Buell Division of
Fisher-Klosterman, Inc.®
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Manufacture of Fine Aggregates - Dry
"Getting the Fines Out of Screenings"

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1. Introduction

In 1989, Luck Stone's Northern Virginia sales staff requested a manufactured sand product to provide to their asphalt customers. At that time, the definition of a manufactured sand for use in asphalt was generally understood to be a minus 1/4 inch screening with no more than 5% passing the 200 mesh. Because most "screenings" have significantly more material passing the 200 mesh, a process to remove this excess material was undertaken. Luck Stone has routinely employed a wet process to remove this excess 200 material, but concerns with space and the environmental aspects of this process pointed to the desirability of a dry processing system. Internally, we refer to this wet processed product as a washed screening. Although consideration was given to this wet process, we did not believe it would be the best solution. As a result, during 1990, we began an investigation of dry alternatives to the dewatering classifying screw.

2. Historical Investigation

As with many aggregate producers, Luck Stone was faced with a dilemma. How could we produce a sand without the associated problems of a wet process?

- We didn't want to sacrifice aggregate stockpile space to locate dewatering ponds.
- We didn't want to process or produce wet material during freezing weather.
- We didn't want the environmental concerns that are inherent with ponds, wet fines containment, water concerns, or slimes disposal.

The challenge of finding a dry solution was given to Luck Stone's Chief Engineer, Bob Stansell. Just as we were compelled to avoid a wet system, we also had concerns about internal fan/vane air separators. This type separator is in use at one of our lime plants. We eliminated it from consideration for several reasons:

- The ultimate tonnage requirements would create a large support structure.
- The existing separator had too many mechanical parts with difficult access.
- The internal wear associated with a diabase material would be excessive.

2.1 Dry Fine Screening

We began this investigation with a suggestion from our plant manager at Leesburg, Lee Nash. Lee suggested we investigate a multi-deck screen which had been demonstrated to him. Our desired result with this type screen would be realized if it could remove a sufficient amount of minus 200 mesh material by either screening or air sweeping to meet a gradation of less than 5% passing the 200 mesh. We shipped several barrels of screenings to the manufacturer for testing and traveled to the testing site to assist in the effort. After several days of testing and subsequent evaluation, we concluded the following:

- Moisture greater than .5% caused the fine screens to blind.
- The cutpoint to achieve a clean product created unacceptable levels of waste.
- This particular screen would not be suited to dry separation at a cutpoint below 50 mesh.

Several options were undertaken to determine ways in which this screen might be utilized.

- These included blending this screen's product back to raw screenings as a way to lower the percent passing the 200 mesh in the final dust product.
- Review of the impact of the screen's co-generated fines product for blending back into the base materials.

We determined that this screening unit would not be effective in the production of a final product due to its moisture sensitivity and our inability to control the weather. When the feed moisture of the screenings was above .5% we noted a decrease in performance. As the plant is automated and capable of running unmanned for hours, a process screen with this moisture sensitivity would not produce a consistent product over a range of inconsistent operating conditions.

2.2 Fluid-Bed Dryer

In our continuing quest for a dry process, we next investigated a fluid-bed style dryer. This process would have the advantage of being able to remove moisture at the same time the fines were being removed. The equipment includes a slightly inclined vibrating pan with many small holes throughout. This arrangement allows heated air to pass through the material both drying and removing fines. The heated air evaporates the moisture in the screenings as they are vibrated down the perforated pan while the air pressure removes the fines. This process offered excellent control regarding the cutpoint and eliminated the moisture problem associated with damp feed. Samples were submitted for evaluation and conducted with our supervision. The results were favorable with good levels of control and predicted consistency. However, several areas of concern preempted our favorable view of this equipment's performance:

- Even though this equipment provided excellent results we determined that the capital required to install such a system would be excessive.
- Our concern extended to the higher maintenance considerations of this process due to abrasion and complex burner requirements.

- The added processing cost to provide the necessary BTUs for drying was also a detriment for this process.
- Our final concern was the safety of such a system to operate unattended with the balance of the automated circuit.

We determined to continue our search for a better process, although the fluid-bed dryer was superior in providing a good, clean and consistent product.

2.3 *Gravitation-Inertial Classifier*

During a market lull, with decreased demand for an asphalt sand, the intensity of this investigation was somewhat abated as we turned to other pressing issues. During this time interval we began a serious study of the in-process screenings moisture content. The study was conducted over a 6 month period and found an average moisture level of 1.5%. This was due primarily to water added at the crusher for dust control Also noteworthy during this time period was the installation of dust collectors on the Bin 3 circuit minimizing the need for water additions at the crushers. These results encouraged Mr. Stansell to investigate a type of air classifier he had installed some 20 years prior. He had not seriously considered this air classifier since his previous experience had shown it to wear rapidly, even in limestone. Other concerns were sensitivity to feed moisture, similar to other fine separation equipment.

Continuing his investigation, Mr. Stansell discovered that the company responsible for this particular classifier had been purchased by GE Environmental (now Marsulex Environmental Technologies, LLC (MET)) which was actively marketing this process. Mr. Stansell also discovered that they had overcome his concern with wear by the utilization of ceramic liners. Due to these discoveries we reactivated our investigations and journeyed to western Pennsylvania to look at an aggregate installation of the Buell Classifier.

As our production personnel are an important part of our investigation process they also accompanied us to assist in this equipment's evaluation. Due to the favorable response, we submitted test samples for evaluation with the Buell Classifier by GE Environmental in the fall of 1992.

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Gravitational-Inertial Classifier, Marsulex Environmental Technologies

Figure 1 - The Buell Logo

Based upon the initial tests as well as an on-site visit of their testing facilities, the design process was initiated to include a Buell classifier at our Leesburg, Virginia Plant. Construction of the facility proceeded during early 1993 with the first material being produced from a single 90" unit during the summer. In early 1994, with support of market projections and the addition of a new HP-300 in the circuit, an additional 90" unit was added to boost final production through the combined units.

3. *Buell - Gravitational Inertial Classifier*

MET manufactures several types of air classifiers which are designed to remove various sizes of material. MET's Centrifugal Classifier can separate at any desired cutpoint between 150 mesh to less than 400 mesh (106 to 15 microns) while their Gravitational Classifier has a coarser cutpoint between 100 and 10 mesh (150 to 1651 microns). Luck Stone selected a third type of classifier for study, the Gravitational-Inertial Classifier (GIC), as it is capable of a cutpoint between the 50 and 200 mesh (297 to 74 microns.) This cutpoint capability around the 200 mesh would provide our customer with a desirable product while limiting production of co-generated products (sand plant fines).

The main features of the GIC classification system would include:

- A feed distribution box to ensure that a uniform curtain of material is distributed along the length of the Buell
- The classifier with its unique half heart shape.
- Ducting required to carry the removed fines to a cyclone or storage tank.
- A baghouse to provide dust abatement.
- A fan providing the draft required to achieve proper separation.
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The Buell unit has a fixed height of 6 feet and 2-1/2 inches (Figure 2). Because the cross-section is fixed, the Buell's design length is changed to accommodate desired tonnages. Luck's production units are sized for 60 tons per hour and are 90" in length. This yields .66 tons per hour per inch of length. The unique shape of the Buell is apparent by the ½ heart shape of the eddy current chamber, all of which is lined with ceramic tile to extend the wear life. Other observable features of the unit are the inlets and outlets for the feed and finished product, the vanes which guide the air flow, and the air ducting system with adjustment gates. Most notable is the lack of any moving parts while the unit is in operation except the two airflow adjustment gates.

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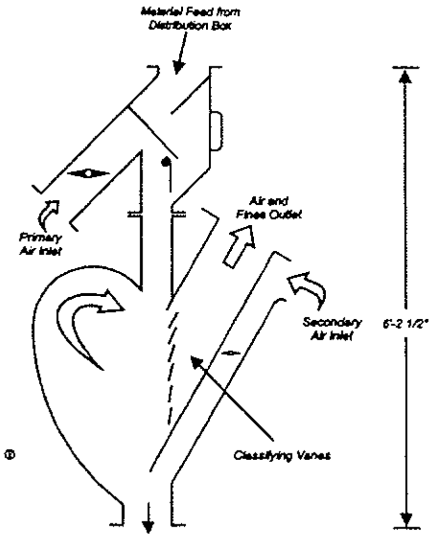


Figure 2 Idealized cross-section of the GIC - Buell

3.1 Operating Principles

The concept of air classification may have had its origins in antiquity with the winnowing of grain by the wind. The classification systems of today, although much more sophisticated and complex, are still dependent upon the same, age-old principles. The desirability of the Buell classifier lies in its simplicity of design and function. This simplicity is achieved by the utilization of an adjustable air flow passing through a curtain of falling material separating particles around the desired cutpoint.

The GIC utilizes the classifying principles of gravitational, inertial, centrifugal and aerodynamic forces. Air enters the classifier's primary air inlet, which is open to the atmosphere, by an induced negative pressure developed by the primary fan. The air mixes with a falling curtain of feed material which has been evenly distributed over the length of the unit by a gravity distribution box. The thickness of the falling curtain of material is less than 2". The primary air inlet velocity ranges from 3,500 to 6,000 feet per minute.

As the curtain of material drops into the classifying zone, it falls in front of the air outlet duct separated by widely spaced and variably angled vanes. The vanes create a laminar flow condition which nearly reverses the gas flow imparting the force required to move the finer particles into the gas stream and out of the unit (Figure 5). Prior to passing through the vanes, the friction of the relatively high velocity gas and particle mix causes the stream to flow in a clockwise current (eddy) within the heart-shaped portion of the chamber (Figure 3). This eddy is reinforced by air introduced through the secondary air inlet located just above the coarse material discharge outlet. The eddy current flowing downward and parallel to the plane formed by the vanes forms a moving wall of feed material within the classifying zone. This wall of air and moving material is important as it provides the proper control to maintain the directional change of the air and fines flow through the vanes.

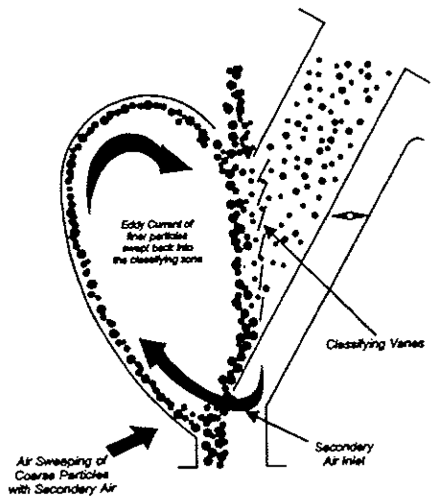


Figure 3 - Detail of Eddy Current and Secondary Air

The advantage occurs because this moving material forms a wall which does not introduce the same drag or wear effects of a solid wall to accomplish the same classification.

The particles not swept through the vanes fall onto an inclined baffle plate located at the bottom of the gas outlet directly beneath the primary gas inlet. The coarse product is scrubbed by the secondary air as it slides off into the coarse discharge outlet. Secondary air flow dislodges fines adhering to the coarser particles which join the stray fine particles entrained by the eddy current. These fines return to the classifier inlet point by the eddy current and are re-introduced into the classifying zone (Figures 2 and 3).

3.1.1 Analysis of Forces Acting on Individual Particles

Each particle entering the classifier has a gravitational force (Fg) proportional to its mass, which in turn is proportional to the cube of its diameter. As the particle is introduced into the classifier's primary gas stream, it is further subjected to an inertial force (Fi) also proportional to its mass. Because the gas stream flows in a downward direction, the inertial and gravitational forces (Fi and Fg) compliment each other (Figure 4). As it passes through the vanes, the gas steam changes direction, exerting a drag force (Fd) proportional to the diameter of the particle and approximately opposite in direction to the gravitational and inertial forces. As the particle is influenced by the drag force (Fd) and changes direction, it is subjected to a centrifugal force (Fc) proportional to its mass, which directly opposes the drag force (Fd).

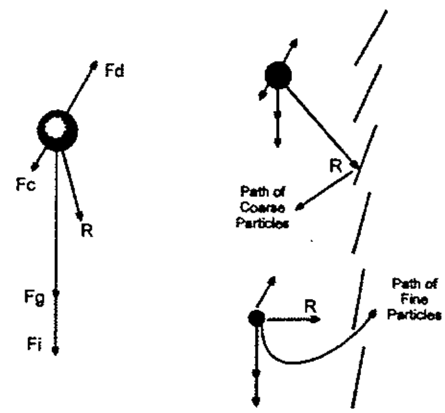


Figure 4 - Forces acting upon particles

Under design conditions, the resultant force (R) acting on a particle diameter (K) (cutpoint) is of a magnitude and direction to cause the particle to either be swept through the vanes with the gas stream or to impinge on the vanes and be thrown back into the feed curtain. The resultant force (R) on particles larger than (K) is in a direction at small variance with the gravitational-inertial forces. The particles will either impinge on the vanes and be knocked out or fall directly into the coarse discharge (Figure 4).

The cutpoint is controlled by the air velocity through the vanes which determines the magnitude of drag force (Fd) and the primary air inlet velocity which determines inertial force (Fi). Varying cutpoint requirements are met by regulating the inlet velocity while keeping the total air volume, i.e., vane velocity, constant. The normal gas-to-feed ratio is 300 CFM per ton per hour of classified feed.

Power requirements are low due to the minimal energy loss involved in the change of direction of the air stream as it is exhausted through the vanes (Figure 5). Energy is lost as a result of the drag force required to effect classification and generally ranges from .5" to 3" of Water Gauge (W.G.), depending on the cutpoint and feed-to-air ratio. The gas flow through the vanes must increase as the diameter of the cutpoint increases. This produces a higher drag force (Fg) required to cut larger particle diameters.

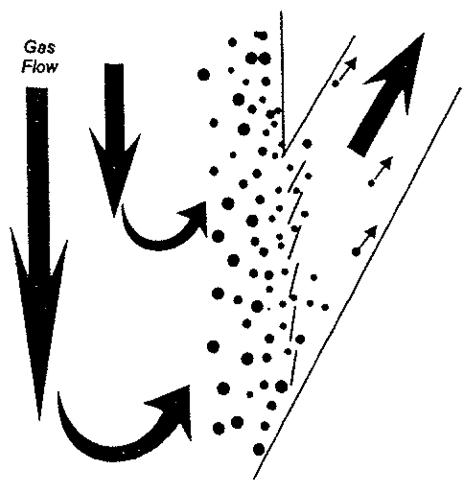


Figure 5 - Detail of gas flow through classifying zone with vanes.

4. *Luck Stone's Experience at the Leesburg Plant*

During the design process, Kevin Rareshide, senior project engineer, provided a structure to support twin 90 inch Buells. A single unit, installed in 1993, absorbed the existing 60 tons/hr of Virginia's #10 screenings produced by a Nordberg 5 1/2 ft. short head. The addition of a Nordberg HP300 to the Bin 3 circuit in 1994 increased feed tonnages to both Buell units to 120 tons/hr.

A single conveyor from the Bin 3 circuit feed both MET units by use of a splitter at the headpully discharge. After passing through the Buells, the finished product falls through a mixer where water is added for dust control. The air-scrubbed product is then conveyed to a stacker for outside storage.

Sand Plant Fines (SPF) pulled from the classifiers are separated by the baghouse, and dropped into a 350 ton bin. Draft for the baghouse and ultimately the GICs is provided by a 100 HP fan capable of producing 24,000 CFM at 14"W.G. As the system operates under negative pressure, fugitive dust is not a problem. The dust collector is equipped with 312 bags (5,000 ft^2 of cloth area). The storage bin for the SPF is equipped with a discharge cone containing a rotary airlock feeder. Injection ports fluidize the fines before the airlock and a mixer adds moisture to the fines as they are discharged onto a conveyor. This fines conveyor is capable of moving the fines to the base for blending or directly to a truck for load out.

4.1 *Product Characteristics and Uses*

The final GIC product (air-scrubbed screenings) provides a more desirable material for the asphalt producer. Limiting the moisture in this dry process limits the amount of energy required by the asphalt producer to remove the moisture. This results in cost savings for the asphalt producer.

Savings may also be realized by the asphalt producer by reducing the amount of asphalt cement required in the mix. In Virginia's asphalt mix design, one criteria of the AC content is dependent upon the amount of minus 200 mesh material present in the final mix. By limiting this minus 200 mesh in the feed material, the asphalt producer may limit the amount of asphalt cement used in the mix. This savings may be significant and is one reason many asphalt plants have been requesting this type of limited fines material.

Figure 6 demonstrates the changed gradation when the fines are removed from the screenings.

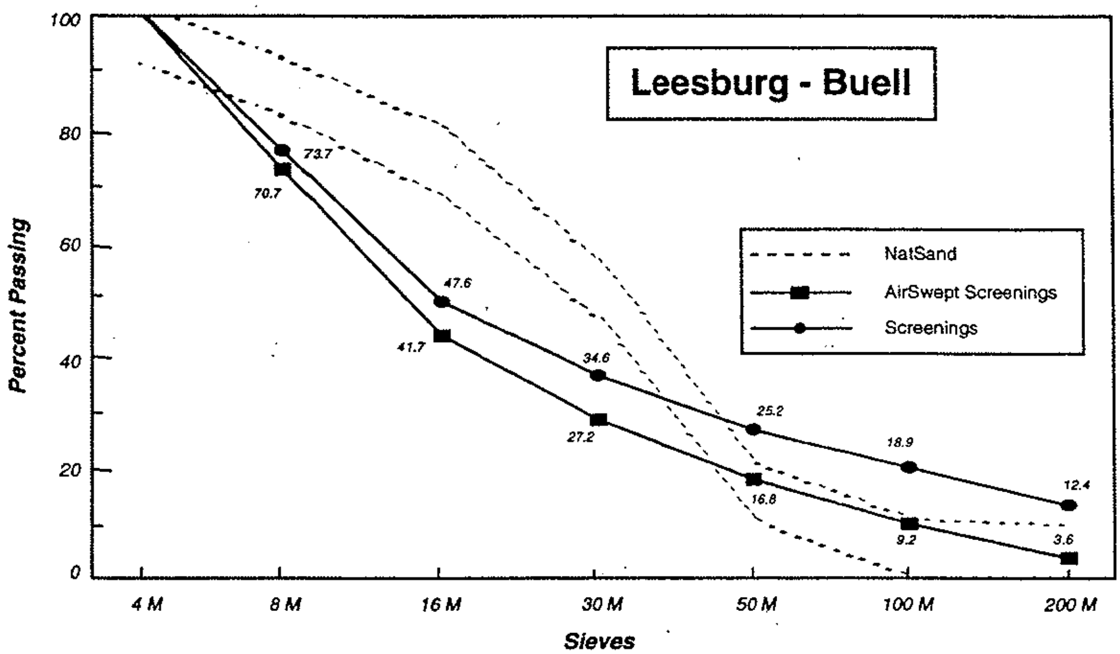


Figure 6 - Gradation plot of feed and product

It is evident from the above figure that the fine side of the gradation has been altered by the fines removal. Prior to processing, the material passing the 200 mesh averaged around 12.4%, while after processing the 200 mesh is reduced to 3.9% passing the 200 mesh. The sand plant fines (SPF) which are removed range between 9 and 11% of the total feed weight.

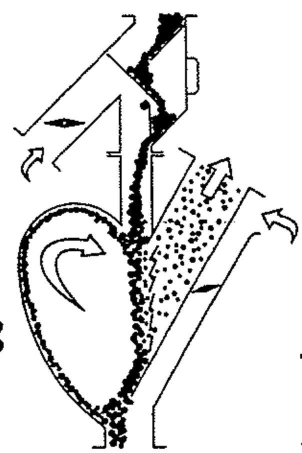
The most significant question which we asked ourselves when considering this process was what could be done with the generated fines (SPF). During this phase we determined that they could be blended back into the base product without any detrimental effects. A handling system to do so was designed into the plant layout. Although these fines range over 90% passing the 200 mesh, their impact upon the base quality is limited due to the differences in comparative volumes. Because these fines are easy to handle, a system for loading them directly into trucks was included in the design. During initial stages of production while fines were accumulating, Luck Stone's regional manager, Oscar Burton, marketed the fines to Virginia Power as utility backfill around electrical wiring installations. The SPF are desirable because they have no coarse angular material which may cut or harm the protective covering on the cables. The SPF have interesting physical properties that are suited to this particular use. When air is entrained, they will flow like water but stabilize to a firm material when allowed to set undisturbed. In effect, the material behaves like a dry flowable bill and has become established in this market.

5. Conclusions

Luck Stone has been very satisfied with the design, application and range of this Gravitational Inertial Classifier. The GIC provided us an alternative to the wet process and satisfied our demands for an environmentally friendly system. It has allowed us to integrate new technology into our automated plants while sustaining our mission for innovation in new processes and products. The GIC has met our standards for quality, consistency, and simplicity for both its process and end products. Our customers are delighted with the product and report it is one of our best.

We believe that the successful conclusion to this search has been possible because the combined efforts of many dedicated professionals supported by a corporate mission of excellence.

LUCK STONE Corporation



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