Australian Oilseeds Federation

Engineering Solutions for the Removal of Meghemite from Canola Seed

Preliminary Evaluation of Potential Separation Technologies

CONFIDENTIAL PROJECT REPORT

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SUMMARY

An investigation of the characteristic properties defining the separation of meghemite contaminants from canola seed has been undertaken, along with a series of trials of potential separation technologies. For the sample studies, accurate screening was capable of removing approximately 75wt% of the total meghemite contaminants at a screening level of 2.58mm round hole over 1.00mm round hole, with canola seed losses of less than 2%. Specific gravity separation was found to be an effective separation technology for those particles within the aforementioned screening limits with a separation efficiency of approximately 99% and canola seed losses of less than 0.25%. Implementing specific gravity separation after accurate screening has the potential to remove 99.7% of the total meghemite contaminants.

These technologies are also likely to be effective on alternative grains such as barley, peas, etc. which are contaminated with meghemite. Screening and specific gravity separation will also enable other contaminants such as foreign seeds, trash, and non-magnetic stones to be removed from the canola seed.

Magnetic separators, such as those supplied by SACBH, were found to be less effective than the technologies discussed above, with separation efficiencies as low as 57% under simulated operating conditions. It is suggested that the magnetic separators may be employed as a primary course separation stage to improve the effectiveness of accurate screening and specific gravity separation, however their implementation as the sole separation technology is not recommended. The inability to remove non-magnetic contaminants must also be considered.

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1.0 INTRODUCTION

Contamination of canola seed with meghemite, a ferro-magnetic mineral species, is a problem currently facing a number of Australian grain regions including the lower Eyre Peninsula and Kangaroo Island grain regions of South Australia, and the South East grain region of South Australia and Victoria. Windrowed crops such as barley, canola, beans, and peas, pose significant problems in that meghemite particles can easily be collected during harvesting resulting in contamination of the grain. During subsequent milling or pressing (in the case of canola), damage occurs to the equipment as a result of the hardness of meghemite. The presence of these contaminants is posing additional problems in the export market with countries such as Japan now refusing to purchase meghemite contaminated canola.

South Australian Cooperative Bulk Handling (SACBH) are a major bulk handler of these contaminated crops, and have recently purchased magnetic separators to be installed under their receival hoppers in an attempt to remove these contaminants based on their magnetic properties. Despite this, SACBH cannot ensure the complete elimination of meghemite using this technology, therefore the potential remains for market rejection to occur.

Given this problem, the Agricultural Machinery Research and Development Centre (AMRDC) was approached by the Australian Oilseeds Federation (AOF) to undertake an investigation of potential technologies and characteristic properties governing the separation of meghemite contaminants from canola seed. Furthermore, an evaluation of the magnetic separators purchased by SACBH was undertaken.

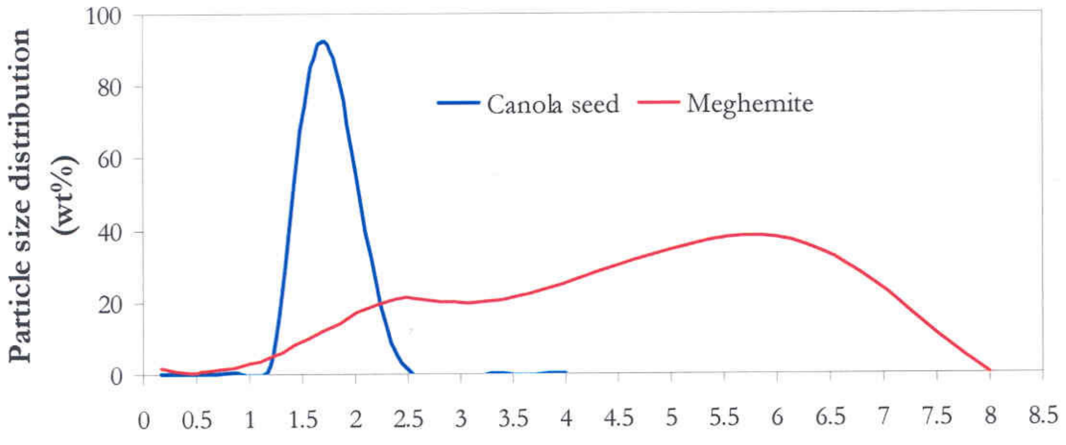
2.0 PHYSICAL PROPERTY TESTING

2.1 Particle Size Distribution

A sample of meghemite was obtained from the Port Adelaide terminal of SACBH. This sample had been extracted from a load of canola seed using the aforementioned magnetic separators and was therefore considered to be characteristic of the contaminants found in a typical canola seed sample. The particle size distribution was determined by sieving using BS410 200mm Endecott Sieves at the following nominal aperture sizes; 355µm, 500µm, 710µm, 1.0mm, 1.4mm, 2.0mm, 2.8mm, and 4.0mm. Table A.1, Appendix A, shows the data obtained from the sieving test, and the corresponding particle size distribution is shown in Figure 2.1.

A sample of canola seed was also obtained from the Port Adelaide terminal of SACBH, and was subjected to a similar sieving test to determine the particle size distribution. The results of the sieving test for the canola seed are shown in Appendix A, Table A.2, and the particle size distribution is compared with that of the meghemite contaminants in Figure 2.1

It is immediately obvious from Figure 2.1 that accurate screening techniques will be capable of removing a substantial fraction of the total mass of meghemite in the canola seed. This can be more easily seen in Figure 2.2, which shows the cumulative mass % undersize of each sample as a function of particle size. Figure 2.2 also highlights the screening limits specified for canola seed by the NSW Grains Board[1] (2.58mm round hole over 1.00mm round hole).



Mean particle size (mm)

Figure 2.1 Particle size distribution of meghemite and canola seed samples obtained from SACBH.

From Figure 2.2 it can be seen that approximately 5% of the total mass of meghemite is likely to he below 1.00mm, while approximately 62.5% lies above 2.58mm. Therefore approximately 67.5% of the total mass of meghemite contaminants could be removed using the recommended screening limits whilst retaining at least 98% of the canola seed.

Agricultural Commodity Standards Manual, National Agricultural Commodity Marketing Association Incorporated, 1991

A further advantage of screening will be the removal of other contaminants such as non-ferrous stones, foreign seeds, trash, etc., which lie outside these screening limits. Given this, screening trials were conducted using a pilot plant scale screening deck at AMRDC to further assess the separation potential of accurate screening technologies.

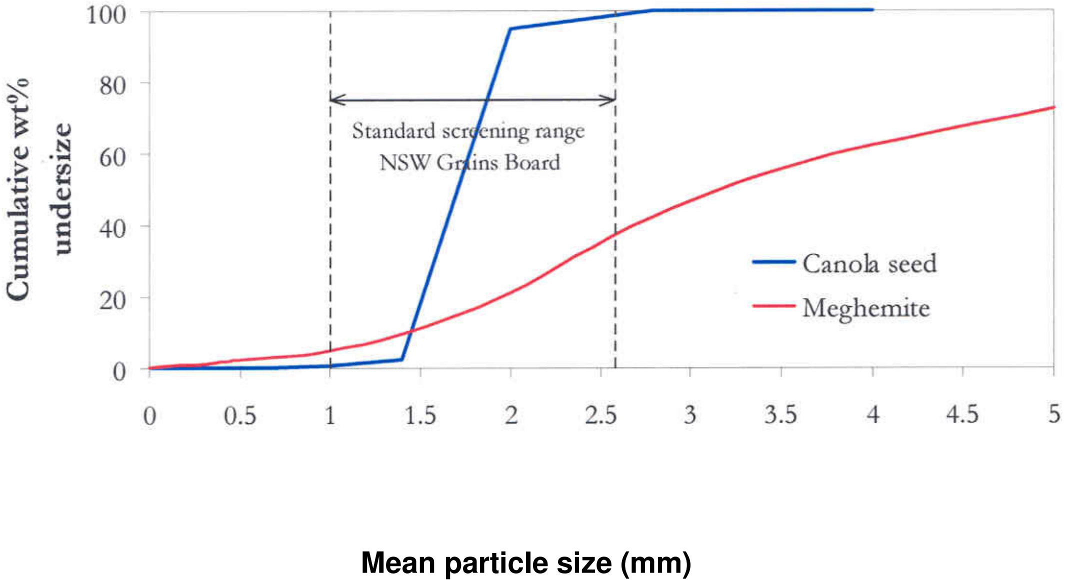


Figure 2.2 Cumulative mass % undersize of meghemite and canola seed samples obtained from SACBH.

2.2 Density

The density of the meghemite contaminants was determined using the water displacement technique. A known mass of meghemite was added to a measuring cylinder containing a known initial volume of water. The change in water volume was measured and used to estimate the particle density. These measurements yielded a density of 3040 ± 30 kg/m^3, or a s.g.of 3.04 ± 0.03.

Despite the potential errors arising from using the water displacement technique for determining the density of canola seed, this technique was implemented yielding a density of 1140 ± 30 kg/m^3 (s.g. of 1.14 ± 0.03). This correlates well with the value of 1100 kg/m^3 reported by Ginestet et. al. (1994)[2].

Given the disparity in the densities of the two materials, it is likely that density based separations techniques will provide potentially viable alternative for separation with a high level of efficiency. Such processes include the use of specific gravity separation tables and de-stoners. Trials were subsequently conducted using the specific gravity separation table at AMRDC to assess the effectiveness of this technique on a laboratory scale.

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[2] Ginestet, A., Guigon, P, Large, J.F., and Beeckmans.J.M., 1994, *Further studies of flowing gas-solid suspensions in a tube at high angles of inclination,* Can J Chem Eng, Vol 72, 582 - 587.

2.3 Shape

Canola seed was found to be spherical and highly uniform in shape when compared to the meghemite contaminants. This difference in shape is likely to be beneficial for separation techniques such as screening and gravity separation, enabling higher than anticipated separation efficiencies to be achieved. The selection of round hole sieves for canola seed screening is likely to result in greater numbers of irregular shaped contaminants being separated from the canola seed. Furthermore, the lateral movement of meghemite contaminants over a specific gravity separation table is likely to be improved by having irregular shaped contaminants, therefore improving the potential for separation from the spherical canola seed. Conversely, the difference in shape is likely to result in the terminal velocity of the meghemite contaminants being closer to that of canola seed based purely on their density. This is expected to reduce the separation efficiency of air separation techniques. These factors are discussed in greater detail in the relevant sections.

2.4 Terminal Velocity

Terminal velocity measurements were collected using a modified fluidised bed to fluidise a small number of the canola seed and meghemite particles separately. A hot wire anemometer was subsequently used to measure the local air velocity when the terminal velocity was reached, and this was deemed to be when the particles became suspended by the upflowing air.

Table 2.1 shows the experimentally determined terminal velocities for canola seed, and a range of meghemite particle sizes, as compared to the theoretically calculated terminal velocities. The theoretical terminal velocities were determined based on the calculations proposed by Perry and Green (1984)[3]. A sphericity of 1.0 can be assumed for canola seed, while an assumed sphericity of 0.9 provided reasonable results for the meghemite particles.

Table 2.1 Terminal velocities of canola seed and meghemite particles in air.

	Experimental terminal velocity (m/s)	**Theoretical terminal velocity** (m/s)
Canola Seed (1.0 - 2.5 mm)	5.0 - 6.5	4.1 - 5.5
Meghemite (1.0 - 1.4 mm)	6.5 - 7.0	5.9 - 7.0
Meghemite (1.4 - 2.0 mm)	7.5 - 8.0	7.0 - 8.4
Meghemite (2.0 - 2.8 mm)	8.0 - 8.5	8.4-9.9
Meghemite (2.8 - 4.0 mm)	9.0 - 9.5	9.9-11.8
Meghemite (> 4.0 mm)	12.5-13.0	>11.8

As can be seen from Table 2.1, the experimental and theoretical terminal velocities correlate well indicating the experimental terminal velocities can be considered reliable. For larger meghemite contaminants, sufficient difference exists between the terminal velocity of the meghemite and canola seed for effective separation to occur. However for meghemite particles in the same size range as canola seed, the terminal velocities are closer than would be expected given the magnitude of the difference in specific gravity. This can be attributed to the irregularity of the meghemite contaminants in comparison to the canola seed resulting in a higher relative drag force on the meghemite contaminants. The additional drag force means that the air

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[3] Perry, R.H., and Green, D.W., 1984, Perrys Chemical Engineers Handbook, 6th Edition, Chapter 5, *Fluid and Particle Mechanics,* pages 5-63 — 5-65, McGraw-Hill Book Company, Singapore.

velocity required to suspend or entrain the meghemite particles in air is lower than if they were spherical. Despite this, trials were undertaken using the air separation equipment at AMRDC to further assess the effectiveness of this technology.

2.5 Specific Magnetic Susceptibility

Meghemite is classed as a "strongly magnetic mineral" with a specific magnetic susceptibility in the range 4 - 6 x 10-^{4} m^3 kg^{-1}. Strongly magnetic minerals being defined as those with a specific magnetic susceptibility[4] greater than 5 x 10^{-5} m^3 kg^{-1}.

No data is presently available on the specific magnetic susceptibility of canola seed, however it is anticipated that it is significantly lower than that of meghemite. This indicates that magnetic separation technologies provide a potential for the separation of meghemite from canola seed, provided a sufficiently high magnetic field can be applied to the flowing grain to ensure capture of the meghemite particles. SACBH has purchased magnetic separators to employ at the outlet of their receival hoppers and trials were conducted using these magnetic separators to assess their separation efficiency under simulated conditions.

3.0 SEPARATION TRIALS

3.1 Screening Trials

The results of the particle size distribution tests indicated that screening has the potential to remove a significant percentage of the meghemite contaminants whilst retaining a high percentage of the canola seed. The NSW Grains Board standards of 2.58mm round hole over 1.00mm round hole are considered ideal screening parameters however the screens available at AMRDC limited the screening range to 2.58 mm round hole over 1.50mm round hole. The aim of these trials was to assess the separation efficiency of the selected screens in comparison to that predicted from the particle size distribution.

Figure 3.1 Screening deck at AMRDC used to trial the separation of meghemite from canola seed

The screening deck used in the screening trials is shown in Figure 3.1. The screening deck employs an upward and forward vibrational action to shift the material across the screen and to ensure good mixing on the screen surface. Approximately 20kg of canola seed was contaminated to 2.5wt%[5] with meghemite contaminants having a particle size distribution identical to that determined in Section 2.1. As the screening deck could only house one screen, the trials were conducted in two stages. In the first stage the entire feed was passed over the 2.58mm round hole screen, with the oversize fraction being collected separately from the product stream. The product stream was then passed over a 1.50mm screen where the undersize fraction was collected separately yielding three individual samples; an undersize fraction, an oversize fraction, and the product stream. The meghemite contaminants were separated from each sample[6] and analysed for their particle size distribution. The distribution of the initial contaminants between the various samples is shown in Figure 3.2 with respect to each particle size range, and the data obtained from the screening trials is summarised in Appendix B, Table B.1.

As can be seen in Figure 3.2, the screening trials confirmed that the potential exists to separate a large percentage of the oversize and undersize contaminants using simple screening technology. In total 85wt% of the contaminants were removed from the product stream. This compares with 79wt% which is predicted based on the particle size distribution data in Section 2.1, and screening limits of 2.58mm over 1.50mm. This slight increase in total separation is attributed to the use of round hole sieves in the screening trials in comparison to the square hole Endecott sieves used in determining the particle size distribution. This highlights the additional level of separation which can be achieved by utilising shape as a separation parameter during screening.

[5] No data was available on the typical meghemite contamination level. While it is anticipated that 2.5wt% is higher than actually occurs it gives a contaminant set from which statistically significant results could be achieved.

[6] The meghemite particles were extracted by passing the fractions very slowly over the magnetic separator obtained from SACBH. A mass balance was used to ensure the majority of particles were recovered.

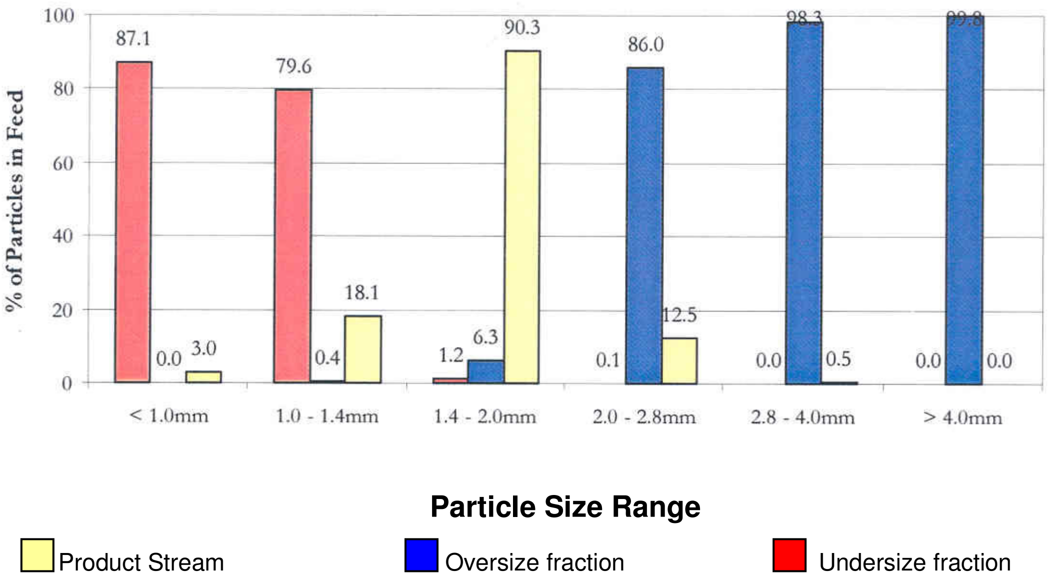

Figure 3.2 Comparison of meghemite levels in the oversize, undersize, and product streams from the screening trials, as a function of particle size.

The screening deck used had a self-cleaning mechanism to reduce any blinding of the screens, however it was observed during the trials that the 1.50mm screen did experience significant blocking. This is not likely to be as significant when using a 1.00mm screen given that a much lower percentage of canola seed exists at this particle size. The screening rate was found to be approximately 4 ton/h per unit metre width of screen for a 1.75m long screen. This is reasonably high which reflects the flowability of canola seed and suggests that screening could effectively be employed at high processing rates.

The total canola seed loss in these trials was in the order of 6.5% which compares with 20% as predicted based on the particle size distribution analysis in Section 2.1. Again it is the selection of round hole sieves which enables lower than anticipated canola seed losses to occur during the trials. Note that some canola seed loss was expected given that the undersize screen employed was 1.50mm in comparison to the 1.00mm screen recommended by the NSW Grains Board. By utilising a 1.00mm undersize screen it is envisaged that higher levels of canola seed recovery (>98%) would be achieved.

The results of the screening trials suggest that accurate screening at 2.58mm round hole over 1.00mm round hole offers a simple and effective means of removing a large percentage of the meghemite contaminants. Based on these screening limits, it is estimated that 70-75% of the meghemite contaminants could be removed whilst retaining in excess of 98% of the canola seed. The highly regular, spherical shape of canola seed lends itself ideally to screening and its flowability ensures that high processing rates could readily be achieved. Additional advantages of screening include the ability to separate other contaminants such as foreign seeds, trash, etc. from the canola seed, which will assist in improving the efficiency of downstream separation processes. In contrast to magnetic separation, the potential also exists to also remove non-magnetic stones. Furthermore, much of the meghemite in other contaminated grain types such as barley, peas, etc. are also likely to be removed by accurate screening at the appropriate levels.

3.2 Specific Gravity Separation Trails

Specific gravity separation utilise properties such as size, surface texture, and specific gravity in order to achieve separation of two or more materials from a mixed product stream. The specific gravity separation table used in the trials at AMRDC is seen in Figure 3.3. The separation table comprises a sloped table with a fine wire mesh surface through which air is passed to act as a fluidising medium. From the feed point under the hopper, the table slopes downward from front to back longitudinally (forward tilt) to ensure movement of the material across the table. The table is also sloped upward from the feed point toward the opposite side of the table (side tilt). When in operation, air passes upward through the table surface fluidising the lighter material which preferentially moves downward toward the feed side of the bed due to gravity. The forward tilt also acts to transport the lighter material along the bed surface toward the exit. The denser material cannot be supported by the fluidising air and falls to the table surface. A sideways vibrational movement of the table conveys these denser particles toward the raised side of the table. By applying the correct selection of side tilt, forward tilt, air velocity, vibrational frequency and amplitude, and flow rate, accurate separation of materials of varying density can be readily achieved.

Figure 3.3 Specific gravity separation table at AMRDC used to trial the separation of meghemite from canola.

Trials were undertaken using approximately 20kg of cleaned canola seed, which was contaminated, to a level of 2.5wt% with meghemite contaminants having a particle size distribution similar to that in Section 2.1. Particles less than 1mm could not be used during these trials as the size of the mesh surface on the specific gravity table would not permit their use.

The feed was passed over the specific gravity table ensuring the lighter canola seed product and denser meghemite contaminant streams were collected. A number of residual contaminants remained on the separation table after the trials and these were also collected yielding three samples; product stream; dense material stream; and residual contaminants. The meghemite contaminants were subsequently extracted from the respective streams and sieved to determine their particle size distributions. The results of the specific gravity separation trials are shown in Figure 3.4, which indicates the distribution of the initial contaminants between the three samples, with respect to the particle size ranges. The data obtained from the specific gravity separation trials is summarised in Appendix C, Table C.1.

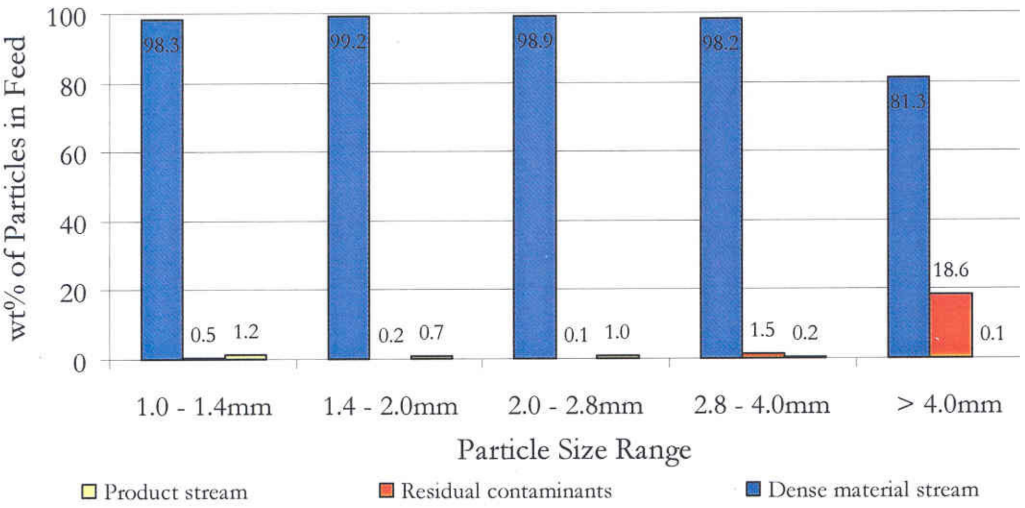

Figure 3.4 Comparison of meghemite contaminants in the product stream, dense material stream, and residual contaminants after the specific gravity separation trials, as a function of particle size.

Figure 3.4 shows that very few contaminants (~1wt%) were found to leave the specific gravity table in the product stream with the bulk of the contaminants leaving in the dense material stream. The removal efficiency is seen to be greater than 98% for all particle sizes except particles >4mm. For particles >4mm, the bulk of the contaminants not removed in the dense material stream were found to be residual contaminants on the table surface. These particles did not show any tendency to be carried away by the clean canola seed however over longer periods of operation this may eventuate. In total, 91% of the contaminants in the feed left in the dense material stream while 8% were residual contaminants leaving only 1% of the original contaminants not separated.

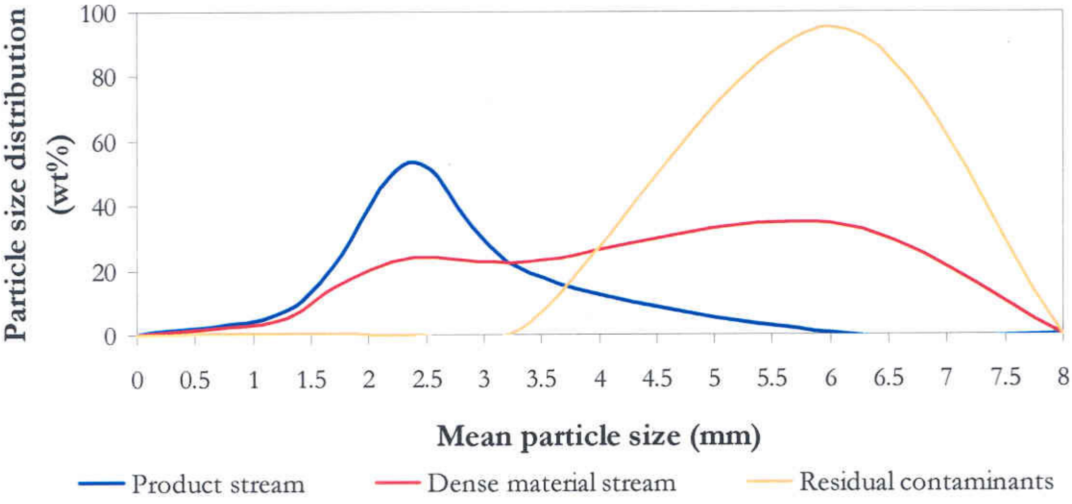

Figure 3.5 Particle size distribution of meghemite contaminants in the respective samples obtained from the specific gravity separation trials.

Figure 3.5 show the particle size distribution of the contaminants found in the product, dense material and residual contaminant samples, respectively. It can be seen that the majority of the contaminants remaining in the product stream were concentrated in the size range defined by the recommended screening limits (1.00mm to 2.58mm). Therefore, by employing screening prior to specific gravity separation the specific gravity table could be optomised to target contaminants in this size range rather than being used to separate a wide range of particle sizes. Based on this result, further trials were conducted using meghemite contaminants between 1.00mm and 2.58mm to investigate whether an improvement in the separation efficiency could be achieved.

During these trials, approximately 20kg of canola seed was contaminated by approximately 140g of meghemite contaminants in the size range between 1.00mm and 2.58mm. This quantity was defined as that which would be present after accurate screening according to the particle size distribution data in Section 2.1, given a total initial contamination level of 2.5wt%. The specific gravity table was optomised for separation of these particles, and the data obtained from these trials is summarised in Appendix C, Table C.2. The results of these trials indicated that a separation efficiency in excess of 99.0% could be achieved with a canola seed loss of less than 0.25%. The residual contaminants accounted for less than 0.5% of the initial contaminants.

While the effectiveness of this technology is attributed mainly to the difference in specific gravities, the difference in shape is also a contributing factor. The side ways vibrational movement of the table has a much lower effect on the uniform spherical canola seed particles than on the irregular shaped meghemite particles as the canola seeds tend to roll easily against the table movement. This ensures that the meghemite particles move toward the dense material exit more rapidly than the canola seed. Once again it was found that reasonably high processing rates could be achieved with an estimated processing rate of 2 ton/hr per square metre of table surface achieved on the laboratory specific gravity separation table at AMRDC.

The results of the specific gravity separation trials indicate that this technology could be effectively applied for the present application with the ability to remove 99% of the meghemite contaminants in the size range 1.00mm to 2.58mm. Given that accurate screening can remove 75% of the total contaminants leaving those within this size range, combining accurate screening with specific gravity separation could potentially remove 99.75% of the total contaminants from the canola seed. Additional benefits of employing this technology include the potential to remove other dense contaminants such as nonmagnetic stones, metal, etc. from the canola seed. Given that the majority of grains have a specific gravity between 1.0 and 1.4, specific gravity separation is likely to be effective for other contaminated grain crops.

3.3 Air Separation Trials

Traditionally, air separators such as that at AMRDC (refer to Figure 3.6) are employed to remove low levels of lighter contaminants from a heavier product. Conversely, in the current scenario the lighter canola seed product is to be removed from the more dense meghemite contaminants. The air separator employs an overhead mounted fan which draws air through a duct directly above the mixed feed stream. The resulting upward flow of air entrains the lighter canola seed, whilst the heavier meghemite contaminants cannot be entrained thus effectively becoming separated from the canola seed. The primary separation criteria in this technology is the air velocity in the duct.

The air flowrate in the air separator was reduced until entrainment of the canola seed occurred readily, and upon further reduction of the flowrate canola seed began to pass under the separator. The flowrate in the duct was measured to be in the range of 6.0 – 6.5 m/s using a hot wire anemometer, and this corresponds well

Figure 3.6 Air separation unit at AMRDC used to trial the separation of meghemite from canola.

with the terminal velocity of canola seed measured experimentally in Section 2.4. Meghemite contaminants with a particle size distribution defined by that in Section 2.1 were added to a 20kg sample of canola seed to achieve a contamination level of 2.5wt%. The resulting mixture was then passed under the air separator with the heavy material and product streams collected separately. The meghemite particles were then extracted from both fractions and analysed to determine their respective particle size distributions. Figure 3.7 shows the results of the trials with the distribution of the initial contaminants between the two samples presented as a function of the particle size range. The data collected during the trials is summarised in Table D.1, Appendix D.

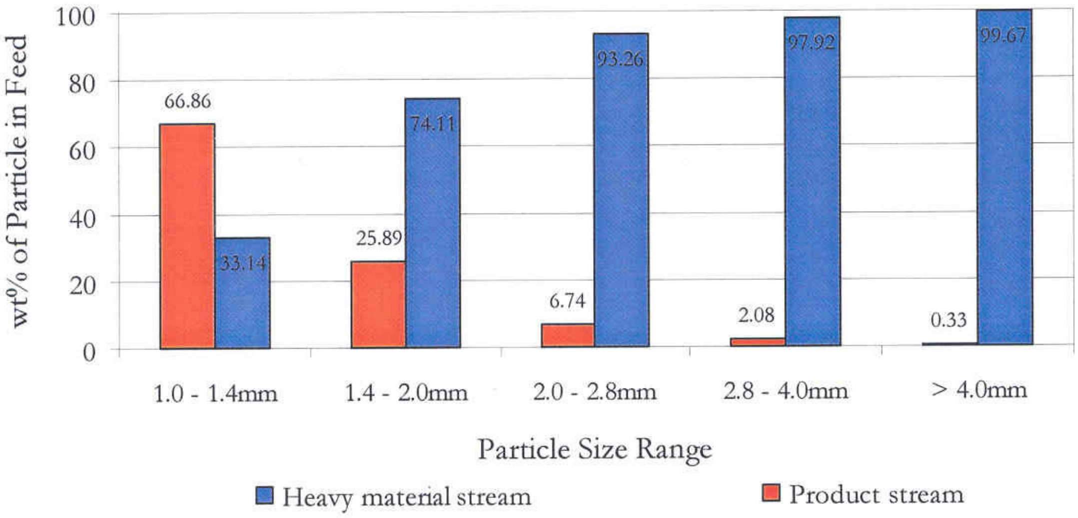

Figure 3.7 Comparison of meghemite levels in the product stream and dens material stream from the air separation trials, as a function of particle size.

As can be seen in Figure 3.7, the efficiency of air separation is high for larger particle sizes as is expected given the larger difference in terminal velocities. However, as the particle size decreases the separation efficiency decreases. This becomes particularly significant for particles between 1.0mm and 1.4mm, and 1.4mm and 2.0mm, where the separation efficiency has dropped to 33% and 74%, respectively. This result is also expected given that the terminal velocity of the meghemite particles in these size ranges approaches that of canola seed. It should be noted that these particle sizes are also within the acceptable range for screening indicating that air separation would not be a suitable separation process downstream of screening.

While air separation has been shown to be effective for the separation of larger meghemite contaminants from canola seed on a laboratory scale, some doubts arise regarding the ability to do this on a commercial scale. When processing continuously on a commercial scale, the duct of the air separator will constantly be drawing off large amounts of canola seed. Therefore the volume of the duct containing canola seed will be significant and this can impact on the airflow profile in the duct. Disturbances in the airflow profile will result in a varying and uneven air profile at the duct inlet and the possibility exists for high velocity and low velocity regions to form. Under these conditions, unwanted meghemite particles can be drawn off at high velocity points while excessive canola seed losses will occur at low velocity points. For these reasons, it is considered that air separation is unlikely to be an effective solution for the separation of meghemite contaminants from canola seed.

3.4 Magnetic Separation Trials

As previously discussed, SACBH has purchased magnetic separators for meghemite contaminants removal which are to be installed at the base of their receival hoppers. An example of these magnetic separators is shown in Figure 3.8. The permanent magnetic tubes (far right) slide into the magnet tube housings which in turn slide into the frame of the magnetic separator. Grain is allowed to flow over the magnetic housings from the receival hopper under its own weight, and the permanent magnets attract the meghemite particles which attach themselves to the tube housings. To clean the separator the housings and magnetic tubes are slid out over the collection tray attached, and the magnetic tubes are subsequently slid out of the housings leaving the meghemite and other magnetic particles to fall onto the collection tray. Figure 3.9 shows a view from die top of a receival hopper at die Port Adelaide terminal of SACBH with the magnetic housings of die magnetic separator visible. Figure 3.10 shows the frame of the magnetic separator installed at the base of the hopper.

Figure 3.8 Magnetic separator supplied by SACBH and used to trial the separation of meghemite from canola seed.

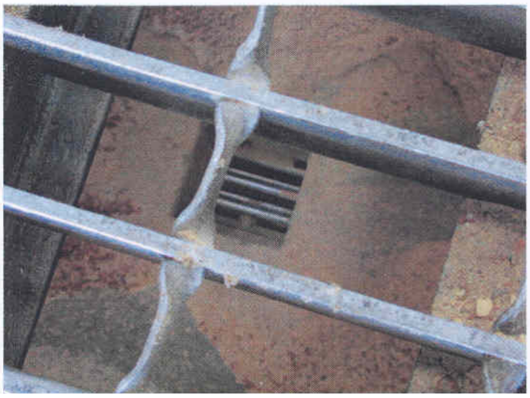

Figure 3.9 Top view of a receival hopper at SACBH showing the tubes of the magnetic separator.

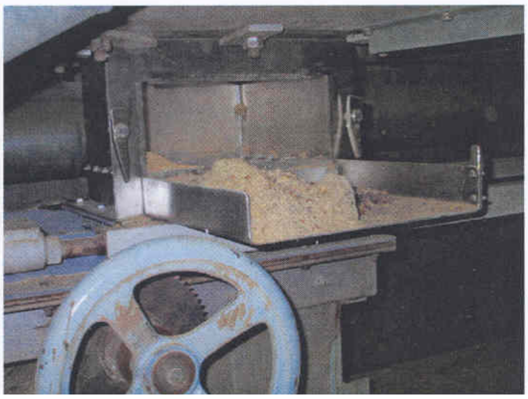

Figure 3.10 View of the frame of the magnetic separator under a receival hopper at SACBH.

To replicate this system at AMRDC, $1m^3$ hopper was modified to enable the magnetic separator to be fitted below the hopper. This is shown in Figure 3.11. The hopper was subsequently filled with approximately 750kg of canola, which was then allowed to run very slowly over the magnetic separator to capture any meghemite contaminants. The cleaned canola seed was subsequently contaminated with around 500g of meghemite contaminants and returned to the hopper in preparation for the trials.


Figure 3.11 The magnetic separator from SACBH under the hopper at AMRDC.

During the trials the canola seed was allowed to run out of the hopper through the magnetic separator, under its own weight. When finished, the meghemite contaminants captured by the magnetic separator were removed, and the mass recorded as a function of particle size. A sliding plate at the hopper outlet enabled trials to be conducted under half open and fully open conditions to investigate the impact of the flowrate on the separation efficiency of the magnetic separator. The data collected during these trials is summarized in Table E1, Appendix E, and the results are summarized in Figure 3.12 which shows the separation efficiency as a function of particle size and flowrate.

The results indicate that the separation efficiency generally decreases with decreasing particle size, and decreases with increasing flowrate. At a flowrate of 20ton/hr, the efficiency drops from approximately 85% for meghemite particles greater than 2.8mm down to 70% for particles between 1.00mm and 1.40mm. At a flowrate of 60ton/hr the respective separation efficiencies were 75% and 57%. As with air separation, the lowest separation efficiencies were observed for meghemite particles in a similar size range to canola seed.

Due to the flowability of canola seed, it will naturally flow rapidly through the magnetic separator which is likely to reduce the efficiency unless some restriction to flow is implemented. At higher flowrates the bulk density of the canola seed in the separator is higher and the movement of meghemite particles toward the magnetic housings will be hindered with the inter-particle forces being more significant resulting in a tendency for the meghemite particles to continue with the bulk flow. At lower flowrates, these inter-particle effects are reduced and the particles have the ability to move more freely within the magnetic separator increasingly the probability of them contacting the magnetic housings.

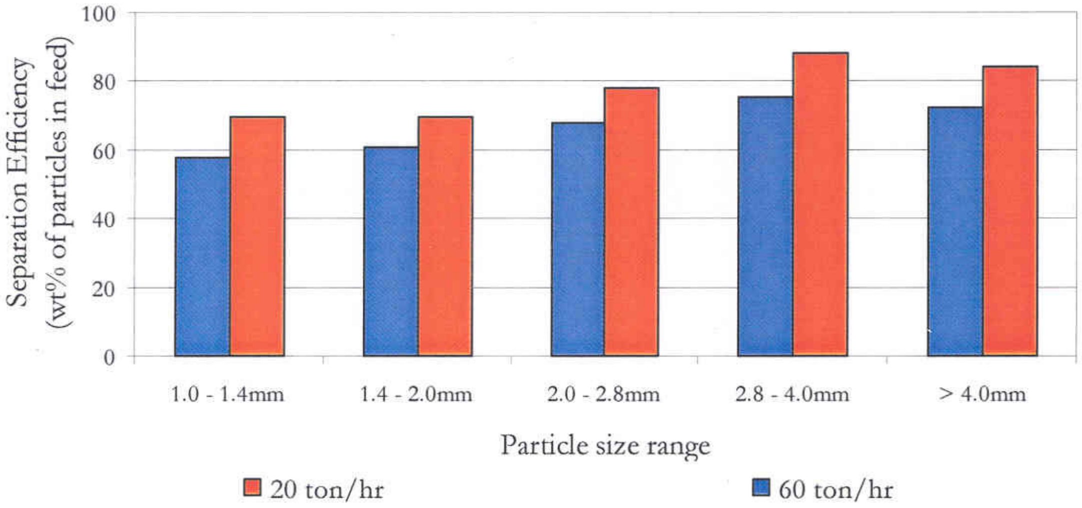

Figure 3.12 Separation efficiency of the magnetic separator from SACBH as a function of particle size and flowrate.

These results tend to indicate that these magnetic separators are limited in their ability to efficiently remove meghemite contaminants from canola seed. At best, efficiencies of 85% were achieved for larger contaminants at the lower flowrate of 20ton/hr. These contaminants are more efficiently removed by screening, and in the particle size range similar to that of canola seed, efficiencies as low as 57% were observed. Magnetic separators are also limited in that they are capable of separating only those materials with a high specific magnetic susceptibility, and non-magnetic contaminants cannot be removed. Blockage of the separator may also pose problems, and excessive build up of contaminants may result in lower separation efficiencies. At high flowrates, the possibility also exists for previously trapped contaminants to be drawn back into the canola seed. Therefore, it is considered unlikely that magnetic separation alone will be an efficient solution for the removal of meghemite from canola seed.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Figure 3.13 compares the separation efficiencies achieved during the trials of the various separation technologies in Section 3. These results indicate that specific gravity separation is capable of achieving the highest levels of separation over the entire range of meghemite contaminants, with the exception of particles >4mm. Screening and air separation are seen to be highly effective for particles >4mm, while in general magnetic separation has the lowest separation efficiency of those technologies tested.

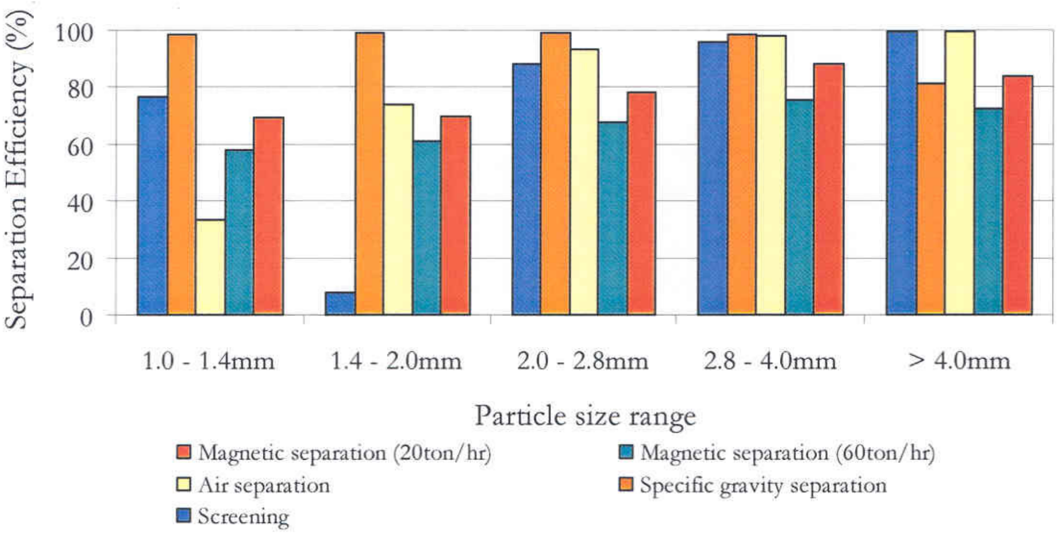

Figure 3.13 Comparison between the separation efficiency of the magnetic separator from SACBH and that of the alternative technologies investigated.

Screening at the NSW Grains Board standard screening level of 2.58mm round hole over 1.00mm round hole is recommended as the first cleaning stage. Screening at this level will remove approximately 75% of the total mass of meghemite contaminants in the feed, while also removing other contaminants such as foreign seeds, trash, and non-magnetic stones from the canola seed.

The remaining meghemite contaminants, having a particle size similar to that of canola seed, will be most efficiently removed by specific gravity separation. Specific gravity separation may remove up to 99% of these remaining contaminants resulting in a potential meghemite contaminant removal efficiency of greater than 99.7%.

These technologies are also likely to be effective for other grain types potentially contaminated with meghemite, such as barley, peas, etc.

Magnetic separation was found to be less effective, however can be employed as an additional contaminant removal stage. It is not recommended that this be installed as the sole technology for meghemite contaminant removal.

APPENDIX A - PARTICLE SIZE DISTRIBUTION DATA

Table A.1 Results of the sieving trials conducted on the sample of meghemite obtained from SACBH.

Meghemite - Total Sample Size = 40.313g

Nominal Sieve Size (mm)	Initial Mass (g)	Final Mass (g)	Mass of Meghemite (g)
4.000	492.270	507.520	15.250
2.800	471.629	479.780	8.151
2.000	406.389	414.810	8.421
1.400	446.177	450.910	4.733
1.000	437.505	439.390	1.885
0.710	419.354	420.030	0.676
0.500	392.541	392.910	0.369
0.355	375.618	375.840	0.222
Bottom tray	394.062	394.660	0.598
		Total Mass	**40.305**
		Mass balance	99.98%

Table A2 Results of the sieving trials conducted on the sample of canola seed obtained from SACBH.

Canola - Total Sample Size = 199.350g

Nominal Sieve Size (mm)	Initial Mass (g)	Final Mass (g)	Mass of Meghemite (g)
4.000	492.270	492.270	0.000
2.800	471.585	471.593	0.008
2.000	406.250	416.750	10.500
1.400	449.700	633.950	184.250
1.000	437.510	441.510	4.000
0.710	419.370	419.800	0.430
0.500	392.550	392.620	0.070
0.355	375.628	375.668	0.040
Bottom tray	394.040	394.070	0.030
		Total Mass	**199.328**
		Mass balance	99.99%

APPENDIX B - SCREENING TRIAL RESULTS

Table B.1 Results obtained from the screening trials for the separation of meghemite from canola seed. The numbers m brackets indicate the weight percentage of meghemite in each sample as a function of the total mass in the feed, with respect to the particle size range.

Trial 1 Mass Canola m Feed (A) = 19941g Mass Canola in Oversize (B) = 0 41g Mass Canola in Product (C) = 18567g	Mass Canola m Undersize (D) = 1246g Total canola recovery (B+C+D)/A = 99 4% Total canola loss (B + D)/A = 6%

Nominal Seive Size (mm)	Mass Stones in Feed (g)	Mass Stones in Oversize (g)	Mass Stones in Product(g)	Mass Stones m Undersize (g)
40	188.49	188.49 (100wt%)	0 (0.0wt%)	0 (0.0wt%)
28	99.77	98.49 (98.7wt%)	0 (0.0wt%)	0 (0.0wt%)
20	102.34	9193 (89.8wt%)	10.41 (11.6wt%)	0 (0.0wt%)
14	60.12	375 (6.2wt%)	47.34 (78.7wt%)	0.96 (1.6wt%)
10	18.72	0.17 (0.9wt%)	3.97 (21.2wt%)	13.60 (72.6wt%)
Bottom tray	0.55	0.00 (0.0wt%)	0.16 (29.1wt%)	0.39 (70.9wt%)
Totals	**469.99**	**382.83 (81.5wt%)**	**61.88 (13.2wt%)**	**14.95 (3.2wt%)**
			Total Stones Recovered	**459.66**
			Mass Balance	97.9%

Trial 2 Mass Canola m Feed (A) = 19123g Mass Canola m Oversize (B) = 58g Mass Canola in Product (C) = 17684g	Mass Canola m Undersize (D) = 1287g Total canola recovery (B+C+D)/A = 99 5% Total canola loss (B + D)/A = 7%

Nominal Seive Size (mm)	Mass Stones in Feed (g)	Mass Stones in Oversize (g)	Mass Stones in Product (g)	Mass Stones in Undersize (g)
4.000	189.39	187.79 (99.1wt%)	1.25 (0 .7wt%)	0 (0.0wt%)
2.800	99.6	92.79 (93.2wt%)	5.63 (5. 7wt%)	0 (0.0wt%)
2.000	96.8	83.27 (86.0wt%)	12.11 (12. 5wt%)	0.06 (0.lwt%)
1.400	54.1	3.39 (6..3wt%)	48.85 (90. 3wt%)	0.65 (1. 2wt%)
1000	18.5	0.07 (0. 4wt%)	3.35 (18.1wt%)	14.73 (79. 6wt%)
Bottom tray	1.32	0.00 (0.0wt%)	0.04 (3.0wt%)	1.15 (87.lwt%)
Totals	**459.71**	**367.31 (79..9wt%)**	**71.23 (15.5wt%)**	**16.59 (3.6wt%)**
			Total Stones Recovered	**455.13**
			Mass Balance	99 0%

APPENDIX C - SPECIFIC GRAVITY SEPARATION TRIAL RESULTS

Table C.1 Results of the specific gravity separation trials with meghemite contaminants ranging from 1.00mm to >4,00mm.

Trial 1
Feed rate = 220 kg/hr
% Product loss = 0.39%

Sieve Size (mm)	**Mass stones added (A)**	**Stones separated *(8)***		**Residual stones on table (g)**		**Total stones recovered (g)**	
		Mass	**%ofA**	**Mass**	**% of A**	**Mass**	**% of A**
>4.0	189.04	150.021	79.36	39.01	20.64	189.031	99.99
2.8 - 4.0	100.97	98.99	98.04	1.57	1.55	100.56	99.59
2.0 - 2.8	104.96	103.72	98.82	0.06	0.06	103.78	98.88
1.4-2.0	64.37	63.764	99.06	0.13	0.20	63.894	99.27
1.0-1.4	18.15	17.896	98.61	0.12	0.66	18.016	99.27
Total	**477.49**	**434.39**	**90.97**	**40.89**	**8.56**	**475.28**	**99.54**

Trial 2
Feed rate = 250 kg/hr
% Product loss = 0.65%

Sieve Size (mm)	**Mass stones added (A)**	**Stones separated (8)**		**Residual stones on table (g)**		**Total stones recovered (g)**	
>4.0	189.25	157.38	83.16	31.38	16.58	188.76	99.74
2.8 - 4.0	100.56	99.01	98.46	1.5	1.49	100.51	99.95
2.0 - 2.8	103.78	102.74	99.00	0.08	0.08	102.82	99.07
1.4-2.0	60.44	59.98	99.24	0.07	0.12	60.05	99.35
1.0-1.4	21.47	21.03	97.95	0.09	0.42	21.12	98.37
Total	**475.50**	**440.14**	**92.56**	**33.12**	**6.97**	**473.26**	**99.53**

Table C.2 Results of the specific gravity separation trials undertaken using meghemite contaminants between 1.00mm and 2.58mm.

Trial No.	**Mass stones in feed (A) (g)**	**Mass residual stones (B) (g)**	**Mass stones in dense material stream (C) (g)**	**Mass stones in product stream (D) (g)**	**Separation Efficiency (C/A) (%)**
1	139.86	0.36	138.65	0.85	99.1%
2	139.01	0.98	137.48	0.55	98.9%

APPENDIX D -AIR SEPARATION TRIAL RESULTS

Table D.I Results of the air separation trials for the separation of meghemite from canola seed.

Trial No. 1 Air velocity ~ 5.5m/s		**Stones separated**		**Stones remaining in canola seed**	
Sieve Size (mm)	**Mass stones added (A)**	**Mass (g)**	**Percentage of A**	**Mass (g)**	**Percentage of A**
>4.0	188.86	188.56	99.84	0.30	0.16
2.8 - 4.0	96.64	94.24	97.52	0.23	0.24
2.0 - 2.8	92.4	86.74	93.87	1.25	1.35
1.4-2.0	49.2	46.29	94.09	2.31	4.70
1.0-1.4	15.55	8.51	54.73	5.89	37.88
Total	**442.65**	**424.34**	**95.86**	**9.98**	**2.25**

Trial No. 2 Air velocity ~ 5.5m/s		**Stones separated**		**Stones remaining in canola seed**	
Sieve Size (mm)	**Mass stones added (A)**	**Mass (g)**	**Percentage of A**	**Mass (g)**	**Percentage of A**
>4.0	188.79	187.85	99.50	0.95	0.50
2.8 - 4.0	97.49	95.85	98.32	0.79	0.81
2.0 - 2.8	96.62	89.51	92.64	2.89	2.99
1.4-2.0	51.28	27.76	54.13	21.44	41.81
1.0-1.4	16.89	1.95	11.55	13.6	80.52
Total	**451.07**	**402.92**	**89.33**	**39.67**	**8.79**

APPENDIX E - MAGNETIC SEPARATION TRIAL RESULTS

Table E.I Results of the magnetic separation trials for the separation of meghemite from canola seed.

Trial No. 1 Flowrate = 20 ton/hr		**Stones separated**		**Stones remaining in canola seed**	
Sieve Size (mm)	**Mass stones added (A)**	**Mass (g)**	**Percentage of A**	**Mass (g)**	**Percentage of A**
>4.0	188.72	158.74	84.11	29.98	15.89
2.8 - 4.0	92.68	81.67	88.12	11.01	11.88
2.0 - 2.8	87.68	68.47	78.09	19.21	21.91
1.4-2.0	49.25	34.29	69.62	14.96	30.38
1.0-1.4	14.32	9.94	69.41	4.38	30.59
Total	**432.65**	**353.11**	**81.62**	**79.54**	**18.38**

Trial No. 2 Flowrate = 60ton/hr		**Stones separated**		**Stones remaining in canola seed**	
Sieve Size (mm)	**Mass stones added (A)**	**Mass (g)**	**Percentage of A**	**Mass (g)**	**Percentage of A**
>4.0	188.72	136.58	72.37	52.14	27.63
2.8 - 4.0	92.68	69.8	75.31	22.88	24.69
2.0 - 2.8	87.68	59.43	67.78	28.25	32.22
1.4-2.0	49.25	29.89	60.69	19.36	39.31
1.0-1.4	14.32	8.26	57.68	6.06	42.32
Total	**432.65**	**303.96**	**70.26**	**128.69**	**29.74**