An Automatic Polariscope

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One of the sugar technologists' most important tools is the polariscope. It permits rapid and reliable determinations of the sugar content of juices during the many stages of manufacture. Most polariscopes now in use permit readings to one tenth of a degree and estimation of five one hundredths of a degree of sugar. When a high degree of accuracy is required, as many as ten readings are generally made and averaged. Such procedure is entirely satisfactory when time is not a limiting factor.

In tare laboratories the polariscope is employed for the determination of the sugar content of beets as they are received from the grower. Because of the large number of samples involved it is not possible to make more than one reading and the accuracy depends upon the skill of the tare chemist. Since the operator must generally make about two hundred readings per hour it is customary to have two such operators, working alternately in half-hour shifts. Fatigue of the operators makes itself felt in a number of ways. The eye may become tired and may no longer be able to determine accurately when the halves of the polariscope field are in balance. Fatigue of the mind results in erroneous reading of the vernier scale and lastly errors occur in the transfer of the readings to the tare ticket. All this points to the human element as the major source of error, and its elimination appears highly desirable. This fact has been recognized for many years, and ever since photoelectric cells were available attempts have been made to substitute such cells for the human eye in the balancing of polariscopes.

Historical Development

Stanek and Sandera (5)[2] of Prague disclosed in 1925 that they had worked on such a scheme for more than 20 years. Instead of using the now customary half-shadow method they attempted to determine photoelectrically the point of extinction, i.e. that point at which the plane-polarized light emanating from the sample tube vibrates at right angles to the plane of polarization of the analyzer. In 1926 they employed a single selenium cell and vacuum tube amplifier, but the degree of accuracy was only on the order of one degree sugar. It was reported that each reading took nearly 10 minutes.

Miss Winifred E. Dickes of London (2), working also on the point of extinction, reported the design of an apparatus involving the use of a slit and a selenium cell. Accuracy was reported to be on the order of 0.01 degree sugar but a number of readings had to be taken roughly 90 degrees apart and averaged. In 1924 Miss Dickes was considering the

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[2]The numbers in parentheses refer to literature cited.

addition of vacuum tube amplification and the design of a self-balancing, recording polariscope.

Halban and Seidentopf (1) of Germany worked on a similar arrangement and were granted a patent in 1922. They claimed a precision of 0.01 degree with light in the ultra violet region.

Strelkow (6) of Russia employed a half-shadow device in 1926 and used two selenium cells in a bridge circuit with a sensitive galvanometer. He utilized the heat of the light source and two thermocouples to produce the potential for the selenium cells. No data on accuracy were published.

Singh and Rao (3) of the Benares Hindu University also worked with a half-shadow device in 1937. They used not only two selenium cells but also two polariscopes and sample tubes in parallel. One tube contained the sugar sample solution and the other distilled water. The selenium cells were first balanced without the tubes in place. The tubes were then placed in the polariscopes and balance established through adjustment of the polariscope containing the sample. The tubes were then exchanged and balance re-established by adjustment of the other polariscope. The mean of the two readings then indicated the polarization of the sample.

Spengler and Hirschmueller (4) of Germany worked on a half-shadow device in 1940. They used Polaroid foil in the polarizer and analyzer. Two photoelectric cells of the barrier layer type were used in a bridge circuit. With the sample in place the analyzer was removed and the cells balanced. The analyzer was then replaced and the cells again balanced by rotation of the analyzer. The degree of rotation was read on a vernier scale. The accuracy was claimed to be on the order of 0.1 degree sugar. The firm of Lange in Germany undertook the manufacture of this instrument but the first model submitted for tests to the Berlin Sugar Institute had some mechanical defects. Due to the war nothing further was heard about this development

Undoubtedly many unnamed investigators have worked on this problem.

Early in 1941, R. A. McGinnis and E. E. Morse of the Spreckels Sugar Company experimented with the idea of reading the polariscope by photoelectric means. During 1944, J. R. Earl, a physicist employed by the Spreckels Sugar Company, advanced an idea involving the use of magneto-optical cells, operating on the so-called Allison magneto-optic effect. Later the use of a mechanical light chopper was suggested. Many tests were made and a preliminary report of January 1945 indicated that the system was workable. The work was interrupted due to the scarcity of materials during the war years. Late in 1946, Mr. Earl resumed this project but left the Company in April 1947 without completing the work. It was believed at that time that the remaining problems could be solved in the near future and the project was brought to completion by the author. The photoelectric circuit and the self-balancing mechanism were soon completed and the first model was demonstrated in July 1947. This model, which adjusted itself to balance without any manipulation by the operator, still required the reading of the vernier scale by eye. The development of a printing mechanism, coupled to the vernier scale, had been undertaken by us some time ago and it was now modified to operate with the self-balancing polariscope. The first model of the now fully automatic polariscope was rushed to completion in time for the latter part of the 1947 campaign. It was in continuous use in the Woodland tare laboratory from October until the end of the campaign. A total of 34,838 tare samples were run through the machine. The standard deviation for the instrument is surprisingly low. The following table will illustrate this point (table 1). The test samples upon which this table is based were interspersed with regular tare samples and, therefore, also include any deviation which may be caused by improper scavenging of the continuous tube. A summation of the table indicates a mean standard deviation for the machine of 0.04 against 0.18 for a skilled operator on a manually operated polariscope.

Table 1.

	Series 1	Series 2	Series 3
High Color Solutions			
Tare chemist, average	17.95	16.07	16.89
Tare chemist, σ ±	.103	.508	.109
Automatic Polariscope, average	17.89	16.04	16.92
Automatic Polariscope, σ ±	.046	.049	.027
High Turbidity Solutions			
Tare chemist, average	16.58	16.33	14.98
Tare chemist, σ ±	.096	.218	.129
Automatic Polariscope, average	16.48	16.57	14.97
Automatic Polariscope, σ ±	.078	.013	.040
Clear Solutions			
Tare chemist, average	15.52		
Tare chemist, σ ±	.117		
Automatic Polariscope, average	15.48		
Automatic Polariscope, σ ±	.035		

Description of Polariscope

The automatic polariscope (figure 1) employs a Bausch and Lomb saccharimeter equipped with a Lippich type double-field polarizer. Fully automatic operation, i.e. automatic balancing of the saccharimeter and printing of the sugar content of the sample onto the tare ticket is achieved by a modulated beam of light which is converted into electrical impulses. These impulses cause operation of a motor in such a manner that the compensating wedge in the saccharimeter moves towards the point of balance. The printing mechanism is coupled to the compensating wedge so that for any point of balance between 0 and 30 percent sugar a result corresponding to the reading on the vernier scale of the saccharimeter is printed onto the ticket.

In the Lippich double-field polarizer the incident light receives a different treatment in the two halves of the field insofar as the plane of polarization in one half of the field differs from that of the other half by a small angle, generally called the half-shadow angle. When the analyzer is so oriented that its plane of polarization essentially bisects the half-shadow angle, the halves of the field transmit the same amount of light and the field appears evenly illuminated. When a substance of rotatory power is placed between the polarizer and analyser the halves of the field no longer appear equally bright. A movement of the quartz compensator wedge in the proper direction then again restores the field to balance. In the automatic polariscope a revolving semi-circular shutter scans the field continuously at a rate of 3,600 revolutions per minute. Thus, in the case of an unbalanced field, the intensity of the light reaching the phototube varies between a minimum and a maximum (see figure 2). The current passed by the anode of the phototube varies with the intensity of the light and since this occurs 3,600 times per minute the phototube and amplifier produces a 60-cycle alternating current. The rotating shutter is so positioned that the resultant A. C. is always 90 degrees or 270 degrees out of phase with the main line A. C., depending on which side of the field is darker. The combination of main line A. C. and that produced by the amplifier causes the balancing motor to operate. The rotation is either clockwise or counterclockwise, depending on the direction of unbalance. The mechanical connections are so arranged that

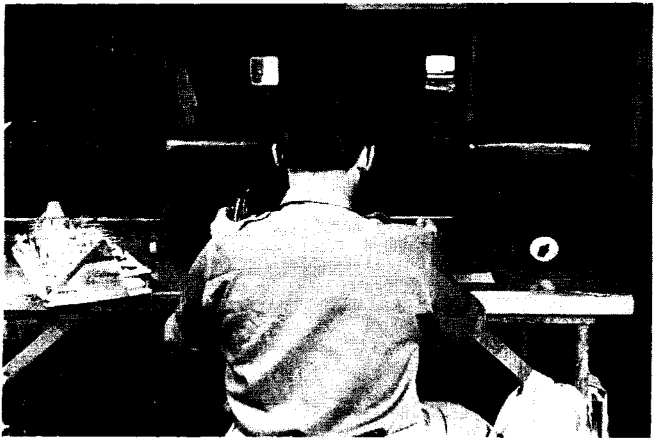

Figure 1. Automatic polariscope in use.

the quartz compensator is always driven toward the point of balance. When the balance point is reached no more alternating current reaches the balancing motor from the amplifier and it no longer moves the compensator. The printer is coupled to the compensator so that at the balance point the percentage of sugar is directly printed onto the tare ticket. In tare laboratory practice the sample is generally read to the nearest one-tenth of one percent. The automatic polariscope permits estimation of one-hundredth of one percent.

Figure 1 shows the operator seated before the instrument. His left hand holds the beaker containing the sample. A slight upward pressure with the beaker against the inlet tube causes the automatic siphon valve to take the sample into the machine, removal of the beaker automatically closes the valve. The tare ticket is in the printer holder. Pushing the holder into the machine causes the printing mechanism to function, and the completed ticket is withdrawn. In the present form polarizations may be read and printed at the rate of 1 every 9 seconds or 400 per hour.

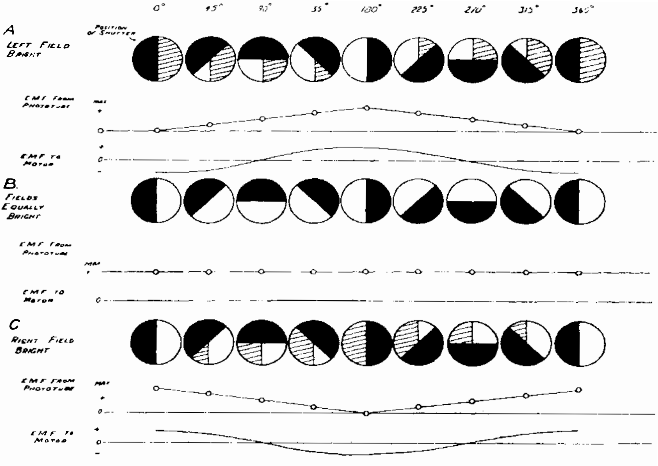

Figure 2.—Principle of phase reversal.

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