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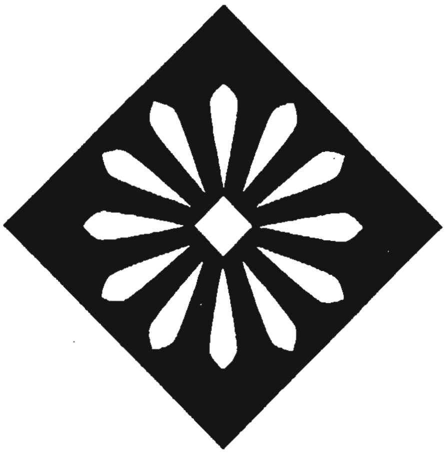
EXPERIMENTAL INVESTIGATION INTO THE APPLICATION OF A MAGNETIC DENSE MEDIUM CYCLONE IN A PRODUCTION ENVIRONMENT



NAMAQUALAND MINES

EXPERIMENTAL INVESTIGATION INTO THE APPLICATION OF A MAGNETIC DENSE MEDIUM CYCLONE IN A PRODUCTION ENVIRONMENT

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ABSTRACT

The magnetic dense medium cyclone project was undertaken at Koingnaas Mine on a 250 mm diameter cyclone during 1998 and a 510 mm cyclone during 2000. The aim of the project was to evaluate the performance of a magnetic DM cyclone in a production environment. Previous test work on magnetic DM cyclones were conducted during 1995 and 1996 on small (100 mm) cyclones in a laboratory environment, with medium feed only.

Solenoid position, magnetic field strength and medium inlet density were varied, while operational parameters such as medium grade, cyclone configuration and inlet pressure were kept constant. Two feed conditions were simulated, namely with medium feed only and with ore feed.

The magnetic field had a similar affect on medium passing through a large and a small DM cyclone. The effect of the magnetic field on the medium of a DM cyclone fed with a medium-ore mixture was found similar to one fed with medium only.

The magnetic field stabilised the medium for all tests conducted, reducing medium segregation. This was observed by a reduction in the underflow medium density. The reduction in underflow density was approximately linearly related to the magnetic field strength, up to a point, after which magnetic flocculation and a disruption in the flow pattern inside the cyclone occurred. It was discovered that the underflow density primarily determines the cut point. Thus the application of the magnetic field allows direct control over the cut point as well as improved separation efficiency due to increased medium stability.

The direct stabilisation of the medium and manipulation of the underflow density with the magnetic field brings metallurgists one step closer to on-line control of all relevant DM cyclone parameters.

OPSOMMING

Die magnetiese digtemedium-sikloonprojek is gedurende 1998 uitgevoer by Koingaas Myn op `n 250 mm diameter sikloon en gedurende 2000 op `n 510 mm sikloon. Die doel van die projek was om die effektiwiteit van `n magnetiese sikloon op `n produksie-omgewing te evalueer. Vorige toetse is gedurende 1995 en 1996 op magnetiese siklone met slegs medium op `n klein skaal in `n laboratorium uitgevoer.

Die posisie van die magneet, die magnetiese veldsterkte en die mediumdigtheid is verander, terwyl operasionele parameters soos die graad van die medium, die sikloongeometrie en die voerdrukval konstant gehou is. Twee voertoestande is getoets, naamlik slegs medium en medium saam met gruis.

Die effektiwiteit van die magnetiese sikloon in `n produksie-omgewing het ooreengestem met die van die sikloon in die laboratorium. Die effektiwiteit van die sikloon met gruis was ook soortgelyk as die met slegs medium.

Die magnetiese veld het die medium in alle gevalle gestabiliseer . Die mate van medium-segregasie in die sikloon is beperk deur die toepassing van die magnetiese veld. Laasgenoemde is waargeneem deur `n vermindering van die ondervloeidigtheid. Hierdie vermindering was lineêr afhanklik van die sterkte van die magnetiese veld. Aangesien die ondervloeidigtheid grootliks die snypunt bepaal, gee die toepassing van die magneetveld beheer oor die snypunt asook `n verbetering in effektiwiteit as gevolg van verhoogde mediumstabiliteit.

Die direkte stabilisasie van die medium en die manipulasie van die snypunt bring metallurge `n tree nader aan volkome beheer oor alle relevante digtemedium-sikloonparameters.

PREFACE

The effect of medium stability on dense medium cyclone separation has been investigated since the 1960's. It is well known that a stable dense medium with low viscosity is crucial for optimum DM cyclone efficiency. Numerous integrated factors affect medium stability and although the theoretical principles are well understood, the technology to stabilise the medium directly without altering DMS operating parameters or increasing medium viscosity has not been available until now.

A variable magnetic field applied to the Ferrosilicon medium passing through a DM cyclone increases the medium stability. For the first time the medium underflow density and consequently the cut point of the cyclone could be manipulated directly, bringing metallurgists one step closer to on-line control of all relevant DM cyclone parameters.

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A = Electric current measured in Ampere
D = Cyclone inner diameter in metre
D50 = Cut point density where 50 % of the feed material reports of the underflow
Ep = Indication of sharpness of the separation
G = Magnetic field strength measured in Gauss
kPa = Pressure measured in kilo-Pascal
ρ = Density measured in kilogram per litre

CHAPTER 1 - INTRODUCTION

The first magnetic cyclones were developed in the late sixties and were applied to the beneficiation of magnetic ores and the recovery of magnetisable heavy medium. These magnetic cyclones consisted of a conventional hydrocyclone with a horizontally orientated magnet placed around the cyclone periphery. The magnetic field would cause magnetisable particles to move in a horizontal plane towards the cyclone periphery. The additional external magnetic field created in this way was used to supplement the gravitational and centrifugal forces that cause classification and separation. (Svoboda *et al* .1997:1).

Dr. Svoboda from the De Beers Diamond Research Laboratory initiated the concept of using a vertically orientated external magnetic field to influence the medium distribution within a dense medium cyclone. The magnetic field, created by winding a simple solenoid around the cyclone axis, would in theory act on the magnetisable Ferrosilicon particles, directing them towards the central plane of the solenoid. This is illustrated in Figure 1.

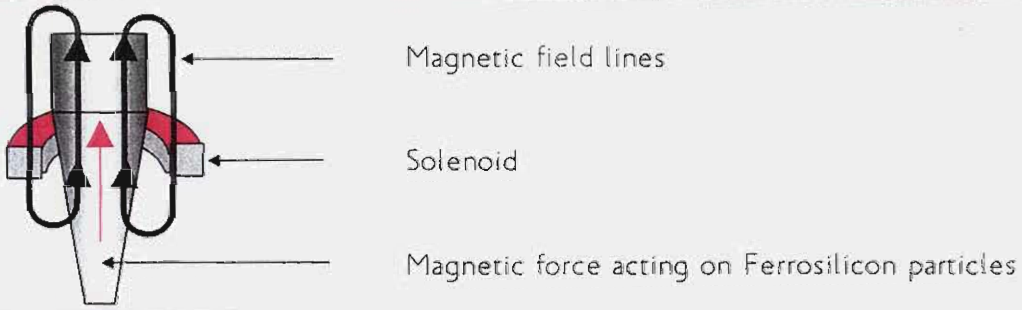


Figure 1: Schematic of magnetic forces created by the solenoid.

In 1995 the Chemical and Minerals Engineering Department of Potchefstroom University were contracted by the De Beers Diamond Research Laboratory to conduct the first tests on a magnetic dense medium cyclone. A pilot DMS plant with a pump fed cyclone was developed and constructed by the university to facilitate the test work. The magnetic test cyclone consisted of a standard 20 °, 100 mm diameter Perspex DM cyclone with a solenoid, capable of supplying a magnetic field of approximately 530 Gauss, wound around its axis(Campbell & Brits, 1995:3).

Tests were conducted with medium feed only. Variables were magnetic field strength and solenoid position. Parameters recorded were density differential, cut point, Ep and volumetric flow split. It was discovered that the vertically orientated magnetic field succeeded in influencing the medium distribution in the cyclone and consequently affected the separation characteristics. The density differential was reduced by increasing the magnetic field strength up to a point, after which magnetic flocculation of the medium occurred disrupting the flow pattern inside the cyclone. Magnetic flocculation is based upon the theory that magnetised particles, when free to move, will be drawn together with unlike poles in contact to reduce the external field to a minimum (Handbook of Mineral Dressing – Taggart 1927:13-37). Magnetic flocculation leaded to a surging at the cyclone spigot as well as a fluctuation in cyclone inlet pressure. Another effect noted was that the offset between the medium inlet density and the cut point density decreased with increasing magnetic field strength. A decrease in underflow medium flow rate in relation to overflow medium flow rate was observed. There was an indication that the application of the magnetic field improved the sharpness of the separation with the optimum point of operation at a magnetic field strength of approximately 55 Gauss.

In 1996 more extensive research was conducted at the De Beers Diamond Research Laboratory on the magnetic DM cyclone. The 500 kg/h Mark III bulk sampling plant at the DRL was utilised for the tests. Tests were done with medium only. The magnetic cyclone consisted of a standard 20 degree, 100 mm diameter, stainless steel, gravity fed, DM cyclone with a solenoid wound around its axis. The solenoid produced a weak (0-250 Gauss) vertically orientated magnetic field (Campbell & Coetzee, 1997:7).

The variables were:

- Solenoid position (top: 15 mm below vortex finder entrance, middle: 135 mm below vortex finder entrance and bottom: 335 mm below vortex finder entrance) (Campbell & Coetzee, 1997:8)
- Magnetic field strength (0 – 120 Gauss)
- Ferrosilicon type (270 D and Cyclone 60) and
- Medium inlet density (2.35 kg/l, 2.45 kg/l and 2.65 kg/l).

Parameters recorded were the density differential between the overflow and underflow medium, Ep value, volumetric flow split and cut point density.

The following results were obtained:

- The density differential could be manipulated by varying the solenoid strength and position. As the magnetic field strength was increased the density differential decreased to a minimum value after which magnetic flocculation of the medium and a disruption in the flow pattern inside the cyclone occurred. Beyond approximately 80 Gauss, magnetic flocculation of the medium occurred disrupting the flow pattern inside the cyclone. (Campbell & Coetzee, 1997:17).

  This was noted for all three solenoid positions, both Ferrosilicon types and for all medium inlet densities. The reduction in density differential was the greatest for the magnet in the top position.
- For 270 D Ferrosilicon the minimum Ep value coincided with density differentials of 0.2-0.3, which is in agreement with plant experience (Svoboda *et al.* 1997:5). The optimum point of operation was found at magnetic field strengths of approximately 40 Gauss.
- The cut point density consistently decreased with increasing magnetic field strength. It was believed that this was due to the decrease in underflow density.
- A decrease in the volumetric flow split was observed. Volumetric flow split was defined as the ratio between the underflow medium density and the overflow medium density. Thus the increased flow split indicated a decrease in underflow medium flow rate in relation to overflow medium flow rate.

From the 1995 and 1996 results it was clear that the application of a variable, vertically orientated magnetic field could potentially improve the separation efficiency of a DM cyclone, and thus reduce DMS yield. (Svoboda *et al.* 1997:1).

The question arose whether a magnetic field would still influence the medium characteristics effectively on a larger scale in a production environment with ore feed. During 1998 and 2000 this project was undertaken at Namaqualand Mines – Koingnaas Mine.

CHAPTER 2 - LITERATURE STUDY

In the literature study, fundamental DMS principles are briefly discussed before focussing on medium rheology and the effect it has on the separation characteristics of a dense medium cyclone.

The literature study consists of four sub-sections:

- Physical forces acting in a dense medium cyclone
- Rheological behaviour of the dense medium in a cyclone
- Effect of medium rheology on dense medium separation
- History of dense medium separation related to density differential

Definition of terms:

Density differential:	Difference between the underflow medium density (kg/l) and the overflow medium density (kg/l).
Cut point:	The separation density (kg/l) where 50 % of the cyclone feed material reports to concentrate and 50% to tailings.
Offset:	The difference between the medium inlet density (kg/l) and the cut point (kg/l)

2.1 PHYSICAL FORCES ACTING IN A DENSE MEDIUM CYCLONE

In a DM cyclone an external force field is applied to liberated mineral particles distributed in a dense medium. The ore and medium are flung tangentially into the cyclone adopting a fast rotational motion, which forms a vortical flow. Separation takes place by differential movement of the particles under action of the force field. In the centre of the cyclone an upward spiralling air core (vortex) is formed, running from the spigot to the vortex finder. Some of the feed thus spirals upwards along the air core and exits through the vortex finder, while some of the feed remains in the downward spiral and exits at the spigot. Whether the material reports to the outer downward spiral or inner upward spiral depends on the distance of the particle from the cyclone periphery (Napier-Munn *et al.* 1981:1)

This in turn is determined by the forces acting on the particle, which are:
a) The centrifugal force, flinging particles towards the cyclone periphery.
b) The gravitational force of the earth.
c) The drag force resisting movement of particles through the medium.
d) The buoyancy force
e) The flow towards the inner vortex.

The magnitude of these forces is in turn determined by:
a) The sizes, shapes and densities of particles moving through the medium.
b) Medium rheology (viscosity, stability, density etc.).
c) Cyclone geometry.

Generally particles with a density higher than the medium density move toward the outer periphery of the cyclone, assisted by a stronger centrifugal force acting upon them due to their higher density. The dense particles are then caught up in the downward spiral toward the spigot. The centrifugal acceleration is the strongest near the cyclone centre, and the weakest near the cyclone periphery. Particles with density lower than that of the medium will have difficulty moving through the medium due to decreased magnitude of the centrifugal forces in relation to the medium drag forces. The less dense particles are thus pushed towards the cyclone centre and report to the upward spiralling vortex.

2.2 RHEOLOGICAL BEHAVIOUR OF THE DENSE MEDIUM IN A CYCLONE

Different grades of milled and atomised Ferrosilicon are available. The most common grades used on diamond plants today are 65D, 100D and 270D milled Ferrosilicon. The size distribution and particle shapes of the different grades, and thus their rheological properties, differ from each other. The rheology of a dense medium has a significant effect on the separation characteristics of the DM cyclone (Collins *et al.* 1974:103). When designing or optimising a dense medium plant it is essential to select the correct grade of ferrosilicon for the application.

The selection of the correct grade is based on a consideration of the following in relation to the medium rheology (Holmes, 2000: 8 – 17):

- The cut point of the separation and thus medium operating density required
- The separator – a dynamic separator generally requires a finer grade than a static separator.
- The size and properties of the ore to be treated
- The sharpness of the separation required
- Cost – coarser grades are generally cheaper than finer grades.
- Circuit design – pump fed systems operating at high pressures increases the rate of medium degradation leading to a preference for coarser medium grades.

Medium rheology is measured in terms of medium stability and medium viscosity (Hunt, Hyland & Napier-Munn, 1981:13).

The rheology of a dense medium is determined by the following factors:

- The size distribution of the medium solids
- The shape of the medium solids
- The density of the medium solids
- Solids concentration

External factors in a DMS plant also affect medium rheology, such as:

- Contamination of the medium with fine clay particles, oil, etc.
- Magnetisation of the medium by the magnetic separators.
- The velocity at which the medium enters the cyclone (inlet pressure).
- The cyclone geometry, which affects the medium flow split.

2.2.1 Medium Viscosity

Viscosity is a measure of resistance to flow, (Holmes, 2000:8-7). Contamination of the medium with fine ore particles, a high medium density, irregular shaped medium particles, residual magnetism or fine medium particles increase medium viscosity. For each grade of Ferrosilicon a critical medium density is reached beyond which the medium viscosity increases sharply, as illustrated in Figure 2, (Cocker *et al.* 1998:33 & 78). For 270D Ferrosilicon the critical density is approximately 3 kg/l. It is not advisable to use the medium in the region close to the critical density since small increases in medium density or the presence of contaminants can lead to a large increase in viscosity with deleterious effects on separation efficiency.

A high medium viscosity can lead to poor separation, inversion and medium loss, (Chaston et al. 1974:121). A high viscosity is also associated with low offset and density differential values. Atomised Ferrosilicon has a lower viscosity than milled Ferrosilicon, thus a DMS using atomised Ferrosilicon can operate at a higher inlet density – typically greater than 3 kg/l. Milled Ferrosilicon is cheaper than atomised Ferrosilicon and is thus widely used on production plants while atomised Ferrosilicon is used where medium corrosion is problematic or where high-density separations are required, (Napier- Munn et al. 1974).

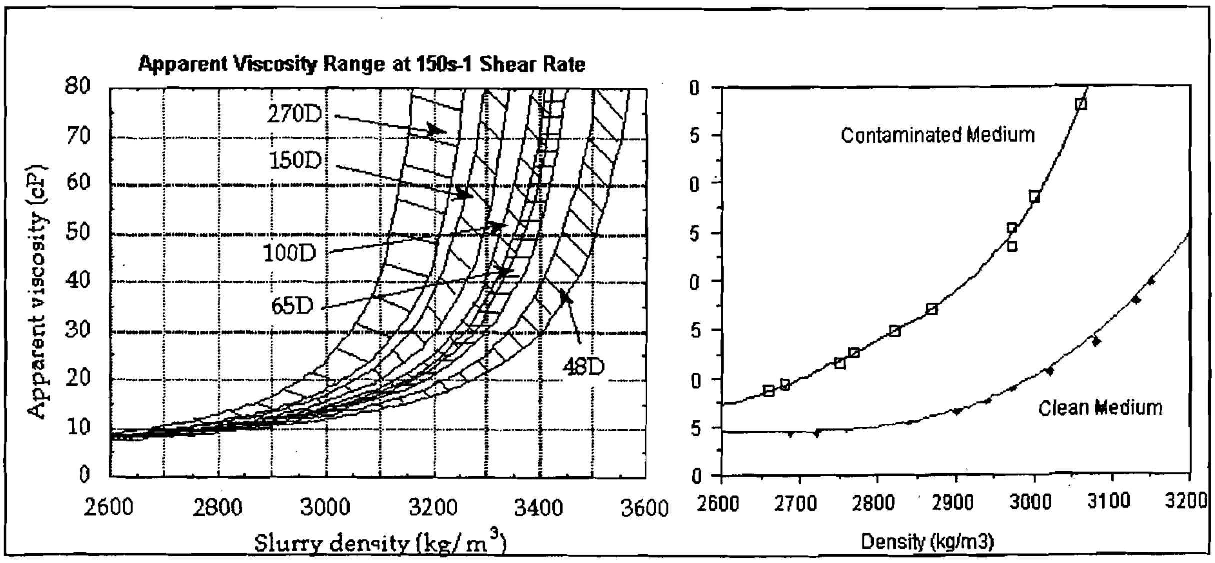


Figure 2: Medium viscosity, density and contamination.

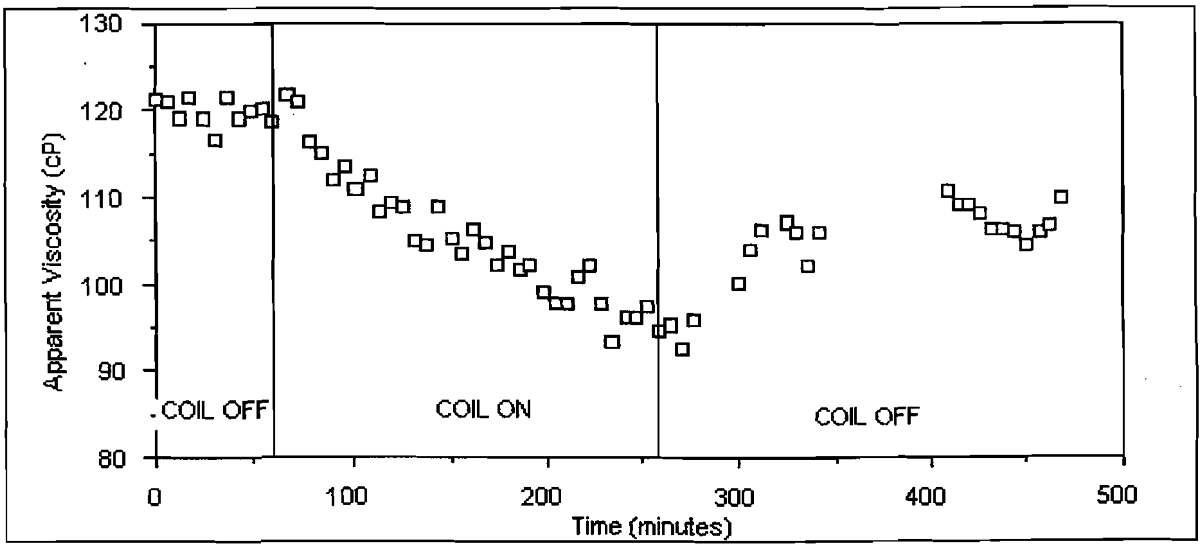


Figure 3: Effect of de-magnetisation on viscosity according to Napier-Munn and Scott (quoted by Cocker et al. 1998:97).

2.2.2 Medium Stability

Medium stability is an indication of how well the suspension simulates a homogeneous liquid. Solid particles in a stable medium segregate less when subjected to the forces in a cyclone than solid particles of an unstable medium. Medium stability and viscosity are positively correlated. Stability is affected by the same variables which determines viscosity. A stable medium would typically have a high viscosity, fine particle size and high density, (Holmes, 2000:8-11).

Like viscosity, stability is also affected by a combination of external factors:

a) Medium particle size and shape - the coarser the solid particles the lower the stability. Medium particle size varies constantly due to fine medium loss at the magnetic separators, the addition of fresh medium and variable medium quality and magnetisation (when operating without demagnetisation coils).

b) Inlet pressure - high pressures decrease medium stability and increase density differential. The pressure depends on dense medium sump and mixing box level, cyclone feed and dense media pump performance and cyclone geometry.

c) Cyclone geometry - high feed pressures coupled with a reduced spigot aperture significantly decreases medium stability.

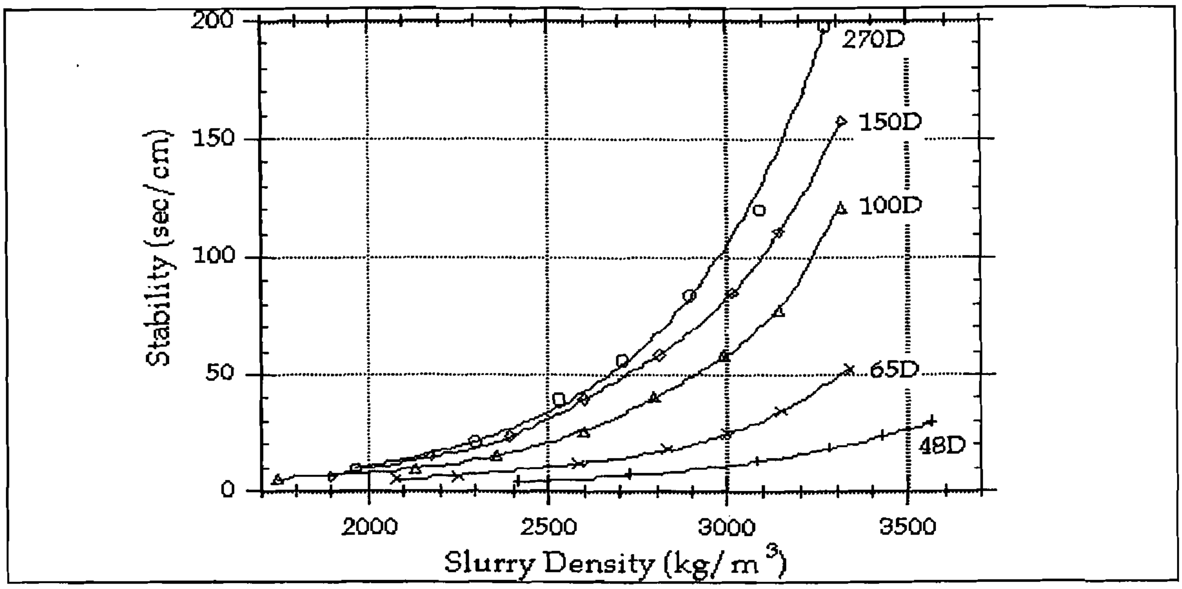


Figure 4: Medium stability plotted against density and grade. (Cocker et al. 1998:66)

2.3 HISTORY OF DMS RELATED TO DENSITY DIFFERENTIAL

Since the 1950's De Beers have been studying the subject of dense medium separation tirelessly. Most group expertise is based on empirical observations. There are many general guidelines on what the cyclone geometry should be, what medium grade to use, what the ideal operating pressure should be, how to determine the ideal inlet density, what the ore to medium ratio should be, etc.

One of these empirical truths is that the ideal dense medium is one with maximum stability and minimum viscosity, closely simulating a homogeneous liquid, resulting in a operation with low density differentials and low offset values. A general De Beers guideline is that the differential should be between 0.2 and 0.5 for optimum sharpness of separation (Campbell & Coetzee, 1997:6).

1950 Early DM cyclones operated with high offset values – typically above 0.4. Even today this is not rare. At Namaqualand Mines offset values of 0.4 to 1.1 are the norm. The large offset is in part a result of using a small spigot diameter (0.2 D) which increases cut point and reduces yield coupled with coarse (65 D) medium grades which reduce medium viscosity and cost.

By reducing the spigot diameter the yield is reduced in two ways:

- Small spigots are incapable of passing large amounts of material.
- Medium segregation is increased, leading to higher underflow densities, density differentials and offsets.

Physical diversion of material from the spigot leads to poor separation and can be seen as a long tail on the upper area of the partition curve. During the 50's however a large density differential and offset was seen as ideal because a lower inlet density was needed to achieve the required cut point, which:

- Reduced Ferrosilicon consumption.
- Made the medium easier to handle.
- Reduced medium viscosity.

Large density differentials and offsets were often accompanied by large inlet pressures, which in turn was associated with high tonnage throughput. Separation efficiency was negatively influenced by this practice but was afforded less significance because it was more difficult to quantify than tonnage throughput and Ferrosilicon consumption.

Increased understanding of DMS operation brought the realisation that high density differentials and offsets are synonymous with poor separation.

The tests necessary to statistically prove this were not conducted due to the tedious and expensive nature. The disadvantages of operating in this manner were therefore not widely appreciated until much later.

In the early 1950's it was first recorded by Morimoto and Stas (quoted by Cocker et al. 1998:128) that the separation efficiency decreased as either the density differential and offset increased or as material was physically diverted from an overloaded spigot. After these publications changes in cyclone operation were more evolutionary than spectacular.

1960's In a publication of Cohen and Isherwood (quoted by Cocker *et al.* 1998: 130) it was stated that more efficient separation and improved recovery of the fine valuable component was achieved by reducing the density differential. Using finer than normal medium solids effected this.

Davies et al. (quoted by Cocker *et al.* 1998: 130) recorded that there was a relationship between offset and separation efficiency. A figure was published showing the variation in Ep with density differential. This relationship was not obsolete but was influenced by factors such as medium viscosity. During the discussion of the paper by Carta (quoted by Cocker *et al.* 1998: 131), he reported that in the concentration of iron ore, the separation efficiency was also improved when operating at low density differentials and offsets.

1970's Collins (quoted by Cocker *et al.* 1998:131) found that an unstable medium causes poor separation efficiency and an increase in the offset. Driessen (quoted by Cocker *et al.* 1998:129) found that excessive density differentials had an adverse effect on separation efficiency.

1980's In a work of Baston and Jennekens, 1980, (quoted by Cocker *et al.* 1998:129) it was also found that high density differentials cause poor separation. Ferrara and Guarascio, 1980, (quoted by Cocker *et al.* 1998:129) noted that high offsets should be avoided unless a high separation density is required, since with smaller offsets a sharper separation can be expected. In 1982 Sehgal (quoted by Cocker *et al.* 1998:130) improved the washing efficiency of fine coal by making the vortex finder and spigot diameters approximately the same size, while increasing the medium feed density, thereby reducing the density differential.

In theory, modern practice is to minimise the density differential and the offset to achieve sharper separation and increased recovery of the finer valuable component. Most De Beers diamond production plants still do not follow modern practice though and still operate in a 1950's style.

The reason for this is that it is practically difficult to operate a diamond extraction DMS with low density differentials and offsets. To achieve a small density differential with current technology, compromises have to be made. These include lowering tonnage throughput (due to reduced inlet pressures), increasing ferrosilicon consumption and cost (due to finer medium grades and higher medium feed densities) and changing plant design to facilitate better DMS feed preparation (to minimise viscosity problems arising from finer medium grades) and reduced cyclone feed pressure. This is often not acceptable in a competitive production environment where more emphasis is placed on throughput and cost effectiveness than on DMS efficiency.

The industry is clearly in need of a simple and effective way to increase medium stability, improve separation efficiency and increase fine diamond recovery without compromising other important effectiveness areas.

2.4 EFFECT OF MEDIUM RHEOLOGY ON DENSE MEDIUM SEPARATION

The ideal medium would be one of high stability and low viscosity with constant rheological properties. A suspension which behaves like a homogeneous fluid (Holmes, 2000:8-10). The Ferrosilicon medium used on diamond plants is thus not ideal. The viscosity and stability of Ferrosilicon are directly related to one another which makes it impossible to increase stability (which improves separation efficiency) without increasing viscosity (which causes a deterioration in separation efficiency). The less stable a medium, the higher the density differential which leads to multiple separation zones in the cyclone, large percentages of misplaced light material in the concentrate and large offsets. As mentioned before, medium rheology in a DMS plant is determined by various and changes continuously. This in turn changes the cyclone efficiency. Currently no simple, direct way exists to directly stabilise and manipulate the rheological properties of the medium passing through a cyclone.

2.4.1 Middling Material in DMS Concentrate

No detailed work has been done to determine the exact amount of quartz (density 2.65 kg/l) in the DMS concentrate of alluvial diamond mines. An educated guess is that it can be 30 to 50 % at Namaqualand Mines.

Figure 5: Photograph of poor quality concentrate from Namaqualand Mines

When conducting tracer tests on a DM cyclone with medium alone, none of the 2.65 kg/l density tracers report to concentrate. Still a significant portion of the concentrate consists of quartz. This irregularity can be explained by the middling theory. As the medium passes through the cyclone, the solid Ferrosilicon particles are separated from the water via centrifugal, gravitational and drag forces. The medium density increases towards the spigot and cyclone periphery to form a density gradient across the radius and down the cyclone axis. The medium does not act as a homogeneous liquid any longer. Density differentials vary from plant to plant and are affected by numerous variables (mentioned under Section 2.2). The medium overflow density is generally close to the medium inlet density while the underflow density can be 0.1 – 1.2 kg/l more dense than the overflow density. This effect leads to multiple separation zones within the cyclone.

Middlings are defined as particles with a density of 0.1 kg/l more or less than that of the medium inlet density (Cocker et al. 1998:141).

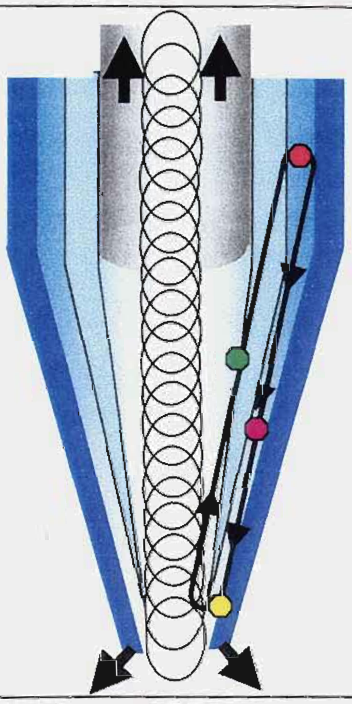
Another definition of middlings is particles of density between the medium overflow and underflow densities. At Namaqualand Mines DMS plants the inlet density is generally 2.5 to 2.6 kg/l, with an overflow density of 2.4 to 2.5 kg/l and an underflow density of 2.9 to 3.5 kg/l. Thus quartz of density 2.65 kg/l can be classified as middlings.

Several investigators traced the motion of middlings in a cyclone with radioactive particles. While dense particles exit at the spigot and light particles move directly towards the spiralling air core at the cyclone centre, middlings follow a more convoluted route as illustrated in Figure 6.

Middlings can travel well into the conical area of the cyclone before moving towards the upward spiralling air core. As the upward spiralling middlings move away from the dense spigot region and into the less dense medium area they become denser than the surrounding medium and move out of the upward flow toward the cyclone periphery once more. The middlings spiral downward toward the spigot region where the medium density and centrifugal forces increase. The middlings are forced out of the downward spiral and towards the ascending inner spiral again. This circular path can be continued for up to 15 minutes until the middlings finally exit through either the spigot or vortex finder. (Cocker *et al.* 1998:141).

This is seen as an advantage in dense medium cyclone separation where middling particles are given repeated opportunities to report to the correct product stream. This phenomenon can also be detrimental to separation efficiency. Above scenario was a description of what happens in a batch fed cyclone, but when feeding continuously, particle crowding comes into play and recycling middling material are forced out through the nearest exit by new middling material entering with the feed material. When the amount of middlings in cyclone feed material exceeds 10 %, and the top size exceeds 15 mm, recycling middling material can also lead to surging inside the cyclone. Surging disrupts the flow pattern and results in high yields and diamond loss.

When the top size is less than 15 mm, surging is unlikely, but excessive entrapment of middlings in the concentrate will occur when the density differential exceeds 0.4 (Cocker *et al*. 1998:141-142).



- ● Middling particle moves to cyclone periphery aided by its relative high density compared to the medium density of the inner bands and centrifugal forces.
- ● Particle gets caught in downward spiral.
- ● At spigot area density increases to typically 3.3 kg/l - particle will not exit unless forced due to crowding.
- ● Particle gets caught up in upward spiral & chance is good to exit via vortex finder.

Figure 6: Movement of middlings within a dense medium cyclone

The DMS feed at an alluvial diamond mine, such as Namaqualand Mines, consists of approximately 90 % middling quartz. The fact that Namaqualand Mines DMS cyclones are generally operated at density differentials exceeding 0.4 aggravates the problem of middling material reporting to concentrate. This is the explanation for the high percentage of quartz in DMS concentrate.

To overcome the problem and remove quartz from the concentrate DM cyclones would have to be operated in such a way that quartz can no longer be classified as middlings. In order to achieve this, the medium inlet density would have to be raised to at least 2.8 kg/l and the density differential would have to be maintained below 0.4. With an overflow density of 2.7 kg/l or above.

This practice has not been implemented in the past due to the following constraints:

- Due to medium instability the DM cyclones operate at high underflow densities and consequently high offsets between the inlet and cut point densities. To maintain a safe cut point, ensuring hundred percent recovery of small diamonds to concentrate it is generally not possible to operate at medium inlet densities exceeding 2.6 kg/l.
- As mentioned under Section 2.2, medium stability is dependent upon many operational factors and can not be manipulated directly.
- The higher inlet density implicates increased Ferrosilicon consumption.
- High inlet densities are associated with high medium viscosity. When operating at a medium inlet density of above 2.7 kg/l medium contamination via clay particles can result in a more pronounced increase in viscosity.

The magnetic cyclone may find useful application in optimising the separation efficiency of DM cyclones at DMS plants with significant fluctuations in medium stability and misplaced middling material in DMS concentrate. If implemented correctly, the magnetic field may directly stabilise the medium passing through the cyclone, reduce the density differential and consequently reduce the offset between the medium inlet density and the cut point density. By reducing the offset the cyclone could be operated at higher medium inlet densities and smaller density differentials without fear of diamond loss. The magnet may also be used to set and maintain the underflow density at chosen values.

Thus by correctly operating a magnetic cyclone a large proportion of middling material could be eliminated from DMS concentrate.

2.4.2 Koingnaas Main Plant DMS Case Study - Effect of Medium Stability on Cut Point

The cut point of a DM cyclone is not primarily determined by the medium inlet density. The cut point typically changes a third of the magnitude of the change in inlet density (Napier-Munn *et al.* 1981:18). The medium stability affects the cut point significantly. The underflow density, is an indication of medium stability. Medium stability is affected by many factors as discussed under Section 2.2 and can vary significantly in a short period of time. The variable medium stability thus suppresses the relationship between medium inlet density and cut point. Sudden changes in cut point, even though no operating parameters were changed, are a common occurrence at Namaqualand Mines DMS plants, especially at the smaller prospect plants, which are more sensitive to fluctuations in medium stability.

This phenomenon is generally poorly understood – even amongst experienced DMS operators. Medium inlet density is measured and controlled diligently at all DMS plants but most do not attempt to measure or control medium stability or underflow density. This approach is partly due to a lack of theoretical understanding of DMS principles but mostly due to not having a simple tool with which to manipulate the medium stability or underflow density.

The impact of fluctuating medium stability on DM cyclone performance is well illustrated in data from Koingnaas Main Plant. The DMS section of the plant is equipped with a single, 500 mm, 20 °, Linatex cyclone. The cyclone is pump fed and operates at high inlet pressures of up to 260 kPa which relates to a head of approximately 20D. The dense medium used is 65D Ferrosilicon at inlet densities of 2.5 to 2.6 kg/l. The pressure is dependant on the performance and wear of both the dense medium and cyclone feed pumps, the dense medium sump level and the mixing box level. This causes the inlet pressure to fluctuate constantly.

Cyclone inlet pressures, medium inlet densities and medium underflow densities are recorded and archived hourly in a metallurgical accounting database together with other statistics such as DMS tons treated, concentrate yield and carats recovered for each shift.

Relevant DMS production data from April 1999 to May 2000 were extracted from this data base and graphically represented in Figures 7, 8 and 9 to illustrate the effect of medium stability on DM cyclone performance.

Figure 7 illustrates the relationship between underflow density and inlet pressure. In Figure 7 the average monthly underflow density and cyclone inlet pressure are plotted against the relevant production month from April 1999 to April 2000. Each average value was calculated from 336 underflow density, inlet density and pressure readings recorded hourly during each of twenty one, sixteen hour shifts. Two month moving average trend lines were constructed for both the inlet pressure and the underflow density

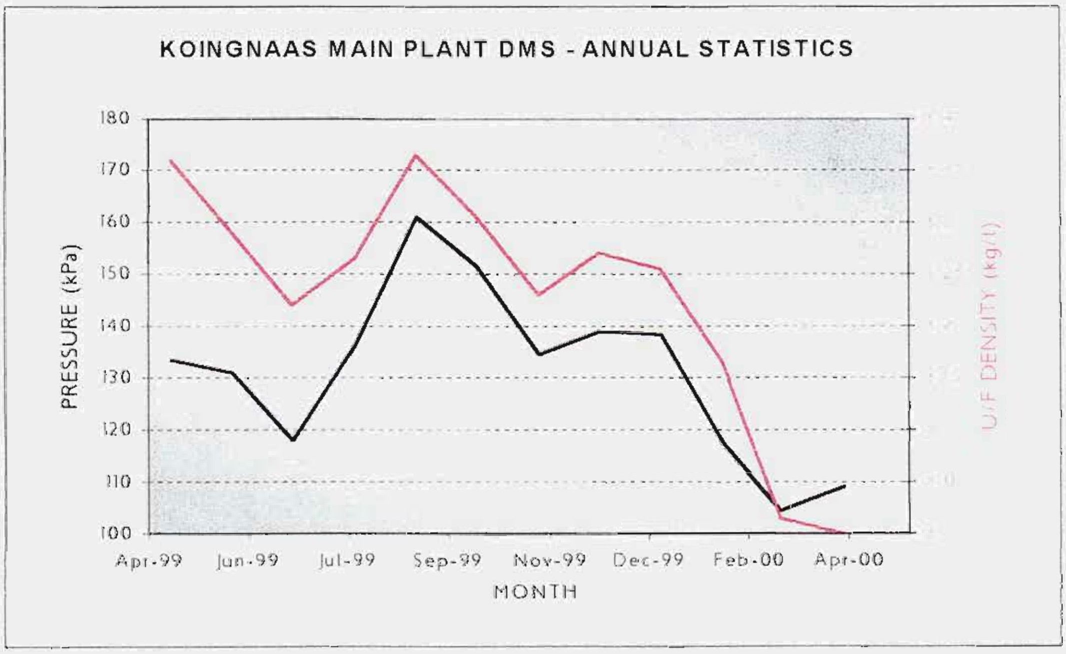


Figure 7: Relationship between cyclone inlet pressure and underflow density.

In Figure 8 cyclone inlet pressure is plotted against density differential. The graph was constructed from a total of 310 pressure and differential data values recorded during May 2000. In this case the differential was the difference between the medium inlet density and medium underflow density since overflow medium densities are not sampled at the plant.

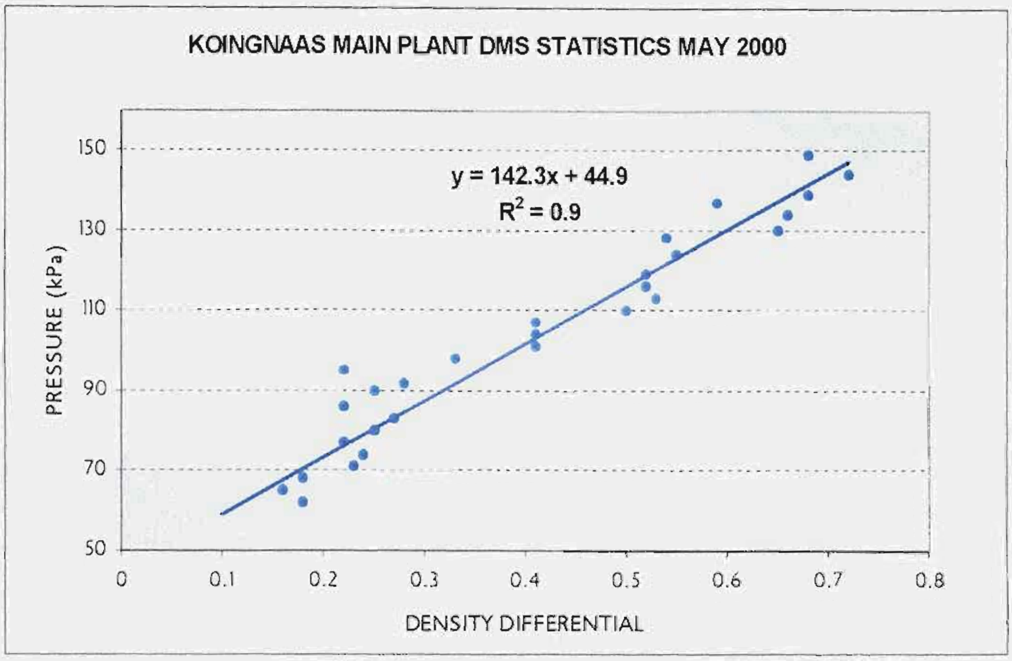


Figure 8: Relationship between pressure and density differential

Figure 8 illustrates that cyclone inlet pressure is the major variable affecting medium stability and consequently medium underflow density and density differential at Koingnaas Main Plant (where the medium is coarse and pressures are high).

In Figure 9 the concentrate grade (carats per ton of concentrate) and density differential are plotted against the relevant production shift from March 2000 to May 2000. This time frame was chosen because the plant treated ore from similar mining areas with similar grades during this period. A seven shift moving average trend line was constructed for both the density differential and the concentrate grade data. This was done to minimise the impact of concentrate bins not being emptied completely after each shift, etc.

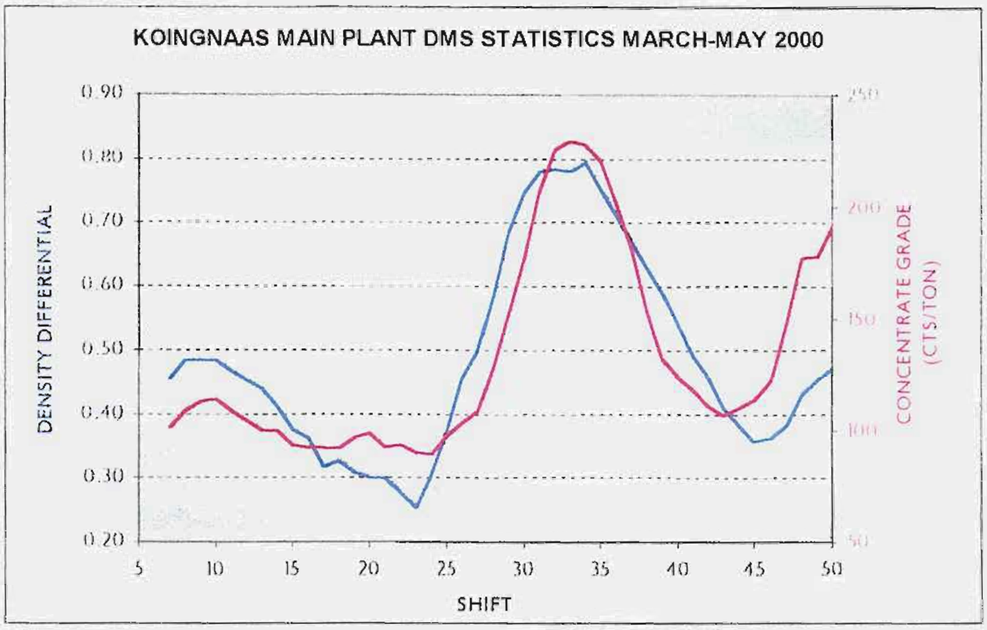


Figure 9: Relationship between concentrate grade and density differential.

Figures 7 and 8 illustrated the fluctuation in medium stability with changing DMS operating parameters. Figure 9 illustrates how this fluctuating medium stability impacts on DM cyclone efficiency. High inlet pressures and coarse medium grades are associated with medium instability, increased medium segregation inside the cyclone, high underflow densities and high cut points. The changing medium stability changes the magnitude of the underflow density, which in turn changes the cut point of the cyclone. Thus when the cyclone inlet pressure drops the cyclone separates at a lower cut point and the yield increases. This is the reason for the relatively lower concentrate grades associated with low density differentials.

CHAPTER 3 - EQUIPMENT SPECIFICATION AND EXPERIMENTAL PROCEDURE

3.1 EQUIPMENT SPECIFICATION

3.1.1 Koingnaas Prospect Plant

The 1998 tests were conducted on Koingnaas Prospect Plant. The DMS capacity is 15 tons per hour. The 250 mm, 20 ° DM cyclone is pump fed with 270D Ferrosilicon as medium. The DMS is equipped with automatic density control.

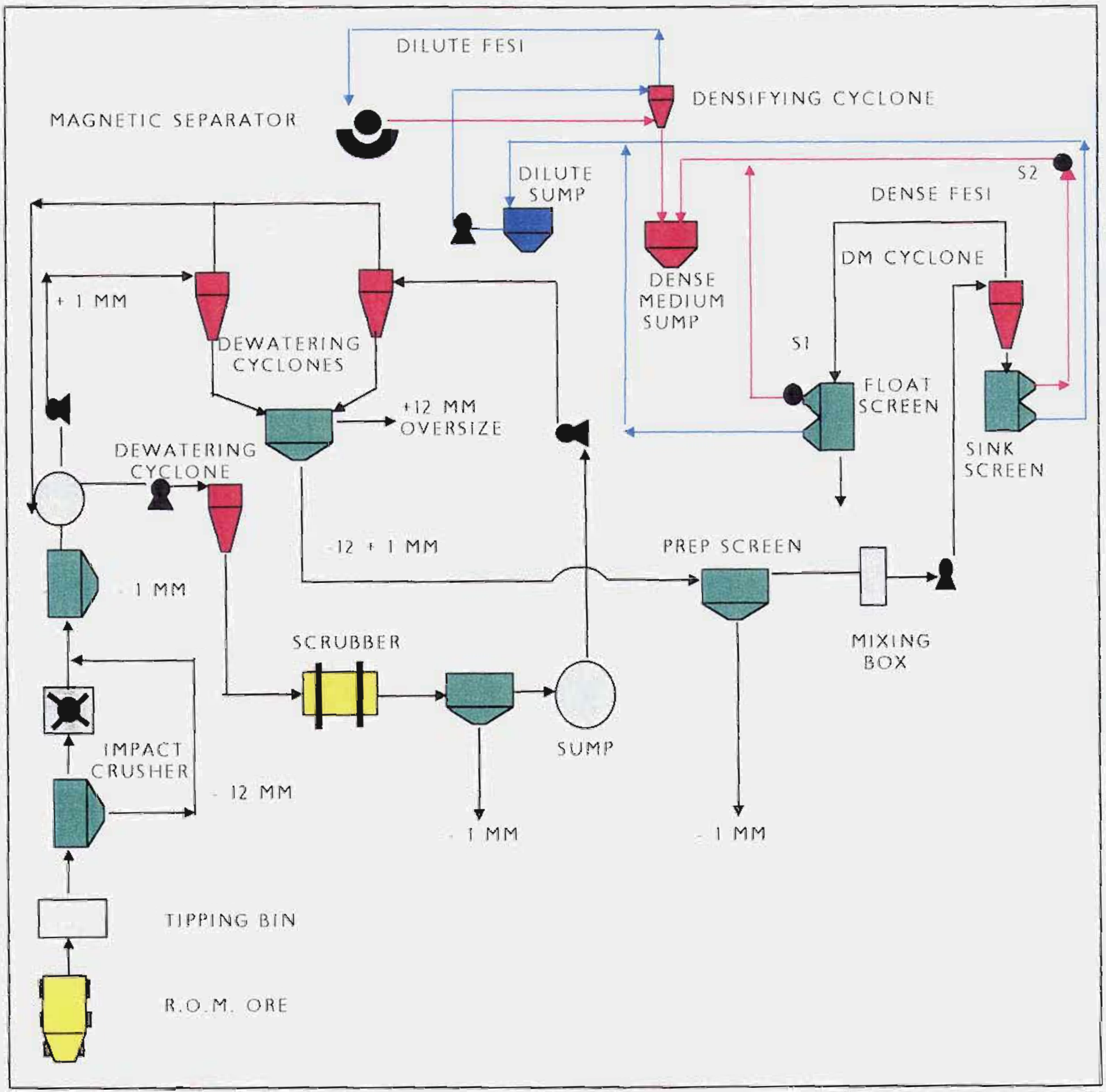


Figure 10: Koingnaas Prospect Plant Flow Sheet

3.1.2 Koingnaas Main Production Plant DMS

The 2000 test program was conducted on Koingnaas Main Production Plant. The DMS capacity is 80 tons per hour. The single 510 mm. 20 ° DM cyclone is pump fed with 65D Ferrosilicon as medium. The DMS is equipped with automatic density control.

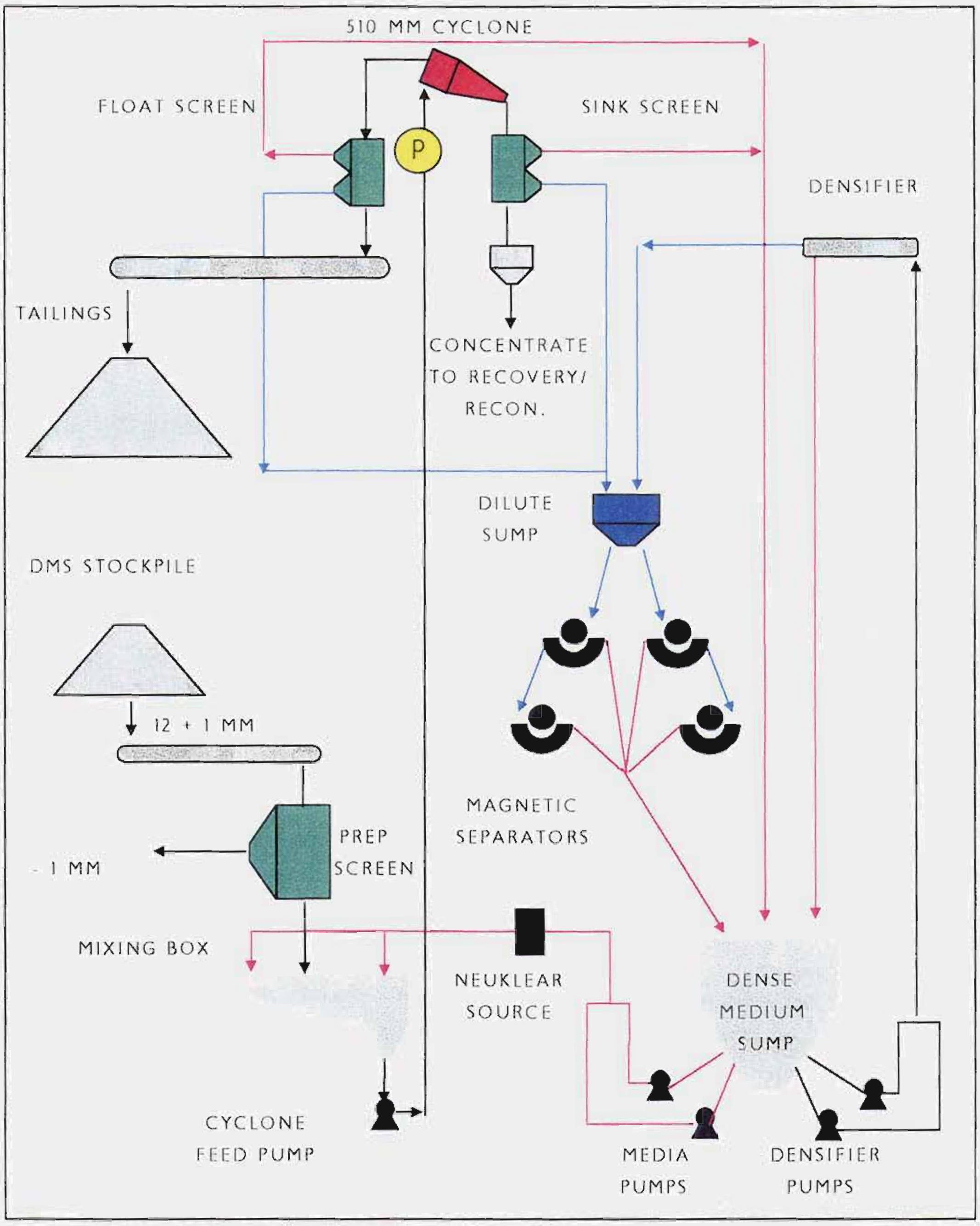


Figure 11: Koingnaas Main Plant DMS Flow Sheet

3.1.2 The Magnetic Cyclone

A magnetic DM cyclone can be manufactured from any non-magnetic or low-magnetic material such as stainless steel, perspex, ceramics, tungsten carbide, etc., as long as it has adequate strength and abrasion properties.

The cyclone chosen for the 1998 test programme at Koingnaas Prospect Plant was a 250 mm diameter, 20 degree polyurethane cyclone with stainless steel flanges, manufactured by Multotec Process Equipment. The polyurethane cyclone was chosen because it was readily available on the market, relatively inexpensive, and its dimensions conformed to De Beers cyclone specifications (Rodel & Hyland, 1997:25).

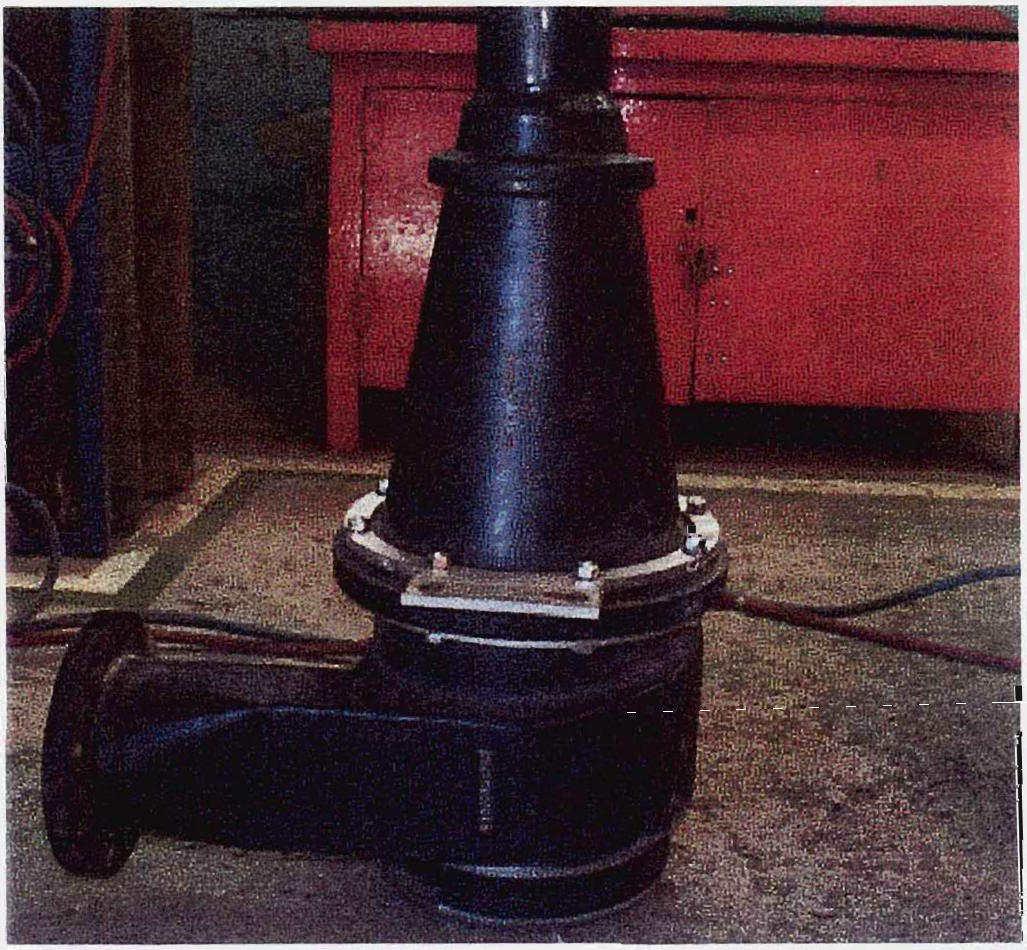


Figure 12: 250 mm Polyurethane Cyclone

The cyclone used in the 2000 test programme at the Main Production Plant was a 510 mm diameter, 20 degree cast iron cyclone with a stainless steel cone lined with 25 mm thick alumina tiles. The cyclone was also manufactured by Multotec Process Equipment. It was the firs time that a ceramic tiled cone was tested in a DMS application in the diamond industry. A cone lined with ceramic tiles were chosen because it was the only affordable non-magnetic option available on the market at the time which would be able to last for the duration of the test programme without significant wear and withstand pressures in excess of three Bar.

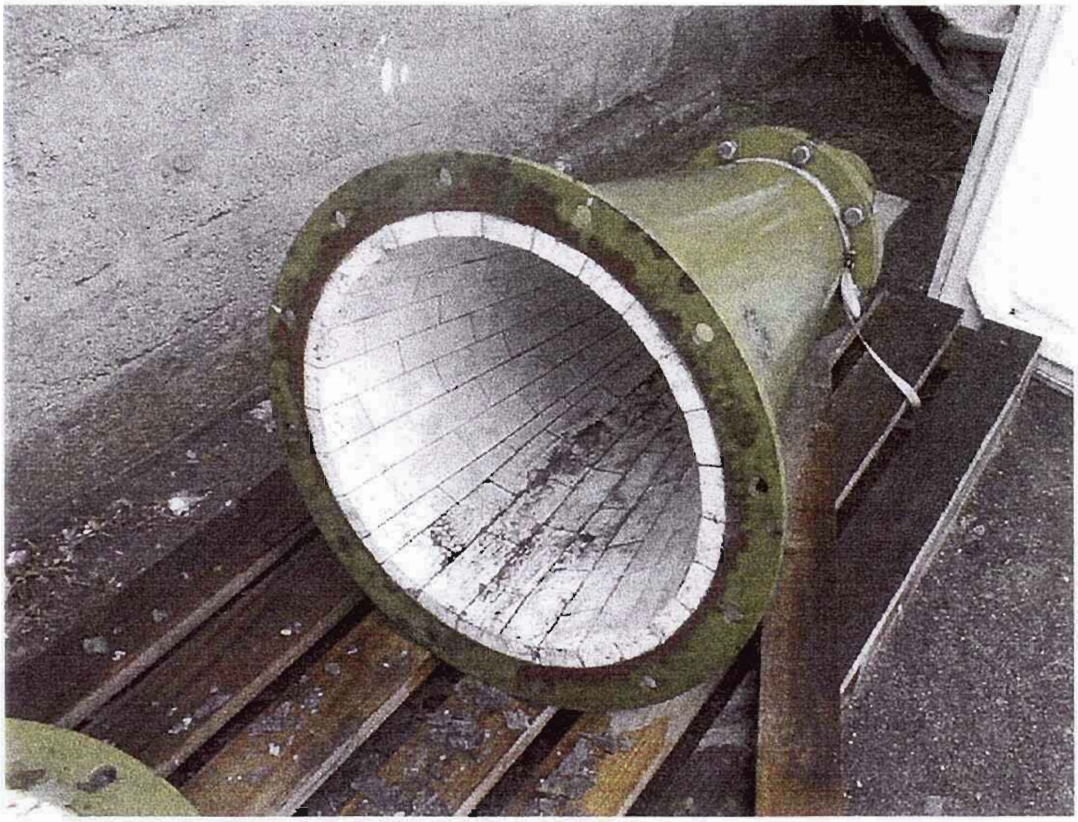


Figure 13: Tiled cone of 510 mm cyclone.

Schematic drawings of the cyclones can be found in Appendix I. The dimensions of the cyclones and feed conditions to the cyclone are discussed in Appendix II.

3.2 EXPERIMENTAL PROCEDURE

3.2.1 1998 Test Programme at Koingnaas Prospect Plant

The new cyclone was installed and commissioned by adjusting cyclone feed parameters until the ideal cut point of 3.15 kg/l was achieved at a medium feed density of 2.65 kg/l. For the duration of the test programme the medium inlet density was maintained at 2.63 – 2.65 kg/l and the cyclone pressure at 13 D. Tests were conducted with the solenoid in the top and middle positions. In the top position the solenoid was installed below the inlet to the vortex finder. In the middle position the solenoid was installed approximately in the middle of the cone.

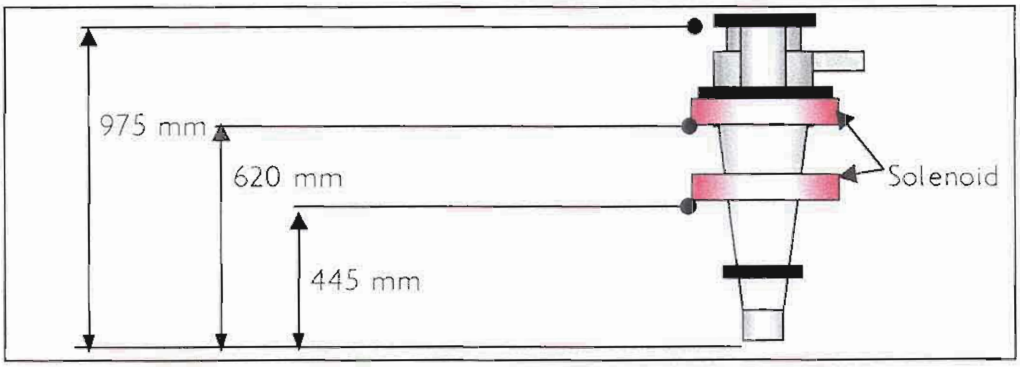


Figure 14: Schematic representation of 1999 solenoid test positions.

Tests were conducted at solenoid settings of 0 – 160 Gauss for both solenoid positions. Tests were conducted with ore feed as well as medium feed only. The duration of a test was approximately thirty minutes. For each test the inlet, underflow and overflow densities were measured three times and a single tracer test conducted. Four millimetre tracers of densities 2.9 to 3.5 kg/l (with 0.1 kg/l increments) were used for the tracer tests. Ten tracers of each density were added to the cyclone feed. The tracer test data was then analysed and a Tromp Curve constructed to obtain the Ep and cut point.

The medium feed density was measured electronically via a nuclear densitometer. Manual inlet densities were taken at the mixing box and the density determined with a Marcy scale to confirm automatic readings.

Inlet pressures were measured with a pressure transmitter and pressure gauge. Overflow and underflow densities were determined manually with a Marcy scale. Underflow medium samples were taken where the medium from the sink screen drain hopper returns to the dense medium sump. Overflow medium samples were taken from beneath the float screen drain panels. Density sampling points are indicated on the plant flow sheet (Figure 10) as S1 – overflow density and S2 – underflow density sampling point.

Two ore types were used, namely washed gravel and run-of-mine clay. The washed gravel was pre-prepared at a nearby screening plant where it was crushed, scrubbed and screened to consist of + 1 – 100 mm material. The clay material was sampled from an ancient river channel in Koingnaas Mine and consisted of a mixture of Kaolin clay and gritty beach sands. Photographs of the clay ore and washed gravel can be found in Appendix V. It should however be noted that for all of the tests the DMS feed material was prepared through the prospect plant's feed preparation section and all DMS feed was sized and clean from clay and fines. The feed rate of the ore to the DMS was constant and low – in the region of 500 kg/h.

SOLENOID SETTING (A)	**CYCLONE FEED CONDITIONS**	**SOLENOID POSITION**	
		TOP	**MIDDLE**
0	MEDIUM ALONE	1 TEST	
	ORE FEED	2 TESTS	
1	MEDIUM ALONE	1 TEST	1 TEST
	ORE FEED	2 TESTS	2 TESTS
2	MEDIUM ALONE	1 TEST	1 TEST
	ORE FEED	2 TESTS	2 TESTS
3	MEDIUM ALONE	0 TEST	1 TEST
	ORE FEED	2 TESTS	2 TESTS
4	MEDIUM ALONE	1 TEST	1 TEST
	ORE FEED	2 TESTS	2 TESTS
6	MEDIUM ALONE	1 TEST	1 TEST
	ORE FEED	2 TESTS	2 TESTS

Table 1: Summary of 1998 test program at Koingnaas Prospect Plant.

3.2.2 2000 Test Programme at Koingnaas Main Production Plant

The existing 500 mm Linatex cyclone was replaced with a 510 mm Multotec cyclone with non-magnetic cone. The spigot and overflow boxes were modified to facilitate sampling points and tracer baskets.

Two types of tests were done. Density tests where only overflow and underflow densities were recorded at different solenoid positions, magnetic field settings and medium densities (135 tests) and tracer tests were densities were recorded and tracer tests conducted at different magnetic field settings and medium densities (42 tests).

Density tests were conducted with the solenoid in the top, middle and bottom positions. In the top position the solenoid was installed below the vortex finder, in the middle position approximately in the centre of the cone and in the bottom position above the connection between cone and spigot. The solenoid positions are illustrated in Figure 15. The magnetic field strength was varied from 0 to 8 Ampere in 2 A increments. Tests were done at medium inlet densities of 2.60, 2.70 and 2.80 kg/l for each solenoid position and magnetic field setting. The underflow and overflow density were measured three times per test. Samples were taken directly from the overflow and spigot and measured with an Unical electronic scale. Tests were conducted with medium feed only with the exception of the tests with the solenoid in the middle at densities of 2.60 and 2.70 kg/l, which was done with medium feed only and repeated with 70 t/h ore feed. This was done to verify whether feeding ore changed the effect of the magnetic field on the medium.

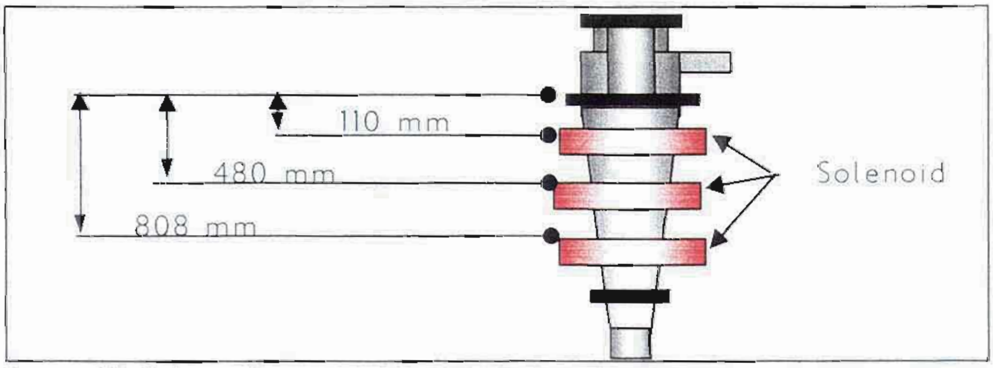


Figure 15: Schematic representation of solenoid 2000 test positions.

Tracer tests were conducted with the solenoid in the middle position only. The magnetic field strength was varied from 0 to 8 Ampere in increments of 2 A. Tests were done at medium inlet densities of 2.60, 2.70 and 2.80 kg/l per solenoid position and magnetic field setting. Tests were conducted with medium feed only. The duration of a test was approximately one hour. During a test the underflow density and overflow density were measured three times. Samples were taken directly from the cyclone overflow and underflow and measured with an Unical electronic scale. The tracer collection baskets were then placed inside the underflow and overflow boxes and a tracer test was conducted. 4 mm Tracers of densities 2.90, 3.00, 3.05, 3.10, 3.15, 3.20, 3.30, 3.40 and 3.53 kg/l were used. Fifty tracers of each density were added to the mixing box. Twenty minutes were allowed for separation after which the cyclone feed pump was stop-started once to purge the system and then stopped to remove the tracers. The data was analysed and a Tromp Curve constructed to obtain the Ep value and cut point. The cyclone inlet pressure was kept as stable as possible during all tests.

		TESTS CONDUCTED PER SETTING								
SOLENOID SETTING (A)	TEST TYPE	TOP POSITION			MIDDLE POSITION			BOTTOM POSITION		
		2.60	2.70	2.80	2.60	2.70	2.80	2.60	2.70	2.80
0	DENSITY	3	3	3	6	6	3	3	3	3
	TRACER	-	-	-	3	3	3	-	-	-
2	DENSITY	3	3	3	6	6	3	3	3	3
	TRACER	-	-	-	3	3	3	-	-	-
4	DENSITY	3	3	3	6	6	3	3	3	3
	TRACER	-	-	-	3	3	3	-	-	-
6	DENSITY	3	3	3	6	6	3	3	3	3
	TRACER	-	-	-	3	3	3	-	-	-
8	DENSITY	3	3	3	6	6	3	3	3	3
	TRACER	-	-	-	3	-	3	-	-	-

Table 2: Summary of 2000 test programme at Koingnaas Main Plant.

CHAPTER 4 – RESULTS AND DISCUSSION

The detailed results of the 1996, 1998 and 2000 test. A summary of the 1998 and 2000 tracer test results are presented in Tables 3 and 4 in Section 4.2. The 1996 and 1998 and 2000 (tracer test and density test) results are graphically represented and discussed in Section 4.3.

4.1 ACCURACY OF THE RESULTS

4.1.1 Measuring of Densities during the 1998 Prospect Plant tests

Measuring of the cyclone underflow medium density was not accurate. Ideally the underflow density should have been sampled directly from the cyclone spigot, but this was not possible due to security constraints.

As discussed under Section 3.2, the underflow medium density was sampled where the medium from the sink screen drain hopper returns to the dense medium sump. Before being sampled, the underflow medium had passed through the sink screen drain panels, the sink screen drain hopper and along a distance of approximately seven metres of 100 mm diameter pipeline.

Periodic build up of medium inside the equipment, the blinding of sink screen panels and the effect of varying ore feed rate on sink screen efficiency reduced the accuracy of the readings.

The sink screen drain panels (aperture 0.8 mm) blinded more readily with Ferrosilicon and fines than the float screen panels. Since the access of personnel to the enclosed sink screen area is restricted, blocked panels are not attended to timeously.

4.1.2 Repeatability of the 1998 Results

The time allocated to the test programme was limited. This placed a restriction on the number of times tests were repeated.

The plant is used to evaluate prospect samples thus any diamond loss would impact negatively on the life of Namaqualand Mines. In light of above, it was agreed that no prospecting samples would be processed during the magnetic cyclone test programme. Due to urgency of prospecting results, a duration of three weeks was allocated to test the magnetic cyclone.

The second limiting factor was the wear rate of the polyurethane cyclone. Polyurethane cyclones have a higher wear rate than standard cast iron or Ni-hard cyclones. In order to be able to accurately compare the results with each other, the test work would have to be completed before any significant wear occurred.

4.1.3 Accuracy of the 1998 Prospect Plant Tracer Test Results

The amount of tracers used per test (ten tracers of each density) was not ideal. At least 200 - 300 tracers of each density would have been required per tracer test to achieve statistically accurate Ep and D50 values. This would however be costly and impractical due to the fact that the tracers had to be hand sorted from the tailings and concentrate. Tracers in the tailings were sorted at the plant and tracers in the concentrate were sorted at the Geological Prospecting Laboratory in Kleinzee (approximately eighty kilometres from Koingnaas Prospect Plant).

The Tromp curves obtained from the tracer tests were constructed with a binomial tracer test analysis programme developed by the Julius Kruttschnitt Mineral Research Centre. The rest of the graphs were constructed with the Excel spreadsheet programme.

4.1.4 Measuring of Densities during the 2000 Main Plant tests

The underflow and overflow densities were sampled directly from the cyclone spigot and overflow pipe via a sample cutter, and was accurate.

4.1.5 Accuracy of the 2000 Main Plant Tracer Tests

Tracers of densities 2.90, 3.00, 3.05, 3.10, 3.15, 3.20, 3.30, 3.40 and 3.53 kg/l were used during each tests. Fifty tracers of each density were used per test and each test was repeated three times. Thus the tracer test results are as accurate practically possible in a production environment.

Three tracer tests (at a medium feed density of 2.70 kg/l and a magnetic field strength of 6 A) were not considered for discussion. During the tests the cyclone pressure fluctuated significantly, which resulted in varying underflow densities. The cyclone inlet pressure was kept as stable as possible during the tests, but it generally varied between 230 and 260 kPa due to the condition of the pumps, medium sump level and mixing box level.

Other factors also influenced the accuracy of the data such as the random addition of fresh medium, variable medium viscosity and the operation of the automatic medium density control system. Tracer tests were done randomly whenever there was an opportunity, with production taking precedence. Generally no more than five tests could be conducted consecutively on one day.

During the test period (which spanned approximately eight weeks) cyclone wear did not affect tests results significantly. The only significant wear occurred at the vortex finder. The inner diameter increased by 10 mm. The spigot diameter increased by 2 mm.

4.1.6 Data considered for Discussion

Data from the 1996 magnetic cyclone test program (Campbell & Coetzee, 1997:38 – 40) was compared to the data of the 1998 and 2000 test programmes.

In 1996 experiments were carried out on a 100 mm stainless steel cyclone with medium feed only. Tests were done using different grades of Ferrosilicon, at various inlet densities and with the solenoid in three different positions. The 1996 results of the tests with 270 D Ferrosilicon at medium inlet densities of 2.35, 2.45 and 2.55 kg/l with the solenoid in the top, middle and bottom positions are considered in the discussion.

4.2 SUMMARY OF THE 1998 AND 2000 TESTS PROGRAM RESULTS

		SOLENOID IN TOP POSITION			**SOLENOID IN MIDDLE POSITION**		
A	**FEED**	**DENSITY DIFFERENTIAL**	**Ep**	**D50**	**DENSITY DIFFERENTIAL**	**Ep**	**D50**
0	CLAY	0.510	0.048	3.166	0.510	0.048	3.166
	CLAY	0.490	0.040	3.197	0.490	0.040	3.197
	AVERAGE ORE	0.500	0.044	3.182	0.500	0.044	3.182
	NO ORE	0.630	0.026	3.173	0.630	0.026	3.173
	AVERAGE	**0.54**	**0.038**	**3.179**	**0.54**	**0.038**	**3.179**
1	CLAY	0.480	0.037	3.225	0.120	0.007	3.195
	CLAY	0.290	0.024	3.138	0.250	0.007	3.202
	AVERAGE ORE	0.385	0.031	3.182	0.185	0.007	3.199
	NO ORE	0.390	0.027	3.184	0.180	0.023	3.168
	AVERAGE	**0.39**	**0.029**	**3.182**	**0.183**	**0.015**	**3.183**
2	CLAY	0.170	0.027	3.184	0.200	0.026	3.176
	CLAY	0.330	0.028	3.126	0.240	0.007	3.195
	AVERAGE ORE	0.250	0.028	3.155	0.220	0.017	3.186
	NO ORE	0.12	0.004	3.121	0.180	0.024	3.138
	AVERAGE	**0.19**	**0.020**	**3.144**	**0.200**	**0.020**	**3.162**
3	CLAY	0.250	0.044	3.117	0.180	0.007	3.099
	CLAY	0.240	0.007	3.102	0.230	0.001	3.153
	AVERAGE ORE	0.245	0.026	3.110	0.205	0.004	3.126
	NO ORE	-	-	-	0.170	0.027	3.088
	AVERAGE	**0.25**	**0.026**	**3.110**	**0.188**	**0.016**	**3.107**
4	CLAY	0.370	0.051	3.159	0.160	0.006	3.098
	CLAY	0.290	0.007	3.102	0.270	0.030	3.118
	AVERAGE ORE	0.330	0.029	3.131	0.215	0.018	3.108
	NO ORE	0.140	0.006	3.105	0.160	0.051	3.073
	AVERAGE	**0.27**	**0.021**	**3.122**	**0.188**	**0.035**	**3.091**

Table 3: Summary of results of the 1998 test program at Koingnaas Prospect Plant.

SOLENOID IN MIDDLE POSITION					
SOLENOID SETTING (A)	**OVERFLOW DENSITY**	**UNDERFLOW DENSITY**	**DENSITY DIFFERENTIAL**	**Ep**	**D50**
INLET DENSITY 2.60 kg/l					
0	2.55	3.60	1.05	0.012	3.21
	2.55	3.60	1.05	0.026	3.20
	2.55	3.60	1.15	0.031	3.23
AVERAGE	**2.55**	**3.60**	**1.05**	**0.023**	**3.21**
2	2.55	3.50	0.95	0.021	3.16
	2.50	3.45	0.95	0.018	3.11
	2.50	3.45	0.95	0.014	3.11
AVERAGE	**2.52**	**3.47**	**0.95**	**0.018**	**3.13**
4	2.50	3.45	0.95	0.019	3.15
	2.50	3.45	0.95	0.017	3.13
	2.55	3.40	0.85	0.011	3.07
AVERAGE	**2.52**	**3.43**	**0.92**	**0.016**	**3.11**
6	2.55	3.45	0.90	0.018	3.08
	2.55	3.40	0.85	0.015	3.11
	2.50	3.35	0.85	0.027	3.08
AVERAGE	**2.53**	**3.40**	**0.87**	**0.020**	**3.09**
INLET DENSITY 2.70 kg/l					
0	2.60	3.60	1.00	0.026	3.26
	2.55	3.55	1.00	0.023	3.20
	2.55	3.55	1.00	0.012	3.21
AVERAGE	**2.57**	**3.57**	**1.02**	**0.020**	**3.22**
2	2.55	3.45	0.90	0.016	3.16
	2.55	3.50	0.95	0.018	3.16
	2.55	3.50	0.95	0.017	3.19
AVERAGE	**2.55**	**3.48**	**0.93**	**0.017**	**3.17**
4	2.55	3.35	0.80	0.024	3.10
	2.55	3.45	0.85	0.023	3.13
	2.55	3.40	0.85	0.025	3.18
AVERAGE	**2.55**	**3.40**	**0.83**	**0.024**	**3.13**
6	2.55	3.40	0.85	0.026	3.188
	2.55	3.40	0.85	0.023	3.181
	2.55	3.40	0.85	0.023	3.185
AVERAGE	**2.55**	**3.40**	**0.85**	**0.024**	**3.19**
INLET DENSITY 2.80 kg/l					
0	2.70	3.60	0.90	0.023	3.26
	2.65	3.55	0.90	0.022	3.25
	2.65	3.55	0.90	0.023	3.23
AVERAGE	**2.67**	**3.57**	**0.90**	**0.023**	**3.24**
2	2.70	3.50	0.80	0.023	3.23
	2.65	3.45	0.80	0.027	3.18
	2.65	3.45	0.80	0.021	3.17
AVERAGE	**2.67**	**3.47**	**0.80**	**0.024**	**3.19**
4	2.70	3.45	0.75	0.027	3.18
	2.65	3.40	0.75	0.019	3.13
	2.65	3.40	0.75	0.022	3.13
AVERAGE	**2.67**	**3.42**	**0.75**	**0.023**	**3.15**
6	2.75	3.35	0.60	0.023	3.12
	2.65	3.35	0.70	0.032	3.13
	2.65	3.35	0.70	0.022	3.12
AVERAGE	**2.68**	**3.35**	**0.67**	**0.026**	**3.13**

Table 4: Summary of tracer test results of the 2000 test program at Koingnaas Main Plant

4.3 GRAPHICAL REPRESENTATION OF THE 1998 TEST RESULTS

4.3.1 Effect of the Magnetic Field on Ep

Figure 16 illustrates the results of the tests with the solenoid in the top position and Figure 17 the results with the solenoid in the middle position. Figure 18 represents the average values of all the tests conducted (six tests per magnet setting). For both solenoid positions and for both the tests with and without ore feed a reduction in Ep with increasing magnetic field strength was recorded. On average the Ep was reduced by approximately 60 %. from 0.038 to 0.015.

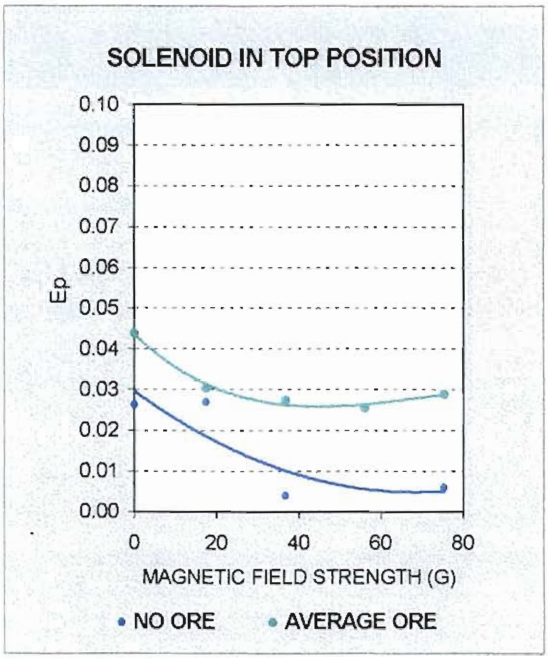


Figure 16: Ep for tests with solenoid in top position - 1998.

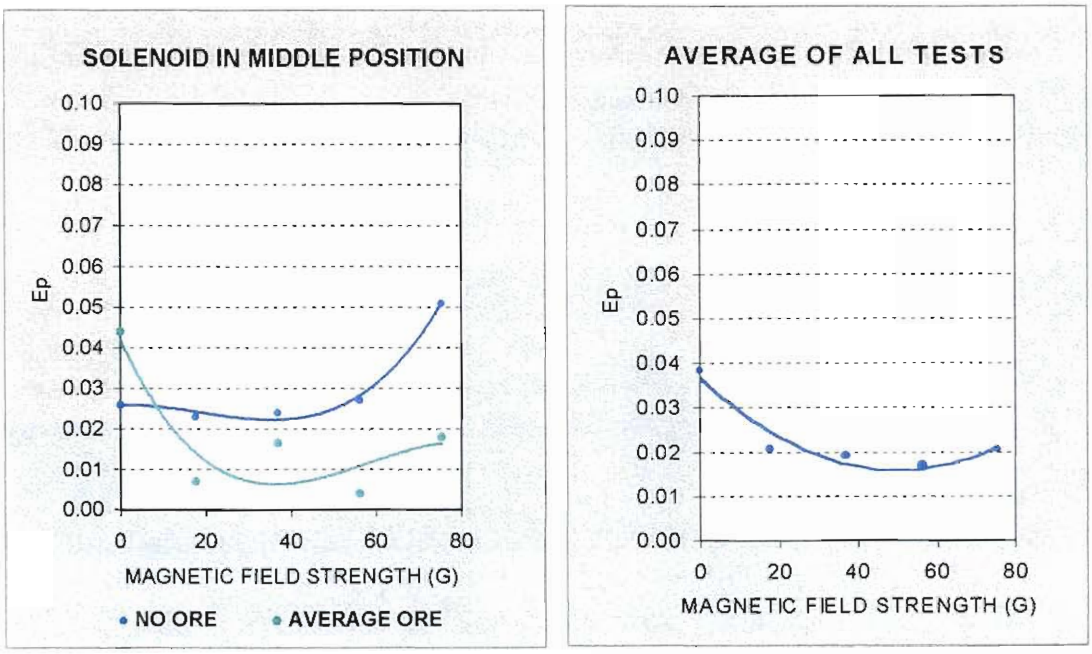


Figure 17 & 18: Ep for tests with solenoid in middle position and average Ep values - 1998.

4.3.2 Effect of the Magnetic Field on Cut Point

Figure 19 illustrates the results of the tests with the solenoid in the top position and Figure 20 the results with the solenoid in the middle position. Figure 21 represents the average values of all the tests conducted (six tests per magnet setting). For both solenoid positions and for both the tests with and without ore feed a reduction in cut point with increasing magnetic field strength was noted.

On average the cut point was reduced by approximately 3 %, from 3.18 kg/l to 3.1 kg/l.

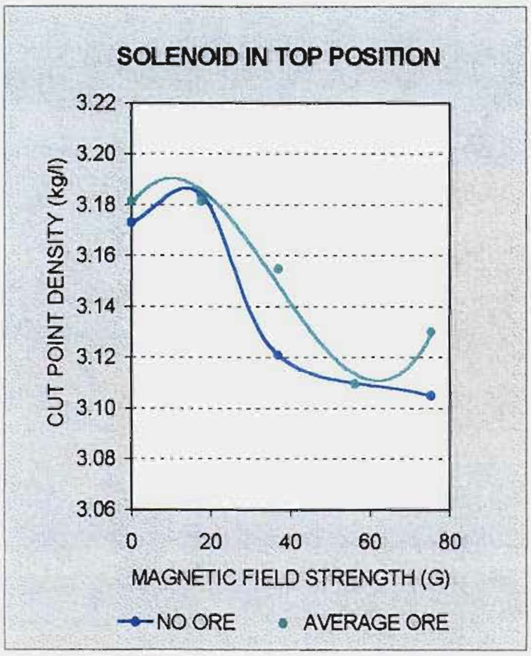
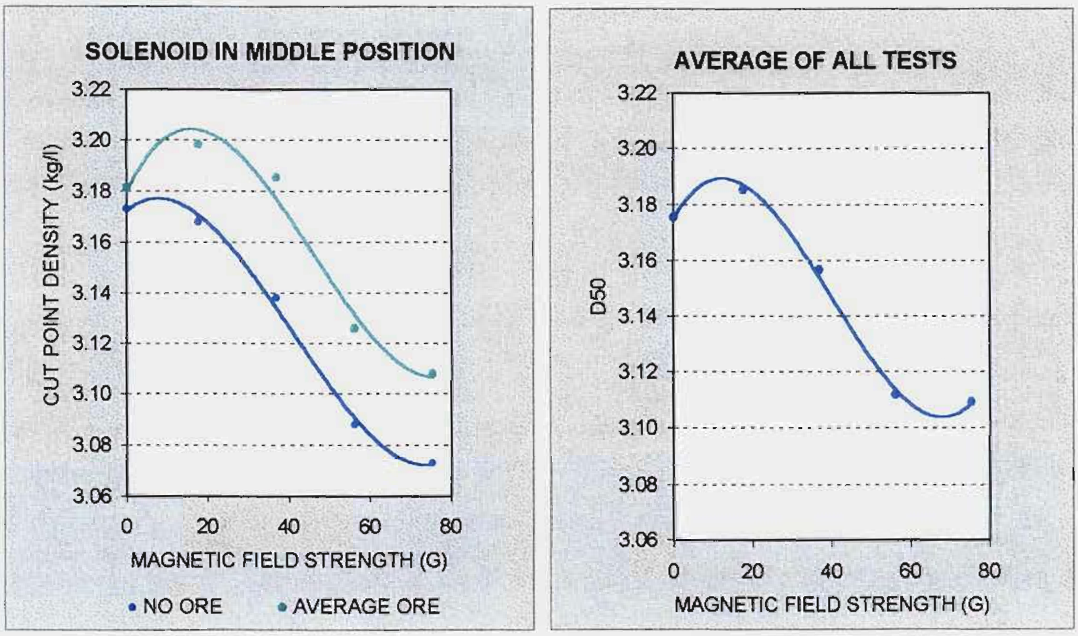


Figure 19: Cut point density for tests with solenoid in top position - 1998.



Figures 20 & 21: Cut point density for solenoid in middle position and average cut points- 1998.

4.4 GRAPHICAL REPRESENTATION OF 2000 TEST PROGRAM RESULTS

4.4.1 Effect of the Magnetic Field on Density Differential

Figure 22 illustrates the relationship between density differential and magnetic field strength for the solenoid in the top position. Each data point represents the average of three tests. For all three medium feed densities (2.60, 2.70 and 2.80 kg/l) the density differential reduced with increasing magnetic field strength. An average reduction in differential of 25 % was recorded. The density differential is the highest for the lowest medium feed density as expected since medium stability decreases as density decreases.

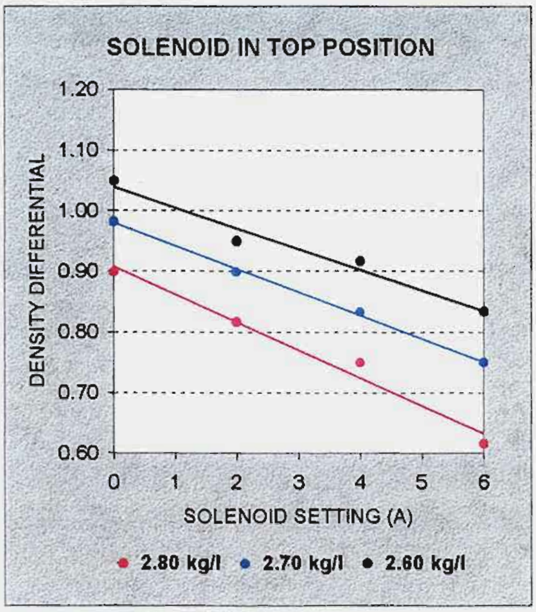


Figure 22: Density differential for tests with solenoid in top position - 2000.

Figure 23 illustrates the relationship between underflow density and magnetic field strength. Each data point represents the average of three tests conducted. An average reduction in underflow density of approximately 7% was recorded. The reduction in density differential was due to a reduction in underflow density. The overflow density remained constant and slightly below the inlet density.

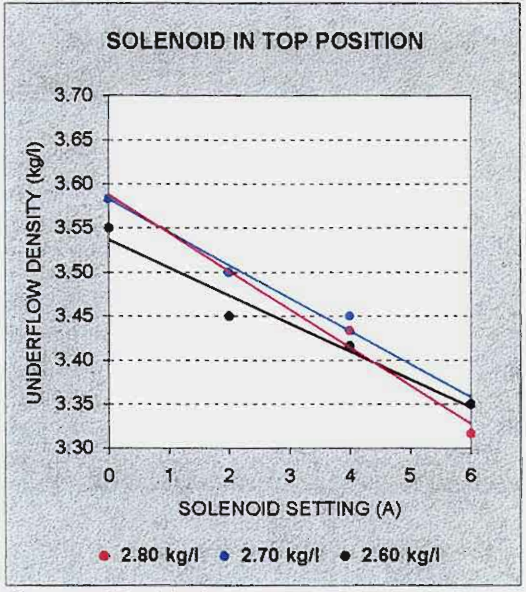


Figure 23: Underflow density for tests with solenoid in top position - 2000.

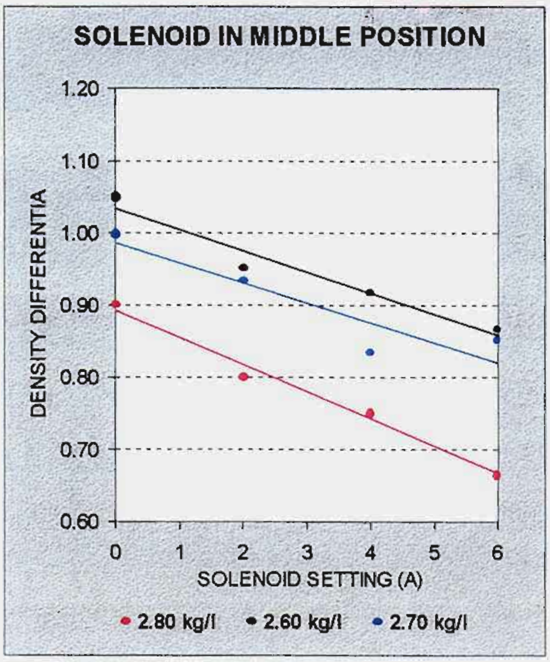


Figure 24 illustrates the relationship between density differential and magnetic field strength for the solenoid in the middle position. Each data point represents the average of three tests. For all three medium feed densities (2.60, 2.70 and 2.80 kg/l) the density differential reduced with increasing magnetic field strength. An average reduction in differential of 19 % was recorded. The density differential was once again the highest for the lowest medium feed density.

Figure 24: Density differential for tests with solenoid in middle position - 2000.

Figure 25 illustrates the relationship between underflow density and magnetic field strength for the solenoid in the middle position. Each data point represents the average of three tests. An average reduction in underflow density of approximately 5% was recorded. It is clear that the reduction in density differential was due to a reduction in underflow density. The overflow density remained constant and slightly below the inlet density.

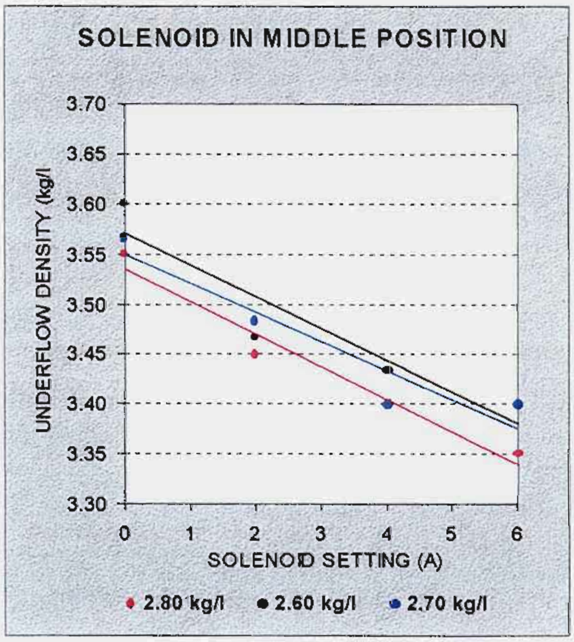
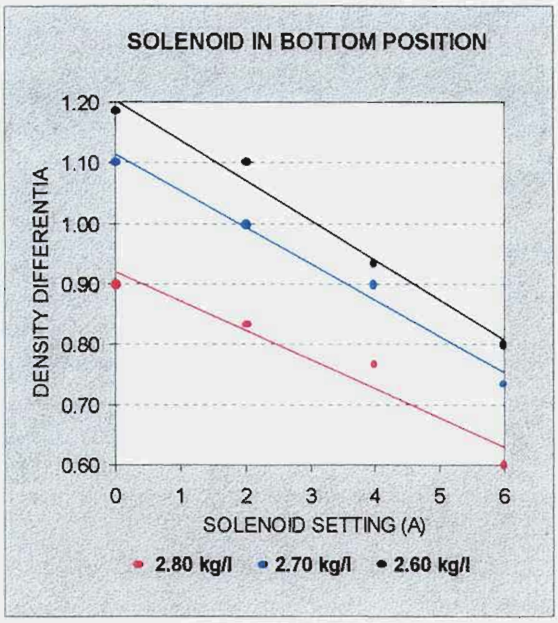


Figure 25: Underflow density for tests with solenoid in middle position - 2000.

Figure 26 illustrates the relationship between density differential and magnetic field strength for the solenoid in the bottom position.



Each data point represents the average of three tests. For all three medium feed densities (2.60, 2.70 and 2.80 kg/l) the density differential reduced with increasing magnetic field strength. An average reduction in differential of 33 % was recorded. As with the solenoid in the top and middle positions the density differential was the highest for the lowest medium feed density as expected.

Figure 26: Density differential for tests with solenoid in bottom position - 2000.

Figure 27 illustrates the relationship between underflow density and magnetic field strength for the solenoid in the top position. Each data point represents the average of three tests. An average reduction in underflow density of approximately 9% was recorded. It is clear that the reduction in density differential was due to a reduction in underflow density. The overflow density remained constant and slightly below the inlet density.

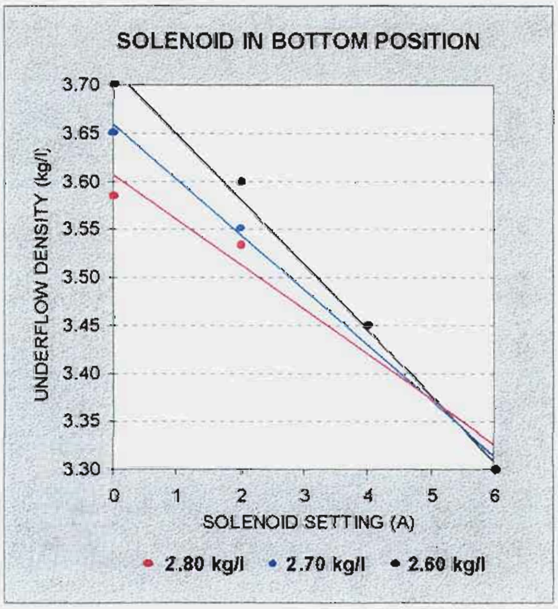
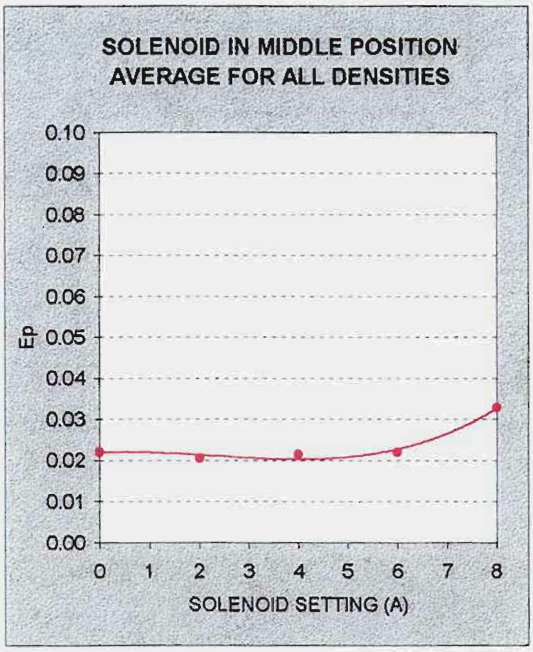


Figure 27: Underflow density for tests with solenoid in bottom position - 2000.

4.4.2 Effect of the Magnetic Field on Ep



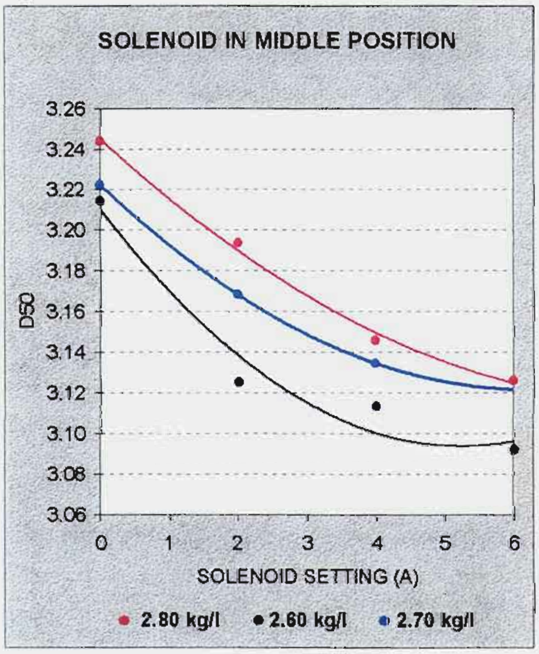
In Figure 28 average Ep values are plotted against solenoid setting for medium feed densities 2.60, 2.70 and 2.80 kg/l for the 2000 tracer test program. Each data point represents the average result of nine tests (three tests per medium inlet density per solenoid setting).

No change in separation efficiency was recorded within the stable region of 0 to 6 ampere. The average Ep value remained approximately 0.02, which can be classified as excellent (Napier-Munn, 1975:23) according to a general guide by Napier-Munn. The separation efficiency did however deteriorate sharply beyond magnetic field settings of 6 amps.

Figure 28: Average Ep values for medium densities of 2.60, 2.70 and 2.80 kg/l - 2000.

4.4.3 Effect of the Magnetic Field on Cut Point

Figure 29 illustrates the effect of an increase in magnetic field strength on cut point for different medium feed densities during the 2000 tracer test program. Each data point represents the average result of three tests.



For all three medium densities a progressive decrease in cut point with increasing magnetic field strength was recorded. The cut point was reduced by approximately 4 % for all three medium feed densities.

As expected, cut points were generally higher for the tests with higher medium inlet densities. However cut point was clearly more sensitive to the magnetic field setting than to the medium feed density.

Figure 29: Average cut points for medium densities of 2.60, 2.70 and 2.80 kg/l - 2000.

4.5 COMPARISON BETWEEN THE 1996, 1998 AND 2000 TEST RESULTS

4.5.1 Effect of the Magnetic field on Density Differential

Only 1996 and 2000 density differential results were compared to one another. 1998 density differential results were excluded from the discussion since the underflow density sampling was inaccurate as mentioned under section 4.1.

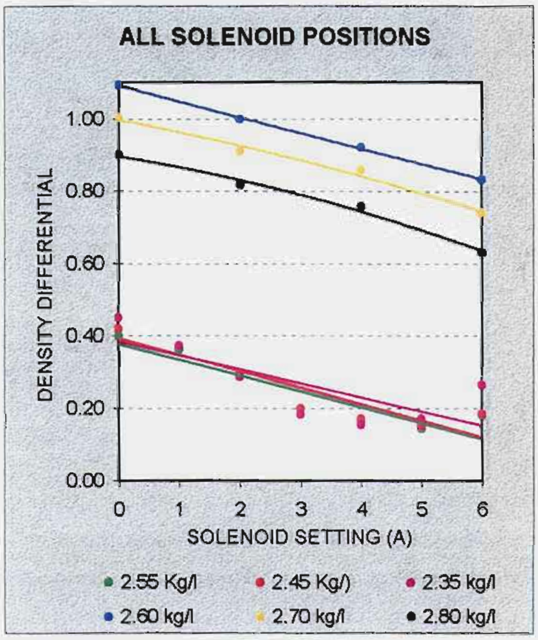


Figure 30: Comparison between density differential results for 1998 and 2000.

The 1996 tests were conducted at medium densities of 2.35, 2.45 and 2.55 kg/l with 270D FeSi. The 2000 tests were conducted at medium densities of 2.60, 2.70 and 2.80 kg/l with 65D FeSi.

Tests were conducted with the solenoid in the top, middle and bottom positions during 1998 and 2000.

Each data point represents the average of nine tests (three tests per solenoid position per solenoid setting, except for the 1996 tests at 0 ampere where more tests were conducted). During each test overflow and underflow densities were sampled three times.

Figure 30 illustrates the following:

- The higher the medium feed density the higher the medium stability and the lower the density differential – provided that the inlet pressure and cyclone geometry is constant.

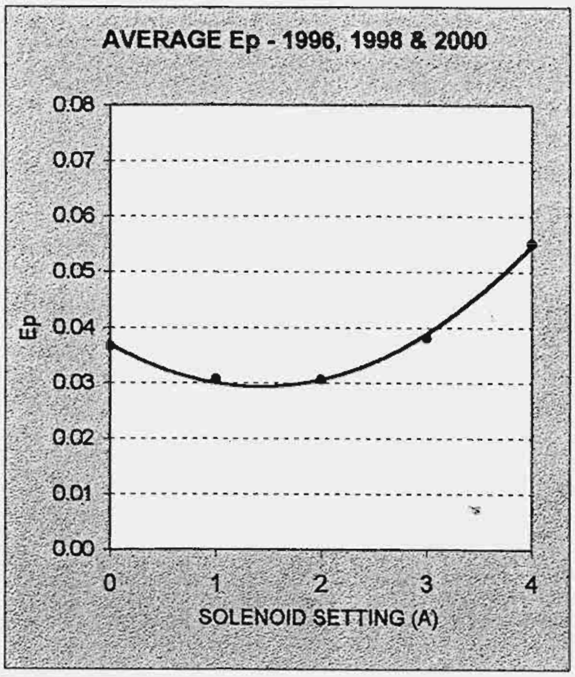
- The density differential for the tests with 65D medium at a cyclone feed pressure of approximately 20D is substantially higher than that of the tests conducted with the finer 270D medium at a cyclone feed pressure of approximately 13D.

- The higher the inlet pressure and medium feed density the less susceptible the medium to the effect of the magnetic field - provided that pressure, cyclone geometry, medium grade and magnetic susceptibility is constant.

- The position of the solenoid does not affect the density differential as significantly as the magnetic field strength does.

4.5.2 Effect of the Magnetic field on Ep

Figure 31 represents the average Ep values for the 1996, 1998 and 2000 test programs.



The following data was used to construct the graph:

- 1996 data with the solenoid in the top, bottom and middle positions at medium densities of 2.35, 2.45 and 2.65 kg/l (each value used was the average of three tracer tests except at 0 A where more tests were done).
- 1998 data with the solenoid in the top and middle positions at a medium density of 2.65 kg/l (each value used was the average of three tracer tests).
- 2000 data with the solenoid in the middle position at densities of 2.60, 2.70 and 2.80 kg/l (each value used was the average of three tests).

Figure 31: Average Ep values for 1996, 1997 and 1998

During the 1996 and 1998 test programs the Ep started deteriorating beyond 4 ampere and during the 2000 test program beyond 8 ampere.

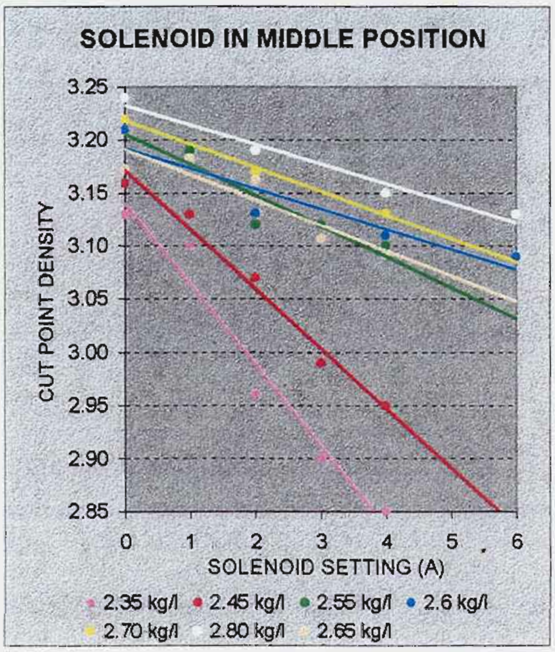
When considering the data in the stable region of each test series separately, some showed significant improvements in Ep with increasing magnetic field strength while in other tests Ep deteriorated or remained constant. When considering all of the data available an average reduction in Ep of 16 % was achieved. This was calculated using:

$$\% \text{ Reduction in Ep} = (Ep_0 - Ep_{min})/Ep_0 * 100$$

with Ep_0 = The average Ep value of all of above tests with no magnetic field
and Ep_{min} = The average Ep value of all of above tests at a magnetic field of 2A

4.5.3 Effect of the Magnetic field on Cut Point

1996, 1998 and 2000 test program tracer test results with the solenoid in the middle position were compared to one another. Figure 32 illustrates the effect of the magnetic field on cut point.



The 1996 tests were conducted at medium densities of 2.35, 2.45 and 2.55 kg/l with 270D FeSi.

The 1998 tests were conducted at a medium density of 2.65 kg/l.

The 2000 tests were conducted at medium densities of 2.60, 2.70 and 2.80 kg/l with 65D FeSi.

Each data point represents the average of three tests (three tests per solenoid setting, except for the 1996 tests at 0 ampere where more tests were conducted).

Figure 32: Average cut point results for 1996, 1998 and 2000

Figure 32 illustrates the following:

- The higher the medium feed density the higher the cut point – provided that pressure, cyclone geometry, medium grade and magnetic susceptibility is constant.
- The higher the inlet pressure and medium feed density the less susceptible the medium to the effect of the magnetic field – provided that cyclone geometry, medium grade and magnetic susceptibility is constant.

4.5.4 Relationship between Underflow Density and Cut Point

In Sections 4.5.1 and 4.5.3 the influence of the magnetic field on underflow density and cut point was discussed. In the literature study, Section 2.4.1, the possible relationship between underflow density and cut point was explored. During the magnetic cyclone test program a direct relationship between the underflow density and cut point was found.

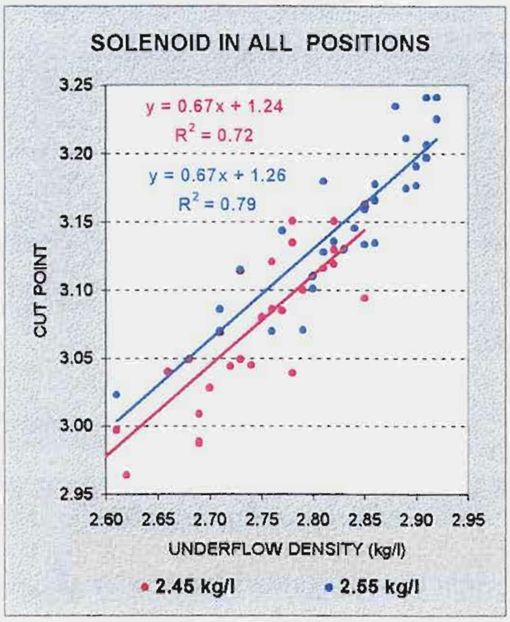


Figure 33: relationship between underflow density and cut point – 1996 data.

The relationship between cut point and underflow density is illustrated in Figures 33 and 34 using tracer test data from the 1996 and 2000 test programs. 1998 data was not considered since the underflow density results were unreliable.

Figure 33 was constructed using 1996 data for the tests with medium inlet densities of 2.45 and 2.55 kg/l with 270D FeSi. Each data point is the result of three underflow density readings and a tracer test. Data with the solenoid in all three positions, at magnetic field settings of 0 to 3 ampere (with three tests per magnetic field setting) were used.

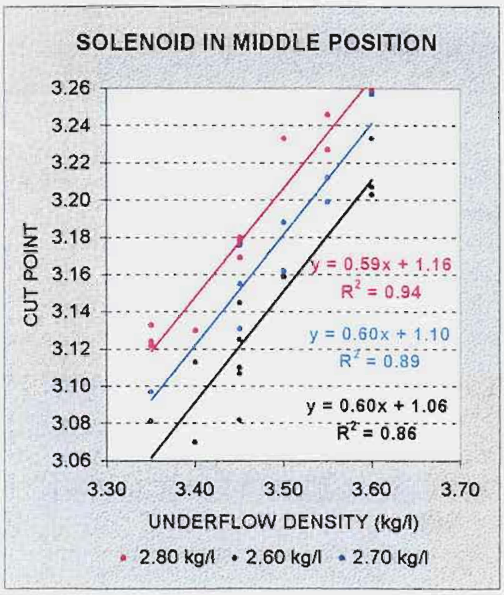


Figure 34: Relationship between underflow density and cut point – 2000 data.

Figure 34 was constructed using 2000 data for the tests with medium inlet densities of 2.6, 2.7 and 2.8 kg/l with 65D FeSi. Each data point is the result of three underflow density readings and a tracer test. Data with the solenoid in the middle position, at magnetic field settings of 0 to 6 ampere (with three tests per magnetic field setting) were used. Beyond 3 ampere for the 1996 tests and beyond 6 ampere for the 2000 tests the Ep deteriorated indicating a disruption in the flow pattern inside the cyclone. Linear tend lines were fitted through the data for each test series. The 2000 data was more accurate than the 1996 data since more tracers in smaller density intervals were used per test.

4.6 EFFECT OF 2000 MAGNETIC CYCLONE PROJECT ON KOINGNAAS MAIN PLANT PRODUCTION STATISTICS

The primary goal of the magnetic cyclone project was conducted at Koingnaas Main Plant from June to October 2000. was to evaluate the performance of a magnetic cyclone in a production environment. An audit was done on the DMS before commencing with the project and a number of changes were made to bring the DMS in line with current best practice before commencing with the magnetic cyclone project.

The following improvements were made:

1. The old Linatex cyclone dimensions were not ideal. The new Multotec cyclone was selected to conform to the ideal group standards.
2. The old cyclone was installed in such a way that back-pressure was created at the overflow. This was eliminated with the new installation.
3. The old cyclone was operated with fluctuating pressures ranging from 90 kPa to 260 kPa. As part of the project the DMS feed was interlocked with the cyclone inlet pressure to ensure a constant and optimum pressure.
4. Control limits were set on the DMS feed rate to ensure a constant feed rate to the cyclone of 60 to 70 tons per hour.
5. The DMS feed conveyor weightometer and the cyclone pressure gauge were calibrated.

The average concentrate yield recorded over a period of three and a half months after implementing the changes was 0.12% of DMS feed. The average DMS yield for Koingnaas from 1997 to 2000 before implementing the changes was 0.25%. Thus as consequence of following technical best practice a 52% reduction in DMS yield was achieved.

From the tracer tests an optimum point of operation for the magnetic cyclone was determined. This was to operate the cyclone with a medium inlet density of 2.80 kg/l, ensuring that quartz is no longer middling material, and to reduce the underflow density from 3.60 to 3.45 kg/l with the solenoid to maintain a cut point of 3.20 kg/l. The solenoid was placed in the middle of the conical section and set at 4 ampere. The magnetic cyclone has been in operation with these criteria for a month prior to this report being written. Routine DMS efficiency audits while operating with the solenoid at 4A and with the medium inlet density at 2.80 kg/l has been satisfactory. No diamonds were found in the two 40 ton tailings samples taken and all tracer tests have indicated cut points of 3.20 - 3.22 kg/l with Ep values of 0.01 – 0.02. When comparing the average concentrate yield of ten shifts before to ten shifts after the magnet was switched on, the yield was reduced by a further 50 % (from 0.14% to 0.07 %). The Multotec cyclone also showed improved wear resistance when compared to the Linatex cyclone. After being in operation for four months and treating 74 844 tons at pressures of 200 – 260 kPa the cyclone performance is still satisfactory, the tiled cone showing little visible wear. Figure 35 illustrates DMS statistics from January to October 2000.

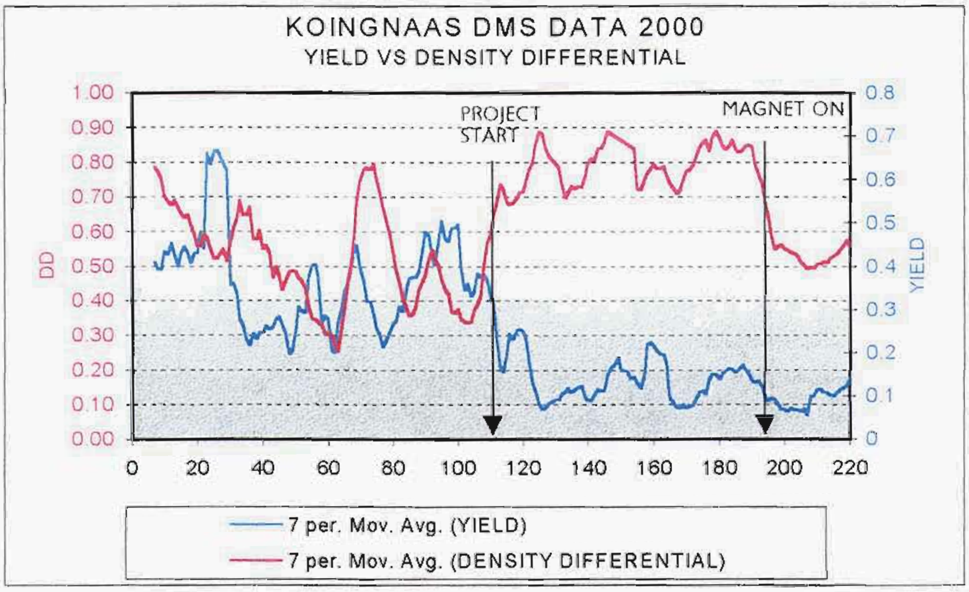


Figure 35: Koingnaas Main plant Production Statistics.

4.7 DISCUSSION OF RESULTS

4.7.1 Effect of the Magnetic Field on Density Differential

For all tests, with ore feed and with medium feed only, on a laboratory scale and on a production scale, a progressive reduction in density differential with increase in magnetic field strength was recorded. The reduction in density differential was due to a reduction in the underflow density. The overflow medium density remained essentially constant. In some cases a slight increase in overflow medium density was noticed.

The medium flow-spilt between the overflow and underflow depends on many variables, which in turn determine the medium underflow and overflow density. The volumetric percentage of feed medium that reports to the cyclone overflow can be calculated using:

% Medium to overflow = $[(\rho_{U/F} - \rho_{IN}) / (\rho_{U/F} - \rho_{O/F})] * 100$..........1
(Gilbert & Hyland, 1996)

with $\rho_{U/F}$ = underflow medium density (kg/l)
ρ_{IN} = medium inlet density (kg/l)
and $\rho_{O/F}$ = overflow medium density (kg/l)

According to above relationship a substantial decrease in underflow medium density and a marginal increase in overflow medium density should result in an increase in the overflow medium flow rate and a decrease in underflow medium flow rate.

During the 1995 and 1996 investigations, medium overflow and underflow flow rates were measured for each test conducted. The results indicated a progressive decrease in the flow rate of the underflow medium and an increase in the flow rate of the overflow medium with increasing magnetic field strength as expected. The region of minimum underflow flow rate also coincided with the region of minimum underflow density. The 1995 results are illustrated in Graph 20 (Campbell & Brits, 1995:14).

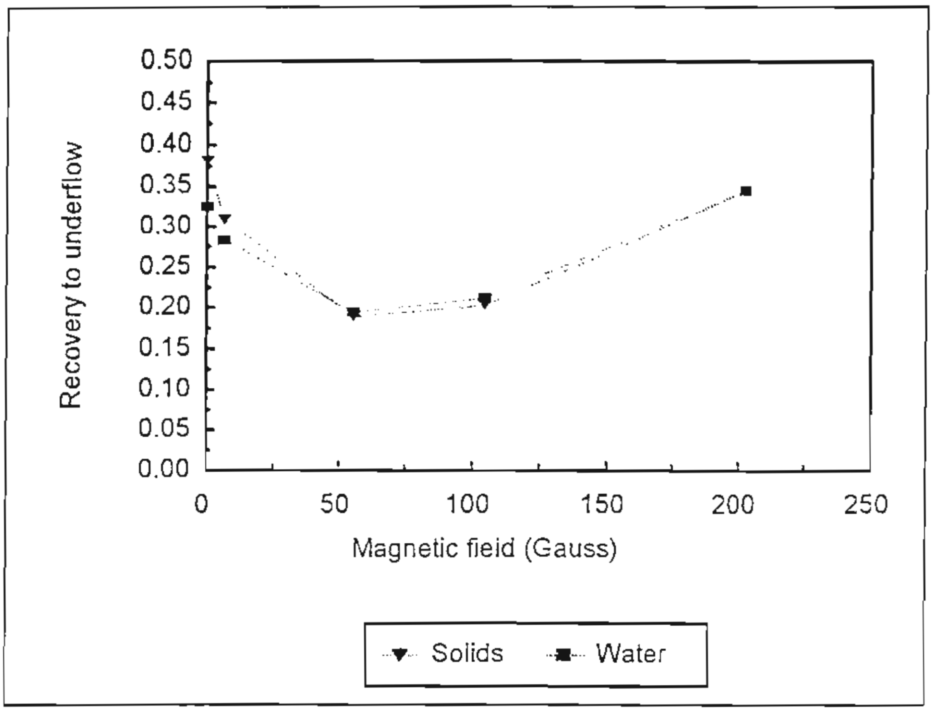


Figure 36: Effect of magnetic field on water and solid recoveries to the cyclone underflow (1995 test program).

By applying the magnetic field, the ferrosilicon within the cyclone is attracted towards the central plane of the solenoid, in this case towards the overflow. This external magnetic force counteracts normal medium segregation in which dense medium bands form towards the cyclone periphery and spigot region. The medium is thus distributed more homogeneously throughout the cyclone. This is the reason for the reduced underflow density and increased overflow flow rate.

4.7.2 Effect of the Magnetic Field on Ep

Both in 1996 and 1998, with ore feed as well as with medium feed only a progressive reduction in Ep with increase in magnetic field strength were recorded. On average the Ep was reduced from 0.04 and above to 0.02 and below. During the 1996 tests (with 270D medium feed only at an inlet density of 2.55 kg/l) the average Ep value for the top and middle positions was reduced from 0.061 at 0 Gauss to 0.016 at 36 Gauss, which is an average reduction of 74 %. During 1998 the average Ep was reduced from 0.038 to 0.017, which is an average reduction of 55 %(refer to Table 3 page 33 for 1998 test results).

The percentage reduction in Ep was calculated using:

% Improvement in Ep $= [(Ep_0 - Ep_{min}) / (Ep_0)] * 100$.....................2

with Ep_0 = Average Ep of 3 tests (with and without ore feed) without magnetic field.

Ep_{min} = Average Ep of 5 tests (with and without ore feed, with solenoid in top and middle positions) with magnetic field at 56 G.

As discussed in the literature study excessive entrapment of middlings in the concentrate occurs when the density differential exceeds 0.4 (Cocker et al. 1998:141-142). In all of the tests conducted the density differential was 0.4 or above before applying the magnetic field. After application of the magnetic field, during the 1996 and 1998 tests, the density differential was reduced to below 0.4. By decreasing density differential the density band of material classified as middlings narrows, improving separation efficiency and reducing concentrate yield.

During the 2000 test program no significant reduction in Ep was recorded. The Ep remained below 0.025, which can be classified as excellent (Napier-Munn, 1975:23), for all tests done below 8 A. Two possible reasons exist for not recording a reduction in Ep.

- Firstly the magnetic field did not reduce the density differential to the ideal region of 0.2 to 0.3 during the 2000 test program. Due to the coarse medium grade (65D) and the high cyclone feed pressure (200 to 250 kPa) the density differential was large (1.0 to 1.1) compared to the 1996 and 1998 density differentials (0.4 to 0.5). The combination of high density differential and high inlet pressure resulted in the magnetic field not being able to reduce the density differential to below 0.3 before magnetic flocculation occurred.
- Secondly the Ep values were excellent from the onset during the 2000 test program making a reduction in Ep of well below 0.2 unlikely.

The reduction in density differential with increasing magnetic field strength (Section 4.4.2), thus leads to a significant improvement in separation efficiency and a reduced yield provided that the density differential is reduced to between 0.2 and 0.3.

4.7.3 Effect of the Magnetic Field on Cut Point

In 1996, 1998 and 2000 with ore feed as well as with medium feed only a progressive reduction in cut point with increase in magnetic field strength was recorded. During the 1998 and 2000 test programs the cut point was reduced by approximately 4% before magnetic flocculation of the medium occurred.

The reduction in cut point can be explained as follows:

The solenoid draws the ferrosilicon particles towards its central plane (away from the spigot, and towards the overflow) and thus counteracts medium segregation in the cyclone creating a more stable medium. This in turn gives rise to a reduced underflow medium density. During the tests all other variables affecting cut point such as medium grade, cyclone configuration inlet density and inlet pressure were kept constant. Thus, the reduced underflow density induced via the magnetic field was responsible for the reduction in cut point.

When comparing the 1998 cut point data (Graphs 7 and 8) with ore feed to the data with medium feed only, it can be seen that the cut point with ore feed is approximately 1 % higher than with medium feed only. This can be attributed to crowding of material at the cyclone spigot when feeding ore, which will in turn lead to the diversion of material to the cyclone overflow and consequently a raised cut point.

4.7.4 Relationship between Cut Point and Underflow Medium Density

Figures 33 and 34 (Section 4.5.4, page 44) illustrate the relationship between cut point and underflow medium density for the 1996 and 2000 test programs. This was the first time that the relationship could be explored. It was not possible in the past to vary the underflow density at will.

It was discovered that the cut point is directly related to the underflow density and decreases with decreasing underflow density. The cut point is also dependent upon the medium inlet density but to a lesser extent. The underflow density is the primary parameter determining the cut point.

As discussed in the literature study, the underflow density of a DM cyclone varies constantly due to variable medium size distribution, medium viscosity, cyclone inlet pressure and cyclone wear. Most diamond production plants do not measure medium underflow density and none control it actively. The reason for this is that the effect of underflow density on separation efficiency has not been well documented and understood and that there was no simple and effective way to manipulate it directly, until now.

From the linear trend lines constructed through the data the following equations were derived:

1996 Data

270D FeSi at 2.45 kg/l inlet density - $D50 = 0.67\rho_{uf} + 1.24$....3

270D FeSi at 2.55 kg/l inlet density - $D50 = 0.67\rho_{uf} + 1.26$....4

2000 Data

65D FeSi at 2.60 kg/l inlet density - $D50 = 0.60\rho_{uf} + 1.06$....5

65D FeSi at 2.70 kg/l inlet density - $D50 = 0.60\rho_{uf} + 1.10$....6

65D FeSi at 2.80 kg/l inlet density - $D50 = 0.59\rho_{uf} + 1.16$.....7

with D50 = Cut point density (kg/l)

and ρ_{uf} = Medium underflow density (kg/l)

From the 1996 data the following equation can be derived which relates cut point to medium inlet density and medium underflow density:

$D50 = 0.67\rho_{uf} + 0.50\rho_{in}$...8

From the 2000 data the following equation can be derived which relates cut point to medium inlet density and medium underflow density:

$D50 = 0.60\rho_{uf} + 0.41\rho_{in}$...9

With ρ_{in} = Medium inlet density (kg/l)

With ρ_{in} = Medium inlet density (kg/l)

The constants in the equations could be a function of medium grade or cyclone configuration. It is possible though, that medium grade and cyclone configuration only plays a role to determine underflow density and that the cut point of any DM cyclone can be derived from a single common equation once the medium inlet and underflow densities are known. This assumption can be made since the constants of the 1996 and 2000 test programs are very similar considering the degree of experimental error when conducting tests in a production environment. More tests should be done with different medium grades and inlet densities to refine the relationship between cut point, inlet and underflow density.

4.7.5 Effect of the 2000 Magnetic cyclone test program on Koingnaas Production Statistics

The magnetic cyclone is an enhancement of current best practise and not a remedy for general poor DMS efficiency.

As consequence of following technical best practice a significant reduction in DMS yield of 52% was achieved.

Operating the magnetic cyclone with a medium density of 2.80 kg/l at a solenoid setting of 4 amps resulted in a further reduction in DMS yield from 0.14% to 0.07% (these values are the average yields ten shifts before and ten shifts after the magnet was switched on). The most likely reason for this reduction is that less middling material reported to concentrate due to the decreased density differential and the fact that quartz could no longer be classified as middling material when operating under these conditions.

In total a 68 % reduction in DMS yield was recorded for the project. This relates to a saving in concentrate treatment cost at the Final Recovery Plant of approximately R250 000 per annum.

The reduction in yield was calculated as follows:
% Reduction = $(\text{YIELD}_{\text{BEFORE}} - \text{YIELD}_{\text{AFTER}})/\text{YIELD}_{\text{BEFORE}} * 100$
$\text{YIELD}_{\text{BEFORE}}$ = Average yield from 1997, 1998, 1999 and 2000 Jan to June
= 0.25%

$\text{YIELD}_{\text{AFTER}}$ = Average yield of 15 shifts from 2 October 2000 onwards after operating with the solenoid on at a density of 2.8 kg/l.
= 0.08 %

CHAPTER 5 - CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The magnetic field had a similar affect on medium passing through a large and a small DM cyclone. The effect of the magnetic field on the medium of a DM cyclone fed with a medium-ore mixture was found similar to one fed with medium only.

By applying a magnetic field to the dense medium passing through a cyclone, the medium is stabilised directly without having to alter physical DMS parameters or increase the medium viscosity.

The stabilisation of the medium is characterised by a progressive reduction in the underflow density with increasing magnetic field strength. This reduction in underflow density occurs due to the attraction of the ferrosilicon particles towards the central plane of the solenoid. The magnetic field thus counteracts the centrifugal and gravitational forces in the cyclone and prevents excessive segregation of the heavy ferrosilicon particles.

This results in a more homogeneous medium with a smaller differential between the dense medium regions at the cyclone periphery/spigot and the less dense region towards the cyclone centre/overflow. By attracting more medium away from the spigot and towards the overflow, the volumetric flow rate of the overflow product is increased.

The direct stabilisation of the medium passing through a DM cyclone and the consequent reduction in underflow density affects separation in three ways:

Firstly, and most significantly, the underflow density can be manipulated directly for the first time. It was discovered that the cut point is directly related to the underflow medium density and that the underflow density has a greater effect on cut point than inlet density. The cut point of a cyclone is the most critical DMS parameter. It primarily determines the DMS yield and recovery of diamonds to concentrate. The underflow density in turn is determined by an array of variables such as medium grade, cyclone configuration, cyclone pressure, viscosity, etc. which makes it impossible to control directly with conventional methods. The constantly varying underflow medium density causes misplacement of light material in concentrate and could lead to diamond loss. The direct stabilisation of the medium density (and thus control of the underflow density) with the magnetic field brings metallurgists one step closer to complete on-line DMS control.

Secondly, the reduction in density differential narrows the middlings density band and reduces the offset between the inlet density and the cut point, both of which is known to improve separation efficiency and reduce DMS yield. On average for all of the 1996, 1998 and 2000 tracer test results the Ep value was improved by 16 %.

Thirdly, it is now possible to operate a DMS at a higher inlet density than ever before. The magnetic field reduces the underflow density, which in turn reduces the cut point. Thus a cyclone that was previously operated with an inlet density of 2.50 kg/l can now be operated with an inlet density of 2.80 kg/l, using the magnetic field to maintain the same cut point. This has specific application for alluvial diamond mines where approximately 90 % of DMS feed consists of middling material. Historically, alluvial DMS plants are operated at medium inlet densities of 2.50 to 2.60 kg/l and underflow densities of 2.9 to 3.6 kg/l. In this application quartz of density 2.65 kg/l can be defined as middling material. It is well known that unwanted middling material is often misplaced in the concentrate due to crowding in the cyclone. An educated guess is that 30 - 50 % of Namaqualand Mines concentrate consists of unwanted quartz.

Theoretically, by operating at medium inlet densities of above 2.80 kg/l, quartz will no longer act as middling material and should report to tailings only. This theory was tested by operating the 510 mm cyclone at Koingnaas Production Plant with a medium inlet density of 2.80 kg/l and using the solenoid to reduce the underflow medium density from 3.60 to 3.45 kg/l to ensure a cut point of 3.20 kg/l. The cyclone was operated for one month under these conditions prior to this report being written. The result was that the DMS performed satisfactory with no loss of diamonds to tailings and a reduced DMS yield. No changes were noted on the diamond distribution curves. The yield was reduced from 0.14% to 0.07% (these values are the average yields ten shifts before and ten shifts after the magnet was switched on) as a direct result of the application of the magnetic field.

The alumina tiled cone tested did not cause turbulence inside the cyclone irrespective of the uneven surface of the tiles. Very low Ep values (0.01 – 0.03) throughout the project confirmed this. The wear properties of the alumina cone were superior to that of a standard Ni-Hard cone. Even though the tiled cone performed satisfactory it is not recommended for permanent application with the solenoid since catastrophic diamond loss will occur should a tile come loose.

In total a 68 % reduction in DMS yield was recorded for the project. This relates to a saving in concentrate treatment cost at the Final Recovery Plant of approximately R250 000 per annum.

5.2 RECOMMENDATION

A magnetic DM cyclone is simple to install and operate. The magnet's capital and operational costs are minimal. It has the same power requirements as a standard light bulb. The magnet is robust and reliable and requires no maintenance as long as it stays dry and is not operated at high voltages for extended periods.

The benefits of a magnetic DM cyclone include:

- Direct on-line control over the underflow medium density. Since underflow medium density is the major factor determining cut point, this will ensure continuous operation at optimum parameters.
- A reduced density differential without compromising on other effectiveness areas, such as medium grade, cyclone inlet pressure or tonnage throughput. This will result in improved separation efficiency and reduced yield.
- Magnetic DM cyclones can be operated at high medium densities. This has specific application where large amounts of middling material in DMS feed cause misplacement of light material in the concentrate. By using the magnetic field to reduce the underflow medium density and thus the cut point, it is possible to operate the cyclone at a medium density of 2.80 kg/l and still maintain the same cut point than when operating at 2.60 kg/l. Under these conditions, quartz no longer acts as middling material and should report to tailings only. This will result in significant cost savings.

The way forward:

- An on-line, automated underflow density measurement and control system must be developed.
- Development of a non-magnetic cyclone. A ceramic cyclone or stainless steel cyclone lined with tungsten carbide would be ideal. The result of cyclone wear tests conducted from 1992-1995 at Argyle diamond mine with a variety of materials was that Tungsten Carbide lined vortex finders had 54.5 times greater wear properties than NiHard (David, 1995:10).
- A research programme should be undertaken to accurately model and optimise the effect of the magnetic field on the medium within a DM cyclone.

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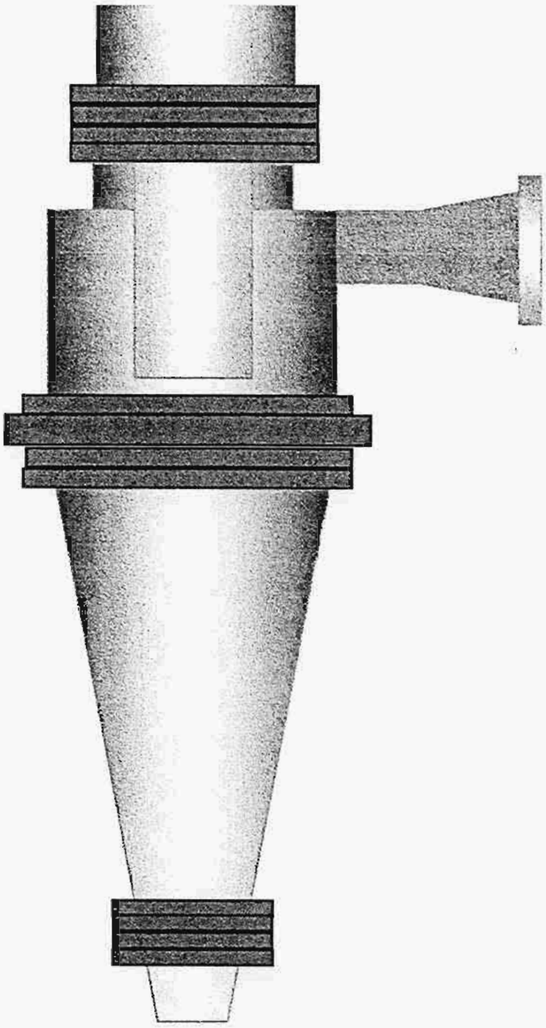
APPENDIX I

CYCLONE DRAWINGS

250 MM MULTOTEC POLYURITHANE CYCLONE – 1998 TEST PROGRAM



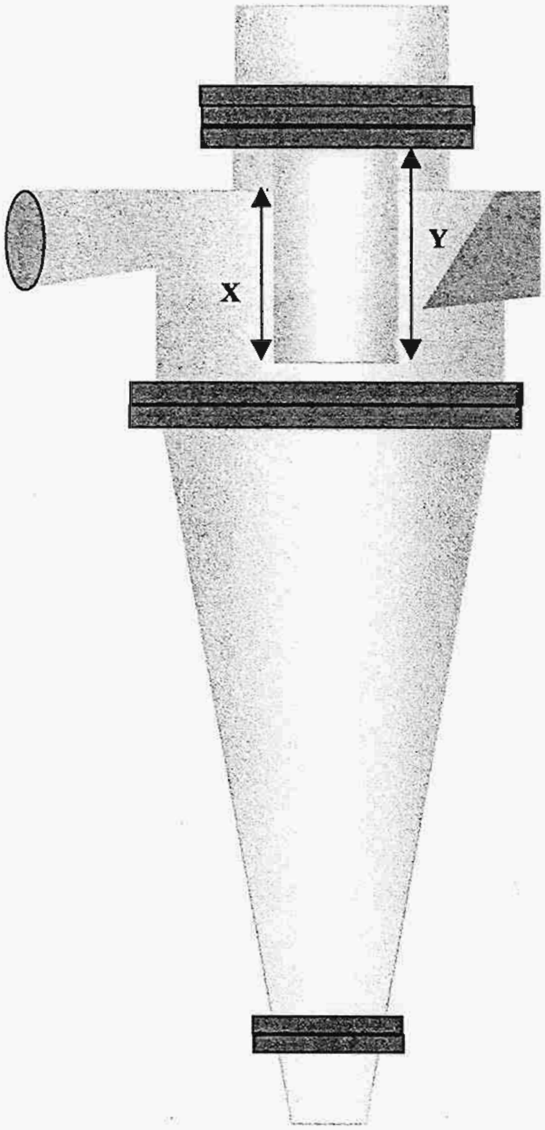
SCROLLED INLET
ROUND (135 MM ID)
TO RECTANGULAR (40 BY 100 MM)

VORTEX FINDER: L = 305 MM
I.D. = 100 MM

CONE: LENGTH = 370 MM

SPIGOT: BOTTOM I.D = 50 MM
LENGTH = 256 MM

510 MM CAST IRON MULTOTEC CYCLONE – 2000 TEST PROGRAM



VORTEX FINDER
LENGTH X = 245 mm
LENGTH Y = 363 mm
ID = 215 mm

SCROLLED INLET
ROUND (150 mm ID) TO
SQUARE (100 mm * 100 mm)
EFFECTIVE ROUND ID = 113 mm

CONE
20 DEGREES
LENGTH = 878 mm

SPIGOT
LENGTH = 375 mm
ID = 110 mm

500 MM Ni-HARD LINATEX CYCLONE - 2000 TEST PROGRAM

VORTEX FINDER
LENGTH = 280 mm
ID = 225 mm

TANGENTIAL INLET
SQUARE (105 mm * 105 mm)
EFFECTIVE ROUND ID = 119 mm

BARREL EXTENSION
DIAMETER = 500 mm
LENGTH = 330 mm

CONE
20 DEGREES
LENGTH = 685 mm

SPIGOT
LENGTH = 520 mm
ID = 100 mm

CYCLONE DIMENSIONS

BARREL LENGTH (WITHOUT EXTENSION) = 355 mm = 0.71D (IDEAL = 0.7D)
BARREL LENGTH (WITH EXTENSION) = 685 mm = 1.37D (IDEAL = 0.7D)
VORTEX FINDER LENGTH = 280 mm = 0.56 D (IDEAL = 0.45D)
VORTEX L: BARREL L (WITHOUT EXTENSION) = 0.79 (IDEAL = 0.65 - 0.8)
VORTEX L: BARREL L (WITH EXTENSION) = 0.41 (IDEAL = 0.65 - 0.8)
VORTEX FINDER ID = 225 mm = 0.45D (IDEAL = 0.42D)
INLET ID = 119 mm = 0.24D (IDEAL = 0.28D)
SPIGOT ID = 100 mm = 0.20D (IDEAL = 0.2–0.25D)

APPENDIX II

CYCLONE DIMENSIONS & FEED CONDITIONS

Feed Parameters and Ore Characteristics

ORE DENSITY	:	2.7 kg/l
FEED SIZE	:	+ 1.5 – 10 mm (1998); +1.5 – 12 mm (2000)
MEDIUM FEED DENSITY	:	2.65 kg/l (1998); 2.60, 2.70 AND 2.80 kg/l (2000)
CYCLONE INLET PRESSURE	:	90 kPa (1998); 230 – 260 kPa (2000)

Recommended relationships

A) CYCLONE INLET PRESSURE

Generally cyclone inlet pressures range from 10 - 20 D in the diamond industry

For a 20 degree cyclone the optimal feed pressure is calculated using:

Head (m) = 1.4 * cyclone diameter (m) * [solids density (kg/l)]^2

Which is a head of approximately 10-11 D.

During the 1998 test programme the cyclone was fed at 90 kPa, which relates to a head of 13 D.

During the 2000 test programme the cyclone was fed at 230 - 260 kPa, which relates to a head of 16 - 20 D.

B) PARTICLE SIZE RANGE

The ideal ration between to top and the bottom cut off sizes is 6:1.

A ratio of up to 8:1 is still tolerable.

The ratio for the 1998 test programme was 10 mm : 1.5 mm, which relates to a ratio of 6.7:1.

The ratio for the 2000 test programme was 12 mm : 1.5 mm, which relates to a ratio of 8:1.

C) SPIGOT DIAMETER

The diameter should ideally range between 0.2 D and 0.25 D.
The spigot diameter for the 1998 test programme was 0.2D.
The spigot diameter for the 2000 test programme 0.22D.

D) VORTEX FINDER

Ideal length for 20° cyclone = 3 * inlet diameter
= 3 * 100
= 300 mm

Or Vortex L: Barrel L should ideally be between 0.65 and 0.8.
For the 2000 test program the value was 0.82.

Ideal diameter for 20° cyclone vortex finder = 0.42 * D

Both the 1998 test cyclone and the 2000 test cyclone vortex finder diameters corresponded with the ideal.

E) CYCLONE INLET

The minim cyclone inlet dimension should be at least four times the maximum particle size.
Thus 4 * 10 mm = 40 mm (for the 1998 test program) and 4 * 12 mm = 48 mm (or the 2000 test program).

The ideal equivalent inlet diameter should be 0.28D. The cyclone used during the 1998 test program had an inlet of 0.28D, while the cyclone used in the 2000 test program had an inlet of 0.22D.

APPENDIX III

SOLENOID CONVERSION CHARTS

CHART FOR 250 MM CYCLONE MAGNET AT KOINGNAAS PROSPECT PLANT

POSITION A:	Field at magnet's centre.
POSITION B:	Field 80 mm off magnet's centre.

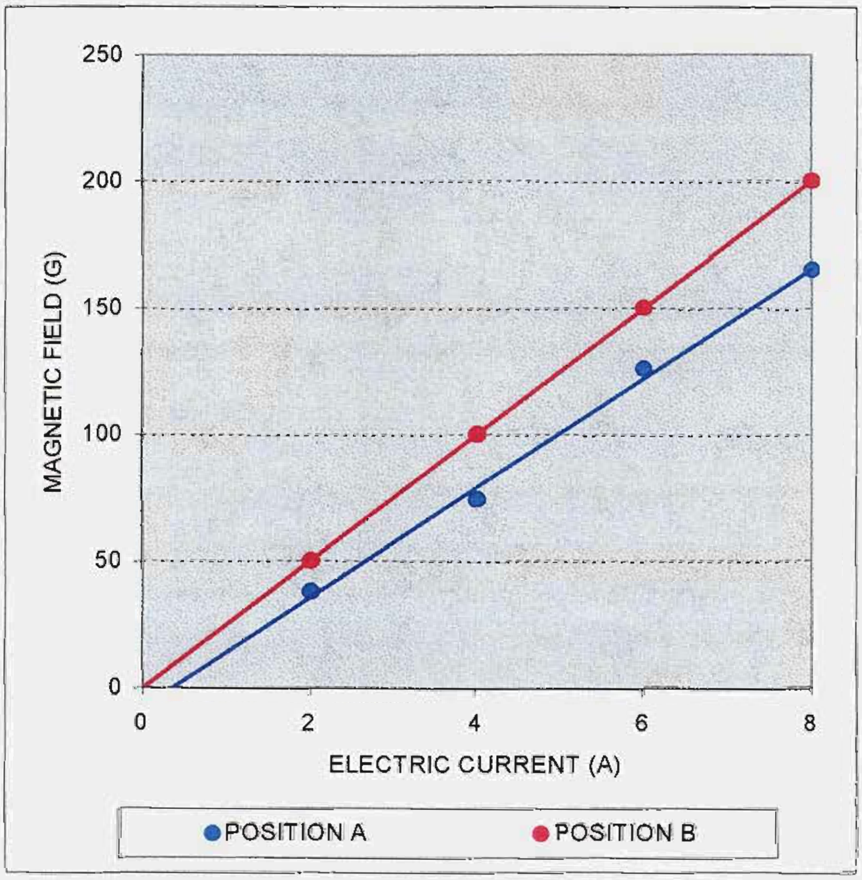
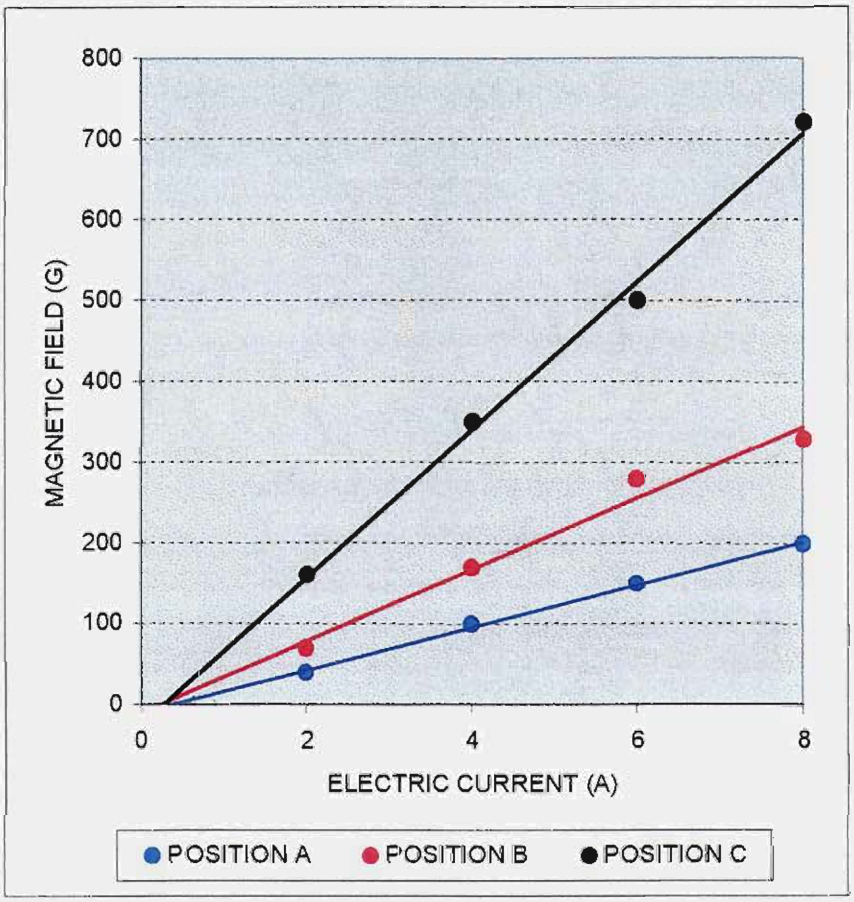


CHART FOR 510 MM CYCLONE MAGNET AT KOINGNAAS MAIN PLANT

POSITION A:	100 mm horizontal distance from magnet's inner diameter.
POSITION B:	50 mm horizontal distance from magnet's inner diameter.
POSITION C:	Next to magnet's inner diameter.



APPENDIX IV

RESULTS OF 1996, 1998 AND 2000 TEST PROGRAMMES

AVERAGE RESULTS OF 1996 MAGNETIC CYCLONE TEST PROGRAM
270D FESI

FEED DENSITY	SOLENOID POSITION	MAGNETIC FIELD (G)	DENSITY DIFFERENTIAL	EP	CUT POINT
2.35 kg/l	OFF	0	0.45	0.02	3.13
	BOTTOM	17.64	0.38	0.02	3.10
		36.86	0.31	0.024	3.08
		56.08	0.28	0.081	2.96
		75.29	0.27	0.056	2.81
		94.51	0.27	0.031	2.72
		113.73	0.41	0.037	2.70
	MIDDLE	17.64	0.36	0.025	3.10
		36.86	0.26	0.06	2.96
		56.08	0.15	0.055	2.90
		75.29	0.16	0.051	2.85
		94.51	0.19	0.07	2.84
		113.73	0.23	0.153	2.85
	TOP	17.64	0.38	0.051	3.01
		36.86	0.29	0.037	2.91
		56.08	0.12	0.026	2.81
		75.29	0.03	0.059	2.81
		94.51	0.05	0.118	2.84
		113.73	0.16	0.182	2.89
2.45 kg/l	OFF	0	0.42	0.037	3.16
	BOTTOM	17.64	0.38	0.033	3.12
		36.86	0.31	0.030	3.10
		56.08	0.28	0.081	3.02
		75.29	0.30	0.085	2.90
		94.51	0.22	0.061	2.74
		113.73	0.29	0.048	2.72
	MIDDLE	17.64	0.36	0.034	3.13
		36.86	0.28	0.060	3.07
		56.08	0.18	0.061	2.99
		75.29	0.16	0.067	2.95
		94.51	0.16	0.174	2.86
		113.73	0.18	0.228	2.80
	TOP	17.64	0.38	0.028	3.12
		36.86	0.30	0.065	3.02
		56.08	0.14	0.064	3.01
		75.29	0.05	0.109	2.99
		94.51	0.07	0.152	3.03
		113.73	0.09	0.248	3.14
2.55 kg/l	OFF	0	0.40	0.061	3.21
	BOTTOM	17.64	0.36	0.038	3.19
		36.86	0.30	0.022	3.16
		56.08	0.27	0.021	3.12
		75.29	0.29	0.083	3.07
		94.51	0.21	0.125	2.92
		113.73	0.28	0.099	2.95
	MIDDLE	17.64	0.36	0.028	3.19
		36.86	0.28	0.015	3.12
		56.08	0.18	0.014	3.12
		75.29	0.17	0.039	3.10
		94.51	0.16	0.058	3.09
		113.73	0.17	0.212	2.93
	TOP	17.64	0.37	0.037	3.18
		36.86	0.28	0.016	3.11
		56.08	0.10	0.029	3.11
		75.29	0.03	0.080	3.11
		94.51	0.06	0.162	3.22
		113.73	0.10	0.421	3.278

DETAILED RESULTS OF 1996 MAGNETIC CYCLONE TEST PROGRAM

270D FESI

Inlet Density	Magnet Position	UF density	UF density	UF density	OF density	OF density	OF density	TRACERS RECOVERED IN OVERFLOW									TRACERS RECOVERED IN UNDERFLOW								
								2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5
2.35	Off	2.735	2.729	2.732	2.294	2.309	2.315	20	16	-	10	-	0	0	0	0	0	2	-	9	-	20	20	20	20
2.35	Off	2.78	2.785	2.79	2.31	2.315	2.31	18	19	17	18	-	3	0	0	0	1	0	1	1	-	12	20	18	18
2.35	Off	2.79	2.78	2.78	2.32	2.33	2.32	20	19	19	20	-	2	0	0	0	0	1	1	0	-	16	19	20	20
2.35	Off	2.77	2.78	2.79	2.31	2.32	2.315	20	19	19	17	-	1	0	0	0	0	1	0	3	-	16	20	20	22
2.35	Off	2.79	2.79	2.79	2.31	2.315	2.32	19	20	19	19	-	3	0	0	0	0	0	1	1	-	14	20	20	21
2.45	Off	2.85	2.86	2.84	2.4	2.41	2.405	20	20	19	17	7	3	1	0	0	0	0	1	2	13	16	19	20	20
2.45	Off	2.85	2.84	2.85	2.42	2.41	2.41	20	20	20	19	11	10	0	0	0	0	0	0	0	9	9	19	20	20
2.45	Off	2.84	2.84	2.86	2.42	2.42	2.425	19	20	18	19	16	5	2	0	0	0	0	1	1	3	18	17	19	18
2.45	Off	2.855	2.858	2.85	2.42	2.42	2.41	20	19	19	19	17	7	0	1	0	0	0	0	1	3	16	18	17	19
2.55	Off	2.91	2.92	2.91	2.515	2.518	2.502	19	19	19	20	18	12	5	0	1	0	0	0	0	1	7	14	18	18
2.55	Off	2.935	2.912	2.918	2.535	2.535	2.53	20	16	19	18	17	9	2	0	0	0	0	0	0	1	7	17	17	19
2.55	Off	2.91	2.915	2.925	2.53	2.53	2.52	19	19	20	21	18	11	7	1	0	0	0	0	0	1	9	10	18	20
2.55	Off	2.918	2.91	2.91	2.525	2.515	2.52	19	19	20	21	17	7	5	2	0	0	0	0	1	1	11	14	17	20
2.35	Off	2.74	2.755	2.74	2.305	2.31	2.31	20	19	19	18	13	1	1	0	0	0	1	0	2	7	19	19	20	20
2.35	Off	2.75	2.75	2.74	2.31	2.305	2.3	19	20	18	20	12	2	0	0	0	0	0	2	0	8	18	20	20	20
2.35	Off	2.76	2.75	2.75	2.3	2.3	2.3	19	19	18	19	19	2	2	1	0	0	1	2	1	1	17	16	18	20
2.35	Off	2.75	2.755	2.75	2.31	2.3	2.295	19	20	19	16	18	4	1	0	0	0	0	1	1	1	16	17	19	20
2.35	Off	2.75	2.755	2.755	2.3	2.3	2.295	19	20	18	17	17	5	1	0	0	0	0	2	2	2	15	15	19	17
2.35	Off	2.735	2.74	2.74	2.3	2.29	2.29	19	19	20	20	18	5	0	0	0	0	1	0	0	2	16	19	19	20
2.35	Off	2.74	2.745	2.75	2.295	2.3	2.28	19	18	20	19	16	5	0	0	0	0	1	0	1	4	16	20	20	19
2.45	Off	2.815	2.815	2.82	2.4	2.405	2.395	18	19	20	16	17	7	3	0	0	0	0	0	1	3	13	12	20	20
2.45	Off	2.825	2.82	2.82	2.415	2.41	2.41	20	18	20	19	19	4	4	0	0	0	2	0	0	1	16	12	20	20
2.45	Off	2.82	2.835	2.835	2.415	2.415	2.4	19	19	20	19	16	3	3	2	0	0	0	0	1	3	17	17	18	19
2.45	Off	2.83	2.84	2.83	2.415	2.415	2.41	19	20	20	20	17	4	2	1	0	0	0	0	0	2	16	18	19	20
2.45	Off	2.84	2.825	2.835	2.415	2.41	2.405	19	18	19	19	15	6	2	0	0	0	2	1	1	4	14	17	20	20
2.45	Off	2.825	2.82	2.82	2.405	2.41	2.405	20	20	19	20	15	3	1	0	0	0	0	1	0	4	18	19	20	19
2.45	Off	2.82	2.82	2.82	2.42	2.415	2.41	20	20	19	20	17	7	1	1	0	0	0	0	0	3	13	19	19	19
2.55	Off	2.92	2.91	2.91	2.51	2.49	2.505	20	20	20	19	16	9	2	2	1	0	0	0	1	4	11	18	18	19
2.55	Off	2.89	2.89	2.905	2.5	2.5	2.5	20	20	20	19	17	8	3	2	0	0	0	0	1	3	13	17	19	20
2.55	Off	2.91	2.905	2.915	2.505	2.5	2.5	16	20	17	19	19	9	5	2	0	0	0	0	0	1	10	14	18	18
2.55	Off	2.91	2.91	2.91	2.505	2.5	2.5	16	19	18	19	18	8	9	0	0	0	0	0	0	2	9	10	20	15
2.55	Off	2.92	2.905	2.91	2.495	2.5	2.49	16	19	18	19	19	10	7	3	1	0	0	0	0	1	9	12	17	18
2.55	Off	2.92	2.925	2.925	2.515	2.525	2.52	20	18	19	18	20	11	7	2	0	0	0	0	1	0	9	12	18	20
2.55	Off	2.91	2.91	2.92	2.515	2.515	2.51	20	19	18	19	19	8	4	2	0	0	0	0	1	1	10	16	18	20
2.45	Off	2.81	2.8	2.79	2.405	2.4	2.4	20	20	20	19	17	6	4	1	0	0	0	0	1	3	14	16	19	19
2.45	Off	2.64	2.61	2.62	2.42	2.42	2.425	20	18	19	18	17	2	1	1	0	0	1	1	2	3	20	17	19	19
2.45	Off	2.625	2.61	2.615	2.45	2.44	2.43	20	20	17	17	17	4	3	0	0	0	0	3	3	3	16	17	20	20
2.45	Off	2.595	2.605	2.595	2.435	2.45	2.435	20	19	19	19	17	2	1	0	0	0	0	1	1	3	18	19	20	20
2.45	Off	2.6	2.6	2.595	2.445	2.44	2.435	19	19	19	19	16	2	0	1	0	0	1	1	1	4	20	18	19	20
2.45	Off	2.82	2.81	2.8	2.42	2.43	2.42	19	18	19	20	18	6	3	0	0	0	0	1	0	2	15	16	20	20
2.45	Off	2.64	2.64	2.65	2.44	2.42	2.435	19	17	20	20	18	8	2	0	0	0	0	1	0	2	14	16	20	20
2.45	Off	2.635	2.63	2.62	2.445	2.45	2.445	19	17	21	19	19	4	2	1	0	0	0	0	0	1	18	16	19	20
2.45	Off	2.595	2.61	2.6	2.45	2.45	2.45	19	17	21	17	17	1	1	2	0	0	0	0	2	3	21	17	18	20
2.45	Off	2.615	2.605	2.59	2.465	2.47	2.45	18	17	16	16	16	2	0	0	0	0	0	0	2	2	20	18	20	20
2.45	Off	2.79	2.805	2.79	2.415	2.415	2.41	20	20	20	20	17	6	6	0	0	0	0	0	1	5	15	15	20	20
2.45	Off	2.645	2.645	2.635	2.42	2.42	2.425	21	17	24	20	20	6	2	0	0	0	4	0	1	2	17	17	19	20
2.45	Off	2.61	2.6	2.61	2.44	2.445	2.43	21	20	23	19	20	6	2	0	0	0	0	0	1	2	15	17	19	21
2.45	Off	2.57	2.6	2.59	2.44	2.43	2.435	21	19	24	17	19	4	0	0	0	0	2	0	4	3	19	19	19	20
2.45	Off	2.6	2.575	2.6	2.45	2.45	2.45	21	18	24	17	19	2	1	1	0	0	3	0	3	3	20	18	18	20

2.35	Top	1	2.695	2.681	2.68	2.315	2.31	2.305	18	13	-	4	-	0	0	0	0	1	6	-	15	-	20	20	20	20
2.35	Top	2	2.59	2.589	2.59	2.34	2.315	2.33	18	6	-	0	-	0	0	0	0	1	13	-	19	-	20	20	20	20
2.35	Top	3	2.44	2.43	2.439	2.37	2.37	2.37	16	3	-	0	-	0	0	0	0	2	17	-	19	-	20	20	20	20
2.35	Top	4	2.38	2.38	2.39	2.37	2.37	2.369	14	6	3	4	-	0	0	0	0	6	14	17	16	-	20	19	20	20
2.35	Top	5	2.42	2.41	2.42	2.355	2.36	2.362	15	8	3	2	-	1	0	1	0	5	12	17	17	-	19	20	19	20
2.35	Top	6	2.495	2.485	2.49	2.33	2.33	2.32	14	6	4	9	-	0	0	1	1	6	13	16	10	-	20	20	19	20
2.45	Top	1	2.815	2.82	2.81	2.425	2.415	2.42	20	19	21	17	11	5	0	1	0	0	0	1	2	6	16	20	18	19
2.45	Top	2	2.775	2.778	2.78	2.44	2.43	2.43	20	20	18	13	5	0	0	0	0	0	0	3	6	13	18	20	18	20
2.45	Top	3	2.66	2.662	2.655	2.465	2.46	2.465	20	19	17	16	1	0	0	0	0	0	1	2	3	16	19	20	19	19
2.45	Top	4	2.57	2.56	2.57	2.48	2.47	2.475	19	18	10	10	0	0	0	0	0	0	3	8	9	17	19	22	19	18
2.45	Top	5	2.525	2.52	2.52	2.485	2.485	2.48	19	15	14	11	7	2	1	0	1	0	4	6	8	11	18	18	20	18
2.45	Top	6	2.53	2.54	2.545	2.475	2.472	2.478	19	18	13	13	12	2	3	4	0	2	4	7	7	7	18	18	14	19
2.55	Top	1	2.91	2.89	2.88	2.54	2.535	2.54	20	20	18	19	17	6	3	1	0	0	0	0	0	2	10	17	17	19
2.55	Top	2	2.85	2.86	2.855	2.551	2.54	2.55	20	19	17	18	14	2	0	1	0	0	0	2	1	5	16	18	17	19
2.55	Top	3	2.705	2.715	2.71	2.58	2.575	2.568	19	20	15	15	12	1	1	0	0	0	0	3	5	8	18	19	20	20
2.55	Top	4	2.635	2.638	2.64	2.6	2.585	2.585	19	18	18	12	9	1	0	1	0	0	0	1	7	10	18	20	19	19
2.55	Top	5	2.605	2.6	2.59	2.59	2.59	2.585	19	-	12	16	16	4	6	5	4	1	-1	5	4	4	17	12	15	15
2.55	Top	6	2.685	2.67	2.67	2.58	2.58	2.58	12	13	14	13	12	6	5	5	2	7	6	5	7	7	12	12	15	17
2.35	Top	1	2.72	2.72	2.715	2.315	2.31	2.31	20	17	16	14	7	0	0	0	0	0	3	3	6	13	20	20	20	20
2.35	Top	2	2.65	2.645	2.65	2.345	2.34	2.335	20	7	11	3	1	0	0	0	0	0	13	9	17	20	20	19	20	20
2.35	Top	3	2.49	2.5	2.5	2.34	2.345	2.34	20	4	4	3	1	0	0	0	0	0	16	16	17	20	20	20	20	19
2.35	Top	4	2.41	2.41	2.41	2.47	2.355	2.36	17	5	6	3	1	2	1	1	0	3	15	14	17	19	17	19	19	20
2.35	Top	5	2.42	2.415	2.41	2.36	2.36	2.35	16	7	9	8	4	1	1	0	0	3	13	11	12	16	19	19	20	20
2.35	Top	6	2.51	2.51	2.51	2.35	2.34	2.35	13	10	10	12	5	3	1	1	0	6	8	10	6	15	16	19	18	19
2.35	Top	1	2.67	2.68	2.68	2.32	2.31	2.3	19	17	20	17	13	0	0	0	0	0	3	0	2	6	20	20	19	17
2.35	Top	2	2.63	2.625	2.61	2.34	2.34	2.315	19	-	16	13	4	1	0	0	0	0	-	4	6	16	16	20	20	20
2.35	Top	3	2.475	2.47	2.48	2.35	2.34	2.34	18	-	10	2	1	1	0	0	0	1	-	10	17	18	20	20	20	20
2.35	Top	4	2.425	2.42	2.41	2.37	2.36	2.355	19	-	12	5	1	0	0	0	0	0	-	8	14	19	20	20	20	20
2.35	Top	5	2.41	2.4	2.405	2.37	2.375	2.375	16	11	10	6	2	4	0	0	0	2	8	10	13	18	16	20	20	20
2.35	Top	6	2.5	2.505	2.52	2.35	2.345	2.34	11	-1	12	10	8	1	0	1	0	8	-	8	10	12	20	20	19	20
2.45	Top	1	2.78	2.79	2.79	2.42	2.42	2.41	19	18	18	18	13	1	0	0	0	0	2	1	1	7	18	16	19	20
2.45	Top	2	2.72	2.72	2.715	2.43	2.43	2.43	19	-	17	15	5	0	0	0	0	0	-	2	4	15	20	15	19	20
2.45	Top	3	2.57	2.565	2.57	2.45	2.445	2.455	18	-	12	13	4	0	0	0	0	0	-	7	6	16	20	16	19	20
2.45	Top	4	2.5	2.485	2.5	2.47	2.46	2.46	18	-	12	13	8	1	1	0	0	0	-	8	7	12	19	17	19	18
2.45	Top	5	2.54	2.52	2.53	2.465	2.44	2.44	16	14	13	8	9	5	0	1	2	4	6	7	12	11	15	19	18	18
2.45	Top	6	2.54	2.545	2.54	2.46	2.45	2.445	18	14	13	11	14	7	3	6	2	2	6	7	9	6	13	15	14	18
2.45	Top	1	2.81	2.8	2.81	2.425	2.415	2.42	17	19	17	17	13	1	0	0	0	0	0	0	0	7	18	20	19	17
2.45	Top	2	2.695	2.69	2.69	2.43	2.425	2.43	18	-	13	9	6	0	0	1	0	0	-	7	11	14	20	20	19	19
2.45	Top	3	2.55	2.55	2.56	2.46	2.46	2.455	18	-	11	11	4	0	0	1	0	0	-	9	9	16	20	18	19	19
2.45	Top	4	2.5	2.5	2.5	2.46	2.48	2.46	16	-	12	12	6	3	1	0	0	2	-	8	8	14	17	17	20	18
2.45	Top	5	2.54	2.55	2.54	2.46	2.465	2.46	19	13	12	12	12	5	1	1	0	0	7	8	8	7	16	19	18	19
2.45	Top	6	2.57	2.56	2.56	2.46	2.46	2.455	13	17	14	14	12	4	10	7	8	7	3	5	6	7	16	10	12	11
2.55	Top	1	2.89	2.885	2.88	2.51	2.505	2.51	20	20	18	20	16	5	4	0	0	0	0	0	0	4	15	16	20	20
2.55	Top	2	2.77	2.75	2.75	2.52	2.53	2.525	20	16	18	17	12	0	1	1	0	0	4	1	3	9	20	19	20	20
2.55	Top	3	2.62	2.61	2.61	2.55	2.55	2.55	20	15	13	17	11	0	0	0	0	0	5	6	3	11	20	19	20	20
2.55	Top	4	2.56	2.575	2.565	2.56	2.55	2.55	19	-	17	15	10	7	2	2	2	1	-	3	5	10	13	17	19	18
2.55	Top	5	2.665	2.655	2.655	2.545	2.52	2.55	19	15	17	14	15	7	5	6	0	1	5	3	6	5	13	14	14	20
2.55	Top	6	2.65	2.63	2.64	2.55	2.545	2.55	12	16	19	15	12	10	12	10	8	7	4	1	5	9	10	7	10	12
2.55	Top	1	2.91	2.91	2.9	2.53	2.53	2.515	20	20	20	19	19	7	4	1	0	0	0	0	1	0	13	16	17	18
2.55	Top	2	2.85	2.83	2.84	2.54	2.535	2.53	20	18	19	19	17	0	0	2	0	0	0	0	0	2	20	19	16	18
2.55	Top	3	2.68	2.665	2.665	2.555	2.555	2.565	20	18	19	19	15	1	1	2	0	0	0	0	1	5	20	19	18	19
2.55	Top	4	2.605	2.6	2.61	2.58	2.58	2.56	19	14	19	16	16	5	2	3	2	0	2	2	4	4	15	18	17	17
2.55	Top	5	2.6	2.64	2.62	2.57	2.565	2.57	19	-	18	15	14	11	5	7	0	1	-	2	5	6	8	15	11	19
2.55	Top	6	2.665	2.665	2.67	2.56	2.56	2.54	13	-	14	15	11	10	11	8	5	7	-	5	4	9	9	10	12	15
2.35	Middle	1	2.673	2.675	2.678	2.34	2.34	2.342	17	18	17	12	-	0	0	0	0	0	1	3	8	-	20	20	20	17

2.35	Middle	2	2.61	2.6	2.6	2.35	2.352	2.36	19	13	4	1	-	0	0	0	0	0	7	16	19	-	20	20	20	20
2.35	Middle	3	2.525	2.513	2.525	2.38	2.38	2.385	17	8	1	0	-	0	0	0	0	1	11	19	20	-	20	20	20	19
2.35	Middle	4	2.55	2.55	2.548	2.37	2.37	2.38	13	3	1	0	-	0	0	0	0	6	17	19	20	-	20	19	19	19
2.35	Middle	5	2.51	2.51	2.51	2.36	2.352	2.355	15	3	3	0	-	1	0	0	0	4	16	17	20	-	18	20	19	21
2.35	Middle	6	2.58	2.595	2.585	2.33	2.35	2.34	11	-	8	6	-	0	0	0	0	8	-	12	14	-	19	20	19	20
2.45	Middle	1	2.81	2.835	2.815	2.43	2.44	2.44	17	18	20	16	12	4	3	0	0	0	0	0	3	6	16	15	18	20
2.45	Middle	2	2.75	2.75	2.76	2.47	2.465	2.46	17	20	19	16	7	1	0	0	0	0	0	1	3	11	20	19	18	20
2.45	Middle	3	2.68	2.68	2.67	2.47	2.47	2.47	16	20	19	14	2	0	0	0	0	0	0	0	5	17	18	22	18	20
2.45	Middle	4	2.61	2.62	2.61	2.47	2.47	2.47	17	16	16	12	1	1	1	0	0	0	2	1	7	18	20	18	19	18
2.45	Middle	5	2.61	2.625	2.625	2.46	2.461	2.47	17	13	11	4	2	0	0	1	0	3	5	9	15	18	20	20	18	20
2.45	Middle	6	2.605	2.595	2.59	2.455	2.445	2.455	14	9	8	7	6	1	0	0	0	5	9	12	12	13	20	19	19	19
2.55	Middle	1	2.9	2.9	2.91	2.54	2.54	2.545	19	19	19	18	16	7	4	0	2	0	0	0	0	3	12	12	20	17
2.55	Middle	2	2.84	2.85	2.855	2.555	2.555	2.56	18	18	18	16	16	1	0	0	1	0	0	1	0	4	18	19	20	19
2.55	Middle	3	2.775	2.765	2.765	2.58	2.58	2.57	19	20	19	16	17	1	0	0	0	0	0	0	1	3	18	20	20	19
2.55	Middle	4	2.745	2.73	2.73	2.57	2.565	2.565	19	20	16	14	10	1	0	0	0	0	0	3	1	9	17	21	20	19
2.55	Middle	5	2.74	2.75	2.735	2.58	2.58	2.575	17	16	15	12	11	2	1	1	0	0	3	4	3	9	17	19	19	19
2.55	Middle	6	2.71	2.7	2.71	2.57	2.55	2.56	17	19	15	8	5	4	0	0	0	3	0	5	12	15	16	20	20	20
2.35	Middle	1	2.68	2.685	2.7	2.33	2.32	2.32	18	20	19	17	16	1	0	0	0	0	0	1	1	4	19	19	18	20
2.35	Middle	2	2.615	2.605	2.59	2.335	2.335	2.34	18	-	17	9	4	1	0	0	0	0	-	3	9	16	18	20	19	20
2.35	Middle	3	2.535	2.55	2.45	2.36	2.36	2.355	18	-	16	7	5	1	0	0	0	0	-	4	12	15	19	20	19	20
2.35	Middle	5	2.535	2.54	2.54	2.35	2.34	2.34	19	-	7	3	1	0	0	0	0	1	-	13	16	19	20	19	19	20
2.35	Middle	6	2.525	2.52	2.535	2.33	2.34	2.34	15	-	8	2	0	0	0	0	0	4	-	12	17	19	20	20	19	18
2.35	Middle	1	2.705	2.68	2.69	2.315	2.325	2.32	18	18	19	18	18	2	0	0	0	0	1	0	1	2	15	20	20	17
2.35	Middle	3	2.515	2.5	2.52	2.355	2.35	2.35	19	-	11	7	2	0	0	0	0	0	-	8	12	19	19	20	20	20
2.35	Middle	4	2.495	2.51	2.5	2.34	2.34	2.35	19	-	9	4	1	1	0	0	0	0	-	10	15	20	17	20	20	20
2.35	Middle	5	2.55	2.54	2.53	2.34	2.34	2.32	15	-	8	7	0	1	0	0	0	4	-	10	12	21	18	20	18	20
2.35	Middle	6	2.575	2.565	2.565	2.32	2.31	2.305	14	-	9	8	3	1	0	1	0	5	-	10	11	17	19	20	18	20
2.45	Middle	1	2.75	2.77	2.75	2.425	2.41	2.415	20	18	19	16	14	0	2	0	0	0	2	1	4	6	20	17	20	20
2.45	Middle	2	2.7	2.69	2.7	2.435	2.435	2.43	20	-	15	12	8	0	0	0	0	0	-	5	8	11	20	19	19	20
2.45	Middle	3	2.615	2.6	2.61	2.45	2.45	2.445	20	-	13	12	4	0	0	0	0	0	-	7	8	15	20	19	19	20
2.45	Middle	4	2.615	2.61	2.61	2.445	2.45	2.45	20	-	11	9	1	0	0	0	0	0	-	8	11	18	20	20	20	19
2.45	Middle	5	2.59	2.58	2.59	2.43	2.43	2.43	13	-	8	10	4	1	0	0	0	7	-	9	10	15	19	19	19	20
2.45	Middle	1	2.77	2.76	2.76	2.425	2.425	2.415	17	20	18	17	16	1	0	0	0	0	0	2	3	3	19	18	19	19
2.45	Middle	2	2.7	2.71	2.71	2.44	2.43	2.43	19	14	14	16	9	0	0	0	0	0	6	5	4	10	18	19	19	18
2.45	Middle	3	2.615	2.63	2.62	2.45	2.45	2.44	19	-	13	8	2	0	1	0	0	0	-	7	12	15	20	18	19	19
2.45	Middle	4	2.62	2.615	2.615	2.44	2.435	2.44	18	-	9	7	2	0	0	0	0	1	-	11	13	16	20	19	19	19
2.45	Middle	5	2.6	2.6	2.62	2.43	2.44	2.43	13	7	10	9	8	1	1	0	0	5	13	10	11	11	19	18	19	19
2.45	Middle	6	2.64	2.64	2.64	2.435	2.435	2.435	11	-	9	8	7	2	0	2	0	8	-	11	12	12	18	19	17	19
2.55	Middle	1	2.86	2.86	2.86	2.52	2.51	2.515	18	20	19	20	19	6	0	0	0	0	0	0	0	2	13	18	20	18
2.55	Middle	2	2.8	2.81	2.79	2.53	2.55	2.54	19	20	19	18	14	1	0	0	0	0	0	0	2	7	19	19	20	20
2.55	Middle	3	2.72	2.705	2.71	2.55	2.54	2.55	19	17	16	16	15	0	0	0	0	0	3	3	4	6	20	19	20	20
2.55	Middle	4	2.7	2.71	2.71	2.54	2.53	2.54	20	15	16	15	8	0	0	0	0	0	4	4	5	13	20	19	20	20
2.55	Middle	5	2.705	2.71	2.72	2.53	2.535	2.54	16	-	-1	15	8	3	4	0	0	3	-	-1	5	13	17	15	20	18
2.55	Middle	6	2.71	2.71	2.71	2.54	2.53	2.53	-1	-	12	7	6	2	5	1	1	-1	-	7	13	14	17	13	19	18
2.55	Middle	1	2.9	2.89	2.9	2.53	2.53	2.53	20	20	20	19	20	5	1	0	0	0	0	0	1	0	15	19	19	19
2.55	Middle	2	2.81	2.81	2.83	2.545	2.54	2.54	20	19	20	18	18	1	1	1	0	0	1	0	2	2	19	19	18	19
2.55	Middle	3	2.73	2.725	2.73	2.545	2.55	2.55	20	20	18	17	18	0	0	0	0	0	0	2	3	2	20	20	20	19
2.55	Middle	4	2.72	2.715	2.72	2.56	2.555	2.55	20	12	14	16	14	1	0	0	0	0	7	6	4	6	20	20	20	19
2.55	Middle	5	2.7	2.69	2.71	2.55	2.55	2.55	18	14	16	15	10	0	0	0	0	2	6	3	5	9	19	20	20	19
2.55	Middle	6	2.715	2.705	2.71	2.53	2.52	2.53	12	-	7	10	10	3	6	1	0	7	-	12	10	10	16	14	19	19
2.35	Bottom	1	2.71	2.7	2.71	2.32	2.32	2.318	19	18	19	14	-1	1	0	0	0	0	1	1	6	-	18	20	19	19
2.35	Bottom	2	2.67	2.662	2.655	2.34	2.335	2.335	19	18	18	9	-1	0	0	0	0	0	2	1	11	-1	19	20	19	20
2.35	Bottom	3	2.64	2.64	2.63	2.35	2.34	2.36	19	10	6	7	-	0	0	0	0	0	9	11	13	-	19	19	19	20
2.35	Bottom	4	2.515	2.525	2.515	2.36	2.35	2.355	17	6	3	0	-	0	0	0	0	2	13	16	20	-	20	19	19	20
2.35	Bottom	5	2.63	2.62	2.62	2.31	2.31	2.32	11	2	0	0	-	0	0	0	0	8	17	18	20	-	17	20	19	20

2.35	Bottom	6	2.75	2.75	2.75	2.24	2.25	2.24	12	1	0	0	-	0	0	0	0	7	18	18	19	-	18	19	17	19
2.35	Bottom	7	2.75	2.76	2.74	2.2	2.205	2.215	13	1	1	0	-	0	0	0	0	8	19	19	19	-	20	20	20	21
2.45	Bottom	1	2.83	2.815	2.81	2.42	2.42	2.43	19	18	20	19	8	6	0	0	0	0	0	0	0	12	14	19	19	20
2.45	Bottom	2	2.765	2.77	2.765	2.45	2.443	2.44	19	20	19	15	6	3	0	0	0	0	0	0	3	14	16	20	19	19
2.45	Bottom	3	2.74	2.74	2.74	2.45	2.434	2.44	20	19	17	18	3	1	0	0	0	0	1	3	2	16	19	19	18	20
2.45	Bottom	4	2.73	2.73	2.73	2.42	2.42	2.425	19	16	13	5	2	0	0	0	0	0	4	7	15	18	19	18	18	20
2.45	Bottom	5	2.65	2.64	2.63	2.46	2.44	2.45	16	6	6	4	1	1	1	0	0	2	14	14	16	17	19	19	18	19
2.45	Bottom	6	2.71	2.72	2.71	2.4	2.42	2.415	15	7	3	2	1	0	0	0	0	2	11	17	18	16	20	16	18	19
2.55	Bottom	1	2.9	2.91	2.905	2.543	2.535	2.532	20	19	20	17	18	6	4	1	1	0	0	0	2	2	12	16	19	20
2.55	Bottom	2	2.845	2.855	2.84	2.547	2.54	2.545	20	19	19	18	19	3	1	0	0	0	0	1	1	1	16	18	20	20
2.55	Bottom	3	2.83	2.835	2.82	2.543	2.545	2.54	20	18	20	17	17	2	0	0	0	0	0	0	2	3	19	18	20	20
2.55	Bottom	4	2.82	2.8	2.79	2.54	2.55	2.54	20	18	20	14	10	2	0	0	0	0	0	0	5	10	17	19	19	20
2.55	Bottom	5	2.73	2.712	2.71	2.555	2.55	2.55	18	15	13	12	4	0	0	0	0	1	4	7	10	15	18	20	20	20
2.55	Bottom	6	2.76	2.745	2.75	2.53	2.535	2.525	18	16	15	14	4	0	0	0	0	0	3	5	8	15	19	18	19	20
2.35	Bottom	1	2.715	2.7	2.705	2.31	2.31	2.3	20	19	20	17	16	2	0	0	0	0	0	0	2	4	18	20	19	20
2.35	Bottom	2	2.635	2.63	2.645	2.34	2.32	2.32	20	19	18	16	13	1	0	0	0	0	0	2	4	7	19	20	19	20
2.35	Bottom	3	2.61	2.61	2.6	2.34	2.325	2.33	19	-	18	10	8	0	0	0	0	0	-	1	10	12	19	20	20	20
2.35	Bottom	4	2.65	2.65	2.66	2.33	2.32	2.31	19	6	7	4	2	0	1	0	0	1	14	13	16	18	19	19	19	20
2.35	Bottom	5	2.55	2.55	2.54	2.32	2.315	2.32	16	2	2	1	1	0	0	0	0	3	19	18	19	19	19	20	20	20
2.35	Bottom	6	2.61	2.61	2.62	2.29	2.285	2.28	13	1	1	1	0	1	0	0	0	6	18	18	19	20	18	19	20	20
2.35	Bottom	1	2.675	2.685	2.685	2.325	2.31	2.31	19	20	20	20	18	1	2	0	0	0	0	0	0	1	18	16	17	20
2.35	Bottom	2	2.625	2.62	2.61	2.33	2.32	2.32	19	19	19	17	15	0	0	1	0	0	1	1	3	4	16	18	18	20
2.35	Bottom	3	2.605	2.6	2.605	2.335	2.335	2.32	18	-	14	10	3	0	0	0	0	0	-	6	9	16	17	19	19	20
2.35	Bottom	4	2.66	2.65	2.655	2.34	2.34	2.335	19	-	8	4	4	3	4	0	0	0	-	12	15	15	15	15	16	16
2.35	Bottom	5	2.565	2.57	2.57	2.32	2.31	2.3	12	2	3	1	0	1	0	0	0	7	18	17	19	19	18	19	18	17
2.35	Bottom	6	2.65	2.63	2.64	2.27	2.25	2.24	7	1	0	0	0	0	0	0	0	12	19	20	20	19	19	17	20	17
2.45	Bottom	1	2.775	2.785	2.775	2.4	2.41	2.405	20	20	17	20	15	4	0	0	0	0	0	2	0	5	16	20	19	20
2.45	Bottom	2	2.735	2.72	2.73	2.42	2.42	2.43	20	17	14	14	14	0	0	0	0	0	3	6	6	5	20	20	20	20
2.45	Bottom	3	2.695	2.685	2.7	2.435	2.43	2.425	19	-	12	10	6	0	0	0	0	1	-	8	10	13	20	20	20	20
2.45	Bottom	4	2.715	2.735	2.72	2.43	2.415	2.42	18	-	7	6	2	0	0	0	0	2	-	13	14	17	20	20	20	20
2.45	Bottom	5	2.645	2.645	2.64	2.415	2.4	2.405	15	3	3	4	0	0	0	0	0	4	17	17	16	19	20	20	20	19
2.45	Bottom	6	2.68	2.685	2.69	2.405	2.41	2.4	5	-	4	3	1	0	0	0	0	15	-	16	17	18	20	19	20	20
2.45	Bottom	1	2.785	2.78	2.78	2.425	2.42	2.42	19	20	20	19	15	2	3	0	0	0	0	0	1	4	18	16	20	20
2.45	Bottom	2	2.745	2.72	2.72	2.43	2.425	2.415	19	19	19	20	12	2	0	0	0	0	1	1	0	7	18	20	20	20
2.45	Bottom	3	2.695	2.69	2.69	2.43	2.42	2.425	19	13	13	11	4	4	2	0	0	0	4	5	5	15	13	17	16	13
2.45	Bottom	4	2.72	2.71	2.715	2.42	2.42	2.4	18	-	9	7	2	0	0	0	0	2	-	11	13	17	19	20	19	17
2.45	Bottom	5	2.65	2.65	2.65	2.42	2.41	2.4	9	5	4	3	1	0	0	0	0	10	15	16	17	18	20	20	19	19
2.45	Bottom	6	2.7	2.69	2.7	2.42	2.405	2.405	11	2	1	3	0	0	0	0	0	8	18	20	17	19	20	20	19	19
2.55	Bottom	1	2.86	2.86	2.86	2.5	2.505	2.5	19	19	20	20	19	5	1	1	1	0	1	0	0	1	16	19	19	19
2.55	Bottom	2	2.81	2.8	2.82	2.515	2.51	2.505	19	20	20	18	16	3	0	0	0	0	0	0	1	4	19	20	20	20
2.55	Bottom	3	2.79	2.785	2.785	2.53	2.53	2.53	19	-	14	15	12	0	0	0	0	0	-	5	3	8	21	21	18	20
2.55	Bottom	4	2.815	2.8	2.81	2.52	2.515	2.5	18	-	15	10	10	1	0	1	0	0	-	5	9	10	20	21	19	20
2.55	Bottom	5	2.74	2.74	2.74	2.5	2.5	2.495	16	9	6	7	6	0	0	0	0	2	11	14	12	13	21	21	20	19
2.55	Bottom	6	2.77	2.775	2.77	2.47	2.45	2.46	15	-	8	8	5	0	0	0	1	3	-1	12	11	14	20	20	20	19
2.55	Bottom	1	2.895	2.86	2.875	2.52	2.505	2.505	16	19	18	19	20	8	7	1	0	0	0	0	0	0	11	12	18	19
2.55	Bottom	2	2.81	2.815	2.815	2.52	2.515	2.515	16	19	18	18	18	3	2	2	1	0	0	0	1	2	16	17	17	18
2.55	Bottom	3	2.8	2.8	2.8	2.52	2.515	2.52	16	17	16	15	16	0	1	0	0	0	2	2	4	4	19	18	19	19
2.55	Bottom	4	2.82	2.84	2.83	2.52	2.52	2.515	15	14	15	12	10	1	1	0	0	1	4	4	6	10	18	18	19	19
2.55	Bottom	5	2.75	2.76	2.76	2.53	2.52	2.51	13	-	8	8	7	0	0	0	0	3	-	8	10	12	18	19	19	19
2.55	Bottom	6	2.79	2.775	2.79	2.5	2.49	2.48	16	-	11	7	4	0	1	0	0	0	-	7	12	16	19	18	19	19

DETAILED RESULTS OF 1998 MAGNETIC CYCLONE TEST PROGRAM

270D FESI

BASE LINE TESTS - WITHOUT MAGNETIC FIELD

SOLENOID SETTING: 0 A

TEST 1 - WITH CLAY ORE

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.6	2.61	2.63	=	2.61		
FESI INLET DENSITY	- AUTO	kg/l	2.62	2.6	2.61	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.22	3.2	3.21	=	3.21		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.68	2.7	2.72	=	2.70		
TAILINGS MASS	- MANUAL	kg	109						
CONCENTRATE MASS	- MANUAL	kg	0.32	0.245					
Ep			0.05						
CUT POINT DENSITY			3.17						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.29	0.22					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	7	5	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	3	5	10	10	10
% TO CONCENTRATE			0	0	30	50	100	100	100

TEST 2 - WITH CLAY ORE

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.59	2.6	2.6	=	2.60		
FESI INLET DENSITY	- AUTO	kg/l	2.6	2.61	2.59	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.14	3.18	3.16	=	3.16		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.64	2.68	2.7	=	2.67		
TAILINGS MASS	- MANUAL	kg	133						
CONCENTRATE MASS	- MANUAL	kg	0.245	0.18					
Ep			0.04						
CUT POINT DENSITY			3.20						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.18	0.14					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	9	5	1	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	1	5	9	10	10
% TO CONCENTRATE			0	0	10	50	90	100	100

TEST 3 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.6	2.64	2.63	=	2.62		
FESI INLET DENSITY	- AUTO	kg/l	2.57	2.59	2.6	=	2.59		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.35	3.32	3.37	=	3.35		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.70	2.73	2.73	=	2.72		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.03						
CUT POINT DENSITY			3.17						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	9	3	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	1	7	10	10	10
% TO CONCENTRATE			0	0	10	70	100	100	100

SOLENOID IN TOP POSITION

SOLENOID SETTING: 1 A

TEST 4 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.62	2.64	2.63	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.64	2.64	2.63	=	2.64		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.17	3.22	3.07	=	3.15		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.66	2.68	2.68	=	2.67		
TAILINGS MASS	- MANUAL	kg	115						
CONCENTRATE MASS	- MANUAL	kg	0.495	0.475					
Ep			0.04						
CUT POINT DENSITY			3.23						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.43	0.41					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	10	6	2	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	0	4	8	10	10
% TO CONCENTRATE			0	0	0	40	80	100	100

TEST 5 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.65	2.65	2.66	=	2.65		
FESI INLET DENSITY	- AUTO	kg/l	2.61	2.62	2.62	=	2.62		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.05	3	2.98	=	3.01		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.69	2.74	2.74	=	2.72		
TAILINGS MASS	- MANUAL	kg	150						
CONCENTRATE MASS	- MANUAL	kg	0.271	0.265					
Ep			0.02						
CUT POINT DENSITY			3.14						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.18	0.18					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	8	1	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	2	9	10	10	10
% TO CONCENTRATE			0	0	20	90	100	100	100

TEST 6 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.63	2.64	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.6	2.63	2.62	=	2.62		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.06	3.08	3.06	=	3.07		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.68	2.66	2.69	=	2.68		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.03						
CUT POINT DENSITY			3.18						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%							
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	9	4	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	1	6	10	10	10
% TO CONCENTRATE			0	0	10	60	100	100	100

SOLENOID SETTING: 2 A

TEST 7 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.65	2.64	2.63	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.64	2.61	2.63	=	2.63		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.83	2.87	2.86	=	2.85		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.67	2.69	2.68	=	2.68		
TAILINGS MASS	- MANUAL	kg	170						
CONCENTRATE MASS	- MANUAL	kg	0.295	0.285					
Ep			0.03						
CUT POINT DENSITY			3.18						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.17	0.17					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	9	4	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	1	6	10	10	10
% TO CONCENTRATE			0	0	10	60	100	100	100

TEST 8 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.61	2.64	2.64	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.63	2.65	2.64	=	2.64		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.9	2.91	3.11	=	2.97		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.65	2.61	2.66	=	2.64		
TAILINGS MASS	- MANUAL	kg	84						
CONCENTRATE MASS	- MANUAL	kg	0.045	0.335					
Ep			0.03						
CUT POINT DENSITY			3.13						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.05	0.40					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	7	1	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	3	9	10	10	10
% TO CONCENTRATE			0	0	30	90	100	100	100

TEST 9 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.66	2.66	=	2.65		
FESI INLET DENSITY	- AUTO	kg/l	2.65	2.62	2.64	=	2.64		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.76	2.76	2.71	=	2.74		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.67	2.67	2.67	=	2.67		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.00						
CUT POINT DENSITY			3.12						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%							
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	9	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	1	10	10	10	10
% TO CONCENTRATE			0	0	10	100	100	100	100

SOLENOID SETTING: 3 A

TEST 10 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.62	2.62	=	2.62		
FESI INLET DENSITY	- AUTO	kg/l	2.62	2.61	2.61	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.94	2.9	2.92	=	2.92		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.67	2.68	2.66	=	2.67		
TAILINGS MASS	- MANUAL	kg	156						
CONCENTRATE MASS	- MANUAL	kg	0.295	0.285					
Ep			0.04						
CUT POINT DENSITY			3.12						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.19	0.18					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	4	2	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	6	8	10	10	10
% TO CONCENTRATE			0	0	60	80	100	100	100

TEST 11 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.62	2.66	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.62	2.63	2.61	=	2.62		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.86	2.92	2.89	=	2.89		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.69	2.63	2.62	=	2.65		
TAILINGS MASS	- MANUAL	kg	82						
CONCENTRATE MASS	- MANUAL	kg	0.195	0.185					
Ep			0.01						
CUT POINT DENSITY			3.10						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.24	0.23					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	6	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	4	10	10	10	10
% TO CONCENTRATE			0	0	40	100	100	100	100

SOLENOID SETTING: 4 A

TEST 12 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.6	2.62	2.61	=	2.61		
FESI INLET DENSITY	- AUTO	kg/l	2.64	2.58	2.57	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.87	3.04	3.13	=	3.01		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.64	2.65	2.64	=	2.64		
TAILINGS MASS	- MANUAL	kg	75						
CONCENTRATE MASS	- MANUAL	kg	0.15	0.14					
Ep			0.05						
CUT POINT DENSITY			3.16						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.20	0.19					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	8	1	2	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	2	9	8	10	10
% TO CONCENTRATE			0	0	20	90	80	100	100

TEST 13 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.63	2.63	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.61	2.62	2.6	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.02	3.01	3.03	=	3.02		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.73	2.72	2.75	=	2.73		
TAILINGS MASS	- MANUAL	kg	97						
CONCENTRATE MASS	- MANUAL	kg	0.865	0.285					
Ep			0.01						
CUT POINT DENSITY			3.10						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	0.89	0.29					
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	6	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	4	10	10	10	10
% TO CONCENTRATE			0	0	40	100	100	100	100

TEST 14 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.64	2.63	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.61	2.62	2.6	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.73	2.73	2.73	=	2.73		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.6	2.59	2.59	=	2.59		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.01						
CUT POINT DENSITY			3.10						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%							
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	6	6	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	3	10	10	10	10
% TO CONCENTRATE			0	0	30	100	100	100	100

SOLENOID IN MIDDLE POSITION

SOLENOID SETTING: 1 A

TEST 15 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.64	2.65	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.61	2.62	2.61	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.88	2.82	2.91	=	2.87		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.77	2.75	=	2.75		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.01						
CUT POINT DENSITY			3.19						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	10	3	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	0	7	10	10	10
% TO CONCENTRATE			0	0	0	70	100	100	100

TEST 16 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.64	2.63	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.6	2.61	2.62	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.98	2.99	2.99	=	2.99		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.75	2.74	=	2.74		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.01						
CUT POINT DENSITY			3.20						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	10	6	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	0	4	10	10	10
% TO CONCENTRATE			0	0	0	40	100	100	100

TEST 17 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.65	2.64	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.61	2.59	2.6	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.91	2.92	2.9	=	2.91		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.73	2.72	2.73	=	2.73		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.02						
CUT POINT DENSITY			3.17						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	9	2	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	1	8	10	10	10
% TO CONCENTRATE			0	0	10	80	100	100	100

SOLENOID SETTING: 2 A

TEST 18 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.65	2.64	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.62	2.59	2.61	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.91	2.94	2.93	=	2.93		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.73	2.75	2.72	=	2.73		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.03						
CUT POINT DENSITY			3.17						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	9	3	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	1	7	10	10	10
% TO CONCENTRATE			0	0	10	70	100	100	100

TEST 19 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.64	2.63	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.59	2.6	2.61	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.98	2.99	2.98	=	2.98		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.74	2.73	=	2.74		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.01						
CUT POINT DENSITY			3.19						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	10	3	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	0	7	10	10	10
% TO CONCENTRATE			0	0	0	70	100	100	100

TEST 20 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.63	2.63	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.63	2.59	2.62	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.93	2.91	2.9	=	2.91		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.72	2.73	=	2.73		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.02						
CUT POINT DENSITY			3.14						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	8	1	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	2	9	10	10	10
% TO CONCENTRATE			0	0	20	90	100	100	100

SOLENOID SETTING: 3 A

TEST 21 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.63	2.64	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.59	2.61	2.62	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.9	2.95	2.94	=	2.93		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.76	2.73	2.75	=	2.75		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.01						
CUT POINT DENSITY			3.10						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	5	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	5	10	10	10	10
% TO CONCENTRATE			0	0	50	100	100	100	100

TEST 22 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.64	2.63	=	2.63		
FESI INLET DENSITY	- AUTO	kg/l	2.59	2.62	2.61	=	2.61		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.96	3.00	2.98	=	2.98		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.75	2.75	=	2.75		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.00						
CUT POINT DENSITY			3.15						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	10	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	0	10	10	10	10
% TO CONCENTRATE			0	0	0	100	100	100	100

TEST 23 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.64	2.64	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.61	2.59	2.6	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.88	2.90	2.91	=	2.90		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.73	2.73	2.72	=	2.73		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.03						
CUT POINT DENSITY			3.09						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	9	5	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	1	5	10	10	10	10
% TO CONCENTRATE			0	10	50	100	100	100	100

SOLENOID SETTING: 4 A

TEST 24 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.03						
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.62	2.61	=	2.62		
FESI INLET DENSITY	- AUTO	kg/l	2.59	2.6	2.62	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.91	2.90	2.89	=	2.90		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.72	2.75	=	2.74		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.01						
CUT POINT DENSITY			3.10						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	4	0	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	6	10	10	10	10
% TO CONCENTRATE			0	0	60	100	100	100	100

TEST 25 - WITH ORE FEED

SEA WATER DENSITY	- MANUAL	kg/l	1.025						
FESI INLET DENSITY	- MANUAL	kg/l	2.64	2.65	2.64	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.59	2.62	2.58	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.98	3.03	3.01	=	3.01		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.75	2.73	=	2.74		
TAILINGS MASS	- MANUAL	kg	-						
CONCENTRATE MASS	- MANUAL	kg	-						
Ep			0.03						
CUT POINT DENSITY			3.12						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	10	6	1	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	0	4	9	10	10	10
% TO CONCENTRATE			0	0	40	90	100	100	100

TEST 26 - WITH MEDIUM FEED ALONE

SEA WATER DENSITY	- MANUAL	kg/l							
FESI INLET DENSITY	- MANUAL	kg/l	2.63	2.65	2.64	=	2.64		
FESI INLET DENSITY	- AUTO	kg/l	2.62	2.59	2.6	=	2.60		
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.9	2.91	2.9	=	2.90		
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.74	2.75	2.74	=	2.74		
TAILINGS MASS	- MANUAL	kg							
CONCENTRATE MASS	- MANUAL	kg							
Ep			0.05						
CUT POINT DENSITY			3.07						
CYCLONE INLET PRESSURE	- AUTO	kPa	100						
YIELD		%	-						
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	GREEN SG = 3.1	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			10	10	10	10	10	10	10
NUMBER OF TRACERS RECOVERED ON FLOAT SCREEN			10	8	3	1	0	0	0
NUMBER OF TRACERS RECOVERED IN CONCENTRATE			0	2	7	9	10	10	10
% TO CONCENTRATE			0	20	70	90	100	100	100

DETAILED RESULTS OF 2000 MAGNETIC CYCLONE TEST PROGRAM

65D FESI

SOLENOID SETTING: 0 A

TEST 1

FESI INLET DENSITY	kg/l	2.60								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.60	3.60	3.60						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.55	2.55	2.55						
Ep		0.012								
CUT POINT DENSITY		3.21								
CYCLONE INLET PRESSURE	kPa	240								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	50	50	32	0	0	0
SINK TRACERS		0	0	0	0	0	17	50	50	50
% TO CONCENTRATE		0	0	0	0	0	34	100	100	100

TEST 2

FESI INLET DENSITY	kg/l	2.60								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.60	3.55	3.60						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.5	2.55	2.55						
Ep		0.026								
CUT POINT DENSITY		3.20								
CYCLONE INLET PRESSURE	kPa	230								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		10	10	10	1	42	29	0	0	0
SINK TRACERS		40	40	40	49	7	21	50	50	50
% TO CONCENTRATE		80	80	80	98	14	42	100	100	100

TEST 3

FESI INLET DENSITY	kg/l	2.60								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.60	3.60	3.60						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.55	2.55	2.55						
Ep		0.031								
CUT POINT DENSITY		3.23								
CYCLONE INLET PRESSURE	kPa	240								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		10	10	10	49	47	39	2	1	0
SINK TRACERS		40	40	40	1	3	11	47	49	50
% TO CONCENTRATE		80	80	80	2	6	22	94	98	100

SOLENOID SETTING: 2 A

TEST 4

FESI INLET DENSITY		kg/l	2.60								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.50	3.50	3.55						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.55	2.55	2.55						
Ep			0.021								
CUT POINT DENSITY			3.16								
CYCLONE INLET PRESSURE		kPa	240								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	46	33	5	0	0	0
SINK TRACERS			0	0	0	4	17	45	50	50	50
% TO CONCENTRATE			0	0	0	8	34	90	100	100	100

TEST 5

FESI INLET DENSITY		kg/l	2.60								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.50	2.45	2.50						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	3.45	3.45	3.4						
Ep			0.018								
CUT POINT DENSITY			3.11								
CYCLONE INLET PRESSURE		kPa	230								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	48	30	2	1	0	0	0
SINK TRACERS			0	0	2	20	48	49	50	50	50
% TO CONCENTRATE			0	0	4	40	96	98	100	100	100

TEST 6

FESI INLET DENSITY		kg/l	2.60								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.50	2.45	2.50						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	3.45	3.45	3.4						
Ep			0.014								
CUT POINT DENSITY			3.11								
CYCLONE INLET PRESSURE		kPa	230								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	34	3	1	0	0	0
SINK TRACERS			0	0	0	16	47	49	50	50	50
% TO CONCENTRATE			0	0	0	32	94	98	100	100	100

SOLENOID SETTING: 4 A

TEST 7

FESI INLET DENSITY	kg/l	2.60								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.45	3.40	3.45						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.5	2.5	2.5						
Ep		0.019								
CUT POINT DENSITY		3.15								
CYCLONE INLET PRESSURE	kPa	230								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	46	20	3	0	0	0
SINK TRACERS		0	0	0	4	30	47	50	50	50
% TO CONCENTRATE		0	0	0	8	60	94	100	100	100

TEST 8

FESI INLET DENSITY	kg/l	2.60								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.45	3.45	3.45						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.5	2.5	2.5						
Ep		0.017								
CUT POINT DENSITY		3.13								
CYCLONE INLET PRESSURE	kPa	250								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	40	10	0	0	0	0
SINK TRACERS		0	0	0	10	40	50	50	50	50
% TO CONCENTRATE		0	0	0	20	80	100	100	100	100

TEST 9

FESI INLET DENSITY	kg/l	2.60								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.40	3.45	3.40						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.55	2.55	2.50						
Ep		0.011								
CUT POINT DENSITY		3.07								
CYCLONE INLET PRESSURE	kPa	220								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	41	3	0	0	0	0	0
SINK TRACERS		0	0	9	47	50	50	50	50	50
% TO CONCENTRATE		0	0	18	94	100	100	100	100	100

SOLENOID SETTING: 6 A

TEST 10

FESI INLET DENSITY		kg/l	2.60								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.40	3.45	3.45						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.5	2.55	2.55						
Ep			0.018								
CUT POINT DENSITY			3.08								
CYCLONE INLET PRESSURE		kPa	250								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	32	13	1	0	0	0	0
SINK TRACERS			0	0	18	37	49	50	50	50	50
% TO CONCENTRATE			0	0	36	74	98	100	100	100	100

TEST 11

FESI INLET DENSITY		kg/l	2.60								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	2.40	2.35	2.40						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.55	2.5	2.55						
Ep			0.015								
CUT POINT DENSITY			3.11								
CYCLONE INLET PRESSURE		kPa	230								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	35	3	0	0	0	0
SINK TRACERS			0	0	0	15	47	50	50	50	50
% TO CONCENTRATE			0	0	0	30	94	100	100	100	100

TEST 12

FESI INLET DENSITY		kg/l	2.60								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.30	3.35	3.35						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.5	2.45	2.5						
Ep			0.027								
CUT POINT DENSITY			3.08								
CYCLONE INLET PRESSURE		kPa	250								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	2	2	13	5	0	0	0	0
SINK TRACERS			0	48	48	37	45	50	50	50	50
% TO CONCENTRATE			0	96	96	74	90	100	100	100	100

SOLENOID SETTING: 0 A

TEST 13

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.55	3.55	3.60						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.6	2.55	2.55						
Ep			0.023								
CUT POINT DENSITY			3.20								
CYCLONE INLET PRESSURE		kPa	250								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	48	47	25	0	0	0
SINK TRACERS			0	0	0	2	3	25	50	50	50
% TO CONCENTRATE			0	0	0	4	6	50	100	100	100

TEST 14

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.60	3.55	3.55						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.55	2.5	2.55						
Ep			0.012								
CUT POINT DENSITY			3.21								
CYCLONE INLET PRESSURE		kPa	230								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	50	49	37	0	0	0
SINK TRACERS			0	0	0	0	1	13	50	50	50
% TO CONCENTRATE			0	0	0	0		26	100	100	100

TEST 15

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.60	3.60	3.60						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.55	2.6	2.6						
Ep			0.026								
CUT POINT DENSITY			3.28								
CYCLONE INLET PRESSURE		kPa	240								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	50	48	50	4	2	0
SINK TRACERS			0	0	0	0	2	1	46	48	50
% TO CONCENTRATE			0	0	0	0	4	2	92	96	100

SOLENOID SETTING: 2 A

TEST 16

FESI INLET DENSITY	kg/l	2.70								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	2.45	2.40	2.45						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.5	2.55	2.55						
Ep		0.016								
CUT POINT DENSITY		3.16								
CYCLONE INLET PRESSURE	kPa	220								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	49	29	3	0	0	0
SINK TRACERS		0	0	0	1	21	47	50	50	50
% TO CONCENTRATE		0	0	0	2	42	94	100	100	100

TEST 17

FESI INLET DENSITY	kg/l	2.70								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.50	3.50	3.45						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.5	2.55	2.55						
Ep		0.018								
CUT POINT DENSITY		3.16								
CYCLONE INLET PRESSURE	kPa	260								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		10	10	10	8	8	1	2	0	0
SINK TRACERS		40	40	40	42	42	49	48	50	50
% TO CONCENTRATE		80	80	80	84		98	96	100	100

TEST 18

FESI INLET DENSITY	kg/l	2.70								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.55	3.50	3.50						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.6	2.55	2.55						
Ep		0.017								
CUT POINT DENSITY		3.19								
CYCLONE INLET PRESSURE	kPa	230								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		10	10	10	8	9	1	2	0	0
SINK TRACERS		40	40	40	42	41	49	48	50	50
% TO CONCENTRATE		80	80	80	84	82	98	96	100	100

SOLENOID SETTING: 4 A

TEST 19

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.40	3.30	3.35						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.5	2.55	2.55						
Ep			0.024								
CUT POINT DENSITY			3.10								
CYCLONE INLET PRESSURE		kPa	250								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			0	48	48	25	9	0	0	0	0
SINK TRACERS			50	2	2	25	41	50	50	50	50
% TO CONCENTRATE			100	4	4	50	82	100	100	100	100

TEST 20

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.45	3.45	3.50						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.5	2.5	2.55						
Ep			0.023								
CUT POINT DENSITY			3.13								
CYCLONE INLET PRESSURE		kPa	230								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	48	38	19	0	0	0	0
SINK TRACERS			0	0	2	12	31	50	50	50	50
% TO CONCENTRATE			0	0	4	24		100	100	100	100

TEST 21

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.45	3.40	3.40						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.6	2.55	2.55						
Ep			0.025								
CUT POINT DENSITY			3.18								
CYCLONE INLET PRESSURE		kPa	220								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	48	36	14	0	0	0
SINK TRACERS			0	0	0	2	14	36	50	50	50
% TO CONCENTRATE			0	0	0	4	28	72	100	100	100

SOLENOID SETTING: 6 A

TEST 22

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.45	3.40	3.40						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.55	2.55	2.6						
Ep			0.026								
CUT POINT DENSITY			3.19								
CYCLONE INLET PRESSURE		kPa	FLUCTUATING								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			49	50	50	48	41	20	0	0	0
SINK TRACERS			1	0	0	2	9	30	50	50	50
% TO CONCENTRATE			2	0	0	4	18	60	100	100	100

TEST 23

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.45	3.40	3.40						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.55	2.55	2.55						
Ep			0.023								
CUT POINT DENSITY			3.18								
CYCLONE INLET PRESSURE		kPa	FLUCTUATING								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	48	39	13	1	0	0
SINK TRACERS			0	0	0	2	11	37	49	50	50
% TO CONCENTRATE			0	0	0	4	22	74	98	100	100

TEST 24

FESI INLET DENSITY		kg/l	2.70								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.40	3.40	3.40						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.55	2.55	2.55						
Ep			0.023								
CUT POINT DENSITY			3.19								
CYCLONE INLET PRESSURE		kPa	FLUCTUATING								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	50	43	14	1	0	0
SINK TRACERS			0	0	0	0	7	36	49	50	50
% TO CONCENTRATE			0	0	0	0	14	72	98	100	100

SOLENOID SETTING: 0 A

TEST 25

FESI INLET DENSITY	kg/l	2.80								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.55	3.60	3.60						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.7	2.7	2.7						
Ep		0.023								
CUT POINT DENSITY		3.26								
CYCLONE INLET PRESSURE	kPa	250								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	50	50	46	7	0	0
SINK TRACERS		0	0	0	0	0	4	43	50	50
% TO CONCENTRATE		0	0	0	0	0	8	86	100	100

TEST 26

FESI INLET DENSITY	kg/l	2.80								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.55	3.60	3.55						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.7	2.65	2.65						
Ep		0.022								
CUT POINT DENSITY		3.25								
CYCLONE INLET PRESSURE	kPa	250								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	50	49	46	3	0	0
SINK TRACERS		0	0	0	0	1	4	47	50	50
% TO CONCENTRATE		0	0	0	0		8	94	100	100

DENSITY DIFFERENTIAL = 0.00

TEST 27

FESI INLET DENSITY	kg/l	2.80								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.55	3.55	3.55						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.7	2.65	2.65						
Ep		0.021								
CUT POINT DENSITY		3.23								
CYCLONE INLET PRESSURE	kPa	260								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	50	48	41	1	0	0
SINK TRACERS		0	0	0	0	2	9	49	50	50
% TO CONCENTRATE		0	0	0	0	4	18	98	100	100

SOLENOID SETTING: 2 A

TEST 28

FESI INLET DENSITY		kg/l	2.80								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.50	3.50	3.50						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.7	2.65	2.7						
Ep			0.023								
CUT POINT DENSITY			3.23								
CYCLONE INLET PRESSURE		kPa	260								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	49	50	40	0	0	0
SINK TRACERS			0	0	0	1	0	10	50	50	50
% TO CONCENTRATE			0	0	0	2	0	20	100	100	100

TEST 29

FESI INLET DENSITY		kg/l	2.80								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.45	3.45	3.45						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.65	2.6	2.65						
Ep			0.027								
CUT POINT DENSITY			3.18								
CYCLONE INLET PRESSURE		kPa	250								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	46	39	15	0	0	0
SINK TRACERS			0	0	0	4	11	35	50	50	50
% TO CONCENTRATE			0	0	0	8	22	70	100	100	100

TEST 30

FESI INLET DENSITY		kg/l	2.80								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.45	3.45	3.45						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.65	2.65	2.65						
Ep			0.021								
CUT POINT DENSITY			3.17								
CYCLONE INLET PRESSURE		kPa	250								
TRACER TEST RESULTS			YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	50	49	36	9	0	0	0
SINK TRACERS			0	0	0	1	14	41	50	50	50
% TO CONCENTRATE			0	0	0	2	28	82	100	100	100

SOLENOID SETTING: 4 A

TEST 31

FESI INLET DENSITY	kg/l	2.80								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.45	3.45	3.45						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.7	2.7	2.7						
Ep		0.027								
CUT POINT DENSITY		3.18								
CYCLONE INLET PRESSURE	kPa	270								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	50	49	34	17	0	0	0
SINK TRACERS		0	0	0	1	16	33	50	50	50
% TO CONCENTRATE		0	0	0	2	32	66	100	100	100

TEST 32

FESI INLET DENSITY	kg/l	2.80								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.35	3.40	3.40						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.65	2.65	2.65						
Ep		0.019								
CUT POINT DENSITY		3.13								
CYCLONE INLET PRESSURE	kPa	250								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	49	43	10	2	0	0	0
SINK TRACERS		0	0	1	7	40	48	50	50	50
% TO CONCENTRATE		0	0	2	14	80	96	100	100	100

TEST 33

FESI INLET DENSITY	kg/l	2.80								
FESI UNDERFLOW DENSITY - MANUAL	kg/l	3.40	3.40	3.40						
FESI OVERFLOW DENSITY - MANUAL	kg/l	2.65	2.65	2.65						
Ep		0.022								
CUT POINT DENSITY		3.13								
CYCLONE INLET PRESSURE	kPa	250								
TRACER TEST RESULTS		YELLOW SG = 2.9	BLUE SG = 3.0	BUFF SG = 3.05	GREEN SG = 3.1	O. GREEN SG = 3.15	L. BROWN SG = 3.2	D. BROWN SG = 3.3	PINK SG = 3.4	ORANGE SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX		50	50	50	50	50	50	50	50	50
FLOAT TRACERS		50	50	48	41	15	2	0	0	0
SINK TRACERS		0	0	2	9	35	48	50	50	50
% TO CONCENTRATE		0	0	4	18	70	96	100	100	100

SOLENOID SETTING: 6 A

TEST 34

FESI INLET DENSITY		kg/l	2.80								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.35	3.35	3.40						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.7	2.75	2.75						
Ep			0.023								
CUT POINT DENSITY			3.12								
CYCLONE INLET PRESSURE		kPa	270								
TRACER TEST RESULTS			YELLOW	BLUE	BUFF	GREEN	O. GREEN	L. BROWN	D. BROWN	PINK	ORANGE
			SG = 2.9	SG = 3.0	SG = 3.05	SG = 3.1	SG = 3.15	SG = 3.2	SG = 3.3	SG = 3.4	SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	48	35	13	0	0	0	0
SINK TRACERS			0	0	2	15	37	50	50	50	50
% TO CONCENTRATE			0	0	4	30	74	100	100	100	100

TEST 35

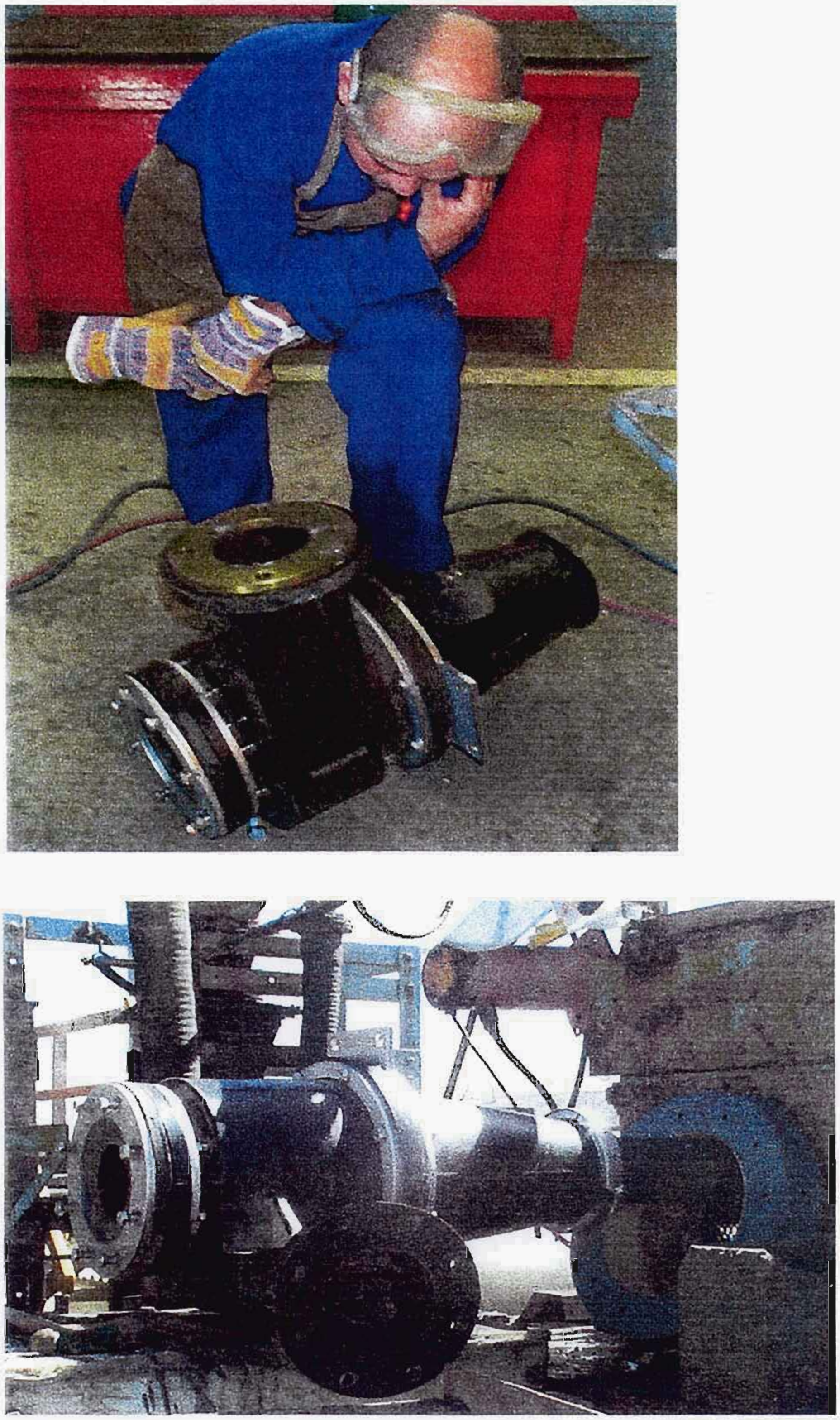
FESI INLET DENSITY		kg/l	2.80								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.35	3.40	3.35						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.65	2.65	2.65						
Ep			0.032								
CUT POINT DENSITY			3.13								
CYCLONE INLET PRESSURE		kPa	250								
TRACER TEST RESULTS			YELLOW	BLUE	BUFF	GREEN	O. GREEN	L. BROWN	D. BROWN	PINK	ORANGE
			SG = 2.9	SG = 3.0	SG = 3.05	SG = 3.1	SG = 3.15	SG = 3.2	SG = 3.3	SG = 3.4	SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	49	32	16	7	0	0	0
SINK TRACERS			0	0	1	18	34	43	50	50	50
% TO CONCENTRATE			0	0	2	36	68	86	100	100	100

TEST 36

FESI INLET DENSITY		kg/l	2.80								
FESI UNDERFLOW DENSITY	- MANUAL	kg/l	3.40	3.35	3.35						
FESI OVERFLOW DENSITY	- MANUAL	kg/l	2.7	2.65	2.65						
Ep			0.022								
CUT POINT DENSITY			3.12								
CYCLONE INLET PRESSURE		kPa	240								
TRACER TEST RESULTS			YELLOW	BLUE	BUFF	GREEN	O. GREEN	L. BROWN	D. BROWN	PINK	ORANGE
			SG = 2.9	SG = 3.0	SG = 3.05	SG = 3.1	SG = 3.15	SG = 3.2	SG = 3.3	SG = 3.4	SG = 3.53
NUMBER OF TRACERS ADDED AT MIXING BOX			50	50	50	50	50	50	50	50	50
FLOAT TRACERS			50	50	48	38	12	2	0	0	0
SINK TRACERS			0	0	2	12	38	48	50	50	50
% TO CONCENTRATE			0	0	4	24	76	96	100	100	100

APPENDIX V

PHOTOGRAPHS



Photos 1 & 2: 250 mm Polyurethane Cyclone

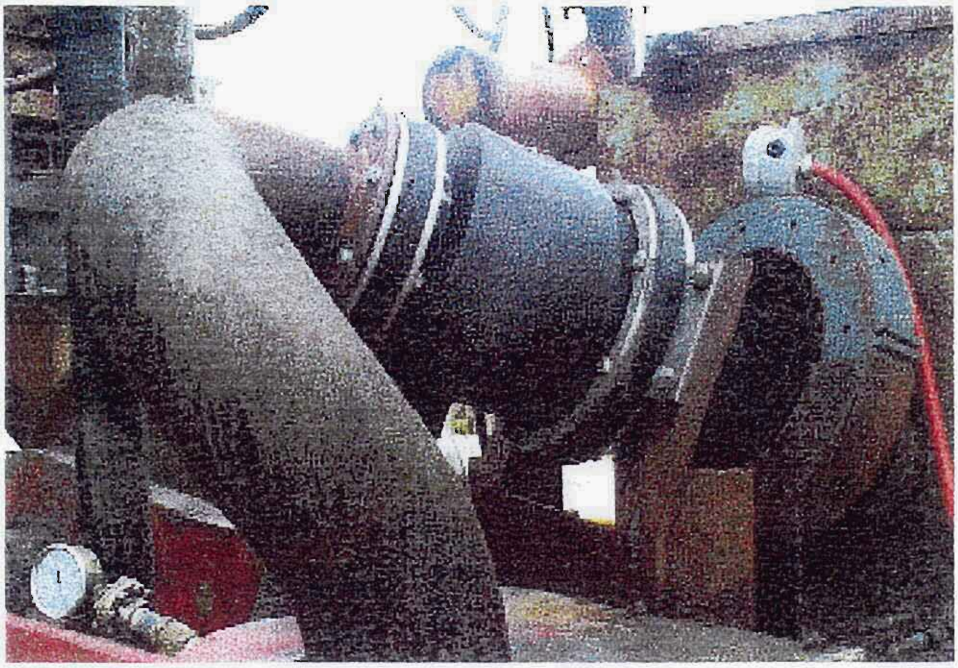


Photo 3: 250 mm Magnetic Cyclone with solenoid in middle position

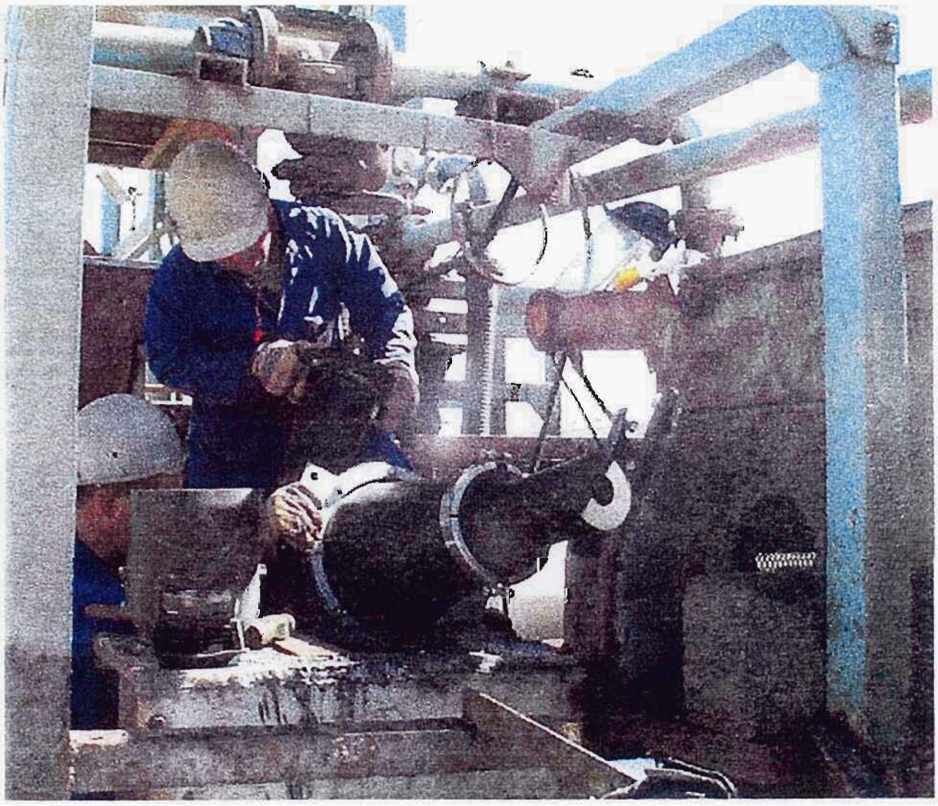
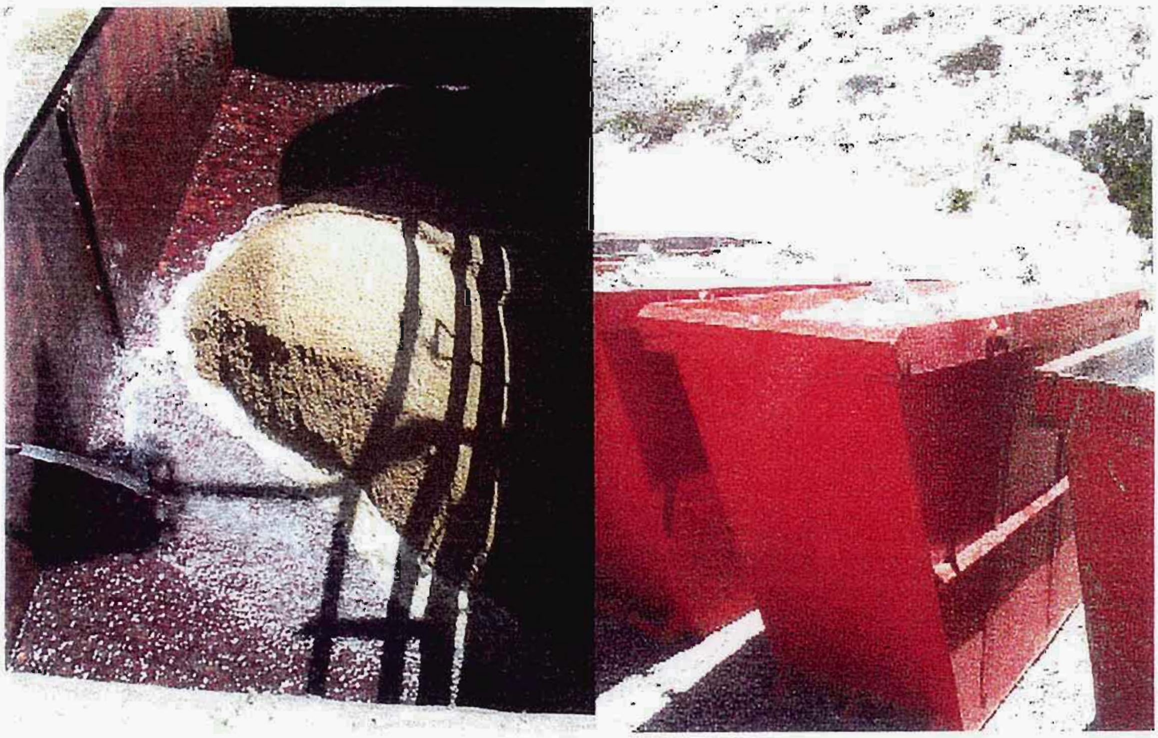


Photo 4: Installation of 250 mm PU cyclone at Koingnaas Prospect Plant

Photos 5 & 6: Inspection of solenoid and picking tracers off float screen



Photos 7 & 8: Ore used for tests at Koingnaas Prospect Plant

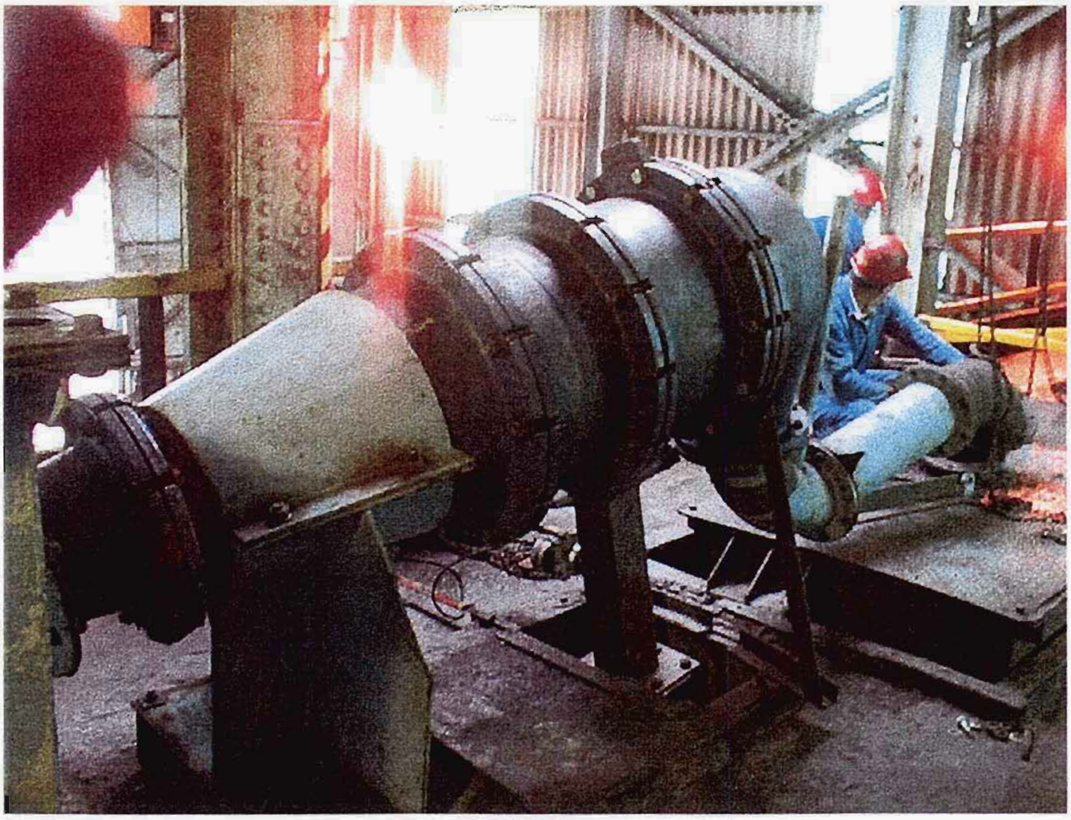
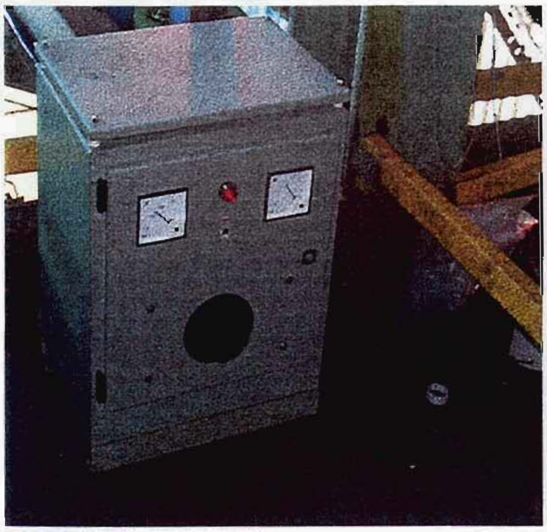
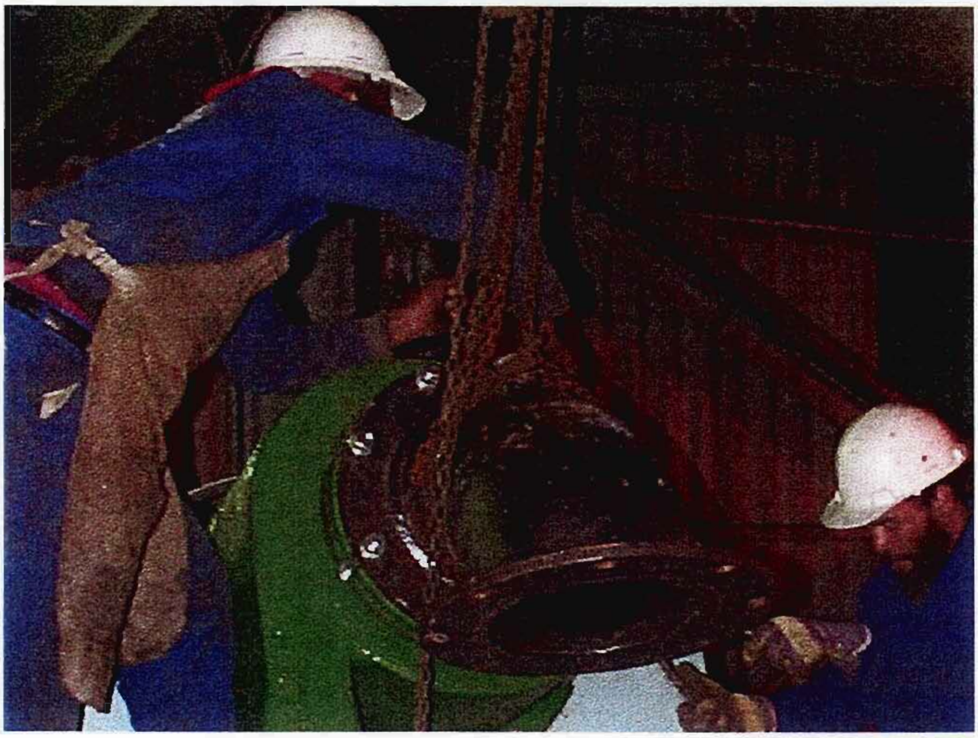


Photo 9: Old 500 mm Linatex Cyclone at Koingnaas Main Plant



Photo's 10 & 11: Solenoid controller and view of tiled cone through overflow



Photo's 12 & 13: Installation of 510 mm Multotec cyclone at Koingnaas Main Plant

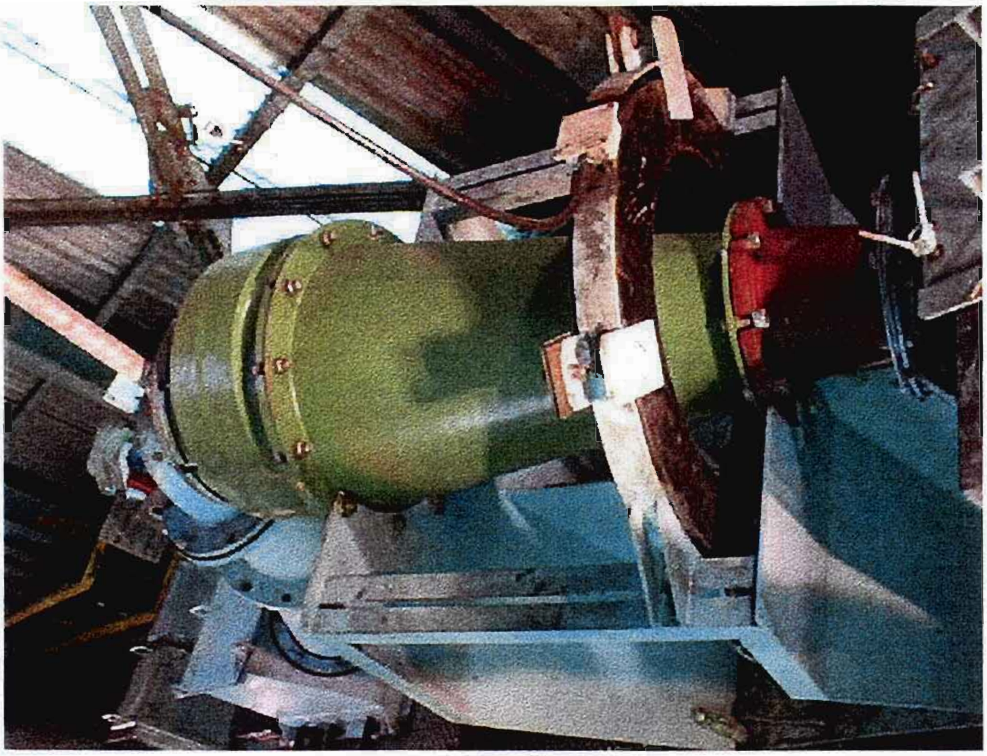


Photo 14: 510 mm Multotec cyclone with solenoid in bottom position

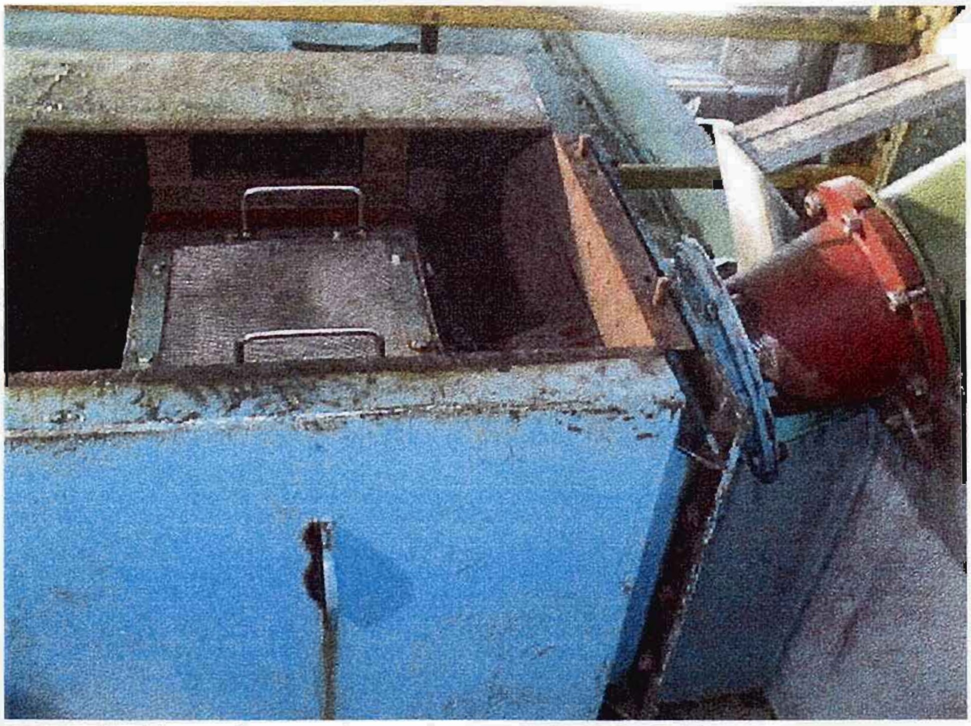


Photo 15: View of spigot box with tracer basket in place.

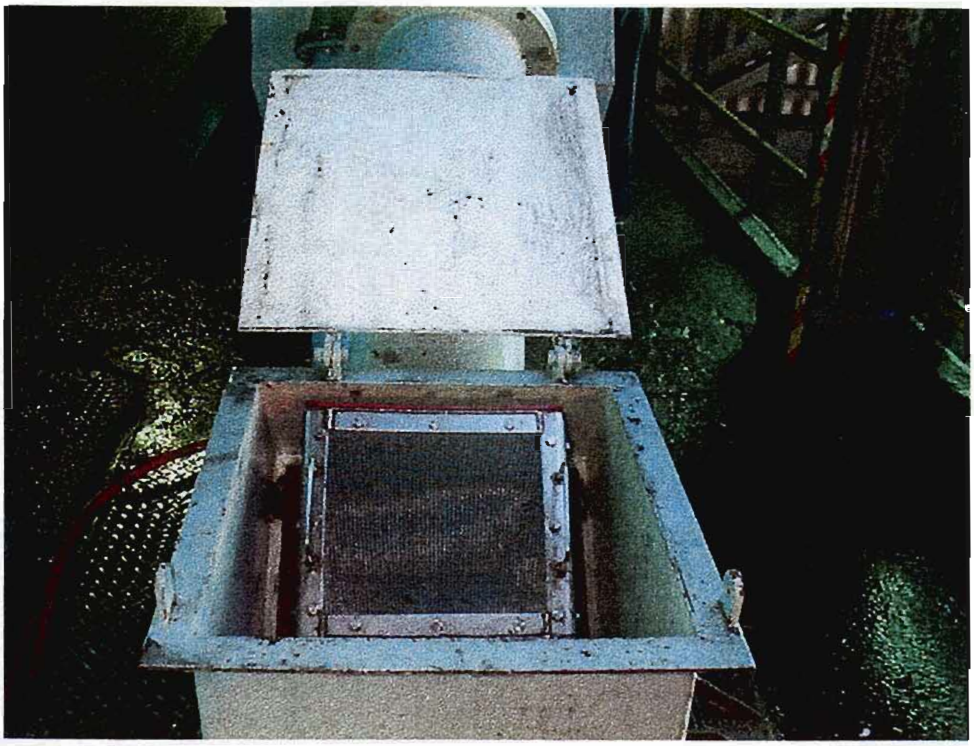


Photo 16: View of overflow basket with tracer basket in place

Photo 17: Sampling of underflow medium density with ore feed

Photo 18: Sampling of medium underflow density at spigot box

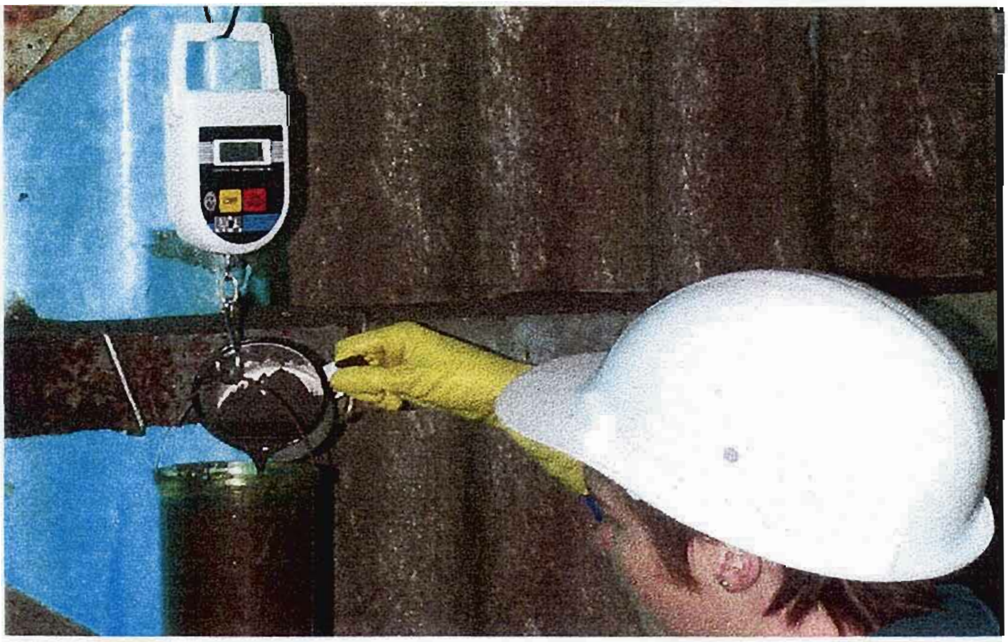


Photo 19: Measuring of medium density

APPENDIX VI

QUOTATIONS FOR SOLENOID AND CYCLONES

RTP
E34679

FACTOTUM ELECTRIC COMPANY

FAX COVER SHEET

DATE:	5-10-99	TIME.	
	ILANA BEITS	PHONE:	
	NAMAQUALAND MINES	FAX:	027 8073280
Fr	Oliver Hollard	PHONE:	011 425 6209
		FAX:	011 425 6208

RE: SOLENOID AND RECTIFIER

Number of pages including cover sheet: ①

Please contact the undersigned immediately of incomplete or illegible transmission.

◆

Message

THANKS FOR YOUR ENQUIRY!

AS QUOTED PREVIOUSLEY :-
(PER IAN SOOBADH'S SPECS)

1 ONLY SOLENOID COIL	R 8265-00
1 ONLY RECTIFIER	R 7590-00

VAT NOT INCLUDED
EX WORKS
VALIDITY = 30 DAYS
DELIVERY = 4/6 WEEKS

REGARDS,

Oliver Hollard

MULTOTEC
PROCESS EQUIPMENT (PTY) LTD.

TELEFAX

28 Forge Road, Spartan, Kempton Park, P.O. Box 224, Kempton Park, South Africa 1620
Tel: (011) 923-6000 Fax: (011) 394-9225 EMAIL: multotec@iafrica.com

To:	**DE BEERS KLEINZEE - KONINGNAAS**	**Date:**	**6TH OCTOBER 2000**
Fax:	**027 807 7080**	**Ref. No.:**	**HA14678 Rev 2/NL/ls**
Attn.:	**ILANA MYBURG**	**Pages:**	**1 OF 17**

Direct telephone numbers - Cyclones Division

Product Manager	Jeremy Bosman	923-6017	Snr Process Engineer	Fernando Monteiro	923-6212
Snr Process Engineer	Niel Lourens	923-6015	Process Engineer	Ernst Bekker	923-6209
Sales Co_ord.	Elsa Purdon	923-6018			

Cyclones Enquiry – C510 Cyclone.

Dear Ilana

Your telephone conversation with Jeremy Bosman during last week refers.

The options for the C510 cyclones available currently are as follows:

1. Old type cast iron cyclone.

   These are of our old designs and are cast form 27% chrome cast iron.

2. New type cast iron cyclone

   These cyclones are manufactured from the same material as the old type, but have a reduced mass due to a different flanging system (CY3-1517 and CY3-1608).

3. Old type cast iron cyclone with stainless steel shell with a ceramic tiled liner.

   The spigot is cast iron (CY1-1310 and CY1-1152).

4. Old type cast iron cyclone with a stainless steel ceramic lined cone-spigot.

   This cyclone is as per 3) above, but the cone and spigot is one unit and has a stainless steel shell with a ceramic tiled liner. (CY7-0426 and CY7-0425).

5. Stainless steel ceramic lined complete cyclone.

   This cyclone has a complete stainless steel shell with a ceramic tiled liner. (CY7-0428 and CY7-0427).

6. Stainless steel silicon carbide lined cyclone.

   As per 5 with silicon carbide solid rings instead of alumina tiles. (CY7-0428 and CY7-0427).

7. Tungsten carbide cyclone.

   Stainless steel shell with ceramic lined inlet head and Tungsten carbide lined vortex finder and cone spigot. (Complete Tungsten carbide rings can only be made up to 420 mm in diameter). (CY7-0428 and CY7-0427).

All the above can be supplied with or without a barrel.

I include a quotation for all the above as well as general outlay drawings for comparison.

I trust that this will meet your requirements. Should you have any further queries, please do not hesitate to contact me.

Yours sincerely
MULTOTEC PROCESS EQUIPMENT (PTY) LTD

Lourens

Niel Lourens
Senior Process Engineer - Cyclones

QUOTATION NO.: HA14678 Rev 2

Item 1:

Description:	Old type cast iron dense medium cyclone.	
Part Number:	C510-20-0/BB-A/110 (OLD) with 90 degree overflow elbow.	
Price each:	R 24 445.00	Packed, Ex Works, and Excl. V.A.T.
Number required:	1 off	
Total price:	**R 24 445.00**	**Packed, Ex Works, Excl. V.A.T.**

Item 1.1:

Description:	Cast iron barrel for old type C510.	
Part Number:	51-BL (OLD)	
Price each:	R 4 560.00	Packed, Ex Works, Excl. V.A.T.
Number required:	1 off	
Total price:	**R 4 560.00**	**Packed, Ex Works, Excl. V.A.T.**

Item 2:

Description:	New type cast iron dense medium cyclone.	
Part Number:	C510-20-0/BB-A/110 (NEW) with 90 degree overflow elbow.	
Price each:	R 22 000.00	Packed, Ex Works, Excl. V.A.T.
Number required:	1 off	
Total price:	**R 22 000.00**	**Packed, Ex Works, Excl. V.A.T.**

QUOTATION NO.: HA14678 Rev 2

Item 4:

Description: Hybrid cast iron cyclone with stainless steel ceramic lined cone –spigot.

Part Number: HY510-20-0/BB-A/110 (SA cone-spigot) with 90 degree overflow.

Price each: R 50 330.00 Packed, Ex Works, Excl. V.A.T.

Number required: 1 off

Total price: R 50 330.00 Packed, Ex Works, Excl. V.A.T.

Item 4.1:

Description: Cast iron barrel for Hybrid cyclone.

Part Number: 51-BL (OLD)

Price each: R 4 560.00 Packed, Ex Works, Excl. V.A.T.

Number required: 1 off

Total price: R 4 560.00 Packed, Ex Works, Excl. V.A.T.

Item 5:

Description: Complete stainless steel cyclone lined with ceramic tiles.

Part Number: SA510-20-0/BB-A/110 with 90 degree overflow elbow.

Price each: R 75 950.00 Packed, Ex Works, Excl. V.A.T.

Number required: 1 off

Total price: R 75 950.00 Packed, Ex Works, Excl. V.A.T.

QUOTATION NO.: HA14678 Rev 2

Item 5.1:

Description:	Stainless steel ceramic lined barrel.	
Part Number:	SA51-BL.	
Price each:	R 10 710.00	Packed, Ex Works, Excl. V.A.T.
Number required:	1 off	
Total price:	**R 10 710.00**	**Packed, Ex Works, Excl. V.A.T.**

Item 6:

Description:	Complete stainless steel cyclone, lined with silicon carbide sections.	
Part Number:	SSD510-20-0/BB-A/110 with 90 degree overflow elbow.	
Price each:	R 70 225.00	Packed, Ex Works, Excl. V.A.T.
Number required:	1 off	
Total price:	**R 70 225.00**	**Packed, Ex Works, Excl. V.A.T.**

Item 6.1:

Description:	Stainless steel silicon carbide lined barrel.	
Part Number:	SSD51-BL	
Price each:	R 8 900.00	Packed, Ex Works, Excl. V.A.T.
Number required:	1 off	
Total price:	**R 8 900.00**	**Packed, Ex Works, Excl. V.A.T.**

QUOTATION NO.: HA14678 Rev 2

Item 7:

Description:	Stainless steel shell with inlet head lined with ceramic tiles and rest lined with Tungsten carbide.	
Part Number:	WY510-20-0/BB-A/110 with 90 degree overflow elbow.	
Price each:	R 397 170.00	Packed, Ex Works, Excl. V.A.T.
Number required:	1 off	
Total price:	**R 397 170.00**	**Packed, Ex Works, Excl. V.A.T.**

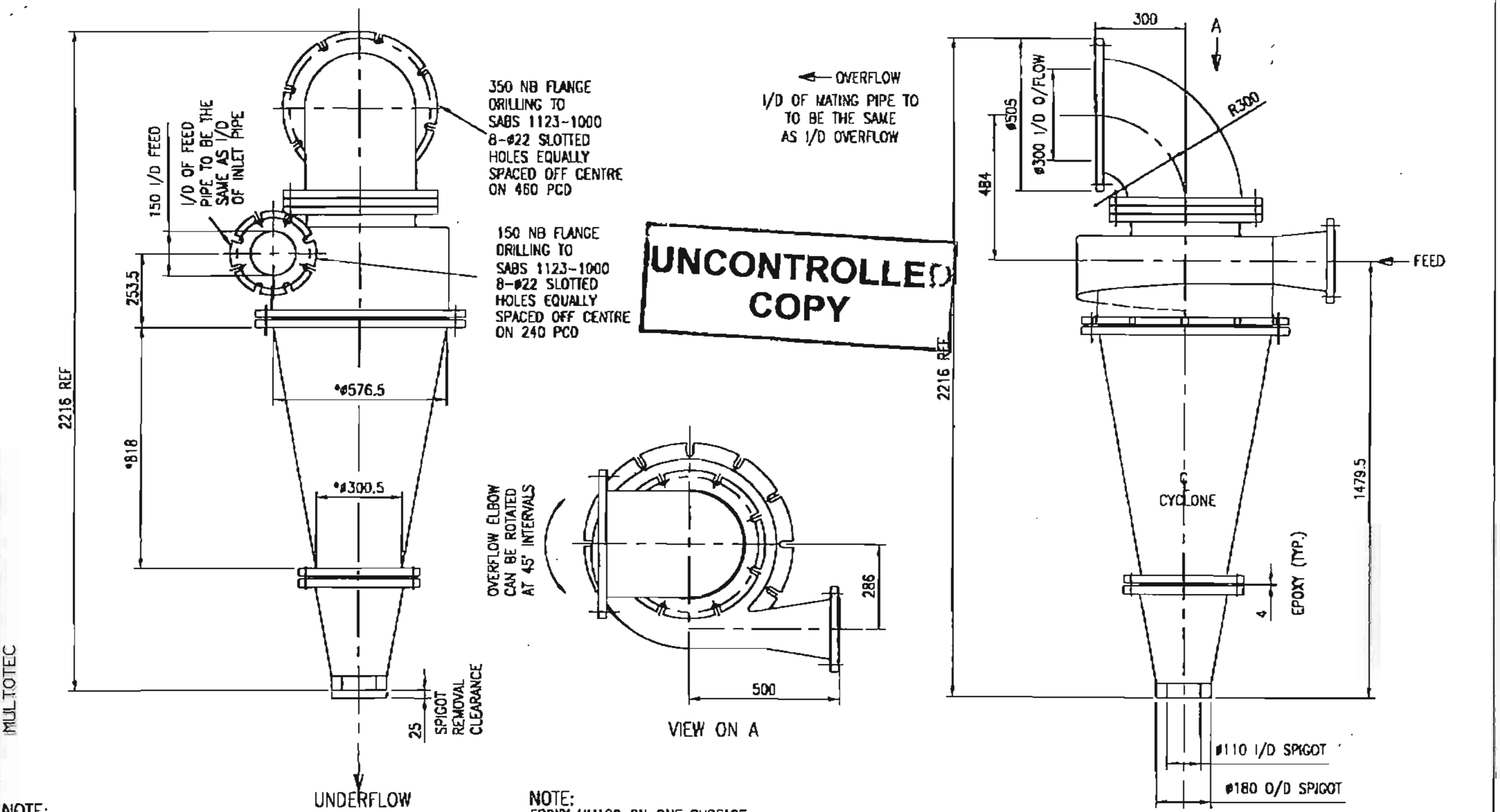
Item 7.1:

Description:	Stainless steel ceramic lined.	
Part Number:	SA51-BL with 90 degree overflow elbow.	
Price each:	R 10 710.00	Packed, Ex Works, Excl. V.A.T.
Number required:	1 off	
Total price:	**R 10 700.00**	**Packed, Ex Works, Excl. V.A.T.**

GENERAL CONDITIONS

Delivery: **Dependant on configuration ordered.**

MULTOTEC



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NOTE:
*DIMENSION FOR
MOUNTING CRADLE

NOTE:
EPOXY MM100 ON ONE SURFACE
RELEASE AGENT
ON OPPOSITE SURFACE.

FOR PARTS LIST REF. CY3-XXXX

ESTIMATED MASS = 940 kg

REV	DESCRIPTION	EWR	DATE	INIT	CHECK
1	DRG. UPDATED	0439	2/11/00	FvY	IJ

GENERAL TOLERANCES			
MACH TOL ±	ABOVE	INCL	FABR TOL ±
0,1	0 5	6	1
0,2	6	30	
0,3	30	120	1
0,5	120	315	
0,8	315	1000	2
1,2	1000	2000	
2	2000	4000	3
3	4000	8000	

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CHECKED	8/3/99	ITS
APPROVED		

SCALE 1:20

ORDER No.

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PROCESS EQUIPMENT (PTY) LTD
REG.No. 61/10037/07

[illegible] Steel Road, Sparton, Kempton Park, South Africa
P.O.Box 2[illegible], Kempton Park, 1620
Tel (011) 923 [illegible] Fax (011) [illegible]

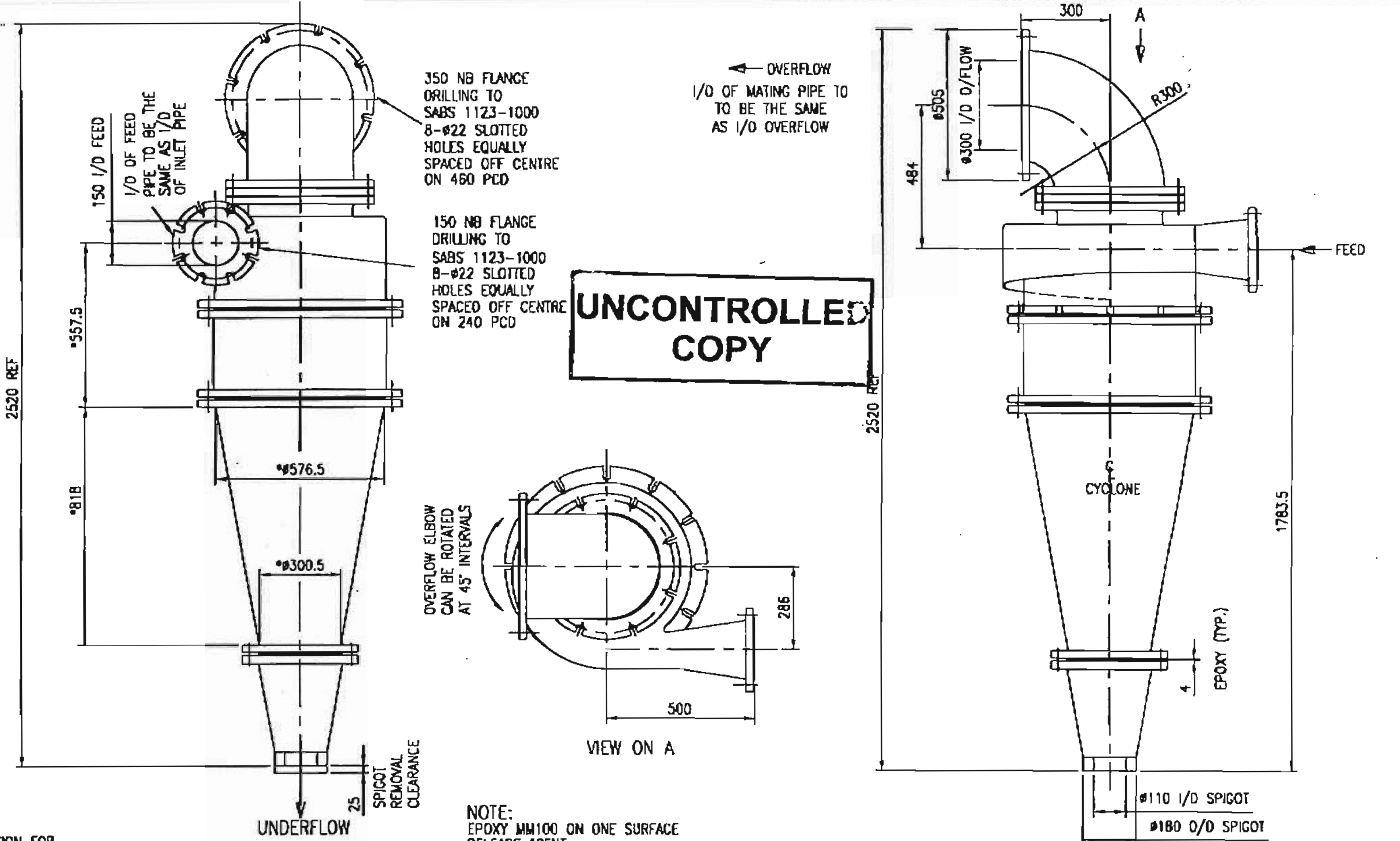
GENERAL ARRANGEMENT C510-20-0 c/w 90° O/F ELBOW C51-S-20/110 SPIGOT

DWG. No CY3-1003

REV. 1

AUTOCAD A3

MULTOTEC



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COPY

NOTE:
*DIMENSION FOR
MOUNTING CRADLE

NOTE:
EPOXY MM100 ON ONE SURFACE
RELEASE AGENT
ON OPPOSITE SURFACE.

FOR PARTS LIST REF. CY3-XXXX

ESTIMATED MASS = 1149 kg

REV	DESCRIPTION	EWR	DATE	INIT	CHECK
1	DRG. UPDATEDED	0439	2/11/00	FvT	I.J

GENERAL TOLERANCES			
MACH TOL ±	ABOVE	INCL	FABR TOL ±
0,1	0 5	6	1
0,2	6	30	
0,3	30	120	1
0,5	120	315	
0,8	315	1000	2
1,2	1000	2000	
2	2000	4000	3
3	4000	8000	

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CHECKED	8/3/99	ITS
APPROVED		

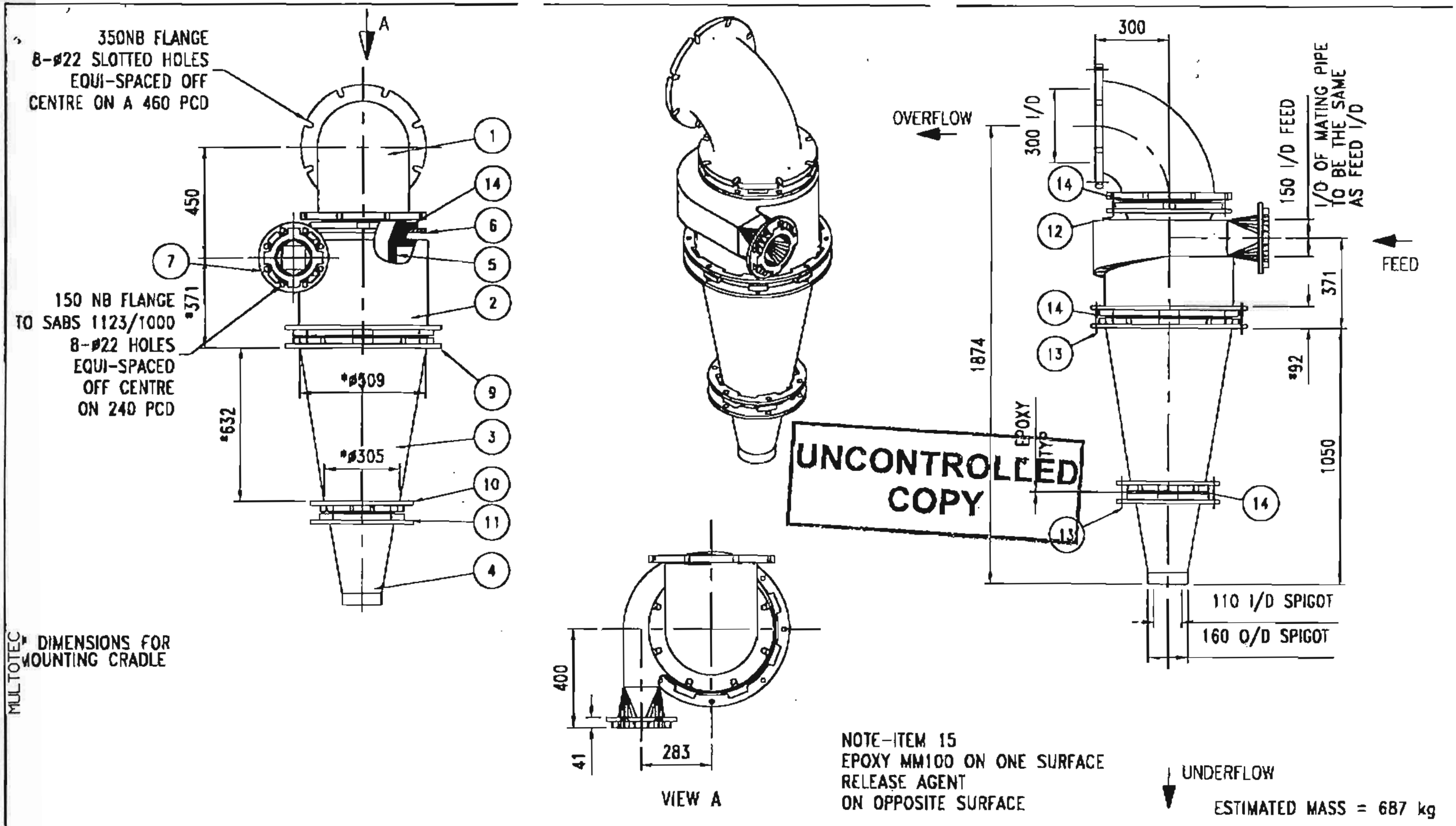
SCALE 1:20

ORDER No.

MULTOTEC
PROCESS EQUIPMENT (PTY) LTD

GENERAL ARRANGEMENT
C510-20-1 c/w
90° O/F ELBOW
C51-S-20/110 SPIGOT

DWG. No	REV.
CY3-1019	1
AUTOCAD A3	



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* DIMENSIONS FOR MOUNTING CRADLE

NOTE-ITEM 15
EPOXY MM100 ON ONE SURFACE
RELEASE AGENT
ON OPPOSITE SURFACE

ESTIMATED MASS = 687 kg

REV	DESCRIPTION	DCR	DATE	INIT	CHECK

GENERAL TOLERANCES

MACH TOL ±	ABOVE	INCL	FABR TOL ±
0,1	0,5	6	1
0,2	6	30	
0,3	30	120	1
0,5	120	315	
0,8	315	1000	2
1,2	1000	2000	
2	2000	4000	3
3	4000	8000	

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DO NOT SCALE

	DATE	NAME
DRAWN	1/11/00	FvT
CHECKED	1/11/00	I.J.
APPROVED	1/11/00	ITS

SCALE 1:12

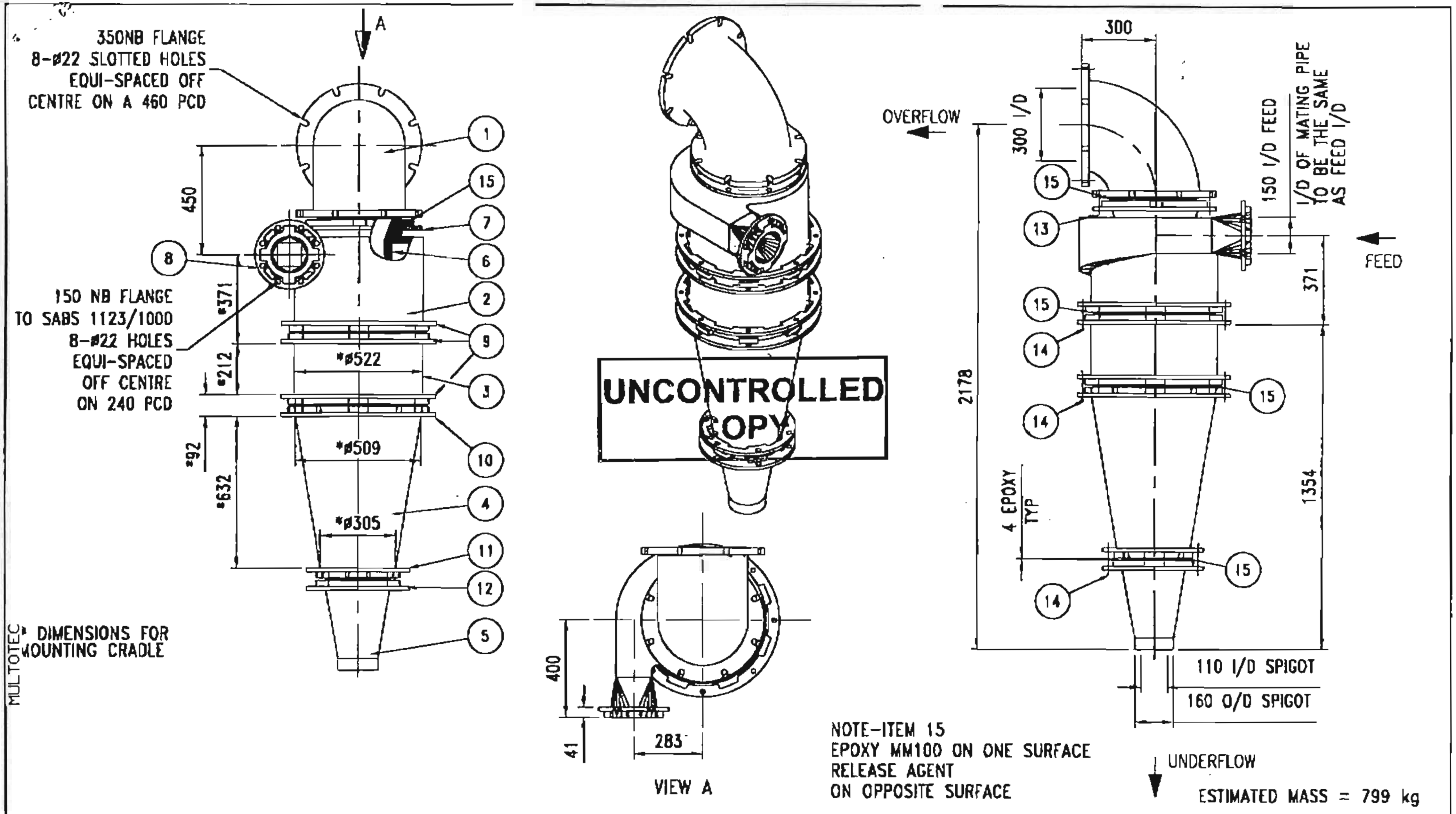
ORDER No.

MULTOTEC
PROCESS EQUIPMENT (PTY) LTD
REG.No. 61/10867/07

61 Steel Road, Sparton, Kempton Park, South Africa
P.O.Box 224, Kempton Park, 1620
Tel (011) 923 6000 Fax (011) 394-0701

GENERAL ARRANGEMENT
CI 510-20-0 LH
90° O/F ELBOW
110 I/D SPIGOT

DWG. No CY3-1608
REV. 0
AUTOCAD A3



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NOTE-ITEM 15
EPOXY MM100 ON ONE SURFACE
RELEASE AGENT
ON OPPOSITE SURFACE

ESTIMATED MASS = 799 kg

REV	DESCRIPTION	DCR	DATE	INIT	CHECK

GENERAL TOLERANCES

MACH TOL ±	ABOVE	INCL	FABR TOL ±
0,1	0 5	6	1
0,2	6	30	
0,3	30	120	1
0,5	120	315	
0,8	315	1000	2
1,2	1000	2000	
2	2000	4000	3
3	4000	8000	

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DO NOT SCALE

	DATE	NAME
DRAWN	06/09/00	CO
CHECKED	7/9/00	I.J.
APPROVED	7/9/00	ITS

SCALE 1:12

ORDER No.

MULTOTEC
PROCESS EQUIPMENT (PTY) LTD
REG. No. [illegible]

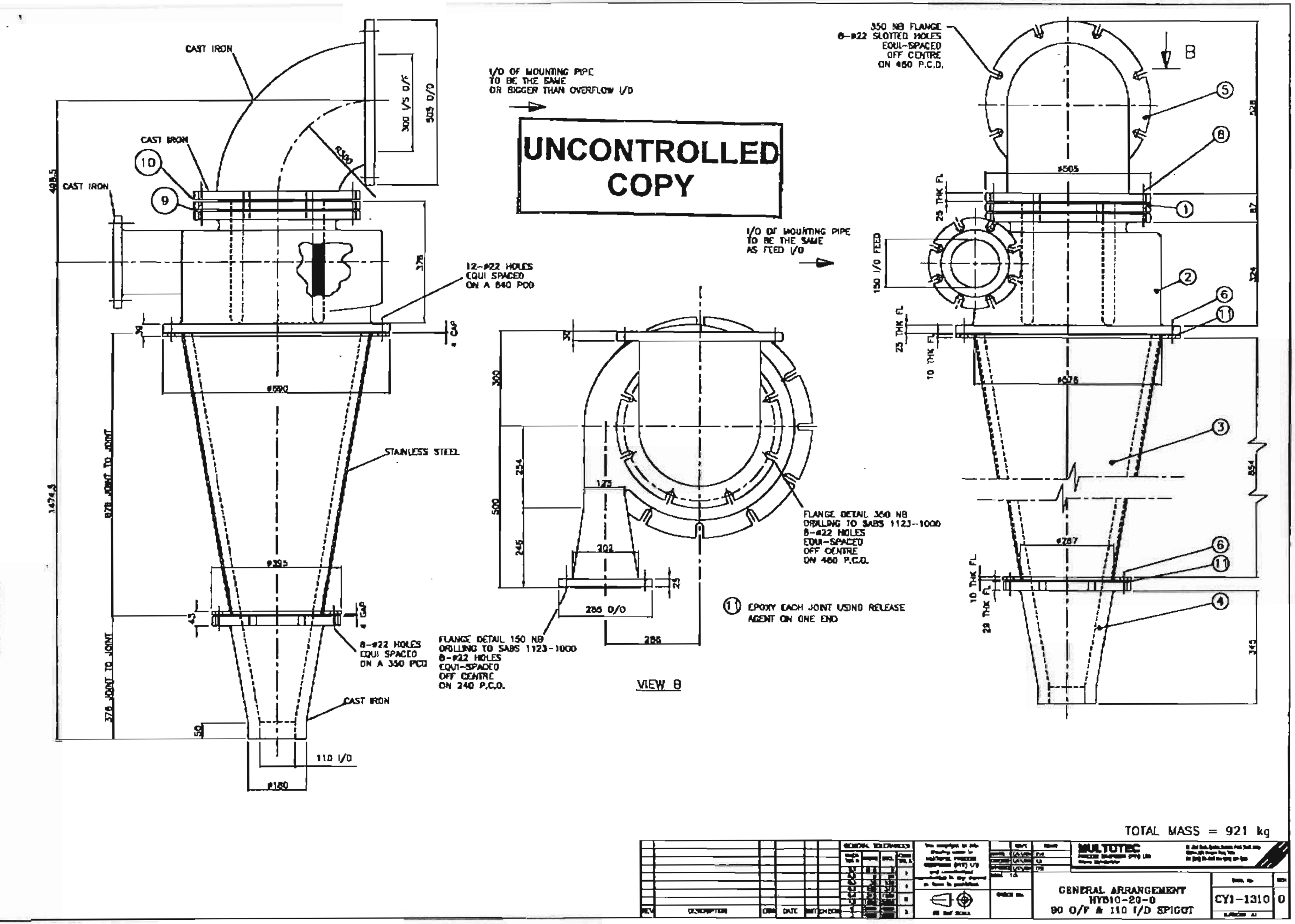
[illegible] Kempton Park, South Africa
P.O.Box [illegible], Kempton Park, [illegible]
Tel: (011) [illegible] Fax: (011) [illegible]

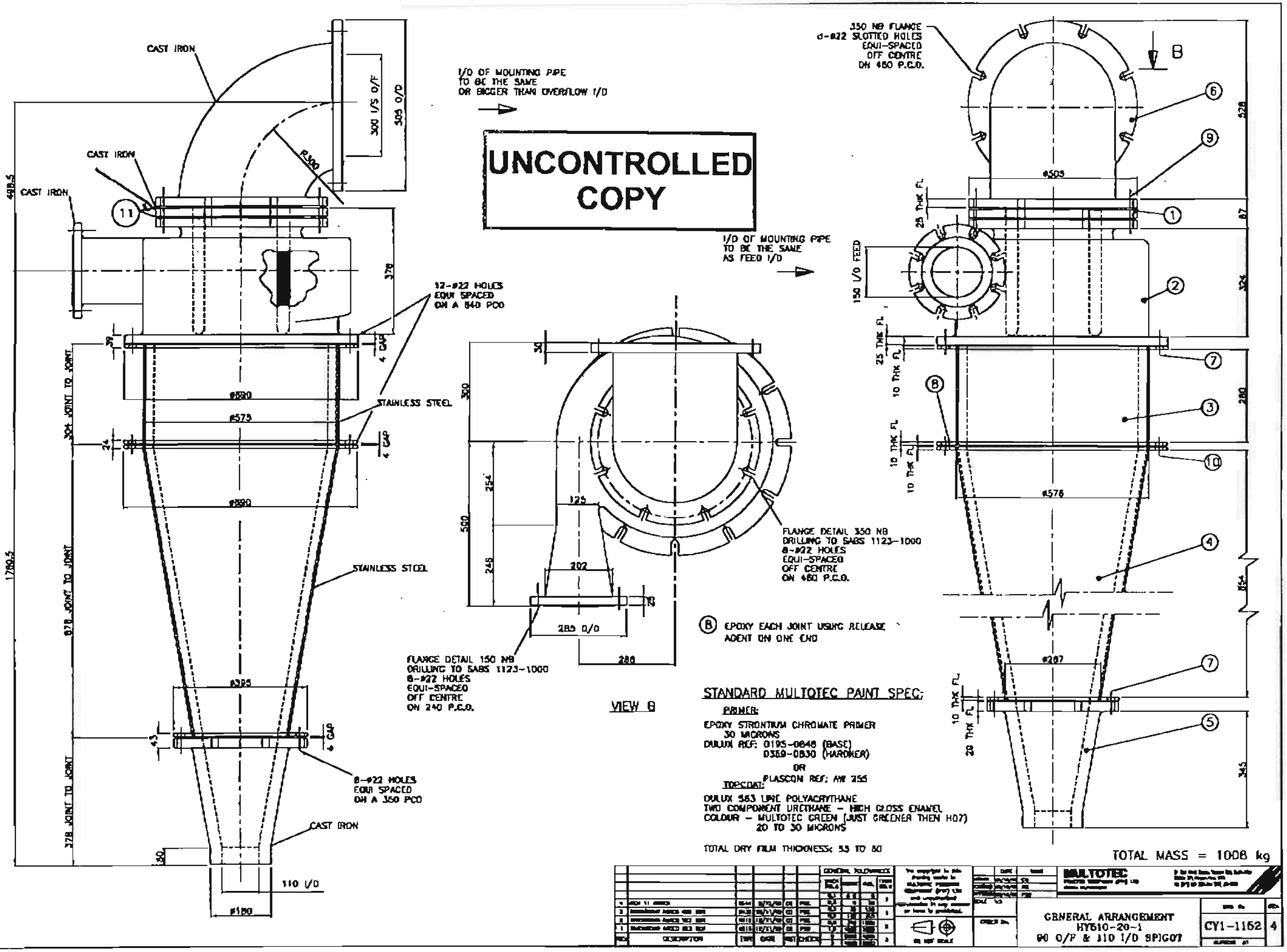
GENERAL ARRANGEMENT
CI 510-20-1 LH
90° O/F ELBOW
110 I/D SPIGOT

DWG. No CY3-1517

REV. 0

AUTOCAD A3


CAST IRON
300 I/S O/F
505 O/D
R500
CAST IRON
10
9
CAST IRON
498.5
375
12-ø22 HOLES
EQUI SPACED
ON A 640 PCD
4 GAP
30
ø590
STAINLESS STEEL
1474.5
828 JOINT TO JOINT
ø395
43
4 GAP
8-ø22 HOLES
EQUI SPACED
ON A 350 PCD
376 JOINT TO JOINT
CAST IRON
50
110 I/D
ø180
I/D OF MOUNTING PIPE
TO BE THE SAME
OR BIGGER THAN OVERFLOW I/D
UNCONTROLLED
COPY
I/D OF MOUNTING PIPE
TO BE THE SAME
AS FEED I/D
30
300
500
254
245
175
202
25
285 O/D
285
FLANGE DETAIL 350 NB
DRILLING TO SABS 1123-1000
8-ø22 HOLES
EQUI-SPACED
OFF CENTRE
ON 460 P.C.D.
FLANGE DETAIL 150 NB
DRILLING TO SABS 1123-1000
8-ø22 HOLES
EQUI-SPACED
OFF CENTRE
ON 240 P.C.D.
11 EPOXY EACH JOINT USING RELEASE
AGENT ON ONE END
VIEW B
350 NB FLANGE
8-ø22 SLOTTED HOLES
EQUI-SPACED
OFF CENTRE
ON 460 P.C.D.
B
5
8
ø505
1
87
25 THK FL
150 I/O FEED
2
324
6
11
528
25 THK FL
10 THK FL
ø576
3
854
ø287
6
11
10 THK FL
20 THK FL
4
345
TOTAL MASS = 921 kg
MULTOTEC
GENERAL ARRANGEMENT
HY610-20-0
90 O/F & 110 I/D SPIGOT
CY1-1310
0
REV
DESCRIPTION
DATE



Ⓑ EPOXY EACH JOINT USING RELEASE AGENT ON ONE END

STANDARD MULTOTEC PAINT SPEC:

PRIMER:

EPOXY STRONTIUM CHROMATE PRIMER
30 MICRONS
DULUX REF: 0195-0848 (BASE)
0359-0830 (HARDNER)
OR
PLASCON REF: AW 255

TOPCOAT:

DULUX 563 LINE POLYACRYTHANE
TWO COMPONENT URETHANE - HIGH GLOSS ENAMEL
COLOUR - MULTOTEC GREEN (JUST GREENER THEN H07)
20 TO 30 MICRONS

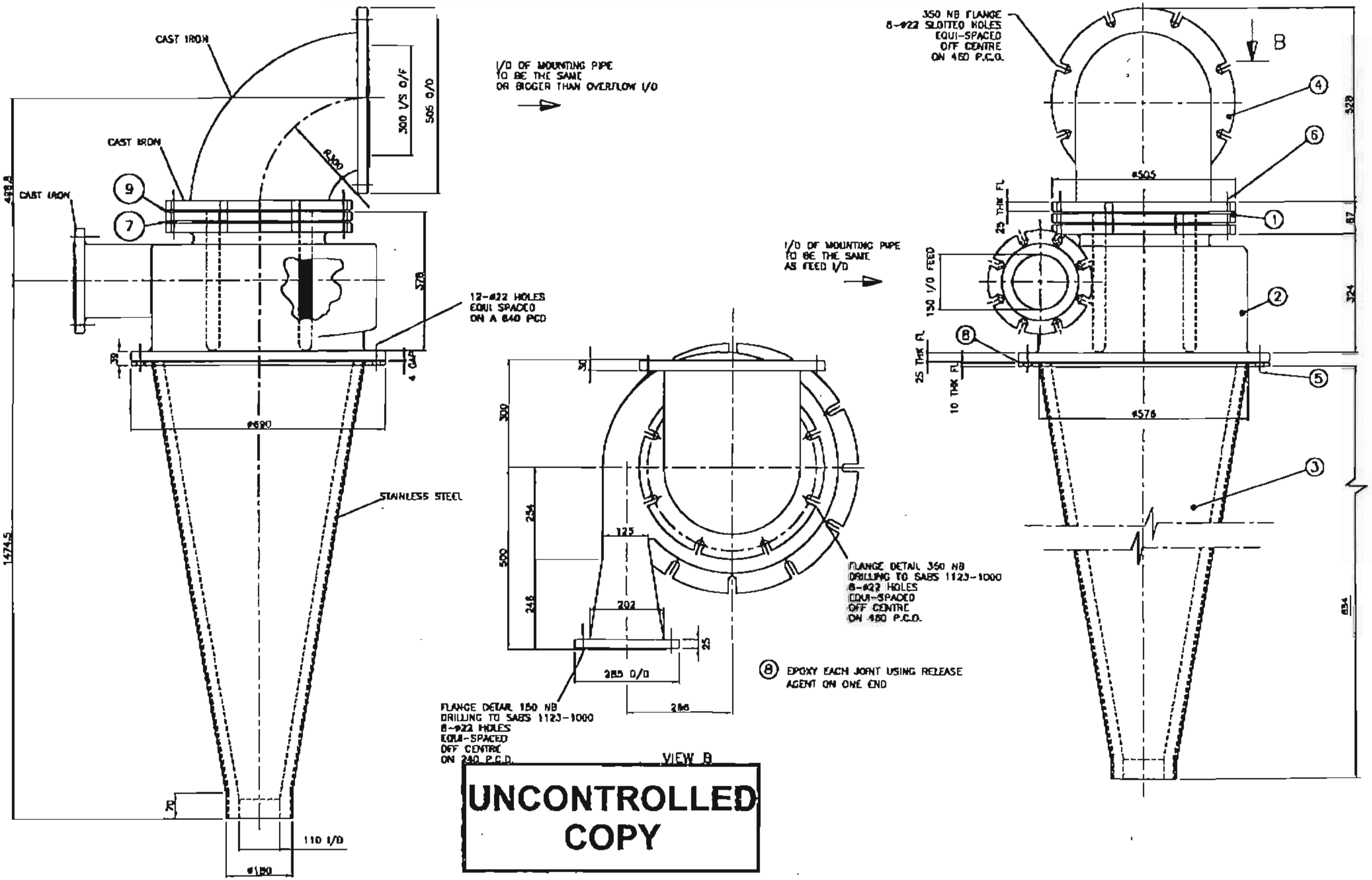
TOTAL DRY FILM THICKNESS: 55 TO 80

TOTAL MASS = 1008 kg

MULTOTEC

GENERAL ARRANGEMENT
HY610-20-1
90 O/F & 110 I/D SPIGOT

CY1-1152 4



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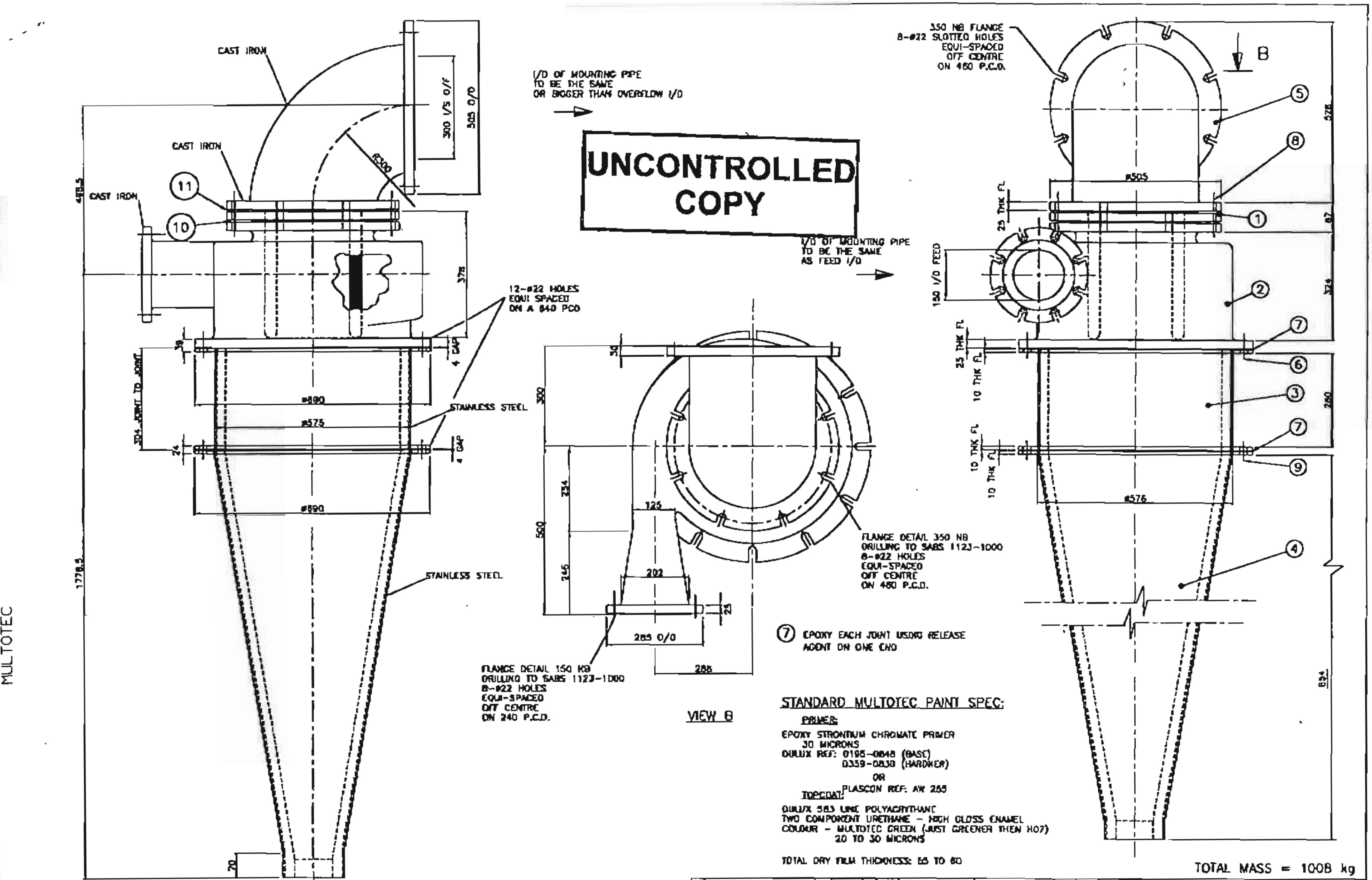
TOTAL MASS = 921 kg

MULTOTEC

GENERAL ARRANGEMENT
HY610-20-D
90 O/F & 110 I/D SPIGOT

CY7-0428 0



⑦ EPOXY EACH JOINT USING RELEASE
AGENT ON ONE END

STANDARD MULTOTEC PAINT SPEC:

PRIMER:

EPOXY STRONTIUM CHROMATE PRIMER
30 MICRONS
DULUX REF: 0195-0648 (BASE)
0359-0830 (HARDNER)
OR
PLASCON REF: AW 265

TOPCOAT:

DULUX 583 LINE POLYACRYTHANE
TWO COMPONENT URETHANE - HIGH GLOSS ENAMEL
COLOUR - MULTOTEC GREEN (JUST GREENER THEN H07)
20 TO 30 MICRONS

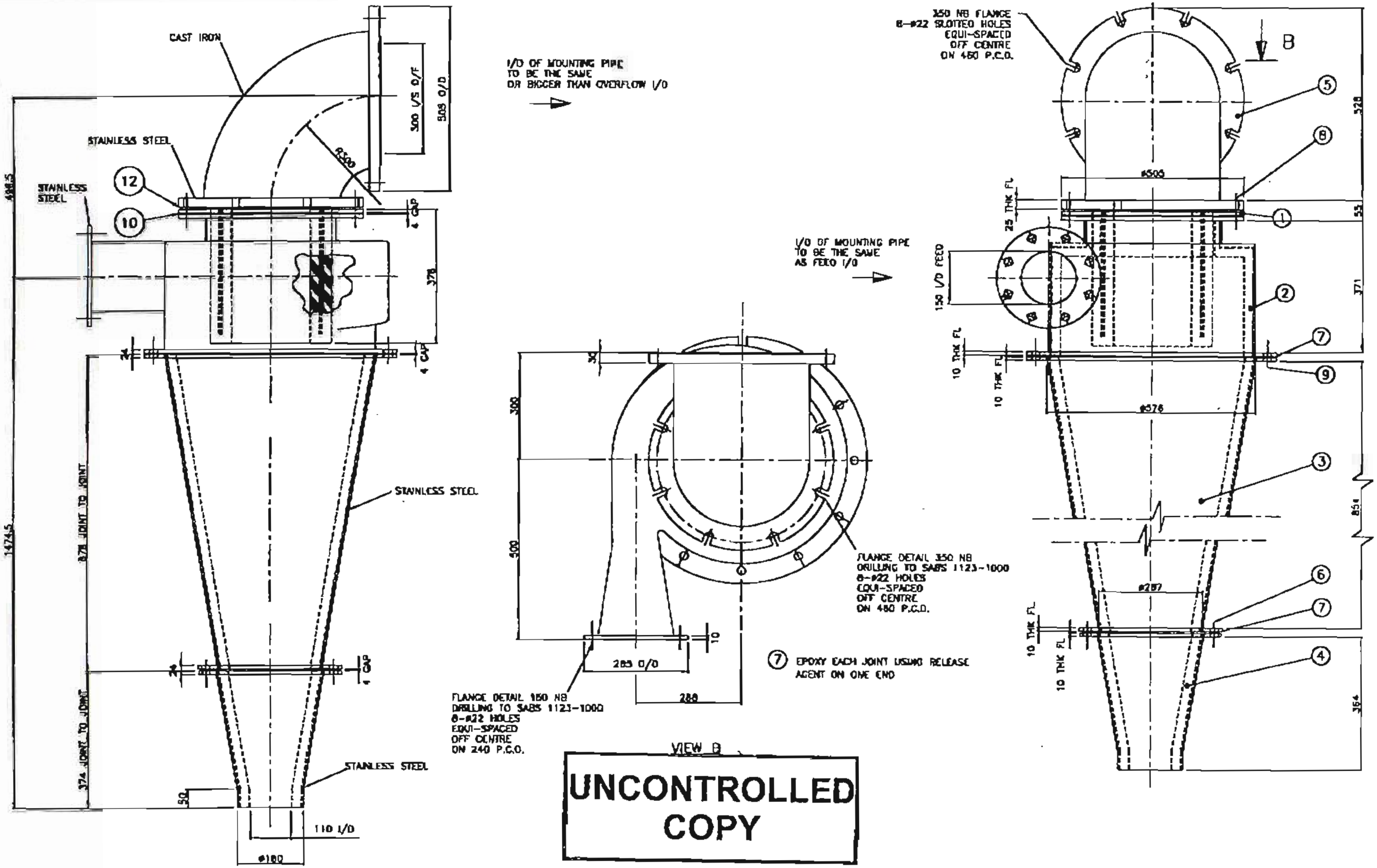
TOTAL DRY FILM THICKNESS: 65 TO 80

TOTAL MASS = 1008 kg

MULTOTEC

GENERAL ARRANGEMENT
HY510-20-I
90 O/F & 110 I/D SPIGOT
COMBINED CONE & SPIGOT

CY7-0425 0



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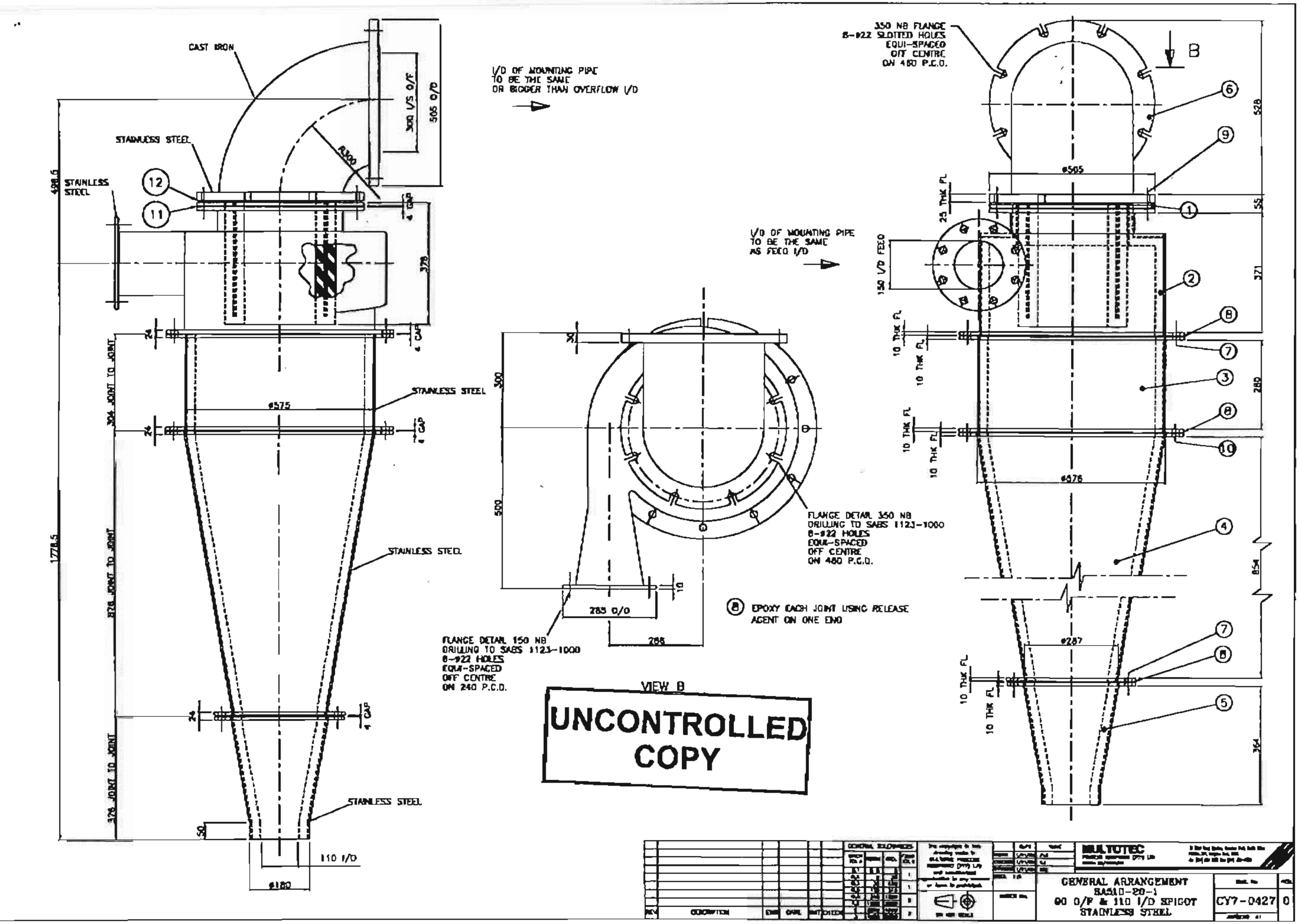
MULTOTEC

GENERAL ARRANGEMENT
SA510-20-0
90 O/F & 110 I/D SPIGOT
STAINLESS STEEL

CY7-0428 0



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DELKOR TECHNIK (PTY) LTD

BUILDING 'D' ROCHESTER PLACE, 173 RIVONIA ROAD, MORNINGSIDE, SANDTON, SOUTH AFRICA
REG. NO. 86/04661/07

✉ 52864, Saxonwold 2132
☎ (011) 884-6666
fax (011) 884-6722/3
e mail delkor@iafrica.com
website www. delkor.co.za

REF	**e2521/21111/la**
DATE	**17 JANUARY 2001**
FROM	**CRAIG NAUDÉ** craign@delkor.co.za
NO. OF PAGES	**5**
TO FAX NO.	374-6103
COMPANY	**DE BEERS**
ATT	**MR. ANTHONY ZEBERT**
RE	**TEST CYCLONE**

We thank you for your valued enquiry, and take pleasure in submitting the following information for your evaluation.

1. DELKOR

Delkor Technik is a wholly owned South African company specialising in process equipment and plant supply. Delkor has built up an excellent reputation over the last 25 years in the mining, metallurgical, sewage, waste water and chemical industries in the South African region and internationally.

2. KREBS CYCLONES

2.1 KREBS CYCLONES (GENERAL)

In terms of a Manufacturing and Distributorship Agreement with Krebs Engineers (Austria and USA), Delkor Technik (Pty) Ltd has exclusive rights for the manufacture and sale of Krebs Cyclones in South Africa and other specified territories.

Krebs Engineers are the largest world-wide suppliers of cyclones with in excess of 62,000 units in operation in various applications, including heavy media separation of coal and minerals. As a result of this extensive experience and installations, Krebs have access to a database which enables it to perform accurate simulations and select quantities, design and configurations of cyclones most suitable for any particular application.

In South Africa Krebs have a substantial market share in the platinum industry.

2.2 REPLACEABLE LINERS

The Krebs design offers replaceable liners. This has numerous advantages including: -

Fast turnaround time in overhauling units, which can be done on site

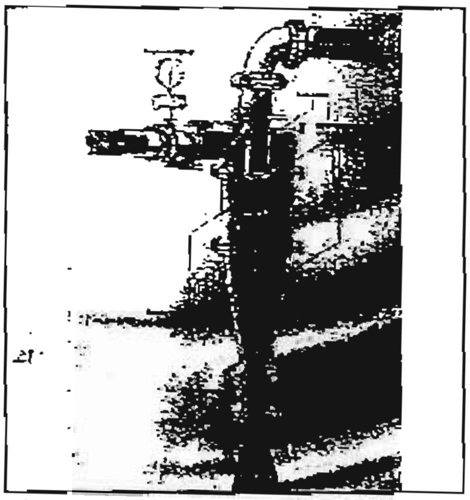
Accurate mouldings, compared to hand laid rubber, resulting in more efficient cut points.

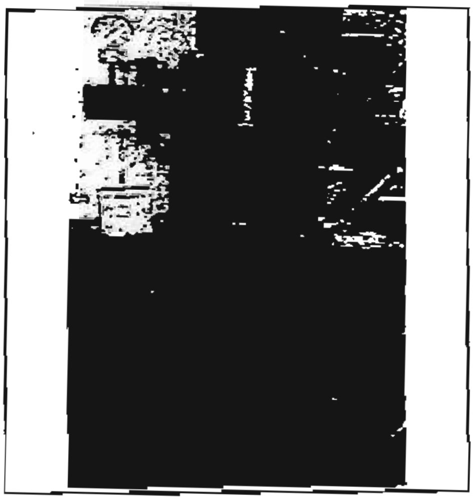
Possibilities in only having to replace worn liner sections, which can be done on site.

2.3 INVOLUTED FEED ENTRY

An original design feature of the Krebs Cyclone is the involuted feed entry, which minimises the turbulence of the feed entering the cyclone. Minimal turbulence in the cyclone inlet head section permits the Krebs Cyclone to make fine separations while using vortex finders of larger diameter to increase cyclone capacity.

Traditional tangential feed entry results in accelerated wear of the inlet head immediately downstream from the feed entry. The Krebs inlet nozzle configuration introduces feed as a narrow ribbon, and the involuted feed path minimises liner wear and this reduces operating costs.





2.4 INTERCHANGEABLE ORIFICES

Capacity and classification characteristics, for each Krebs Cyclone, can be modified by interchanging liners and/or orifice fittings as indicated below:

- Inlet Head Liner
- Vortex Finder
- Apex Valve Liners or Inserts
- Cylinder and Cone Section

2.5 SECTIONALISED CYCLONE HOUSINGS

Metal cyclone housings fitted with moulded liners offer the advantage that relatively inexpensive liners can be replaced as necessary. Wear due to normal abrasion tends to be most severe in the lower cone sections, and smaller cone housing liners can be replaced easily and at low cost. For resistance to severe abrasion, lower cone housings can be fitted with ceramic liners.

2.6 FEED AND OVERFLOW CONNECTIONS

Feed inlet and overflow adapters for Krebs Cyclones can be supplied for connection to piping by means of Victaulic couplings, grooved or plain end, or with standard flanges.

2.7 LINERS

A large range of liner types are available including:

- Rubber
- Urethane
- Nihard
- Nitrile bonded Silicon Carbide
- Alumina Ceramics
- Reaction bonded silicon carbide.

2.8 DESIGN PHILOSOPHY

Krebs philosophy in cyclone design is to:

- Offer a flexible cyclone system
- Reduce operating costs by installing replaceable liners
- Optimise the cut point and cyclone efficiency
- Specify the optimum cyclone configuration for each application.

3. CYCLONE SIZING

Based on the information provided by yourselves, we advise that we can offer one of two cyclones.

Due to the fact that Krebs' cyclones can treat a greater duty than equal sized competitor units, we can offer either our D15LB or D20B.

Should you be able to provide more details on the expected flows, we can provide further detail on the size of the Vortex finder, Apex and ultimately the better cyclone.

4. LINERS

We have quoted for our top of the range monolithic ceramic liners, CMC. The CMC material, Ceramic Metal Compound, is composed of Silicon Carbide grains in an Alumina Ceramic Matrix which includes metal Alumina particles. Thus the material is impact resistant as well as providing excellent wear characteristics. Normal ceramic liners have a 2-3mm wearing surface, and once this is worn away, rapid deterioration occurs. This is not the case with CMC which has a very even wear pattern throughout the thickness of the liner.

5. PRICE

For the supply of one off D15LB cyclone with 316L Housing and CMC liners, delivered to Kleinzee = 381 mm	R 185,000.00
For the supply of one off D20B cyclone with 316L Housing and CMC liners, delivered to Kleinzee = 608 mm	R 213,000.00

Commissioning is available at R 2,500.00 per day with travel and accommodation at cost with documented proof.

1" = 25.4 mm

6. TERMS OF PAYMENT

- 100% of contract value on delivery to site.
- 100% of supervision on completion of each separate function.

7. DELIVERY

We anticipate a delivery period of 12 weeks from date of order.

8. GENERAL

We trust our offer meets with your approval, and look forward to participating in this existing test campaign..

Yours faithfully,
DELKOR TECHNIK (PTY) LTD

CRAIG NAUDÉ
MANAGING DIRECTOR
(Email Address: craign@delkor.co.za)