SECTION 12

COMMISSIONING AND OPERATION OF THE PASTE THICKENING FARM AT KIMBERLEY COMBINED TREATMENT PLANT

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ABSTRACT: De Beers has recently commissioned a new treatment facility to extend the mining operations in Kimberley by combining existing underground feedstock with tailings re-treatment. The varied nature of the feedstock presented considerable technical challenges during the commissioning and production ramp-up phase. The thickening and slimes disposal system incorporates several unique features not used before on a large scale project in the diamond industry. The new treatment facility makes De Beers a leader in terms of dump re-treatment and paste disposal of this magnitude. This paper describes the motivation behind the choice of process and experiences during commissioning and production build-up of the paste disposal system. Specific system areas such as thickeners, pumps, pipelines, deposition site and their associated challenges are discussed.

12.1 INTRODUCTION

Diamond mining started in Kimberley in the early 1870's following the discovery of the Kimberley (Big Hole), DuToitspan, Bultfontein, De Beers and Wesselton pipes. Mining activities at Kimberley and De Beers Mines ceased in 1914 and 1990 respectively with the remaining pipes also approaching the end of their economical lives. Mining of the above Kimberlite deposits resulted in the manifestation of a large number of surface tailings dumps that are scattered over a wide area in and around Kimberley. Due to lower levels of efficiency from older technology used in the treatment and recovery processes over the last 125 years, these dumps still contain diamonds and constitute a significant mineral resource.

The current treatment plant was commissioned during the mid 1950’s and has reached the end of its economic and metallurgical life. This plant still makes use of pan technology for the extraction of diamonds. As a result of previous treatment, the tailings dump material is mainly devoid of the ultra-fine fractions that are required for puddle generation necessary for efficient pan operation. The plant is therefore not capable of treating dump material only and could not be used if processing of the remaining surface tailings resources has to continue, following the closure of the underground operations.

A pre-feasibility study commenced during 1997 to evaluate the technical and financial viability of exploiting the remaining underground and surface tailings dump resources at Kimberley Mines. A total of 11 different scenarios were evaluated and the construction of a Combined Treatment Plant (CTP) was found to be the best option.

A feasibility study was subsequently approved at the May 1998 De Beers Board meeting with the implementation phase for a 1050 ton per hour plant approved at the March 2000 De Beers Board meeting.

12.2 LOCATION AND ENVIRONMENT

Kimberley is located in the Northern Cape Province, 1200m above sea level. The area is characterised by extreme temperature ranges between summer and winter with a mean annual rainfall of 419mm. With mining, quarrying and agriculture as the main contributors to the Gross Geographic Product in the Northern Cape, Kimberley Mines play an extremely important role in supporting the economy in the province.

12.3 DESIGN PHILOSOPHIES

The main design objective was to minimise capital expenditure, working cost and project implementation time. In order to achieve these objectives, best practice, “fit for purpose” design philosophies were adopted. Following international and local best practice visits to various operations, several workshops and brainstorming sessions were held to optimise designs. These designs resulted in a small plant footprint, low building heights, minimal surge capacity, limited standby equipment, a high level of automation and minimum personnel compliment. The CTP has been designed on a continuous operation (Contops) philosophy.

De Beers is committed to maintain high environmental standards and to this end the CTP has been ISO 14001 accredited. Supporting De Beers’ commitment towards environmental management, one of the key design philosophies was to rehabilitate the open pits by disposal of the CTP residue into the pits.

The specific nature of the CTP feed stock necessitates an innovative approach to the process design. It was decided at project inception that the process route and process equipment selection would not be compromised. The process design parameters to meet the overall objectives included:

- The plant throughput to be 1050 tons per hour;
- Modern proven technologies to be utilised;
- A 25-year plant design life;
- The plant footprint to be as small as possible;
- Innovation over invention;
- The use of existing open pits for residue (slimes and tailings) disposal;
- A high level of automation;
- Minimal conveyor drives and transfer points within the plant;
- Spillage-free designs to be adopted throughout the plant area;
- Metallurgical modelling to be carried out.

12.4 SYSTEM DESCRIPTION

Dump material is trucked and ore from the underground operations is transported by conveyor to the CTP. The ore is treated by conventional scrubbing, screening and dense media separation processes followed by a state of the art, dry recovery process. Figure 12.1 shows a basic description of material flow within the CTP.

The fine tailings streams consist of effluent from the de-grit plant, DMS plant, concentrate handling area, dust collection system and several bund area spillage pumps. These effluent streams are pumped via a launder to a common thickener feed distributor that feeds five 15 m diameter deep cone, raked paste thickeners.

Each thickener is fitted with a centrifugal recirculation pump and recirculation loop pipeline that ensures that underflow material in the compaction zone at the base of the thickener is continuously sheared and circulated. Each recirculation facility is instrumented with a flow meter, density meter and two pressure transmitters to measure the pressure gradient and flow rate and hence provide an indication of the rheology of the underflow slurry.

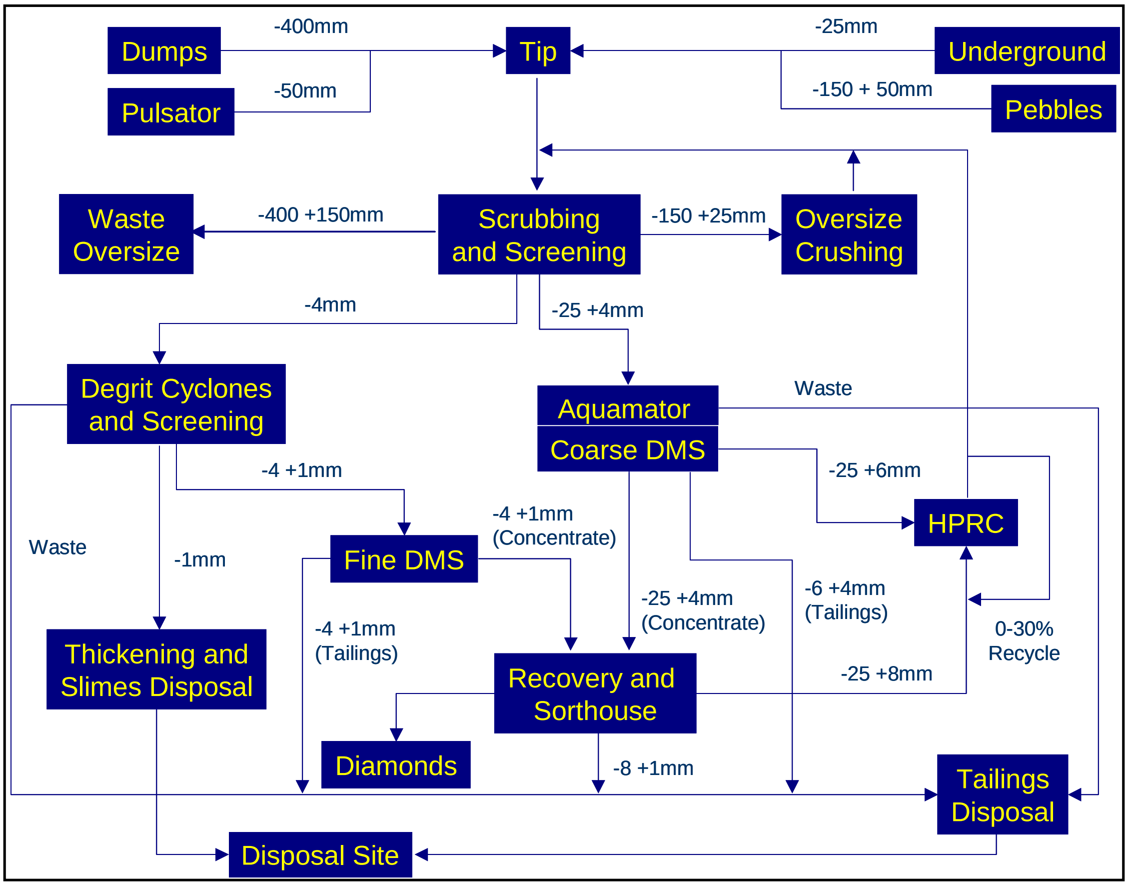

Figure 12.1: CTP Block Flow Diagram

The position of the mud bed level is monitored be means of two small diameter off-take pipes located above and below the normal mud bed levels. The density of the slurry or water in each pipe off-take is monitored using a nuclear density meter. The pipe off-takes drain to a floor sump pump that returns the slurry to the thickener feed distributor.

Each thickener is equipped with a variable speed centrifugal underflow pump. The underflow pump speed is controlled by several inputs:

- The optimum operating density as determined in the recirculation loop;
- Flow rate in the underflow discharge line;
- Thickener bed level;
- Rake torque.

The five thickener underflow pumps discharge into a common slimes transfer tank and the clarified thickener overflow reports to process water tanks. Three centrifugal charge pumps pump from the slimes transfer tank to three variable speed driven positive displacement piston diaphragm (PD) pumps (two duty and one standby). The charge pumps are equipped with variable speed drives and maintain a constant elevated suction pressure at the PD pumps. In-line strainers between the charge pumps and the PD pumps intercept oversize tramp material that could damage or unseat the PD pump valves. Figure 12.2 shows a diagrammatic layout of the thickening and disposal pumping system.

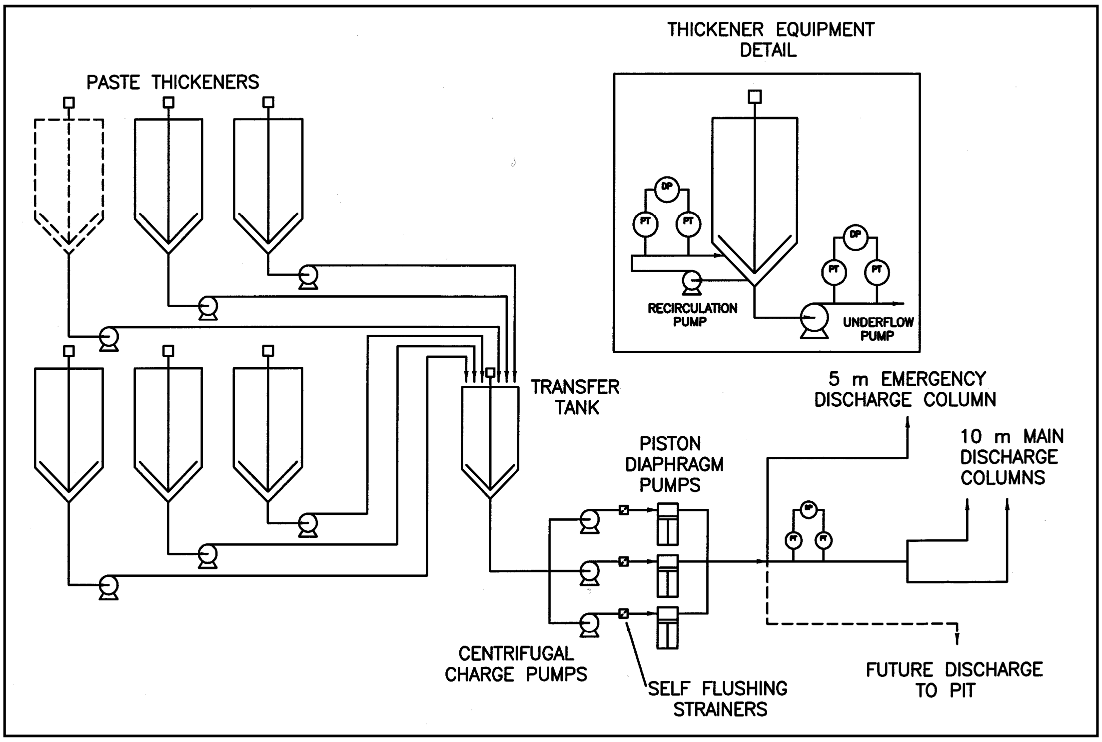

Figure 12.2: Layout of the Thickening and Disposal System

The two operating PD pumps discharge via a manifold into a 350 mm NB high pressure slimes delivery pipeline. The pipeline is constructed of 12.7 mm wall thickness API 5L Grade X52 longitudinally welded steel piping and is designed to the ASME B31.11 Code for Pressure Piping for Slurry Transportation Piping Systems. The maximum operating pressure for the pumping system is 12 MPa.

At present the slimes are pumped a distance of 5.5 km to a surface slimes disposal area located on the site of an old slimes dam. The slimes are discharged via two 10 m high discharge towers that can be raised if necessary to accommodate the rising deposition cone. In future, when the Bultfontein mining pit becomes available for backfilling, the slimes pipeline will be diverted and the pumping distance reduced to 3.1 km.

An emergency disposal facility is provided in case the main pipeline is blocked or not available. The 350 mm NB emergency pipeline length is 1.3 km and the pressure rating is 6 MPa. Pipeline change-over is achieved by a spectacle flange arrangement located adjacent to the pump station. Figure 12.3 indicates the layout of the thickener and slimes pumping system.

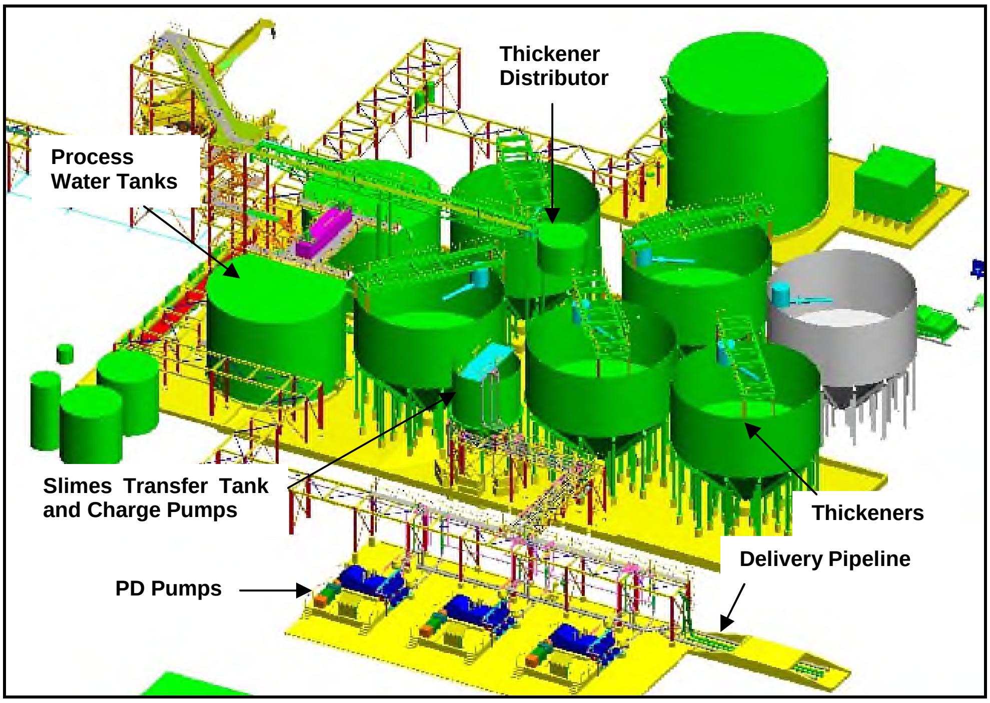

Figure 12.3 Thickener and Slimes Pumping System Layout

12.5 COMMISSIONING EXPERIENCES

The majority of the CTP personnel were recruited from the existing diamond recovery plant (NTP) in Kimberley. The NTP was commissioned in the mid 1950s and the technology and processes are outdated and require a hands-on approach. The operating personnel have had very little exposure to the modern technology and had to undergo training at one of the other De Beers' operations. The decision to incorporate paste technology within the CTP process was a technological leap forward for the De Beers operations, but more so for the Kimberley Mine's operational staff.

To bridge the technological gap, extensive training was conducted on-site by commissioning personnel as well as the suppliers. The operational staff was actively involved in the commissioning from the outset, learning through application.

12.5.1 Blockages

One of the most important learning points was for the operational staff to understand the difference between dilute settling slurries and pastes. At the design densities for this system, settling of coarse particles during the pipeline transit time is negligible. At lower densities the slimes behaves as a settling slurry and grits will settle out at low pumping velocities.

Two type of blockage are likely, viscous and grits blockages. Viscous blockages occur when excessively high viscosity slurry is allowed into the pipeline and the pumping pressure exceeds the capability of the pumps. The control system should prevent this from happening but it is possible in the case of instrument failure or if operated incorrectly in manual mode. This type of blockage is cleared by effectively shortening the pipeline by opening up unblocking tees or removing flanged bends along the pipe route.

Grits blockages can be caused by two distinct mechanisms. If the grits fraction of the slimes is allowed to settle out in the slimes transfer tank and this coarse material is then pumped into the pipeline, a stiff dense plug with minimal fines content can form that is extremely difficult to remove. In general this type of blockage will affect a relatively short section of pipeline downstream of the pump station. The system was designed to avoid this type of blockage by automatically recirculating and mixing the contents of the slimes transfer tank after any lengthy system shutdown.

The alternate grits blockage mechanism involves the gradual settling out of grits in the pipeline due to a combination of low density and low operating velocity. This blockage can result in the deposition of a settled bed along the entire pipeline length and can be very time consuming to clear.

Several grits blockages have occurred to date and these can be ascribed to the following:
- Operator inexperience;
- Stop-start plant operating conditions;
- Dilution in slimes transfer tank due to water valve leakage;
- High grits to slimes ratios during commissioning;
- Operation of the thickening and slimes disposal system at reduced feed, necessitated by the ramp-up profile;
- Source material variations, e.g. Variations in size distribution.

On a number of occasions viscous blockages in the recirculation loops and underflow pumping systems have been experienced. This can be ascribed to stop-start operating conditions with periods of extended plant standing time. If the plant stands for an extended period (in excess of 4 days) without discharging from the thickener, material degradation with fines liberation takes place in the recirculation loop and the base of the thickener. If the slurry rheology increases beyond the capability of the recirculating and underflow pumping systems, a viscous blockage occurs.

The slimes transfer tank is equipped with a scraper rake mechanism to prevent the build-up of solids on the tank walls. A high grits content at the base of the tank results in an abnormally high rake torque and in the early stages of commissioning a premature failure of part of the rake mechanism occurred before the rake torque instrumentation had been correctly calibrated.

12.5.2 Centrifugal Pump Problems

Problems were experienced with centrifugal pump gland wear, resulting in significant plant downtime. The charge pumps, operating with a discharge pressure of approximately 350 kPa, were particularly problematic. Mechanical seals were eventually installed on these pumps on a trial basis and to date have proved to be very successful. Similar mechanical seals will be installed on the recirculation and underflow pumps in future.

Problems were also encountered with many of the vertical spindle drain pumps, used as spillage pumps within the bund areas. It had been assumed at design stage that any paste that reported to the sump pumps would be dilute. Large volumes of dense paste were spilled into the bund area during commissioning for various reasons and the sump pumps did not have the head capability to pump this viscous material away. These pumps have been replaced with more powerful submersible units (equipped with suction agitators).

12.5.3 In-Line Strainers

Several problems were experienced with the in-line strainers installed between the charge pumps and PD pumps. During the early stages of commissioning, large amounts of oversize (+4mm) stone and construction debris reported to the strainers and rapidly filled the strainer baskets. This necessitated frequent flushing and unexpectedly large volumes of flushed paste containing oversize were generated. This material was difficult to dispose of because it was too viscous to pump back to the thickener distributor and also contained oversize that could not be returned to the slimes stream. This material had to be loaded into trucks with a front-end loader for removal, resulting in considerable inconvenience.

Lumps of extremely viscous consolidated clay created a further unexpected problem with the consistency of stiff glazing putty that caused blinding of the wedge wire screen baskets. It is believed that these lumps are the result of ultra-fine material building up on the wall of the thickeners and slimes transfer tank and being periodically sheared off by the rakes.

The phenomenon of lump formation is unlikely to be solved and the design and location in the process flow of the in-line strainer will have to be changed to suit. At present the volume of oversize material has reduced sufficiently to allow the removal of the screen baskets, effectively bypassing the strainer. A new design of screen will be installed and tested in the future.

12.5.4 Piston Diaphragm Pumps

The PD pumps have operated very reliably to date with few operational problems directly relating to PD pump component failures. Tramp material bypassing the in-line strainers caused a number of valve jamming and valve damage incidents during the early stages of commissioning.

It was found that a fairly high PD pump suction pressure of 350 kPa was required when pumping paste at the design viscosity. Lower suction pressures resulted in a drop off in PD pump flow rate and also in slamming of the pump suction valves due to cavitation. This high suction pressure requirement was not anticipated at the design stage and the charge pump drive pulley ratio had to be changed to allow higher pump discharge pressures. The high suction pressures and relatively low plant instrument air pressure created problems with the PD pump diaphragm positioning system and a dedicated high pressure compressor will be installed. The initial PD pump variable speed drive ramp up time was set at 30 seconds and this resulted in a pressure rise on start up that ruptured the PD pump protective rupture discs. The ramp up time was incrementally increased until the start up pressure rise was negligible.

12.5.5 Pipe Vibration

Problems of vibration of the PD pump suction piping were experienced at certain operating speeds. Whereas the heavy wall delivery piping was supported by substantial fixed and sliding anchors at floor level, the suction piping was suspended from an overhead pipe bridge and this arrangement was not rigid enough to prevent pipe movement. The vibration caused failures to the electronic components of the magnetic flowmeters. Additional supports for the suction piping and remote mounting of the flowmeter electronics is in progress.

12.5.6 Valve Problems

Heavy duty ported knife gate valves were used for most slurry duties in the thickener and pumping system. The valve design incorporates a vented cavity into which the knife blade moves upon valve closure. It was found that large volumes of paste were discharged from the cavity vents during valve stroking, resulting in low slump paste draining into the bund area and building up beneath the valves. Sealing off the vent ports and pressurising the ports with process water has reduced this problem.

Unexpected valve problems were also encountered with valve seal damage and leakage. These problems will be addressed by the gradual replacement and upgrading of unreliable valves.

Wear and failure of the PD pump non-return valves is monitored by a flow comparator (expected displacement multiplied by the stroke rate) in the plant control system. Abnormal deviations from the magnetic flowmeter are flagged. Premature failure of the non-return valves, due to tramp material resulted in the full discharge pressure being exerted on the suction arrangement and consequential failures of the installed valves.

12.5.7 Instrumentation

The thickener and slimes pumping system is extensively instrumented and during the early stages of commissioning many instrument failures occurred. Some of these failures were due to incorrect instrument selection and others were due to faulty installation and harsh operating conditions.

A general fault was encountered with many of the numerous pressure transmitters in the system. The pressure transmitter diaphragm seal assembly was found to be unreliable and had to be modified. This resulted in prolonged periods of operation without critical instruments and may have contributed towards the conditions that resulted in some of the pipeline blockages.

12.6 OPERATING EXPERIENCES

12.6.1 Thickener Underflow Density

During commissioning it was possible to consistently achieve underflow densities in excess of 1.55 t/m^3 (57% solids by mass) by careful manual operation of the underflow pumps. Operation at high density resulted in high pump station discharge pressures with the risk of pipeline overpressure. Although there are multiple protective features to prevent an overpressure event from causing equipment damage, it was decided to reduce the density and viscosity control set points to avoid high pressures and to gradually increase them as the operating staff gains experience.

12.6.2 Residual Pipeline Pressure

At high slurry densities and viscosities, the presence of yield stress was dramatically demonstrated. The pipeline is essentially level with minimal static head present at any point along its length. On shut down of the pumping system, the pump station discharge pressure typically reduces by approximately 15% and then stabilises at an elevated pressure until the system is restarted, sometimes in excess of an hour later. On hot days (in excess of $38^{\circ}C$) the discharge pressure actually increases with time due to heating and expansion of the paste in the pipeline. This phenomenon presents a safety risk to maintenance personnel who would not expect residual pressure to be present in a static pipeline.

12.6.3 PD Pump Valve Life

It is expected that the PD pump valves should have an operating life of 3000h. Failures to date have been as a result of damage by tramp material and not wear. The actual replacement cycle and valve life still needs to be verified.

12.6.4 Deposition Area Stacking Angle

During commissioning a wide variety of paste densities were discharged to the deposition area and on several occasions water was inadvertently pumped for several hours. The plant is currently operating within the design envelope with paste densities ranging from $1.38t/m^3$ (44% solids by mass) to $1.55t/m^3$ (57% solids by mass). Stacking angles of more than 2 degrees are being achieved. The deposition facility was designed for a stacking angle of 1.5 degrees and it is expected that as the average paste density increases, the angle will increase.

12.7 CONCLUSION

Through best practice and in line with the long-term environmental strategy De Beers has successfully built and commissioned one of the largest paste installations in the world. Simultaneously De Beers has been entrenched as a leader in terms of dump re-treatment and paste disposal of this magnitude.

The CTP is currently embarking on an extensive test programme to enhance the process operation, verify rheological properties of the varying feedstock and improve the overall reliability of the peripheral equipment.

12.8 ACKNOWLEDGEMENTS

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12.9 REFERENCES

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