Application of the Enviro-Clear Clarifier for Steffen Heated Cold Filtrate

O. Bonney and J. Thomas*

Received for Publication May 6, 1983

INTRODUCTION

Since being developed by Carl Steffen (1) in 1883 and 1884, the Steffen process, in which lime is used to precipitate sugar from diluted beet molassses, is still used by many sugar companies. Its use has been dependent upon economic conditions and in some factories the process has been discontinued. It does require considerable capital investment and energy and in today's environment it also creates a waste disposal problem.

Much attention has been given to improving the cold precipitation part of the process. In 1936 Meredith (2) of the Spreckels Sugar Company patented a continuous cold precipitation method. More recently, in 1973, Vandewijer (3) of the Raffinerie Tirlemont, Tienen, patented a cold process that allowed using a cold solution of relatively high sugar content (3). Other recent modifications have been summarized by Hartmann (4)(5).

As indicated by the scarcity of references in the literature, hot saccharate precipitation has not received as much attention. Originally, the heating of cold filtrate was done stepwise in a series of tanks. The heated solution was filtered in plate and frame or thickening type filters. Use of multitray clarifiers of the Dorr type and rotary vacuum filters came into use around 1920. The introduction of the latter equipment contributed to continuous processing and greatly improved the overall process efficiency.

The major improvement, however, in the hot saccharate process was the development by Shafor (6), in 1923, of a new type of cold filtrate heater. In this heater, a small

---

*Sr. Research Associate and Research Associate, respectively, Spreckels Sugar Division, Woodland, CA 95695.

volume of cold filtrate is rapidly mixed into a large volume of heated cold filtrate. The heating is done by steam injection and the temperature is controlled at about 85°C. Shafor had found the optimum temperature range for rapid settling and maximum sugar recovery to be in the range of 80° to 85°C. With the advent of this heater, the entire process became continuous. This continuous process of heating, clarification, and filtration is the system used by the Spreckels Sugar Company today.

Very heavy scaling occurs in the hot process and periodic shutdown of the Steffen house is required to clean the equipment. Cleaning of the multitray clarifier is especially time consuming and labor intensive because of limited access to the interior surfaces. The working conditions also present a safety hazard.

When the Spreckels Salinas plant was modernized a few years ago, the multitray clarifier was replaced with a single tray, top entry, Enviro-Clear clarifier (7) to eliminate some of the operating problems previously mentioned. Certain difficulties were encountered that were attributed to pooor control of cold waste heater temperature, poor control of the sludge bed level required for this type of clarifier, and poor deaeration of clarifier feed. Scaling still occurred, with the heaviest scale being deposited in the inlet piping system. The scale appeared to be associated with the addition of settling aid used to promote settling of the hot saccharate precipitate. With the top entry, only a small static head was available for gravity feed so scale deposition rapidly restricted the capacity of the system. In addition, the inlet piping arrangement did not allow filling the pipe with acid to dissolve scale and therefore frequent manual cleaning was required.

An opportunity arose to replace the multitray clarifier at the Spreckels Woodland plant in order to improve the safety of personnel during cleaning of the Steffen house. The design of the new unit and its initial operation performance are discussed below.

DESIGN AND INSTALLATION

Clarifier Design

Based on previous laboratory tests, a covered 10-ft diameter, bottom-entry type of Enviro-Clear clarifier was considered adequate when processing 300 gpm of Steffen cold solution containing 7% sugar. With the bottom-entry clarifier, the installation could be readily arranged to allow for a large increase in static head required for gravity flow and the feed pipe could be filled with acid for cleaning, if necessary. The liquid depth in the clarifier is 4 feet 6 inches to facilitate cleaning which will be described later. This unit replaced a 16 ft diameter, 12.5 ft high 3-tray Dorr clarifier.

The general arrangement of the new installation is shown in Figure 1. With the new single tray unit, surfaces subject to scaling are minimized and there is ready access to the interior. The height of the clarifier was extended one foot above teh interior overflow launder. This was done to allow easy access into the overflow launder for cleaning, since the clarifier is covered. The cover has four removable sections, one in each quandrant, so personnel can work inside with little or no restriction

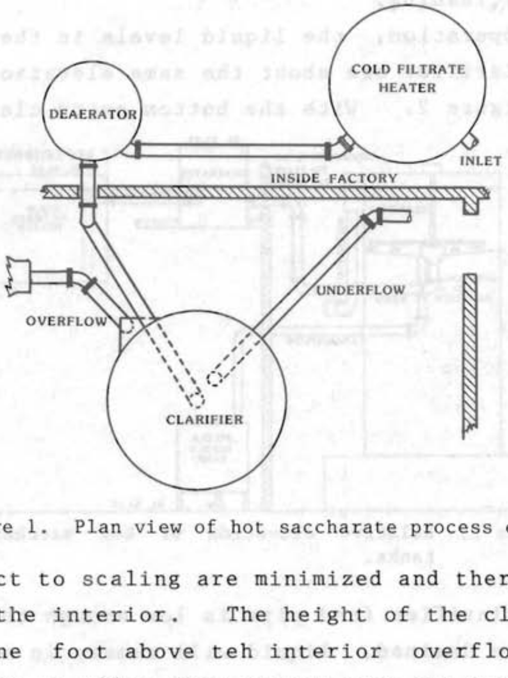

Figure 1. Plan view of hot saccharate process equipment.

of working space. The mud rake design in the small clarifier consists of four rake arms bolted to a central drive shaft. As part of the inlet design, a deflector plate is positioned over the end of the feed pipe inside the clarifier. This defector plate is fastened to the mud rakes and rotates with the rakes. With this simplified design, there is a minimum of surface area to be cleaned.

A deaeration tank, 5 ft in diameter and 6 ft high was installed between the cold waste heater and clarifier. This tank has a removable cover, a drain, and a manhole in the side to provide ready access. All piping between the cold waste heater, deaeration tank, and clarifier was designed as flanged sections so the piping could be easily dismantled for descaling when required. Underflow and overflow piping was also fabricated in flanged sections for ease in cleaning.

During operation, the liquid levels in the deaeration tank and clarifier are about the same elevation as indicated in Figure 2. With the bottom entry clarifier design, the clarifier feed pipe is low enough that when the clarifier is drained, liquid will remain in most of the pipeline from the deaerator. With this arrangement the feed pipe could be filled with acid, if necessary, and allowed to stand to dissolve scale.

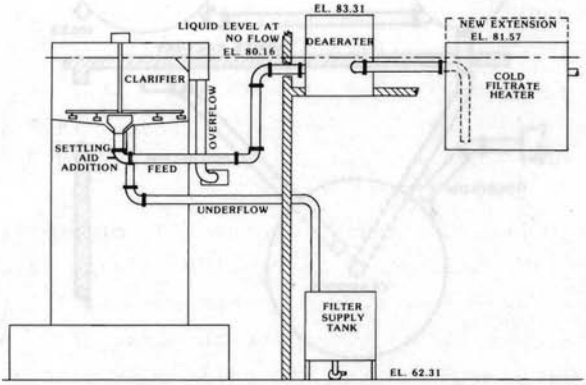

Figure 2. Relative elevation of hot saccharate process tanks.

Existing equipment such as the cold waste heater, final waste weir box, and underflow filter supply tank were left in place. The old multitray clarifier and its accessory equipment such as the Dorrco mud pumps were removed. The new equipment was arranged to allow gravity flow of heated cold filtrate through the deaeration tank into the clarifier. Clarifier overflow and underflow are discharged by gravity into the corresponding weir box and filter supply tank.

The elevation of the deaeration tank and clarifier was critical with respect to requirements for gravity flow without danger of air entrainment in the clarifier feed. Piping changes were minimized by connecting new pipelines as directly as possible into existing lines. To meet these requirements it was necessary to support the clarifier on a 13 ft high, cylindrical support column anchored to the existing concrete pad used for the old clarifier. The new clarifier, deaeration tank, and associated piping were insulated.

System Control

Factory operators were consulted on various aspects of the new Steffen operation to anticipate possible problems with the new system. It was intended that the gravity flow system and clarifier operate with a minimum of attention. In the clarifier, underflow is discharged automatically.

Sample ports were placed in the side of the clarifier where it was desired to control the sludge bed level. Piping from the sample ports was arranged so liquid would pass through a glass tube or flow-through cell. An infrared beam was passed through the cell. As sludge or clear liquid flows through the cell to affect the amount of light transmitted, a signal is generated by the infra-red detector to control the air to an air-operated underflow discharge valve. A parallel flow-through cell arrangement was provided, along with means to acid clean the cells. Means were also provided to manually bore out the sample lines if they become plugged with scale.

The clarifier has a sightglass in the side wall, but a high sludge bed level alarm was installed to alert operators to this condition so corrective action might be taken before sludge was carried into the overflow. A manual override was incorporated into the underflow discharge during process upsets. During processing a need was found for an alarm to indicate a high liquid level in the filter supply tank. This signal was integrated into the underflow valve control system to prevent discharge of underflow when the filter supply tank is full.

Settling Aid

Tests had shown that the same settling aid used for clarification of first carbonation juice could be used in the Steffen hot saccharate clarifier. Separate metering pumps were installed for pumping settling aid stock solution into the hot saccharate clarifier feed. For the most efficient use of settling aid, it has been found necessary to use soft water to make up settling aid stock solutions. A system was set up to dilute the stock solution with clarifier overflow prior to the solution being added to clarifier feed. Piping was arranged to allow use of water for dilution when overflow was not available. The flow of dilution liquid is monitored by a rotometer.

The settling aid was added into the clarifier feed line at a 90° elbow just below the clarifier where a horizontal section of feed pipe changed to a vertical direction at the inlet to the clarifier. As shown in Figure 3a, the addition nozzle pointed upstream into the horizontal section of pipe to enhance mixing of settling aid into the feed.

STARTUP AND OPERATION

Startup

The Steffen house was started up in the normal manner at the beginning of the 1982 Spring campaign. Heated cold filtrate flowed from the heater through the deaerator and into the new Enviro-Clear clarifier under only a slight static head. Addition of settling aid was verified and flocculated particles could be seen in the clarifier through the sightglass in the side of the clarifier. As

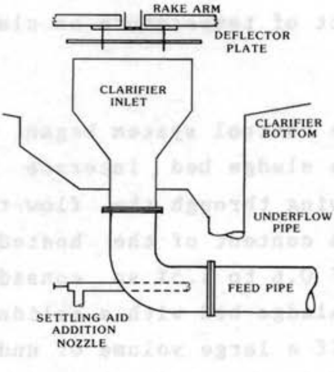

Figure 3a. Original settling aid addition point.

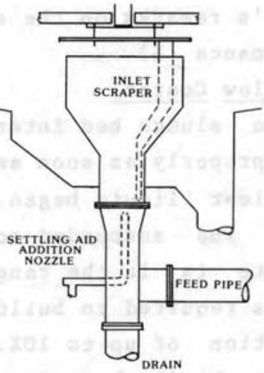

Figure 3b. Inlet scraper and revised settling aid addition point.

time passed, however, it appeared that the suspended solids were not settling to form a normal sludge bed and sludge was being carried out in the overflow. The automatic control system for underflow control would not work without a sludge bed interface and operation was placed on manual control.

Tests were quickly made to verify that the settling aid being used was fully effective. Brief beaker tests indicated the hot saccharate precipitate could be flocculated but comparative tests with fresh cold filtrate heated to 85°C in the laboratory indicated the laboratory prepared samples flocculated better and settled faster. The temperature in the clarifier was checked and found to be in the range of 60-65°C. Past experience at the Salinas installation had shown that clarifier operation would be adversely affected if the heated cold filtrate temperature was below 78°C. On inspection of the Woodland cold waste heater, it was found that steam addition was inadequate although a temperature indicator showed the temperature to be near 90°C, and that possibly the agitator had not been turned on. The temperature recorder was found to be out of calibration. As more steam was added the temperature in the clarifier rose to 78°C and finally up to about 90°C. Clarifier performance improved immediately and a good sludge bed was formed. This experience confirmed

Shafor's remarks on the effect of temperature on clarifier performance (6).

Underflow Control

The sludge bed interface control system began operating properly as soon as the sludge bed interace formed and clear liquid began flowing through the flow-through cell. The suspended solids content of the heated cold filtrate is in the range of 0.6 to 1.5% so considerable time is required to build a sludge bed with a solids concentration of up to 10%. If a large volume of underflow were to be discharged quickly, the sludge bed interface would fall a considerable distance and a relatively long time would be required to increase the sludge level. The large four-inch underflow discharge valve was much larger than required to handle the estimated average underflow rate of 25 gpm, but was chosen so if relatively large pieces of scale lodged at the valve, the valve could be opened completely to allow the scale to pass. To minimize sludge bed level fluctuations, air pressures and needle valves in the air lines were adjusted to cause the valve to open slowly to a preset point but to close immediately. A schematic diagram of this system is shown in Figure 4. Adjustments were made to suit the conditions encountered

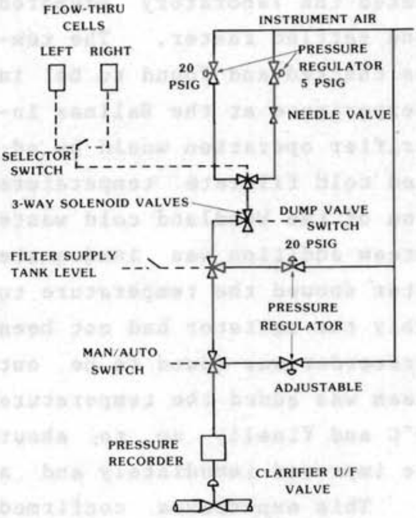

Figure 4. Underflow valve control system.

during normal Steffen house operation. During process upsets the valve could be controlled manually. On occasions when the valve remained closed for a relatively long period, the somewhat sticky sludge would not start to flow when the valve opened. Completely opening and closing the valve manually once or twice usually resulted in the sludge starting to flow. On a few occasions it was necessary to inject air or water into the underflow line near the valve to start flow.

Filtration

Filtration of the sludge appeared to be improved as compared to Dorr sludge. Not only did settling aid usage result in flocculated particles in the underflow but the underflow density was higher. Three small rotary vacuum filters were available and all had normally been used with the previous system. With the new system only two filters were usually required. The filter cake was thicker and easier to wash although it was necessary, as in the past, to keep the filters clean by acid washing. If the filters were not kept clean, there were times that the filter supply tank would become full enough that the high level sensor would override the automatic clarifier underflow discharge valve system and the sludge level in the clarifier would begin to rise.

Scale Formation

Of primary concern was the rate of scale buildup in the system and possible plugging of the clarifier feed line. Since gravity flow was used, any restriction in the feed line would cause the liquid level to rise in the deaerator and cold waste heater. As shown in Figure 2, the elevation of the top of the cold waste heater is lower than the top of the deaeration tank so the cold waste heater would eventually overflow as liquid backed up in the system. To monitor feed line clogging, the liquid levels in these tanks were periodically recorded. Based on the liquid level in the clarifier, the available freeboard in the deaerator tank was 27 inches but in the cold waste heater was only 16 inches. However, initial measurements indicated the liquid level in the cold waste heater was bout 6 inches higher than that in the deaerator. This difference in liquid levels was attributed to the piping arrangement in the cold waste heater and the effect of stirring the steam injection on gravity discharge of liquid from the heater. The effective freeboard in the cold waste heater therefore was only about 12 inches and after about 25 days operation liquid started running out the cold filtrate heater overflow pipe.

The Steffen operation was shut down to determine where the feed line was restricted. Inspection revealed that very little scale had formed in the feed line until the point of settling aid addition. Between this point and up to the enlarged end of the feed pipe inside the clarifier, the pipe was almost closed with scale. Ahead of the settling aid addition point in the horizontal section of the 8 inch diameter pipe, sludge had settled to fill the bottom third of the pipe. At this level the fluid velocity kept the pipe from filling further. A layer of scale about ¼inch thick had formed on the inside wall. The settled sludge in the horizontal section was easily flushed out.

Sludge had also settled in the bottom of the deaerator tank to a depth of about 10 inches, after which fluid velocity apparently prevented further settling. Little or no scale had formed on the interior surfaces.

Inside the clarifier, a layer of scale had formed on all interior surfaces. Below the sludge bed interface the walls had a very thin layer of scale as did the underflow discharge line. Above the interface level a layer of scale 1/2 to 3/4 of an inch thick had formed on the wall. Scale was particularly heavy around the top of the overflow weir where it formed a layer at the notched edge about 4 inches thick. This buildup contributed to an increased liquid level in the clarifier which in turn caused an equivalent increase in liquid level in the deaerator and cold waste heater. The overflow box and pipeline were relatively clean.

During operation, the flow-through cells became coated with a brown film. This reduced the light transmission sufficiently to affect automatic operation of the underflow valve control. It was necessary to flush the cell with acid at least once a shift to keep it clean. It was also necessary to bore out the sample line with the device provided about once a day for flow to be maintained in the sample line.

Modifications

Based on the experience gained during the Spring campaign, a few modifications were made to the system prior to the fall operation season. They included:

1. An increase in the height of the cold waste heater by about 20 inches.
2. Relocation of the settling aid addition nozzel from the horizontal pipe section to a point nearer to the feed distributor in the short vertical inlet section into the clarifier as shown in Figure 3b.
3. Installation of a scraper blade on the rotating deflector plate over the inlet inside the clarifier. The arrangement is shown in Figure 3b. The blade extended down into the vertical inlet pipe section to scrape scale from the pipe wall that might form after settling aid addition.
4. Placement of a standpipe in the overflow box to raise the liquid level in the clarifier to submerge the overflow weir.
5. Replacement of the 8 inch diameter horizontal inlet pipe section with a 6 inch diameter pipe.

Operations were resumed and liquid levels in the deaerator tank and cold waste heater were again monitored. However, other commitments precluded obtaining adequate records. There was one instance of an apparent blockage in the inlet pipe, but it was attributed to a period of low flow and a surge of sludge being carried into the system. A brief blowdown of the feed line appeared to clear the line. After about 31 days of operation, weather conditions caused the factory to shut down.

Inspections showed little or no scale buildup from the cold waste heater to the point of settling aid addition. Sludge still settled in the deaerator tank but none was noted in the new horizontal section of feed pipe. After the point of settling aid addition, scale had built up on the pipe wall but apparently the scraper blade kept this to a minimum and there was very little reduction of the pipe cross section area.

Scale still formed on the clarifier walls as before and scale still built up around the edge of the overflow weir. Sludge had been carried into the overflow box at some time and had been deposited around the standpipe. It had also backed up a short distance into the overflow launder on each side of the opening into the overflow box.

These conditions indicated the modifications that had been made would extend the time between cleaning. A few minor modifications have been planned for the future to minimize scaling on the overflow weir and in the overflow box. The overflow weir is to be trimmed to remove the notches in the weir and the standpipe in the overflow box will be shortened and made removable. With a removable standpipe, the overflow box can be flushed out periodically if sludge is carried into the box.

BENEFITS

Most of the advantages anticipated with the Enviro-Clear clarifier installation have been realized. The working conditions have been greatly improved; it is no longer necessary for personnel to work in a cramped position in a restricted space. In previous years, six to seven injuries, primarily from lime burns, occurred during cleaning of the Steffen clarifier. During the last year, since the installation of the new clarifier, no injuries have been associated with this particular task. Although initially the periods between cleanouts were about half of the previous 8-week periods, the time required for cleaning was greatly reduced. Cleaning had taken from 20 to 22 hours and this time has been reduced to about 10 hours. Fewer personnel are required and there has been a reduction of about 40 man hours per cleaning.

Maintenance costs have been reduced. There are no underflow pumps to be maintained and there are fewer problems with the simplified sludge rake design. Energy usage has been reduced because of reduced power requirements. Instrumentation has proven to be reliable so the system requires very little operator attention except for cleaning of the flow-through cell and associated sample lines.

Filter operation has been improved. With the more dense underflow and flocculated solids there has been an improvement in filterability and the number of filters on stream has been reduced.

Clarification has been more efficient. Typical data for seperation of suspended solids in the multitray and Enviro-Clear clarifiers are shown in Table 1.

Table 1. Solids Separation in Steffen Hot Saccharate Clarifiers.

	Suspended Solids, %			
Feed	Underflow		Overflow	
	Dorr	E-C	Dorr	E-C
0.9	4.4	10.3	0.0151	0.0033
1.3	4.0	10.1	0.0083	0.0045
1.1	3.5	7.9	0.0040	0.0026
1.1	4.6	8.9	0.0101	0.0028

These data for the multitray clarifier were obtained when the factory cold solution rate was about 270 gpm. The data for the Enviro-Clear were obtained with a 3-foot diameter pilot unit when using 1.0 ppm settling aid. No settling aid was used in the multitray clarifier. For the factory Envior-Clear, analysis on two consecutive days show the underflow suspended solids content varied from 5.7 to 9.9%, while the overflow contained from 5 to 110 ppm solids. The settling aid addition level has been very low, about 0.5 ppm on clarifier feed. Higher levels of addition would give higher underflow density.

During the comparisons of the Envior-Clear pilot unit and the Woodland factory multitray clarifiers, analyses showed a 0.020% lower sugar content for the Enviro-Clear clarifier overflow. Other data indicated degradation of hot saccharate in the factory clarifier contributed to the higher sugar content in the factory clarifier overflow. Analyses have not been made since installing the new clarifier to confirm the earlier data.

SUMMARY

In summary, the new clarifier performance has been satisfactory. A safer work environment has been provided and the number of personnel injuries has been reduced. Cleaning of the clarifier is still required and scale buildup has been rapid in a couple of areas, but the shutdown for cleaning has been shortened since cleaning is relatively easy. Less manpower is required for maintenance. Because of the short fall operating period after modifications were made to minimize scale buildup, the effect of the changes has not been fully evaluated. Inspections have indicated the change will probably extend the period between shutdowns to a least the previous interval. The remaining problem of scale buildup around the overflow system will be studied during the next campaign.

ACKNOWLEDGMENTS

We wish to acknowledge the contributions of Trevor Newman, Woodland resident engineer, and Clarence Pacheco, Woodland chief instrument technician, to the design and installation of the equipment described in this report.

LITERATURE CITED

(1) Steffen, C., U.S. Pats. 277521 (1883), 294159 (1884).

(2) Meredith, S. C., assgn. to Spreckels Sugar Co., U.S. Pats. 2,042,724 (1936), 2,036,818 (1936).

(3) Vandewijer, R. G. F., assgn. to Raffinerie Tirlemontoise, U.S. Pat. 3,687,727 (1973).

(4) Hartmann, E. M., in McGinnis, R. A., Beet Sugar Technol., Beet Sugar Development Foundation, Ft. Collins, CO 3rd Ed., (1982) pp. 595-615.

(5) Hartmann, E. M., Sugar Technol. Reviews, Elsevier Publ. Co., Amsterdam, Vol. 2, No. 3 (1972), pp. 213-252.

(6) Shafor, R. W., Chem. Met. Engr., 31 (1924), pp. 107-110.

(7) Eis, F. G., Assgn. to American Sugar Co., U. S. Pat. 3,523,889 (1970).