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The Krebs Gmax Cyclone Development In The Coal Industry

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ABSTRACT: The gMax[IM] development program for coal illustrated that no single cyclone design is optimal for all applications in all industries. A cyclone designed for one application can not necessarily be directly applied in another industry, because the separation mechanics, feed characteristics, and operating mode of a cyclone is loo complicated for that simplistic an approach. Specific process requirements must always be considered in any cyclone application. The coal gMax development program demonstrated that the unique geometry of the gMax provides a finer separation through increased centrifugal acceleration in the lower sections of the cyclone, along with optimal inlet and vortex-finder geometries. This characteristic makes the gMax most advantageous for coal applications.

1.1 INTRODUCTION

In 2000, Krebs Engineers implemented a program to study the impact of various inlet and cone designs on the performance of hydrocyclones. This program, which featured laboratory testing, plant testing, and Computational Fluid Dynamics studies (CFD) resulted in a new Krebs Engineers cyclone product line called gMax[lw].

This program centered on the performance of the hydrocyclones in closed circuit grinding (CCG) operations for minerals such as iron ore, gold, and copper. The results were impressive (l), as indicated by the comparative classification curves (Figure l), which shows the 20-in. diameter-gMax[m] configuration to have a D50 size roughly 62 percent of a standard 20-in. cyclone. Similar D50 decreases were seen in other mineral applications as well.

Typically, any design that decreases the D50 cut point of a cyclone occupying the same physical volume and with equal capacity provides customers with an advantage. As showen in Figure 2 The specific design of the gMax[IM] enables it to essentially occupy the same physical volume as Krebs 10.5° Series design (10.5° cone angle), but provide a finer separation.

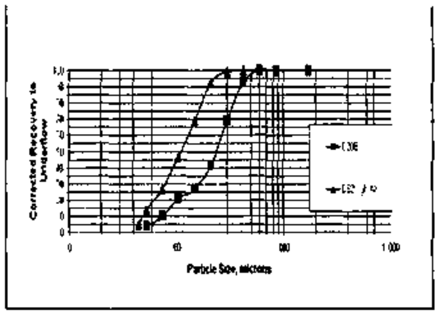

Figure 1 : Corrected Recovery Curce.
Dal;i tor Standard D20B and DS20-gMax Cyclones Wesiern xI'S Copper Concertrator. March 2001

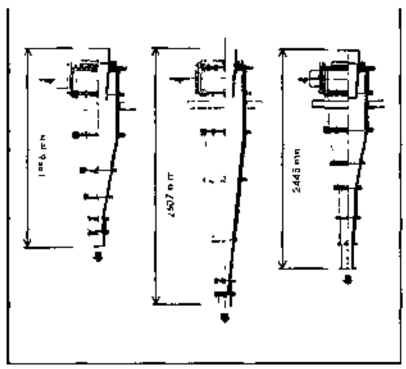

Figure 2 : Comparison of Cyclone Lengths KrebsD15LB, D15LB-T. and D15LB-gMax

Alternately the gMax^{IM} design allows a larger-diameter cyclone, with its greater capacity, to be employed to achieve the same separation as a smaller-diameter cyclone. Thus the gMax^{1M} design provides the potential advantage of permitting the installation of fewer cyclones to process the same volumetric feed rate at the same separation size.

2. 1 BASIS OFGMAX^{IM} IMPROVED PERFORMANCE

In order to determine the basis of the improved gMax^{IM} performance, Krebs Engineers investigated computation fluid dynamic studies of cyclone How patterns. Although cyclone flow patterns are extremely difficult to predict, with CFD the

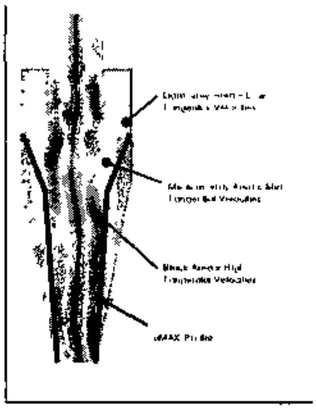

Figure 3 : CFD Image of Tangential Velocities in a Cyclone

modeling has provided evidence of the gMax^{IM} improved performance.

Figure 3 illustrates CFD predictions of tangential velocities in a conventional cyclone, along with a superimposed gMax^{IM} profile (2). This CFD illustration indicates, as have experimental data, that the highest tangential-velocity regimes reside near the air core. The gMax^{IM} profile forces the descending slurry into the higher-tangential velocity region and, by virtue of the higher centrifugal acceleration forces in this region, enhances the migration of particles to the cyclone wall.

Figure 4, which shows the predicted CFD tangential velocities, further supports this theory(3)(4). As shown in Figure 4, the gMax^{m} profile allocates a greater volume of the cyclone to higher tangentially velocities. This results in the descending slurry, in the lower section of the cyclone,

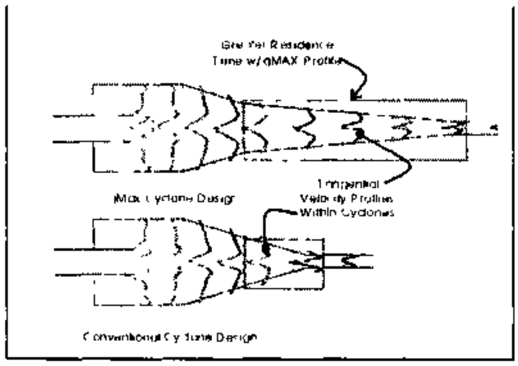

Figure 4: Comparison of Tangential Velocities Between Conventional & gMAX Cyclones

being exposed to greater centrifugal acceleration for a greater period of time than a conventional cyclones. This exposure to greater centrifugal acceleration coupled with greater residence time in this region results in the finer separation achieved by a gMax^{IM} cyclone in comparison to a conventional cyclone of the same diameter,
in grinding circuits where the solids densities and the flow splits to underflow are much higher than typical coal applications.

Initial gMax^{IM} coal testing did not show the same decrease in separation size shown by previous testing in closed circuit grinding applications. It is postulated that the reason for this was tied to two variables:

- Coal typically has densities from 1 .25 to 1 .60 SG. Lower particle densities result in much lower induced settling velocities in the upper section of the cyclone.

- For typical coal classification applications, flow splits to underflow range from 10 to 20 percent (v/v). A much lower percentage of the feed slurry is exposed to the high tangential velocities region of the gMax^{IM} (typical CCG applications have flow splits to underflow of 30 to 60 percent).

In order to apply the gMax^{IM} design to coal, a series of lab tests were performed on a 10-in diameter cyclone. These tests featured various combinations of new inlet and vortex-finder designs as well as varying combinations of gMax^{IM} cones and apexes.

Initial base-line testing indicated that the critical operating parameters and particle characteristics in coal applications differ enough from CCG that although the "metallurgical" g-Max^{IM} did provide a finer D50 than the "T" Series design, the decrease was not as great as that established in CCG commercial and test installations. Figure 5 shows the corrected recovery curves for the baseline testing.

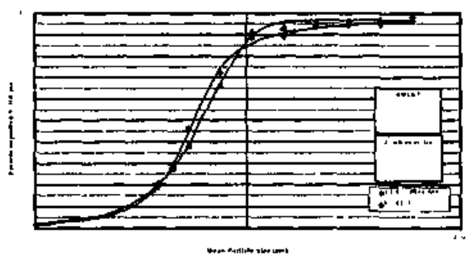

Figure 5 : Connected Recovery Curves for D10LB-T vs Metallurgical "M1" D10LB-gMax Lab-Test Results

Theoretical assessment of the initial lab results, from this testing, led to the conclusion that the following physical characteristics of coal required a modified gMax^{m} design different than thai used in minerals:

- Coal size distributions are typically bi-modal with the size distribution comprised primarily *of* coarser, low-density particles and finer, high-density particles, with a low mass percentage of particles occupying the sizes between these two extremes.

- The shape of the lower-density coal particles (non-spherical) make these particles more susceptible to being drawn to the overtlow by drag forces in the upper region of the cyclone.

These physical characteristics require a cyclone design that provides greater residence time to the incoming slurry before accelerating it in the high-centrifugal-force region of the gMax^{,M} lower cones.

Figure 6 shows the comparative corrected-recovery curves for the original "metallurgical" gMax^{IM} design (Ml), two variations of the modified gMax^{,M} design for coal (CI & C2), and the "T" series design.

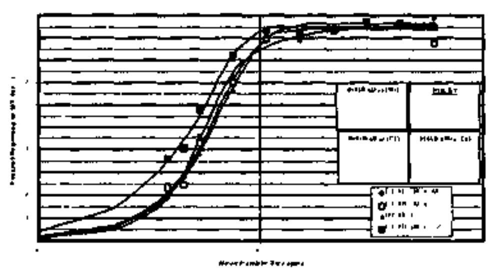

Figure 6 : Connected Recovery Curves for D10LB-T, "M1" "D10LB-gMax, and "C1& C2" DIOLbgMax Lab Test Results

Review of the corrected-classification curves indicates that the initial changes made to the coal gMax^{m} design (CI) resulted in slightly lower coarse-particle bypass than the "M1 " design, but with no improvement in D50 size.

Further modifications were made to the Coal gMax^{,M} design and subsequent testing of the new "C2" design indicated that coarse-particle bypass was reduced below that of the "T" series. Furthermore, the "C2" D50 size decreased roughly 21 percent below that of the "T" series (49pm versus 62pm).

The results shows that the design modifications embodied in the "C2" design provided the same improvement in performance with a coal feed, that the "Ml"
gMax design provides in CCG.

Generally, the changes in the gMax^{IM} design for coal uses less radical cone-angle relationships than in minerals. These changes were necessitated because of the physical differences of coal versus minerals, as well as the different operating mode of typical coal cyclones versus cyclones used in closed-circuit grinding.

.2 FINAL RESULTS OF THE COAL GMAX DESIGN

Although Krebs determined the optimum geometry tor the Coal gMax, based on the "C2" design, testing continued in the laboratory to further confirm the performance improvements. Figure 7 shows a comparison of subsequent lab testing for the "Coal" gMax^{IM} and the "T" Series design. These tests were performed with the same inlet and vortex size in both the gMax and "T" Series units. These results confirm the original testing results, showing the gMax"[1]' design provided a finer separation and greater recovery than the "T" Series design.

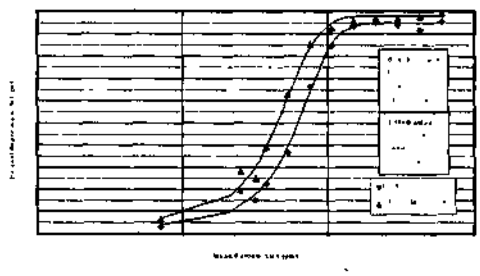

Figure 7 : Actual Recovery Curves for D10Lb-T and D10LB-gMax in Confirmation Lab Tests

Table 1 shows the critical performance results of this comparative test. Most notably is the decrease in separation size (-30% finer than the "T" Series) and greater recovery of plus 75um size particles (97.2 versus 92.6 wt%).

To put this improved performance into perspective: One (1) cyclone, fed 272 gpm of 5 percent solids slurry, results in 3.46 t/h of feed solids. If 19 percent of that feed is plus 75pm, a 5 percent increase in recovery of this size, would result in each cyclone recovering an additional 0.039 st/h of coal. This seems rather minimal, however if that tonnage is calculated for twenty (20) operating units, the improved performance of the gMax would potentially result in an additional recovery of 4,000-5,000 short tons annually.

1.3 GMAX '">' FOR COAL FIELD TEST RESULTS

n i t Midwestern U.S. Plant Testing

After completing the preliminary lab testing of the revised gMax^{IM} design for coal, several field tests were conducted to verify the results determined in the lab. Testing was conducted in a Midwest plant comparing a 15-in. diameter "standard" cyclone and a 15-m. gMax^{IM} cyclone in a raw-coal classification application. The results of the testing indicated the gMax^{IM} cyclone provided a D50 roughly 20 percent finer than the standard 15-in. model. This decrease m separation size resulted in a 5.37 percent increase in recovery. Based on these results, the gMax-model cyclones were selected lor commercial installation.

After commissioning, the «Max cyclones were sampled and Figure 8 shows the comparative results of the installed gMax units and the standard D15LB results from testing.

The recovery curves show the gMax units are providing a ~ 26 percent finer separation and ~ 3.69 percent higher recovery. Of more importance however, is that the gMax underflow ash content is slightly lower than the original D15LB units (29.12 percent ash for the gMax versus 30.14 percent ash for the D15LB).

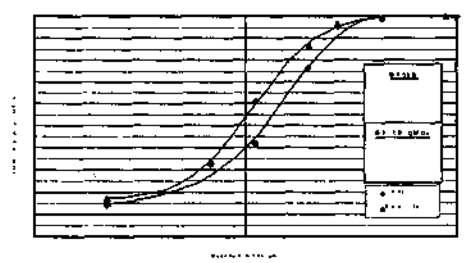

Figure 8 : Actual Recovery Curves for D15LB-20^{0} and D15LB-gMax in a Midwestern Coal Application Test.

The reason that the underflow ash decreased is because the gMax recovered additional plus 44pm size fractions without additional fine-particle bypass. Normally, the oversize fractions errantly reporting to overflow contain the lowest-ash coal particles. Since the gMax's additional recovery is concentrated in these sizes, the underflow ash is now lower than the original DI5LB's. Figure 9 shows the comparative underflow yields and ash contents for the gMax and original DI5LB's, with the increased recovery of the 44pm x 150pm size fractions. Of course, increasing carbon recovery is of paramount importance to the steam-coal producer.

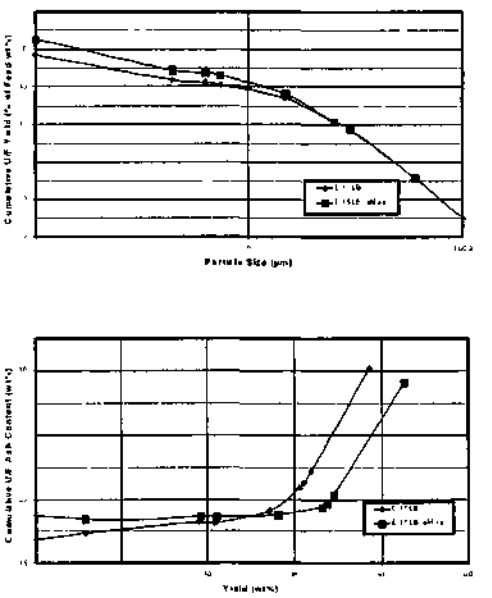

Figure 9 : Conparison of Underflow Yields and Ash Content for a D15Lband D15LB-gMax in a Midwestern Coal Application Test.

13 i : Eastern U.S. Plant Testing

Testing of a U6-gMax design (6-in. diameter, all-polyurethane) was also performed in a eastern *U.S.* plant. This testing was in a secondary-stage application where the objectives included maximum recovery of primary-stage ,raw-coal-classifying overflow prior to flotation.

Figure 10 shows the actual recovery curve achieved during testing. The unit achieved a D50 of 29pm. Although the indicated fine-particle bypass of- 38 percent seems rather high, the underflow solids was 25.7 percent and the water split was 84/16 (DO/Du). This indicates that the cyclone was creating centrifugal forces sufficient to affect a separation on some of the minus 44pm particles.

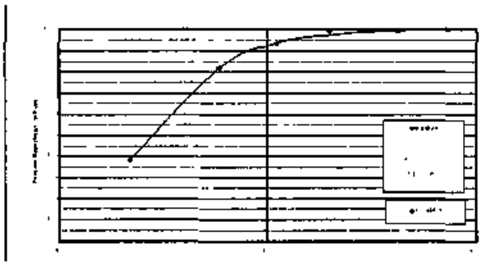

Figure 10 : Actual Recovery Curves for a U6-gMax in a Eastern U.S. Coal Application Test

These high centrifugal forces resulted in the cyclone recovery 99 percent of the 250pm x 149pm size, 94 percent of the 149pm x 74pm size, and more importantly, 82 percent of the 74pm x 44pm size fraction - those size fractions which normally contain the highest percentage of carbon.

1.4 CONCLUSIONS

The gMax[m] development program for coal illustrated that no single cyclone design is optimal for all applications in all industries. A cyclone designed for one application can not necessarily be directly applied in another industry, because the separation mechanics, feed characteristics, and operating mode of a cyclone is too complicated for that simplistic an approach. Specific process requirements must always be considered in any cyclone application.

The coal gMax development program demonstrated that the unique geometry of the gMax provides a finer separation through increased centrifugal acceleration in (he lower sections of the cyclone, along with optimal inlet and vortex-finder geometries. This characteristic makes the gMax most advantageous for coal applications where the objective is maximizing solids recovery, such as:

- secondary-stage classification applications up stream of notation, and

- raw-coal classification in plants without • flotation.

As a major cyclone supplier to both the minerals as well as the coal industry, we are continually studying the fluid dynamics of free-vortex How regimes to improve cyclone design. Major breakthroughs will likely be tied to greater understanding of the energy profiles in a cyclone and adjusting the geometry to better comply with natural energy distributions.

A perfect example of this was caught by a photograph of a transparent cyclone. The embellished photograph (Figure 1 !) shows the shape of the air core during cyclone shut down, and its similarity to the cone profile of a gMax^{IM} cyclone.

1.5 REFERENCES

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Table 1 Performance Data for D10LB-T and D10LB-gMax-Confirmation Lab Tests

Unit:	D10LB-T	D10LB-gMax
Test	Lab Test 1	Lab Test 11
Capacity		
Flow Rate (gpm)	276	272
Head (PSIG)	20	20
Recovery		
Total Recovery (wt%)	24 2	43 3
Avg Recovery +75p.m (wt%)	92 6	97 2
% Increase in +75nm Rec	Base	4 96
Performance		
D50 (pm)	62 5	45 1
% Decrease in D50	Base	27 85
Bypass (a)	60	42
Alpha	2 52	2 32
Ep	25 4	193
Recovery Numbers		
(Mean Size (jm)		
600	95 5	99 4
425	91 8	97 8
300	93 8	968
212	95 5	97 1
150	93 5	95 5
106	84 9	92 4
75	66 6	85 4
53	36 7	62 8
38	22 2	39 1
32	14 7	25 0
25	18 7	28 0
20	12 4	36 2
7	30	64