The clarification of uranium pregnant solution at Buffelsfontein by a circulator-clarifier

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SYNOPSIS

Owing to the strategic value of organic solvents, an investigation was conducted on the reduction of solvent losses at the Buffelsfontein solvent-extraction plant. It was established that the major cause of the high solvent losses was the high content of suspended solids in the uranium pregnant solution. To improve the clarification of the pregnant solution, it was decided to replace the conventional sand clarifiers that were being used at that stage.

After pilot-plant tests had been conducted, a circulator-clarifier 16 m in diameter was installed to treat 9000 m^3 per day of pregnant solution containing approximately 500 p.p.m. of suspended solids. The clarifier was commissioned successfully, and yielded an overflow containing approximately 80 p.p.m. of suspended solids compared with the previous value of 250 p.p.m. This reduction in suspended solids immediately resulted in a decreasing trend in losses of organic solvent, finally yielding a reduction in these losses of approximately 50 per cent.

SAMEVATTING

As gevolg van die strategiese waarde van organiese oplosmiddels, is 'n ondersoek gedoen om verliese van organiese oplosmiddels by die Buffelsfontein vloeistof ekstraksie aanleg te verminder. Dit was bevestig dat die hoof oorsaak vir die hoë verliese van oplosmiddels te wyte was aan die hoë konsentrasie swewende vaste stowwe in die uraanhoudende oplossings. Om hierdie oplossings se helderheid te verbeter is daar besluit om die konvensionele sand verhelderaars te vervang.

Nadat proewe op loodsaanlegte uitgevoer is, is 'n 16 meter deursnee 'Circulator' verhelderaar geïnstalleer om 9000 m^3 per dag uraanhoudende oplossing bevattende ongeveer 500 d.p.m. swewende vaste stowwe te hanteer. Hierdie verhelderaar is suksesvol in bedryf gestel en verskaf 'n oorvloeistroom wat ongeveer 80 d.p.m. swewende vaste stowwe bevat in verhouding met vorige waardes van 250 d.p.m. Hierdie vermindering in swewende vaste stowwe het 'n onmiddellike verlaging in verliese van oplosmiddels tot gevolg gehad, met 'n uiteindelike besparing van ongeveer 50 persent in gebruik van organiese oplosmiddels.

Introduction

At Buffelsfontein Gold Mining Company Limited, a two-stage uranium filtration is conducted after uranium leaching.

The first-stage filtrate is fed to a clarification circuit for the removal of excess suspended solids contained in the uranium pregnant solution before passing on to a solvent-extraction plant. A high content of suspended solids affects the efficient operation of the Purlex plant, and results in abnormally high losses of organic solvent in the plant raffinates.

The uranium pregnant solution for clarification was originally treated by conventional gravity-flow sand clarifiers. With suspended solids in the clarifier feed solution amounting to about 200 p.p.m., the clarifier effluent contained approximately 40 p.p.m. of these solids.

Owing to tonnage pressure, needlefelt filter cloths were fitted to the rotary filters, increasing the suspended solids in the clarifier feed solution to a typical 600 p.p.m., with effluent solution from the sand clarifiers containing up to 200 p.p.m. of suspended solids.

This increase of suspended solids in the pregnant solution reporting to the Purlex plant adversely affected the losses of organic solvent. The total organic solvent lost in waste raffinate increased from a typical 289 p.p.m. to 1076 p.p.m. A decision was made that the efficiency of clarification should be improved, and tests were conducted on the available commercial pilot-plant clarifiers. The Aquazur circulator-clarifier-supplied by Aquazur Reunert (Pty) Limited, Johannesburg, for Degrémont, France — yielded satisfactory results, and a full-scale unit was installed and commissioned in January 1980.

Coagulation and Flocculation

The processes of coagulation and flocculation are employed to separate suspended solids from a liquid whenever the natural settling rates of these solids are too slow to provide effective clarification.

Colloidal material in the uranium pregnant solution includes clay and silica, which are insoluble in the weak acid. Each colloidal particle is stabilized by an electrical charge on its surface, causing it to repel other particles just as magnetic poles repel each other. This prevents the particles from colliding to form larger particles, called 'flocs', that are heavy enough to settle.

Coagulation is the destabilization of colloidal particles by the neutralization of the forces that keep them apart. Chemical coagulants may be either ionic or non-ionic. Ionic coagulants work by neutralizing the charge on the colloidal particles, allowing them to come into contact with one another. Non-ionic coagulants rely on the polar nature of non-ionic bonds, large molecular mass, and molecular shapes to attract and hold colloidal particles. Also, because of their extremely large size, they can bridge together many smaller particles. Non-ionic coagulants are not influenced by the pH of the solution and are therefore ideal for this application.

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Flocculation is the building up of the coagulated material into 'flocs'. This is accomplished by gently stirring of the solution to bring the particles together. As more coagulated particles adhere to the large polyelectrolyte molecule, a heavy 'floc' is formed, and the flocculation process can be greatly improved if the freshly treated water is brought into contact with some of the previously formed 'flocs'.

The unique design of the Aquazur circulator–clarifier ensures that both the processes of coagulation and flocculation occur efficiently and without the need for frequent adjustment of process parameters.

Once the optimum rate of polyelectrolyte dosing has been determined, firstly in pilot-plant trials and secondly in periodic jar tests, this amount is injected into the clarifier feed line. An in-line mixer ensures that the polyelectrolyte is thoroughly mixed with the incoming acid solution.

The process of coagulating the colloidal particles begins immediately in this zone of rapid mixing. The charged particles of the colloidal particles are brought into contact with the polyelectrolyte, where the colloidal forces are destabilized. The rapid mixing also ensures agglomeration of the particles by forcing them to collide with one another.

Once this fully mixed solution enters the diffusion cone in the centre of the clarifier, the process of rapid mixing is replaced by one of gentle stirring. As the solution rises in the cone, the design velocity is such that it promotes the gentle mixing of the coagulated particles with the large polyelectrolyte molecules to form flocculated particles.

Also, the unique design of the nozzle in the bottom of the circulator causes the recirculation of previously formed 'flocs' by drawing in a portion of the sludge in the bottom of the clarifier into the diffusion cone. This greatly increases the concentration of 'flocs' in the cone and, in so doing, increases the number of collisions among the flocculating particles. 'Flocs' formed in this type of clarifier are thus much larger and heavier than those formed in conventional clarifiers.

Clarification

Clarification is the process by which the suspended solids in a liquid are allowed to settle out.

For a sludge to settle, the ascending velocity of the liquid must be less than the descending velocity of the settling solids. With continuous dosing of polyelectrolyte, the Aquazur circulator–clarifier can accommodate a liquid rise of up to 2,0 m/h.

Variations in flowrates to the clarifier should be kept to a minimum since these can cause eddy currents, which may carry the settling sludge back to the surface. Temperature variations between the solution in the clarifier and the incoming solution can cause convection currents, which can have the same effect.

The deep cone shape of the circulator eliminates the need for any mechanical scraping device to remove the settled sludge. Apart from being expensive, a mechanical scraper can interfere with the settling process and break up the formed flocculated particles.

Pilot-plant Tests

Tests were conducted on an Aquazur circulator–clarifier, 2500 mm in diameter and with a total height of 4600 mm. Runs were done at various flowrates and polyelectrolyte dosages so that the conditions for optimum efficiency could be determined. Non-ionic polyelectrolyte was used in all the tests.

The results are given in Table I. Run 6 took place over a continuous period of ten days as confirmation (or otherwise) of the results obtained in run 4.

TABLE I

PILOT-PLANT RESULTS

Run	Flowrate m³/h	Test period days	Suspended solids in feed p.p.m.	Polyelectrolyte dosage p.p.m.	Suspended solids in discharge p.p.m.
1	6,3	2	534	3,3	128
2	6,3	8	552	1,0	44
3	8,9	4	463	3,3	69
4	8,9	2	457	1,0	43
5	10,3	3	504	3,3	79
6	8,9	10	475	1,0	29

On the basis of the results, it was decided to install a full-scale unit to handle 9000 m³ of uranium pregnant solution per day.

Design of the Full-scale Plant

Based on the pilot-plant tests and the experience gained by the supplier on similar applications, between 1,8 and 2,0 m/h was taken as the design rise rate for the clarifier. The design flowrate of 375 m³/h required a circulator–clarifier 16 m in diameter. All the other physical dimensions were then determined according to the supplier's standard design parameters. Fig. 1 shows the full-scale circulator–clarifier.

The clarifier was manufactured in welded all-steel construction, and all the internal surfaces were lined with hard rubber as protection from the acid environment. The pipes for the collection of clarified solution were made of fibre-glass, and the sludge-discharge cone was fabricated in 316 stainless steel. All the construction work was done by South African specialized sub-contractors.

The details of the uranium pregnant solution (sulphuric acid) are as follows:

Free H_2SO_4	: 5 g/l
Suspended solids	: 300 p.p.m. to a maximum of 500 p.p.m.
Flowrate	: 9000 m³ per day of 24 hours, or 375 m³/h.

Description of the Flowsheet

The uranium pregnant solution, which is a weak acid solution, is collected in a preliminary settling tank situated adjacent to the circulator–clarifier. From this tank, the solution is pumped into the bottom of the clarifier through the nozzle. At this point it picks up some of the sludge from the bottom of the tank, and rises to the top of the diffuser cone. The solution overflows the top of the diffuser cone, and is forced under the weir skirt

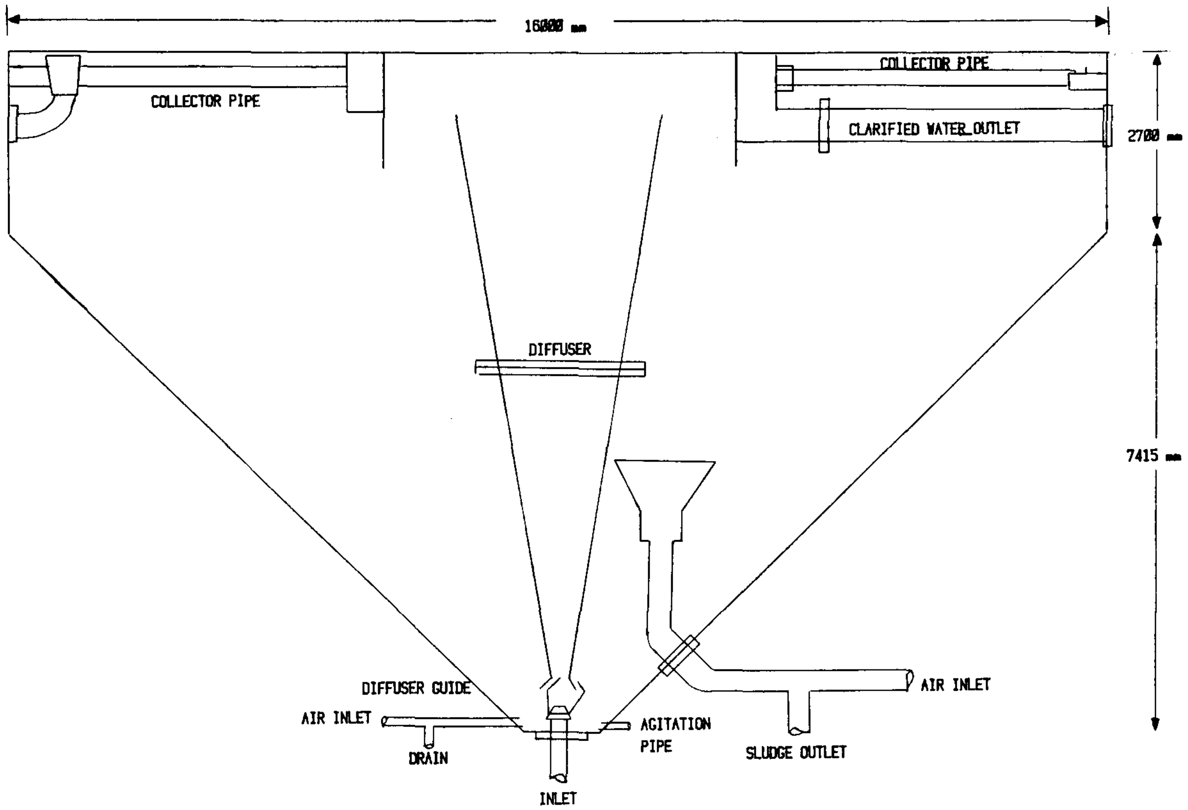

Fig. 1—Circulator–clarifier

separating the diffuser cone from the clarifier tank. The large 'flocs' formed in the diffuser cone then settle to the bottom of the tank, while the clarified solution is collected in the perforated pipes round the top of the clarifier. The clear solution is then gravity-fed to either of two clear-solution tanks.

Polyelectrolyte solution is added to the solution between the main pump delivery and the entrance to the circulator. There is an in-line mixer immediately downstream of the point of injection to ensure proper mixing. Polyelectrolyte solution is fed from the chemical dosing plant by a manually controlled Mono dosing pump.

Desludging of the clarifier is carried out automatically by an air-actuated, spring-loaded diaphragm valve. The operation of this valve is controlled by a double-timer mounted in a weatherproof box next to the clarifier. In addition, the clarifier drain valve has to be opened for one or two minutes every shift.

Operating Results

Commissioning of the full-scale circulator–clarifier (16 m in diameter) during January 1980 was virtually trouble-free, and the unit was operating to full capacity within a few days. The clarities of the solutions decreased considerably, and a corresponding decrease in solvent loss was noted. The automatic desludging system was in operation, and the correct frequency of desludging was found by trial and error. In addition to this, the drain valve was opened once during every shift for a very short period.

After about one week's operation, the efficiency decreased and the clarity of the solution deteriorated. Investigation indicated that the solid particles had become over-flocculated, and the polyelectrolyte dosage was decreased from 1 to 0,3 p.p.m. The efficiency improved immediately.

Good efficiencies were maintained for only a few days, when a disaster occurred. The solids in the clarifier overflow increased rapidly, although this was not detected from the desludged pulp since the solution was clear after a few minutes of desludging. Eventually the clarifier was taken off-line. On inspection, it was found that solids had accumulated in the upper conical part of the clarifier, forming a bridge between the side of the clarifier and the diffuser. The clarifier was subsequently drained and recommissioned.

Air was now introduced into the cone of the tank, and the bed was air-lanced from the top twice weekly. The introduction of air into the system affected the efficiency of the clarifier but prevented the bridging of solids and, therefore, the accumulation of solids in the tank. Further investigation indicated that the bridging of solids occurred possibly because the design rate of rise in the clarifier was not being maintained. A drop in feed rate had been caused by a decrease in the level of pregnant solution in the presettler tank, which had resulted in pump surging and a subsequent decrease in flowrate.

A recycle column was therefore fitted into the presettler tank to maintain a constant level of solution and to ensure that the design rate of solution rise was main-

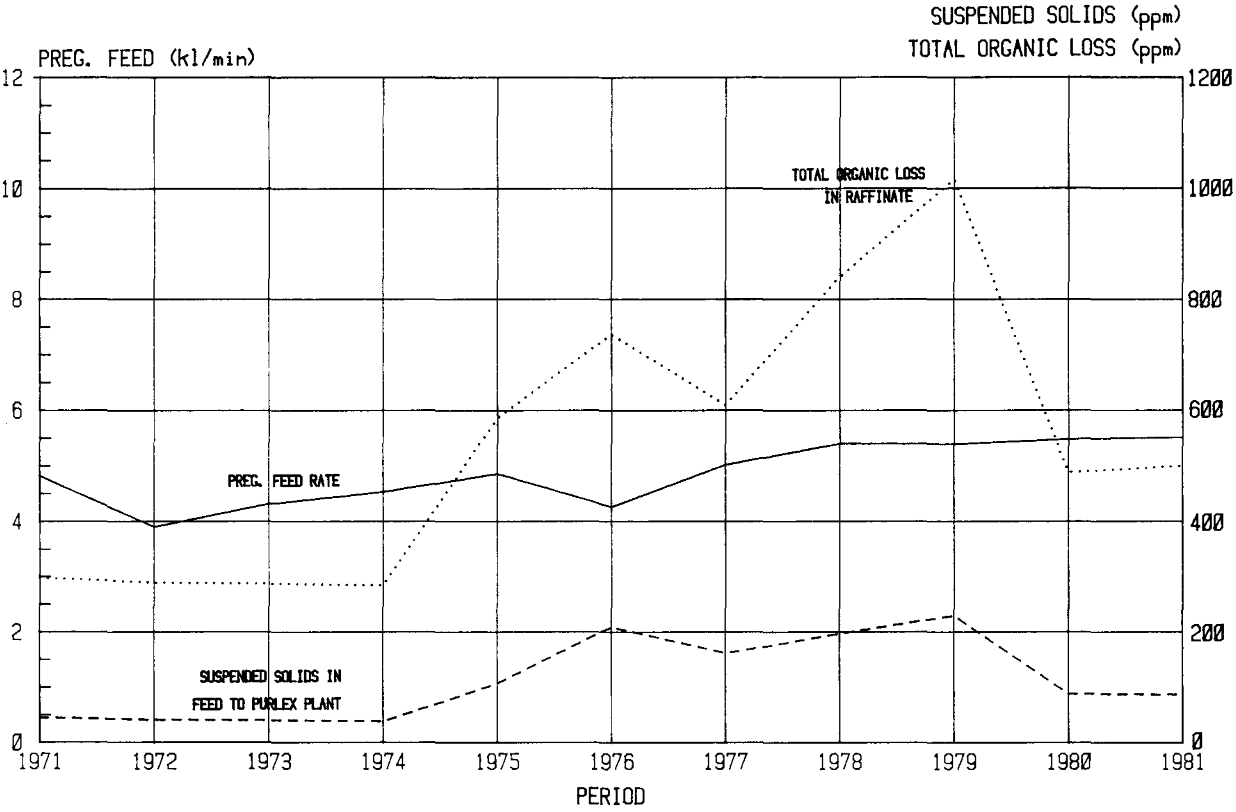

Fig. 2—Effect of suspended solids in pregnant solution on solvent loss

tained in the clarifier. This change improved the operation of the clarifier and ensured a constant flow through the system, especially during periods of plant maintenance. Eventually the system settled down, and indications are that the design efficiency is being achieved, with a resultant drop in the loss of organic solvent.

The results before and after commissioning are shown in Fig. 2. The decrease in solvent losses after commissioning (in 1980) can clearly be seen.

Table II gives the losses of solvent for the year 1979 and the monthly losses for 1980 after the circulator–clarifier had been commissioned.

TABLE II

SOLVENT LOSSES ON THE PLANT

Period	Suspended solids in pregnant solution, p.p.m.	Solvent loss per per month litre
1979	230	245 046
1980 January	147	180 079
February	140	153 265
March	94	133 924
April	92	190 274
May	60	134 733
June	50	135 082
July	55	139 758
August	70	90 000
September	60	80 770
October	78	69 886
November	88	55 842
December	80	76 754

Financial Evaluation

The total cost of the plant, which was erected towards the end of 1979, amounted to R235 000.

The saving resulting from the decrease in solvent losses totalled R268 124 for the first six months after commissioning, and R753 636 after one year's operation.

Owing to the simplicity of the clarifier, the maintenance cost is virtually zero, and involves only an overhaul of the feed pump and the polyelectrolyte supply pump.

The operating costs are very low, the costs of polyelectrolyte and power supplied by transfer pumps being the only contributing factors:

	Operating cost per month
Power consumption	R900
Polyelectrolyte* 3 kg per day at R3,70 per kg	R333
Total	R1233

At a treatment rate of 240 000 m^3 per month, the treatment cost is R0,0051 per cubic metre treated.

Conclusion

After the successful commissioning of the 16 m diameter circulator–clarifier at Buffelsfontein, the plant clarified uranium pregnant solution from a typical 500 p.p.m. of suspended solids to 80 p.p.m. of solids. The decrease in suspended solids in the uranium pregnant solution entering the Purlex plant resulted in a saving of 50 per cent or more of organic solvent.

* Non-ionic polyelectrolyte was supplied by Allied Colloids and Cyanamid.