CALIBRATION OF A NUCLEONIC DENSITY GAUGE FOR MOLASSES BRIX CONTROL IN VACUUM PAN OPERATION.

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SUMMARY.

In order to establish a strict control of the molasses to be feed to the vacuum pan station during industrial evaluations of this facility in the next season, the calibration of a prototype of nucleonic density gauge, constructed in close collaboration between CEADEN and ICINAZ has been performed. Some preliminary results of this complementary task of the project are described.

EXPERIMENTAL.

The nuclear instrument compromise a 400 mCi sealed shielded ^{137}Cs source (Robotron) and a home made Ratemeter with a NaI (Tl) 2x2” scintillation detector. This configuration was chosen in order to achieve an accuracy in density measurements as low as 0.5-1.0 % /13 / with the objective to fulfill the requirements of this parameter in the industrial test.
Nuclear density measurement almost exclusively is based on the transmission (absorption) method (reflection method is less used for this purpose). The process that takes place in this case is described by the following equation:

$$n(t) = n_o(t)\, e^{-\mu\rho x} \qquad (4)$$

where n_o (t); count rate without attenuation by the material to be measured, n(t). Count rate attenuated by the material characterized by thickness x (cm), density ρ (g/cm^3) and mass absorption coefficient μ (cm^2/g).
According to this equation, if the absorption path length or thickness of the material and the mass absorption coefficient are constant (for γ energy higher than 250 KeV, μ practically remains constant and is independent of the chemical composition of the medium), the measured radiation intensity depends exponentially only on the material density.

Procedure:

Taking in account, that in a raw sugar cane factory, normally pipes with diameter between 4-6 inches are used to conduct molasses from storage tank to the vacuum pan station, bench calibration was performed using pieces of pipe with an appropriate length and with these extreme diameter values. As it is recommended pipes were arranged in a vertical position between the source and the detector device. After the common electronic adjustment of the detection system, reference sugar solutions (99% purity) were prepared within the range of density (1 – 1.4) and Brix (0 –78) that predominate in factory (really molasses A and B exhibit higher values of these parameters, but more concentrated solution at room temperature was impossible to obtain due the crystallization process). These solutions so as industrial molasses type A and B were used to fill the pipe. In all cases a routine aerometric method (relative error <1%) was used for density determinations of the material under test. The previous calibration of the aerometric method was performed through the well establish picnometric method.

From Fig.1 it can be observed that an acceptable correlation was achieved.

The calibration in the 4 inches pipe using reference sugar solutions is shown in Fig.2 and the relationship between density and Brix that is illustrated in Fig.3, shows that the nuclear device can be use for the measuring of both parameters with an adequate accuracy (count rates are in the order of 3-4 $x10^4$ c/s).

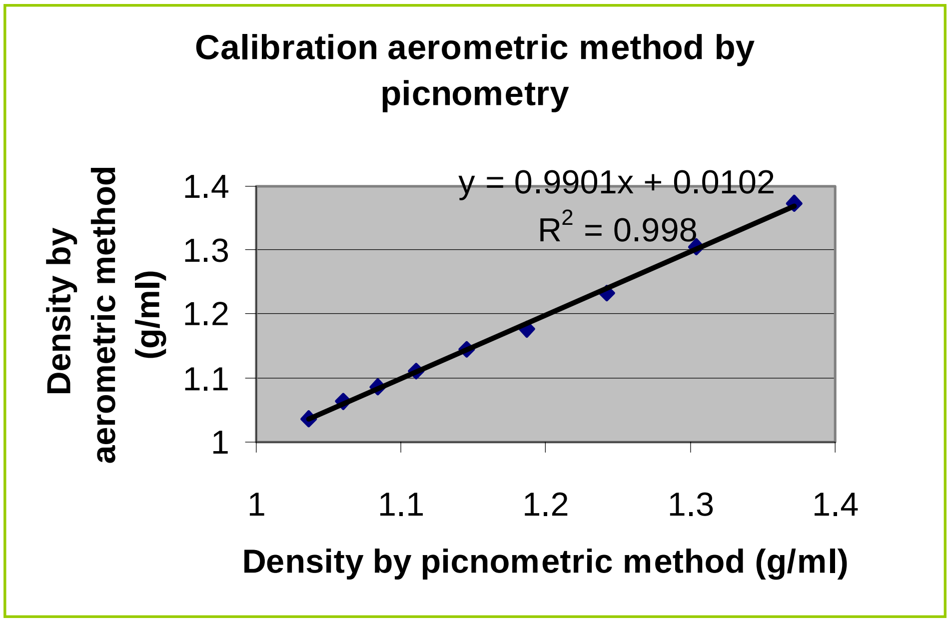

Fig.1 Calibration aerometric method by picnometry.

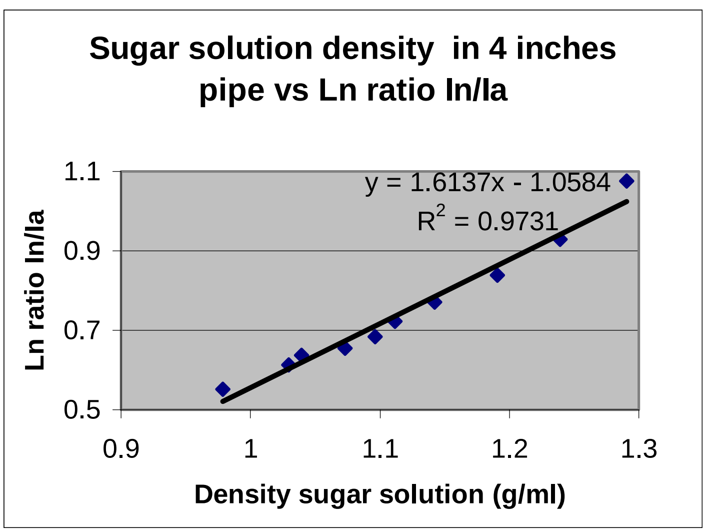

Fig.2 Dependence of Ln ratio In/Ia with density of sugar solutions in 4” pipe diameter

In - count rate non-attenuated radiation

Ia – count rate attenuated radiation

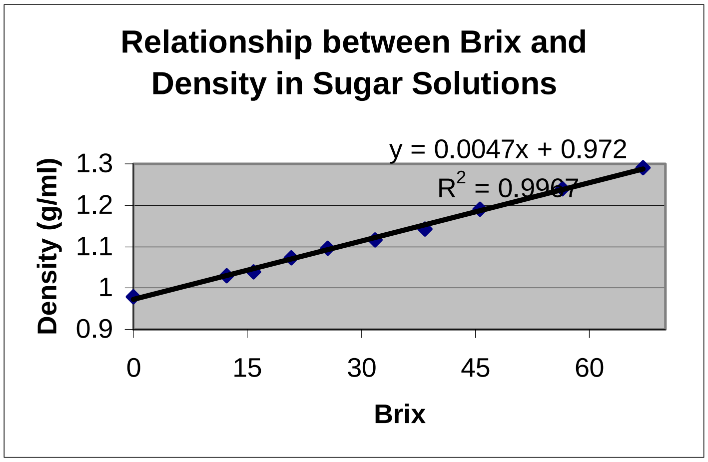

Fig.3 Relationship between Density and Brix in sugar solutions.

The dependence of density with the temperature for the reference sugar solutions is shown in Fig.4. Through the expression for the lineal correlation, a correction factor could be introduce in order to take in account this effect. Nevertheless the first attempt to determine density in real industrials molasses A and B, using these previous calibration curves was unfortunate. Real density values determined by the picnometric method (1.4019 for A and 1.4282 for B) were clearly distant from those given by the nuclear device. Only in the cases of relative low density sugar fluxes as clarified juice and syrup (ρ< 1.32 g/ml) values achieved by the nuclear method were close to those determined by the conventional method (see table 1).

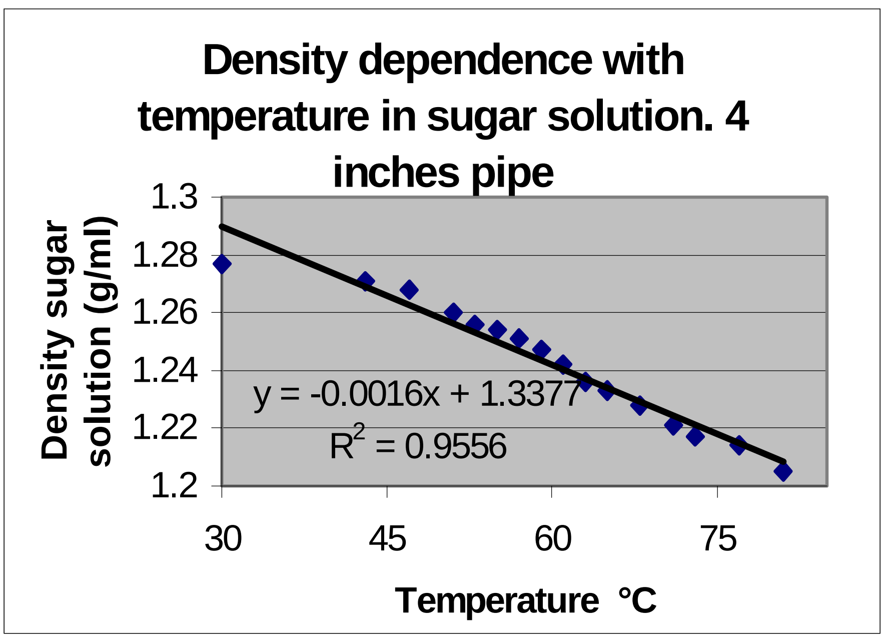

Fig.4 Density dependence with temperature for sugar solution in 4” pipe diameter.

Table 1. **Density determinations in sugar fluxes by Aerometric and Nuclear methods**.

Samples	Density by Nuclear Method (g/ml)	Density by Aerometric Method (g/ml)	Difference	Relative error (%)
Raw Juice	1.0581	1.0503	0.0078	0.7
Mixed Juice	1.0385	1.0329	0.0056	0.54
Clarified Juice	1.0395	1.0361	0.0034	0.33
Syrup	1.2018	1.2041	0.0023	0.24

At the same time, the dependence for molasses A and B was no more linear. A second order polynomial (Fig.5) gave a better fitness in this case. The same unexpected results were obtained for density values when a pipe of 6" diameter was used. Even in this case the dependence of the reference sugar solution with the temperature approach a second order polynomial (Fig. 6).

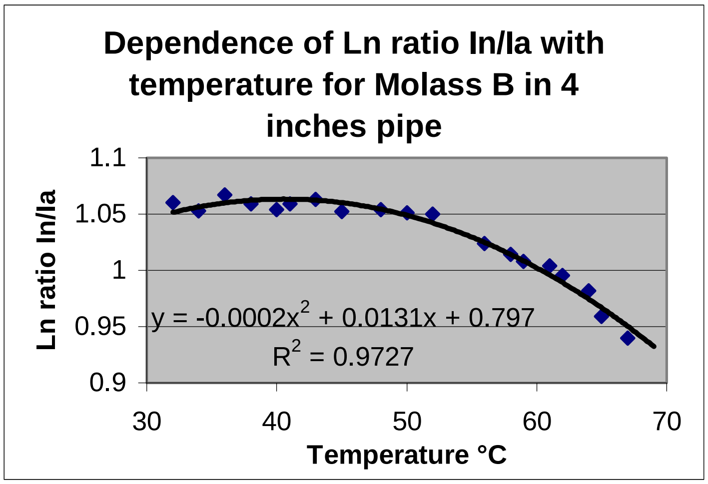

Fig.5 Dependence of Ln ratio In/Ia with temperature for molasses B in 4" pipe diameter

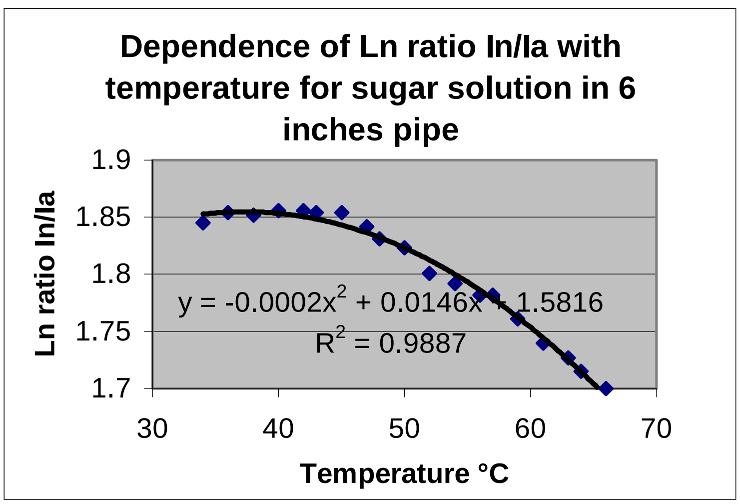

Fig.9 Dependence of Ln ratio In/Ia with temperature for sugar solution in 6" pipe diameter

If the original molasses samples is diluted a good correlation between density and Ln ratio is obtained (Fig.7)

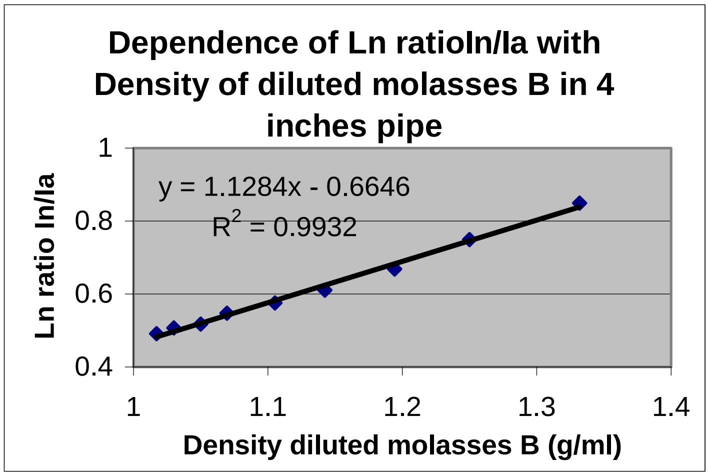

Fig.7 Dependence of Ln ratio In/Ia with density of diluted molasses B in 4” pipe diameter.

CONCLUSIONS.

1st It is evident, that in the case of industrial molasses, in order to perform density determination using the nuclear method, a special calibration has to be carry out employing real molasses samples.

2nd. The achieved results are in clear contradiction with the well acceptable statement that for high γ energy; the medium composition has little effect over density determination by the absorption method. It seems that the high Brix and viscosity that characterize these products have a certain influence in the essence of the phenomenon that take place in the interaction of γ radiation with this medium.

3rd In the range between 30 to 50°C, molasses density practically remains constant. At higher temperature density decreases linearly in the same way as the viscosity does. Taking in account that the temperature of the molasses normally employed to feed the vacuum pan station is close to 50°C, it seems that no correction factor will be needed during the industrial evaluation of this facility.

Special tests will be perform during industrial evaluation in order to clear up all these uncertainties related to the use of the nucleonic gauge for molasses density control at the vacuum pan station.

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