Experiences with the Enviro-Clear System for Rapid Clarification of First Carbonation Effluent

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Received for publication March 29, 1972

Introduction

The Spreckels Sugar Co. installed a 14-ft dia. Eis Clarifier at the Woodland, California plant in 1969 and a second unit of 23-ft dia. at the Spreckels, California plant in 1971. Further development and application have been assigned to Enviro-Clear, Inc. The method and apparatus are now known as the Enviro-Clear system. The first unit replaced a 26-ft dia., 4-tray, and the second a 30-ft dia., 4-tray clarifier. The nominal capacity of the Woodland plant is 3600 tons/day and the Spreckels plant 6500 tons/day beet slice.

The two Enviro-Clear units operate on the same principle which has been previously described (3)[2]. The Woodland unit is fed from the bottom whereas the Spreckels unit is fed from the top. The Spreckels unit was installed five feet above floor level to allow gravity feed of underflow to rotary vacuum filters to be located in the future on the same floor.

Clarifier Flow

The clarifier flow patterns are shown in Figures 1 and 2. The feed juice mixed with the necessary flocculating aid enters the clarifier from the bottom through the central standpipe at Woodland, and similarly, but from the top, at Spreckels. A deflector plate just beyond the inlet pipe directs the flow radially into a settling bed of thickened sludge.

The sludge bed is controlled at the desired level by the rate of underflow withdrawal. The suspended solids content of the sludge bed increases from the top to the bottom, allowing conventional sludge rakes to move the sludge toward the central sludge boot at its maximum density where it is discharged by gravity flow.

The sludge bed level can be controlled by any suitable level-sensing system. A sonic sensor (National Sonics Corp. *400S*) is used at the Spreckels, California plant. A photo-electric sensor as well as a sonic sensor has been used with success at the Woodland plant to control the valve regulating the underflow discharge.

The feed juices entering the clarifier must be comparatively free of gas bubbles to allow sedimentation rather than flotation of light

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[2]Numbers in parantheses refer to literature cited.

particles. An 8.5 ft. dia. tank with a juice level of less than 2 feet is used at Woodland while a trough of equivalent area is used at the Spreckels installation for degassing the clarifier feed. The Woodland factory is converting to a trough deaerator, as level control in the shallow tank has not been completely satisfactory.

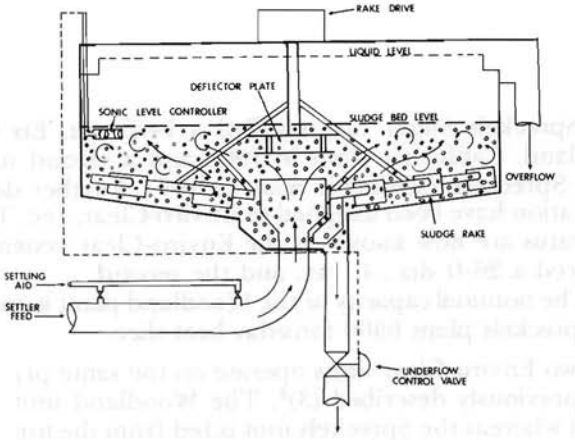

Figure 1.—Woodland Clarifier Flow Pattern.

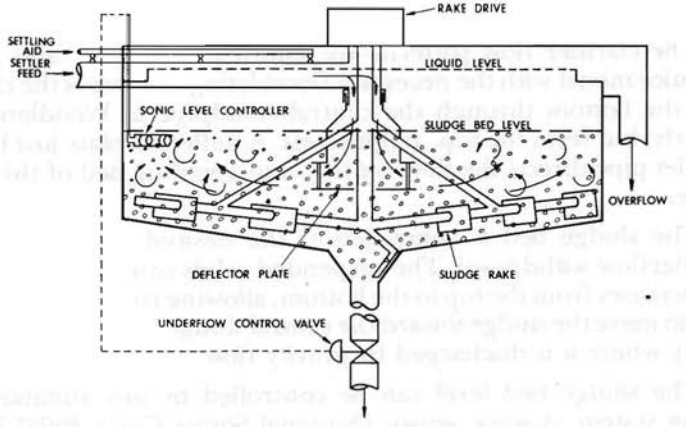

Figure 2.—Spreckels Clarifier Flow Pattern

Clarifier Design

Physical data comparing the conventional 4-tray clarifiers with the new clarifiers are given in Table 1.

Table 1.—Physical comparison of conventional 4-tray clarifiers with Enviro-Clear replacements

	Woodland Factory		Spreckels factory	
	4-Tray	Enviro-Clear	4-Tray	Enviro-Clear
Liquid height, ft	17.8	4.5	17.8	6.0
Diameter, ft	26	14	30	23
Utilized volume, cu ft	9400	770	12500	2490
Settling area sq ft	2100	154	2800	415

It should be noted that the new clarifier for the Spreckels factory is considerably larger in relation to the old clarifier than that for the Woodland factory. There are two reasons for this apparent anomaly; first, the Spreckels 4-tray unit did not have sufficient capacity at high slice rates; and second, the Woodland clarifier was sized for 5 gpm/ft^2 at nominal capacity whereas the Spreckels unit was sized for 4 gpm/ft^2. The Spreckels factory also has relatively greater lime load due to a greater ratio of molasses worked to beets sliced.

Principle of Operation

Coe and Clevenger (1) first pointed out that the area required in a clarifier is governed by the slowest settling mixture of sludge particles and clear juice, and all possible mixtures of sludge and juice are found ranging from the clear overflow to the thickened underflow sludge. The limiting mixture is generally encountered in the free settling zone for lime suspensions in sugar juice. By introducing the clarifier feed into a thickened sludge bed while maintaining a sharp boundary between the top of the sludge bed and clarified liquor, the zone of free settling is eliminated. A sharp boundary between the sludge bed and clarified liquor is readily maintained when using flocculating aid. The combination of bypassing the normal rate-limiting zone and maintaining a minimum distance for particles to settle accounts for the great acceleration of clarification and thickening experienced with the Enviro-Clear system.

Advantage of the Enviro-Clear

The primary advantages of the Enviro-Clear system lie in the short retention time required for juice clarification and sludge thickening. McGinnis (3) gives data showing a 25% increase in color and 36% increase in lime salts for a laboratory conventional tray clarifier over that of the Enviro-Clear unit, and the same increase in color for a simulated tray thickener over the factory operating Enviro-Clear clarifier.

Operating data with the new unit for the Woodland and Spreckels factories show an improvement in color and a decrease in juice degradation as indicated by lime salts. The level of lime salts at the Spreckels factory remained nearly constant before and after use of the new clarifier but the amount of soda ash used for lime salts control was

reduced from 0.254 lb/ton beets for the 1970 fall campaign to 0.139 lb/ton beets for the 1971 fall campaign. Operating data on lime salts for the Woodland factory are given in Table 2.

Table 2.—Woodland Factory thin juice lime salts, % Cao on rds before and after Enviro-Clear installation.

Before			After		
Year	Spring	Fall	Year	Spring	Fall
1966	0.145	0.178	1969	0.127	0.179
1967	0.301	0.217	1970	0.123	0.158
1968	0.172	0.189	1971	0.113	0.149
Avg.	0.206	0.195		0.121	0.162
		Percentage decrease		41	17

Accurate data are not available on the amount of soda ash added for control of lime salts at the Woodland factory; however, less has been used since the new clarifier was installed and very little was used during the 1971 fall campaign. A significant decrease in thin juice lime salts with the new clarifier is evident.

Another factor of concern in beet-sugar manufacture is the decrease in pH of juice across the evaporators in certain areas. Data are tabulated in Table 3 for the three years prior to installation of the new clarifier at Woodland, and the three years of new clarifier operation. A significant improvement in juice pH values has been gained with the new clarifier.

Table 3.—pH values of thin and thick juice, Woodland factory, campaign average values.

		Spring campaign			Fall Campaign		
	Year	Thin juice	Thick juice	Decrease	Thin juice	Thick juice	Decrease
4-tray clarifier	1966	8.8	8.3	0.5	8.4	8.2	0.2
	1967	9.1	8.7	0.4	8.4	8.0	0.4
	1968	8.8	8.3	0.5	8.5	8.1	0.4
Average		8.9	8.4	0.5	8.4	8.1	0.3
Enviro-Clear	1969	9.1	9.0	0.1	8.8	8.8	0.0
	1970	8.7	8.6	0.1	8.9	8.9	0.0
	1971	8.6	8.5	0.1	8.6	8.8	-0.2
Average		8.8	8.7	0.1	8.8	8.8	0.0

The stability of factory liquors toward color development during processing is highly important. Beets containing high amounts of invert are usually considered best processed by mild carbonation processes with gentle treatment in evaporators and the sugar end. However, years of operating experience have led some operators to the conclusion that vigorous defecation is preferable (4). Jesic (2) shows a greater color formation due to invert sugar destruction during evaporation of thin juice than when the invert is destroyed during carbonation.

Data are given in Table 4 which show that although the Woodland thin juice contains appreciable invert sugar, little color build-up occurs during evaporation under Woodland processing conditions.

Table 4.—Juice color values of thin and thick juice, Woodland factory.

1971	% Invert on Sugar		Color values*		
Campaign day	Raw juice	Thin juice	Thin juice	Thick juice	Color increase
Sept. 18,	2.72	1.22	26	27	1
19	1.56	0.70	30	30	0
20	1.10	0.47	24	27	3
21	0.96	0.30	22	22	0
22	1.22	0.50	25	25	0
Avg.	1.51	0.64	25	26	1

*10 (-log T/bc) at 420 nm, 7pH

Data are given in Table 5 for juice color values at the Spreckels factory.

Table 5.—Juice color values, Spreckels factory.

	% Invert on sugar		Color values*				
1971 Campaign day	Raw juice	Thin juice	1st. carb.	Clarifier overflow	2nd carb.	Thin juice	Thick juice
Sept. 26,	0.62	0.05	15	16	18	17	17
27	1.12	0.49	17	21	22	20	22
23	1.28	0.02	17	17	20	17	18
29	0.88	0.00	24	26	25	22	26
30	0.84	0.00	22	24	21	22	26
Avg.	0.95	0.11	19	21	21	20	22

*(-log T/bc) at 420 nm, 7pH

The Spreckels factory was processing better beets as judged by color and invert content of thin juice than the Woodland factory; yet with an appreciable amount of invert at times, little color increase during processing is shown.

Both factories practice mild defecation but the Woodland factory uses five-effect, long-tube verticle evaporator bodies with a short retention time; while the Spreckels factory has four-effect horizonal tube bodies with a long retention time plus a concentrator for pan charges. The type of evaporator and the retention time apparently has little effect on color build-up during evaporation in these instances.

The fate of the invert sugar that passes through carbonation is interesting. Data for the past three years for the Woodland factory indicate that the invert remaining in thin juice is nearly quantitatively recovered in the molasses produced. Another interesting result is a reduction in molasses purity nearly equivalent to the invert content. Data illustrating the effect are given in Table 6. Plots of the data are shown in Figures 3, 4, and 5.

Table 6.—Woodland factory invert content of thin juice, and invert content and purity of molasses produced.

1971 Processing period	X_1 Thin juice % Invert on sugar	X_2 Molasses % Invert on sugar	X_3 Molasses True purity
6/29-7/13	.34	1.24	62.3
7/13-7/27	49	2.14	61.4
7/27-8/10	1.18	4.15	60.4
8/10-8/24	1.36	5.13	59.8
8/24-9/7	1.18	5.42	60.3
9/7-9/21	1.00	3.98	61.1
9/21-10/5	0.39	1.43	62.5
10/5-10/19	0.25	1.19	62.8
10/19-11/2	0.32	1.42	62.4
11/2-11/16	0.20	1.17	62.6
11/16-11/30	0.22	1.75	62.9
Avg.	0.63	2.64	61.7

Correlations:

$X_2 = 0.3518 + 3.629\ X_1$; r= 0.973, $\sigma X_2 = 0.368$

$X_3 = 63.21 - 2.430\ X_1$; r= -0.973, $\sigma X_3 = 0.247$

$X_3 = 63.35 - 0.6338\ X_2$; r= -0.946 $\sigma X_3 = 0.346$

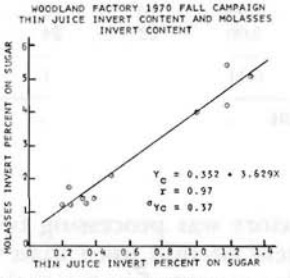

Figure 3.—Woodland factory 1970 fall campaign thin juice invert content and molasses invert content.

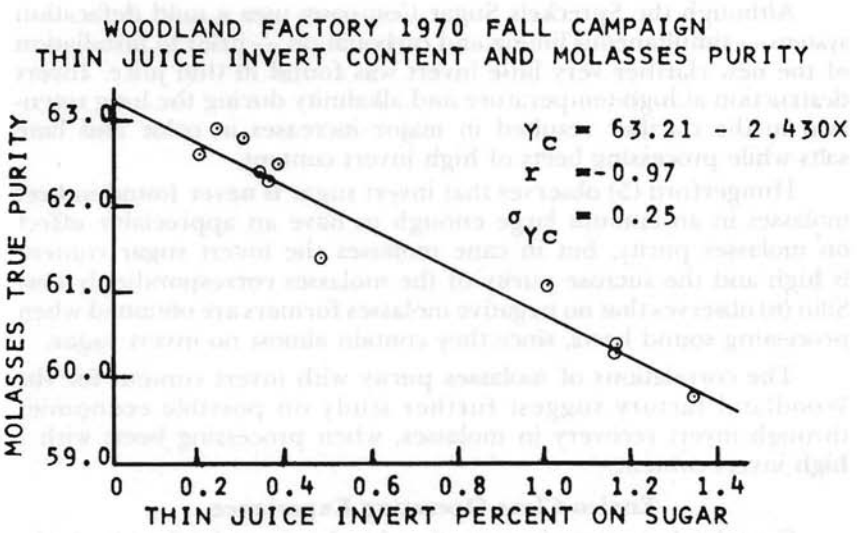

Figure 4.—Woodland factory 1970 fall campaign thin juice invert content and molasses purity.

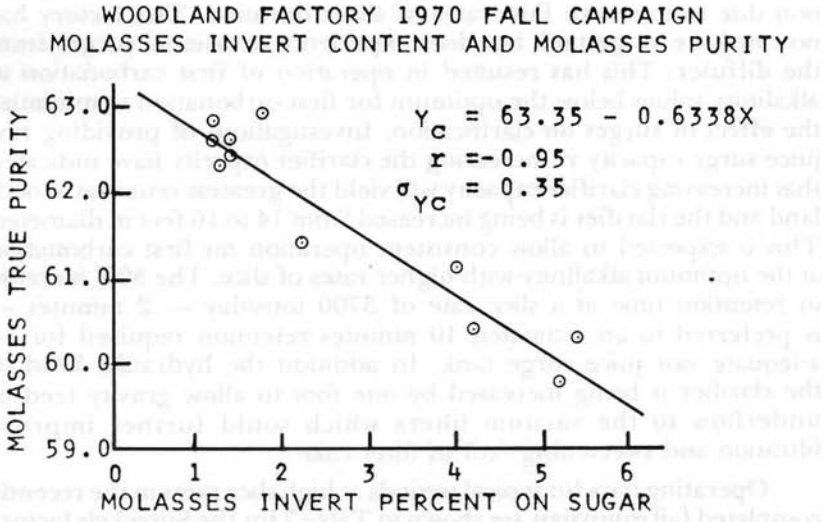

Figure 5.—Woodland factory 1970 fall campaign molasses invert content and molasses purity.

Although the Spreckels Sugar Company uses a mild defacation system — simultaneous liming and carbonation — prior to installation of the new clarifier very little invert was found in thin juice. Invert destruction at high temperature and alkalinity during the long retention in the clarifier resulted in major increases in color and lime salts while processing beets of high invert content.

Hungerford (5) observes that invert sugar is never found in beet molasses in an amount large enough to have an appreciable effect on molasses purity, but in cane molasses the invert sugar content is high and the sucrose purity of the molasses correspondingly low. Silin (6) observes that no negative molasses formers are obtained when processing sound beets, since they contain almost no invert sugar.

The correlations of molasses purity with invert content for the Woodland factory suggest further study on possible economies through invert recovery in molasses, when processing beets with a high invert content.

Enviro-Clear Operating Experience

Completely automatic operation has been attained at both the Woodland and Spreckels installations. Experience at Woodland has allowed a reduction in settling aid requirements to 3 ppm on beets for the 1971 fall campaign, which is below the level previously used for the 4-tray clarifier. The slice rate has not been limited by the new clarifier, but was limited on occasions by the old 4-tray unit.

The Woodland factory has experienced upsets in clarifier operation due to excessive flow rates of short duration. The factory has no raw juice surge tank but does experience occasional surges from the diffuser. This has resulted in operation of first carbonation at alkalinity values below the optimum for first carbonation to minimize the effect of surges on clarification. Investigations of providing raw juice surge capacity vs increasing the clarifier capacity have indicated that increasing clarifier capacity will yield the greatest return at Woodland and the clarifier is being increased from 14 to 16 feet in diameter. This is expected to allow consistent operation on first carbonation at the optimum alkalinity with higher rates of slice. The 30%-increase in retention time at a slice rate of 3700 tons/day — 2 minutes — is preferred to an estimated 10 minutes retention required for an adequate raw juice surge tank. In addition the hydraulic head of the clarifier is being increased by one foot to allow gravity feed of underflow to the vacuum filters which sould further improve filtration and sweetening - off of filter cake.

Operating data for typical periods at high slice rates in the recently completed fall campaign are shown in Table 7 for the Spreckels factory and in Table 8 for the Woodland factory. The increase in area of the Woodland unit by 30% will reduce the flow rate to 5 gpm/ft^2 and increase the average retention time to about 7 minutes at a 3700 tons/day slice rate.

Table 7.—Typical operating data for Enviro-Clear clarifier Spreckels, California factory.

1971 date	tons slice	Mol. Wkd. % on beets	% CaO on beets	Juice to Clarifier gpm/ft²	Juice to Clarifier Average retention minutes	Weight percentage Suspended Solids Feed	Weight percentage Suspended Solids Underflow	Weight percentage Suspended Solids Overflow	Weight percentage of feed to overflow
10/6	6609	5.54	2.93	4.1	11	4.1	23.9	0.015	83
10/7	6526	6.01	3.32	4.4	10	4.9	21.7	0.018	77
10/8	6680	5.79	3.32	4.5	10	5.3	20.1	0.021	74
10/9	6379	5.60	2.92	3.8	12	4.5	17.6	0.029	74
10/10	6756	5.95	3.22	4.4	10	5.0	21.8	0.015	77
Average	6590	5.78	3.14	4.2	11	4.8	21.0	0.020	77

Weight percentage
Suspended solids

Table 8.—Typical operating data for Enviro-Clear clarifier Woodland, California factory.

1971 date	Tons slice	Mol. Wkd. % on beets	% CaO on beets	Juice to Clarifier gpm/ft²	Juice to Clarifier Average retention minutes	Weight percentage Suspended solids Feed	Weight percentage Suspended solids Underflow	Weight percentage Suspended solids Overflow	Weight percentage of feed to overflow
8/28	3587	6.02	3.21	6.3	6	4.6	20.4	0.012	77
8/29	3716	5.63	3.30	7.1	5	4.0	18.1	0.023	78
8/30	3869	5.17	3.04	7.2	5	4.2	18.7	0.006	76
8/31	3682	5.54	3.06	6.9	5	4.5	19.6	0.010	77
9/1	3706	5.23	2.98	6.7	6	4.6	17.1	0.005	73
Average	3712	5.52	3.12	6.8	5	4.4	18.8	0.011	76

Summary

Experiences with the Enviro-Clear system for rapid clarification of first carbonation effluent at the Woodland and Spreckels factories of the Spreckels Sugar Company are described. Advantages over the former 4-tray clarifiers include suppression of color and lime salts formation during clarification, a reduction in pH drop across the evaporators, a reduction in use of soda ash, and improvement in the thermal stability of juices when using a mild defacation system.

A high degree of correlation between invert content of thin juice and invert content of molasses produced is shown. Correlations of molasses invert content with molasses purity suggest that invert has a negative melassigenic coefficient under processing conditions at Woodland.

Typical clarifier operating data are given. At a feed rate of 4 gpm/ft^2 of settling area for a 6600 tons/day slice rate at the Spreckels factory, the clarifier underflow contained 21% suspended solids and the overflow 0.020%. At a feed rate of 7 gpm/ft^2, 3700 ton/day slice rate, the Woodland factory underflow contained 19% suspended solids and the overflow 0.011%. The weight percent of overflow based on clarifier feed was greater than 75% at each location.

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