 500 KW. TURBINE UNIT IN SERVICE

	Live or exhaust steam consumption in lbs. of steam per lb. juice per hour.	Live or exhaust steam consumption in lbs. of steam per lb. juice per hour.	B. T. U. consumption per lb. juice per hour.	B. T. U. consumption per lb. juice per hour	B. T. U. consumption in per Cent of total B. T. U. consumption.	B. T. U. consumption in per Cent of total B. T. U. consumption.
	Quadruple	Quintuple	Quadruple	Quintuple	Quadruple	Quintuple
POWER:						
Turbine 500 K. W.	0.1849	0.1849	18.74	18.74	3.73	4.56
Corliss Engines	0.1054	0.1054	10.19	10.19	0.03	2.46
Steam Engines	0.0616	0.0616	1.57	1.57	0.31	0.37
EVAPORATION & BOILING:						
Heating of juice	0.1370	....	118.80	....	23.67	....
Reheating of juice	0.0464	0.0052	40.14	4.50	8.01	1.08
Evaporation	0.2230	0.3135	192.44	270.47	38.57	65.53
Boiling in Cal Pan	0.0931	0.0809	80.66	70.04	16.06	16.96
Boiling in Coil Pan	0.0068	0.0068	6.54	6.54	1.30	1.58
Preparation of added water in Pan	0.0212	0.0212	20.42	20.42	4.07	4.95
LOSSES:						
Steam pipe Losses	0.0020	0.0020	2.00	2.00	0.40	0.48
Condensation Losses	0.0105	0.0087	10.05	8.40	2.00	2.03
			501.55	412.87	100.00	100.00

Comparative Heat Balance in Pounds Steam per Pound Juice per Hour, 500 KW. Turbine Unit in Service

WITHOUT PRE-EVAPORATOR SYSTEM:

Exhaust produced by—			
Turbine	0.1849		
Corliss engines	0.1054		
Steam engines	0.0616		
		0.3519	
Exhaust required—			
First heating	0.1370		
Reheating	0.0464		
Evaporation	0.2230		
Boiling in calandria	0.0931		
			0.4995
Deficit in exhaust steam		0.1476	
		0.4995	0.4995
Deficit in exhaust steam			0.1476
Deficit in live steam equivalent			0.1321

Using Pre-evaporator System:

Exhaust produced by—			
Turbine	0.1849		
Corliss engines	0.1054		
Steam engines	0.0616		
		0.3519	
Exhaust required—			
First heating	0.0000		
Reheating	0.0052		
Evaporation	0.3135		
Boiling in calandria	0.0809		
			0.3996
Deficit in exhaust steam		0.0477	
		0.3996	0.3996
Deficit in exhaust steam			0.0477

Now, let us discuss the figures obtained for the 750 KW. turbine unit, which is our most convenient condition in the actual installation.

Without the pre-evaporator, 0.0746 pound of live steam per pound juice per hour must be added to the exhaust for the heating requirements. If we could save this live steam, the economy for a 24-hour day would amount to—

$162{,}250 \times 0.0746 \times 24 \div 7.37 = 39{,}415$ pounds of coal, or 17.6 metric tons per day.

Coal is considered as having 11,850 B.T.U.

Efficiency of boilers as 60 per cent.

Equivalent Evaporation $= 11{,}850 \times .6 \div 963.61 = 7.37$.

If a \$10 price per metric ton of coal is considered, and if it were posible to maintain the 1,500 tons per day rate of grinding during 125 days of the season, the saving would amount to—

$17.6 \times 10 \times 125 = \$22{,}000$ for the year.

With the installation of the pre-evaporator under the scheme explained, it is seen from the tabulations, that working with the 750 KW. turbine unit, there will not be the necessity to add any live steam to the exhaust; to the contrary, there will be an excess of exhaust steam of 0.0165 pound per pound juice per hour, which represents about $0.0165 \times 100 \div 0.4161 = 4$ per cent of the total exhaust steam produced. This excess may be employed to substitute live steam in the coil pans, and thus its loss be avoided.

For the 500 KW. unit, the difference between the deficit of exhaust steam in both cases is $0.1476 - 0.0477 = 0.0099$ pound exhaust per pound juice, or 0.0894 pound equivalent live steam per pound juice per hour, in favor of the projected system. This is a saving of 21.08 metric tons coal per day, or $26,350 per 125 days grinding.

With this turbine in service, there will always be required a small amount of live steam for the normal evaporating load, and there will rarely be occasions of excess exhaust. We expect that it will prove to be the most economic scheme for the factory.

Since a pre-evaporator installed under the discussed system, completely erected with its accessories, will cost about $25,000, it is our opinion that it is a worthwhile investment to be made in any sugar factory. Its cost may be saved almost completely in just a year of grinding.

A paragraph of explanation before I close. The amount in dollars that we claim may be saved in a year of grinding, we don't mean it to be necessarily in dollars. The saving made will appear in the value of the coal economized during the year and in the value as a fuel of the bagasse pile left over as excess.

To those interested in this matter, the tabulations of results given in this paper may be helpful in some other considerations that come along with the problem, but that I do not deem proper to discuss now. Our aim has been merely now to call your attention to the distribution of the steam load in the factory and to the large saving that may be made in fuel consumption, if schemes are worked toward the diminution of the steam consumption in the evaporating and graining stations of the factory.