The Processing and Recycling of Automobile and Industrial Shredder Residue

By Dr. Paul Olivier

Shredding & Liberation

The first step in the recycling of automobile and industrial waste consists of shredding to the largest size at which its basic constituents become granularly distinct from one another. This essential step of liberation is carried out by means of large hammer-mills that pound and shatter the waste. But if the waste is pulverized to a grain size too small, many valuable materials are reduced

Shredding & Liberation

to fines that become difficult to recycle, the capacity of the shredder decreases, the shredder consumes a lot more power, and the cost of shredder maintenance rises. If however the waste is shredded to a grain size too large, then the basic constituents of the waste remain embedded within one another and cannot be separated properly. If ferrous is not properly liberated from non-ferrous,

Shredding & Liberation

highly valuable non-ferrous metals end up in the steel scrap reporting to the electric arc furnace, more slag and dust are created, and the quality of the steel produced is impacted negatively, especially by the presence of copper.

And if ferrous is not properly liberated from non-ferrous, ferrous ends up in the non-ferrous reporting to separation, magnets must be situated

Shredding & Liberation

throughout the entire separation line, and the capacity of the separation process is significantly reduced. We see more abrasion, higher maintenance costs, additional material handling, and worst of all, we see non-ferrous metals separating incorrectly: for example, iron embedded in aluminum and even organics entrained in heavy metals.

Shredding & Liberation

Therefore shedding scrap to the right grain size, through a grate no larger than about 70 mm x 150 mm, is essential. Shredder grates of significantly larger openings effect such poor liberation that at times as much as 50% of the non-ferrous metals are lost in the ferrous and never report to non-ferrous separation.

Separation in Water

Once the scrap has been shredded and well liberated, and once magnets have removed the ferrous fraction, the remaining non-ferrous fraction is then presented to a separator using only water as a medium. Precisely how this separator works will be described a bit further on in this presentation, and since only water is used, we refer to it as a 1.0 separator.

Light and Heavy Fractions

A few years ago shredder operators were satisfied in processing only the heavy fraction that remains behind after magnets extract the ferrous. But there is a light fraction produced within the shredder that they understandably avoided: a fraction loaded with oil, grease, hydraulic fluids, dust, lint, sand, foam rubber, plastics, ferrous wire, fine copper wire and many other non-ferrous metals.

Light Fraction

This light fraction is an extremely messy, unmanageable and highly heterogeneous material, whose size, shape, density and volume vary a lot, making it very hard to clean and separate.

Light & Heavy Combined

Nonetheless this light fraction contains far too much metal and plastic to be discarded in landfill. So we suggest that it be blended with the heavy fraction in the same proportions they were produced, and that both should be presented without any further preparation to this 1.0 separator.

Why Not Scrub?

It might appear that the most logical procedure would be to scrub this difficult material prior to separation. But this combined fraction is not so easy to scrub: it contains a large percentage of wire, and when retained for several minutes within a scrubber, it has a high probability of embedding itself in foam rubber and textile.

Why Not Scrub?

Also the presence of such a large volume of foam rubber hinders and impedes the scrubbing action of the scrubber, and it also interferes with the draining, rinsing and screening action of the scrubber vital in the removal of lint and fiber loaded with oil, grease and other problematic substances. The scrubbing of raw ASR prior to separation creates more problems than it solves.

The 1.0 Separator

Therefore the light and heavy fractions are fed directly to the 1.0 separator. Within a matter of seconds this separator splits the raw feed into two separate but manageable streams where screening, sizing, rinsing, scrubbing and fines concentration can all take place more efficiently. On the float side, we find foam rubber, textile, wood, lint and some plastic (< 1.0 RD), and on the sink

Floats Trommel

side, we find everything else: rubber, plastics >1.0 RD, glass, stone, concrete, coarse sand, metals and even the smallest free copper wire. The floats of this separator are presented for dewatering to a rotary trommel screen fitted with stainless steel wedge wire panels of an aperture as large as possible (2 to 5mm). With such large openings, dewatering takes place in an instant.

Floats Trommel

High pressure spray nozzles mounted on the top of this floats trommel prevent the wedge wire panels from blinding up. Lint adhering to the foam rubber is blasted off by spray nozzles mounted on the inside of this trommel. No wire or metal is present to trap lint and interfere with its passage through the wedge wire. Then the entire slurry stream passing the floats trommel is allowed to flow by

Floats Trommel

gravity to roto-sieves for lint removal. This assures that lint is never exposed to the frothing action of a pump and that it is removed from the circuit as fast as it enters. The underflow of the roto-sieves is pumped back into the separator, and the lint from the roto-sieve is routed to a screw press for final dewatering. The foam rubber, textiles and plastics exiting the floats trommel are relatively clean and

Foam Rubber Separation

are in an ideal state for further separation. At this point three techniques are employed to isolate foam rubber: sizing, foam shooting and magnetite extraction. The capture of large foam rubber by means of elongated fingers is easily done at the discharge end of the 1.0 floats trommel. The impregnation of the remaining foam rubber and textile with magnetite renders this water-

Magnetite Foam Removal

absorbent material magnetic and allows it to be isolated by means of magnets. Since organics of a density greater than 1.0 situate on the sink side of the separator, they never report to this magnetite foam removal circuit. The larger foam rubber isolated by fingers and the smaller foam rubber from the magnetite circuit are then routed to a screw press for final dewatering.

Magnetite Foam Removal

There are several technologies that allow for the recycling of foam rubber. Cleaning and re-bonding would appear to be the simplest. Foam rubber can also be used as a cement kiln fuel. The plastics of a density less than 1.0 can be combined with the sinks of the 1.0 separator for further separation.

The Sinks Scrubber Barrel

The sinks of the 1.0 separator, free of the huge volume of foam rubber and lint, is now in an ideal state for scrubbing, rinsing and sizing. These three functions are carried out by means of a scrubber barrel. This scrubber barrel receives everything discharged by the sinks cone of the separator. Clean water is added to the scrubber to supplement the water discharged by the cone.

The Sinks Scrubber Barrel

At the end of this scrubber is a drain section equipped with wedge wire panels of a 0.5 mm aperture. This small opening assures the retention and capture of the finest copper wire. The underflow of this scrubber drain section is then routed to 15-inch classifying cyclones to effect a final concentration of the coarse “sand” already separated and pre-concentrated by the 1.0 separator.

15-inch Classifying Cyclones

The underflow of these cyclones is routed to a high frequency dewatering screen so that these solids can be neatly conveyed and stockpiled, and eventually sold as low-grade aggregate. Free of organics and sufficiently dewatered, this material requires no further processing, and most importantly, it does not end up in landfill.

The Larger Sinks

The larger sinks of the 1.0 separator are now ready for the next separator in the ESR process, a separator that obviously must operate at a density greater than 1.0. But how do we change the density of the water in this next separator? The answer here is simple.

Ultra-fine Inorganics

Raw ASR contains inorganic material that is so fine that it immediately goes into suspension when presented to the 1.0 separator. A portion of the underflow of the roto-sieves is therefore routed to 10-inch classifying cyclones that cut at about 18 microns. The underflow of these cyclones, having a true density greater than 3.0, represents an ideal suspension-creating material.

Ultra-fine Inorganics

This cyclone underflow, too fine to dewater properly with a high-frequency dewatering screen, is routed to containers that allow this slurry of a high concentration by volume to rapidly decant and solidify. Should these fines contain valuable metals, they could be subjected to further processing using froth flotation techniques.

Sinks Scrubber

The clay slurry overflow of these 10-inch cyclones is then routed to the ESR 9-meter diameter clarifier and 2-meter wide filter belt press. Hydrocarbons and other pollutants adhering to this clay are concentrated in the filter press cake. The clean water overflow of the clarifier is returned to the sinks trommel to effect the final rinsing of the sinks of the 1.0 separator.

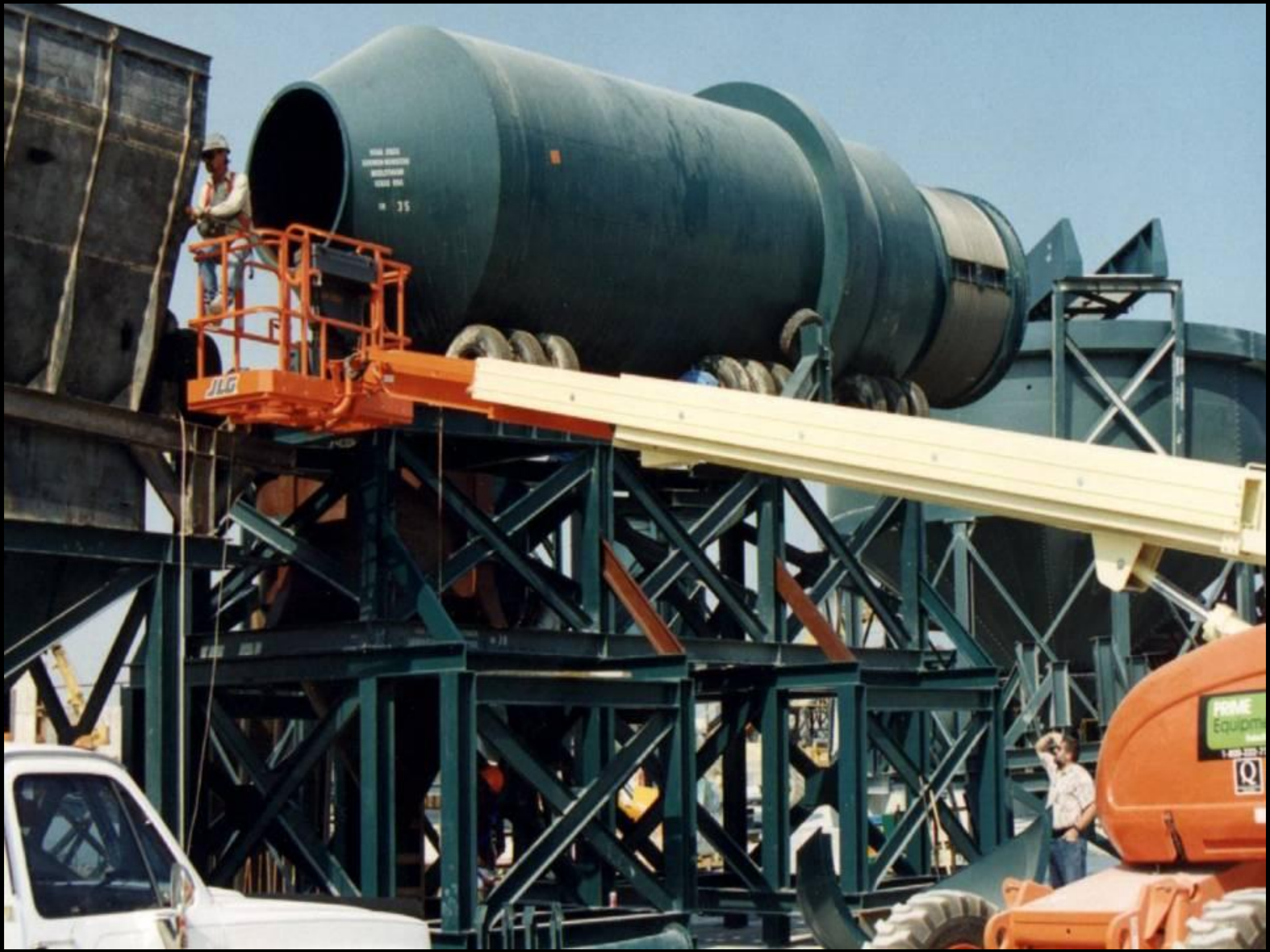
Sinks Scrubber

This water also fulfills a secondary function of preventing an undesirable rise in density within the 1.0 separator.

The ESR Chain Feeder

The 10-Foot 1.0 Separator

at Chaparral Steel



Sinks of the 1.0 Separator

Lint Removal & Concentration

Classifying Cyclones

ESR Clarifier & Filter Belt Press

Products of the 1.0 Separator

So the products of the process thus far:

1. foam rubber, textiles, wood & plastic < 1.0 RD,
2. fine organic lint and fiber (roto-sieve product),
3. non-ferrous metals, rubber, plastics, glass, and stone of a grain size > 0.5 mm (sinks 1.0),
4. coarse sand from 60 to 500 microns (15-inch),
5. fine sand from 10 to 60 microns (10-inch),
6. clay, hydrocarbons and other fluids (filter cake).

Products of the 1.0 Separator

Since only the relatively small quantity of material in fraction # 6 is routed to water treatment, the the cost of water treatment in the ESR process is minimal. Since fine organics are removed from the circuit as quickly as they enter, the cost of anti-foaming agents is minimal. Since the ultra-fine sand of fraction # 5 has a true density greater than 3.0, it has a significant value within the ESR

Ultra-fine Sands

process as an excellent suspension-creating material, easily generating Newtonian liquids as high as 1.6 in density. In all ESR separations from 1.0 to 1.6, clays, salts or magnetite are not required. We find everything we need to create a dense medium bath right within the waste itself.

Let us summarize the advantages of doing a 1.0 separation prior to scrubbing. The 1.0 separator:

Advantages

- circulates 5 times more water than a scrubber barrel, very effectively wetting and pre-scrubbing the raw feed;
- forces the incoming feed to scatter, segregate and separate over a broad 3-dimensional plane;
- immediately splits the raw feed into two separate but manageable streams where screening, sizing, scrubbing and rinsing can take place more efficiently;

Advantages

- minimizes the formation of wire balls,
- reduces the probability of copper wire becoming embedded in foam rubber and textiles;
- removes large foam rubber and concentrates the remaining foam rubber and textiles for further separation and;
- concentrates fine lint for roto-sieve removal;

Advantages

- separates and concentrates < 1 mm sand for final 15-inch cyclone separation and concentration, eliminating the need for high-maintenance grit augers, eliminating the need for other devices to remove organics from the product of grit augers;
- throws ultra-fine sand in suspension for final 10-inch cyclone separation and concentration, thereby preparing the suspension fines needed for the following dense medium separations;

Advantages

- handles all grain sizes from the largest foam rubber to the finest free copper wire, and therefore
- does not have to be preceded by expensive dry or wet screening devices; and
- does not have to be preceded by accordion screens, air separators, eddy current separators or other inefficient dry sizing or separating techniques;

Advantages

- represents the fewest number of steps and the lowest possible cost in accomplishing all of the above;
- concentrates a sinks product that is in an ideal state for truly effective scrubbing, cleaning and even sizing, if necessary;
- and presents this scrubbed and cleaned material to the dense medium separator that follows.

Dense Medium Separation

But exactly, what do we mean by dense medium separation?

Dense Medium Separation

Here we find the dynamic of a quiescent bath where the density of water is changed by means of fine particles in suspension. At first glance, nothing could be simpler: one fraction floats, while the other fraction sinks. But the simple mechanical requirements associated with introducing solids into a bath and removing floats and sinks, and at the same time, assuring the fluidity and

Dense Medium Separation

integrity of the medium, make this a challenging task. Historically inventors and manufacturers responded poorly to this challenge.

Twenty years ago most dense medium drums on the market were mono-directional, with floats and sinks reporting on the same side of a relatively short horizontal drum. This concept fails for four simple reasons.

1) Correct Injection

At the critical moment of introducing solids into the drum, the floats of the typical DM drum are easily buried with sinks and cannot find their way to the surface of the bath. However in the ESR drum, the medium together with solids is injected over a broad three dimensional plane, making it almost impossible to bury floats with sinks.

2) Stable Medium

A typical dense medium bath is relatively deep, and this makes it difficult for the suspension particles to remain in suspension. If a medium is not stable, we find water at the top of the bath and a dense sludge at the bottom of the bath, and of course, in this stratified liquid, no separation takes place. The industry in general responded by allowing clay to accumulate in the medium.

2) Stable Medium

This clay imparts viscosity that very effectively provides stability but at the same time it also reduces the speed by which particles float and sink and thereby destroys the accuracy of separation. Instead of a deep bath and instead of working with clay, ESR chose a shallow bath, and the gentle action of the sinks scrolls pulling underneath the bath provides just the right amount of agitation to

2) Stable Medium

keep the suspension medium stable. As medium flows to the float side and as the scrolls pull to the sink side, a gentle elliptical fluid dynamic is created within the bath. Nowhere within the separation zone is it necessary to inject medium to assure stability. Stability is assured by the fluid dynamics of the bath itself.

3) Correct Floats Dynamic

The typical mono-directional bath is quite short, and it often happens that before a particle can float or sink, it is already out of the bath. Therefore, ESR extended the length of the separation zone, greatly increasing the residence time of a particle in the bath, and thereby making it almost impossible to find sinks in floats. ESR dense medium drums range from 4 to 5 meters in length.

4) Correct Sinks Dynamic

In the typical mono-directional drum, the curtains needed to prevent floats from crossing over with sinks are located in the separation zone and, due to turbulent fluid movement in the vicinity of these curtains, floats are easily sucked under these curtains and report with sinks. In the ESR drum, however, the curtain that prevents floats from crossing over with sinks is situated completely

4) Correct Sinks Dynamic

outside the separation zone, making it hard to find floats in sinks. In the classical mono-directional design, sinks are continually lifted out of the bath by means of a series of lifters welded to the wall of the drum, and at each rotation of the drum, these sinks are removed from the bath while still in the separation zone. The action of these sinks evacuation lifters, passing underneath the

4) Correct Sinks Dynamic

curtains running the full length of the separation zone, creates a great deal of turbulence, a turbulence that destroys the accuracy of separation. This severely limits the speed of rotation of the drum as well as the tonnage of sinks evacuated within a given period of time. Consequently a mono-directional drum cannot handle a large quantity of sinks.

4) Correct Sinks Dynamic

In the bi-directional design however, sinks are lifted up and out of the bath only when they are completely outside of the separation zone. Scrolls welded to the bottom of the bi-directional drum gently move the sinks in one direction, while the floats flow out on the surface of the bath in the opposite direction. When the sinks exit the separation zone, they drop down underneath a

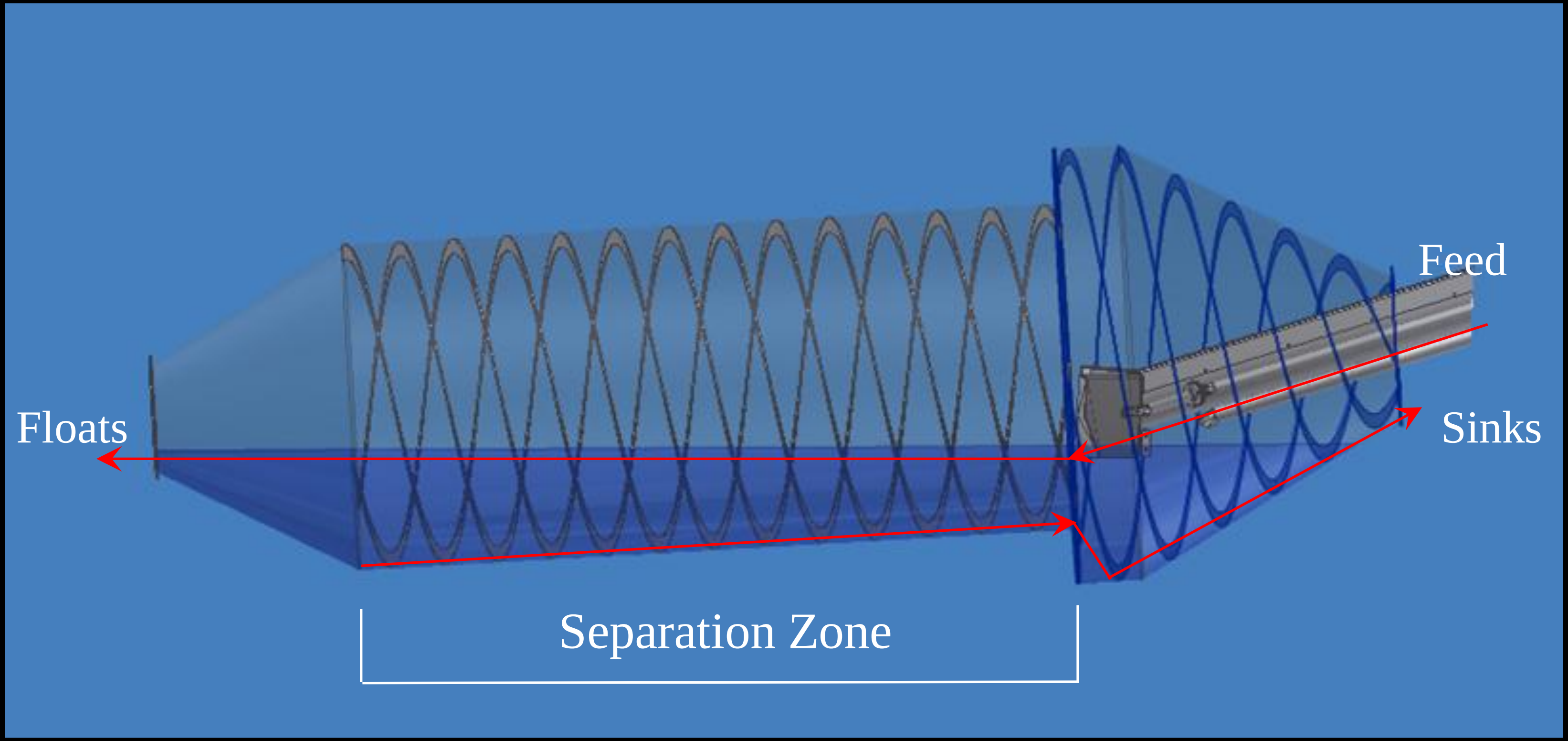
4) Correct Sinks Dynamic

curtain into an expanded cone and only at this point are they screwed up and out of the bath. Since there are no lifters and curtains within the separation zone, the ESR drum can be rotated at relatively high speeds without jeopardizing the accuracy of separation. Since there are no lifters and curtains within the separation zone, the entire surface of the bath is available for separation

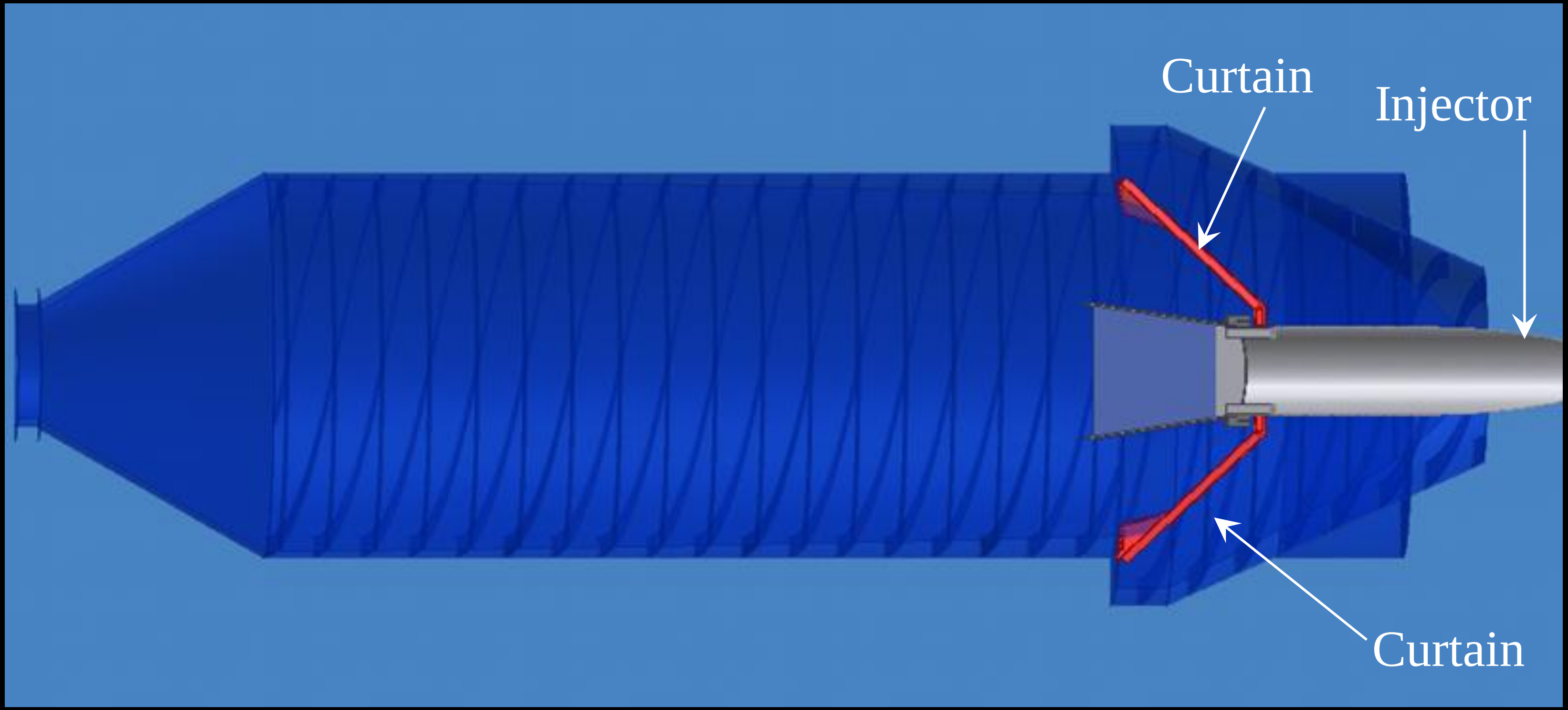
4) Correct Sinks Dynamic

and remains fully visible to the operator. The next slide shows a cross-sectional drawing of this unique bi-directional drum:

Cross-Sectional View



Top View



Interior of Drum

New Design

New Design

Carrot Separation

Back in the summer of 1985 when this bi-directional drum was first put in operation in the separation of carrots, it was hard to believe the initial results. Not only were all the stones and metals removed from the carrots, but this separator also removed all near-gravity extraneous material such as corn stubble, fly ash and bits of plastic.

Good Carrots/Bad Carrots

But the biggest surprise of all was the precise separation of a good carrot from a partially dehydrated carrot. It happens often that when a load of carrots is dumped outdoors on a concrete slab, some of the carrots on the surface of the pile that see the sun become soft and partially dehydrated. With a loss of moisture, there is an increase in density, and

Good Carrots/Bad Carrots

and with an increase in density by only a few points to the third decimal place, this bi-directional dense medium drum has all that it needs to make a precise separation. If we want to recover all of the metals in ASR and allow none of them to go to landfill, then we must deploy dense medium separators that display this degree of accuracy.

Sixteen Separators

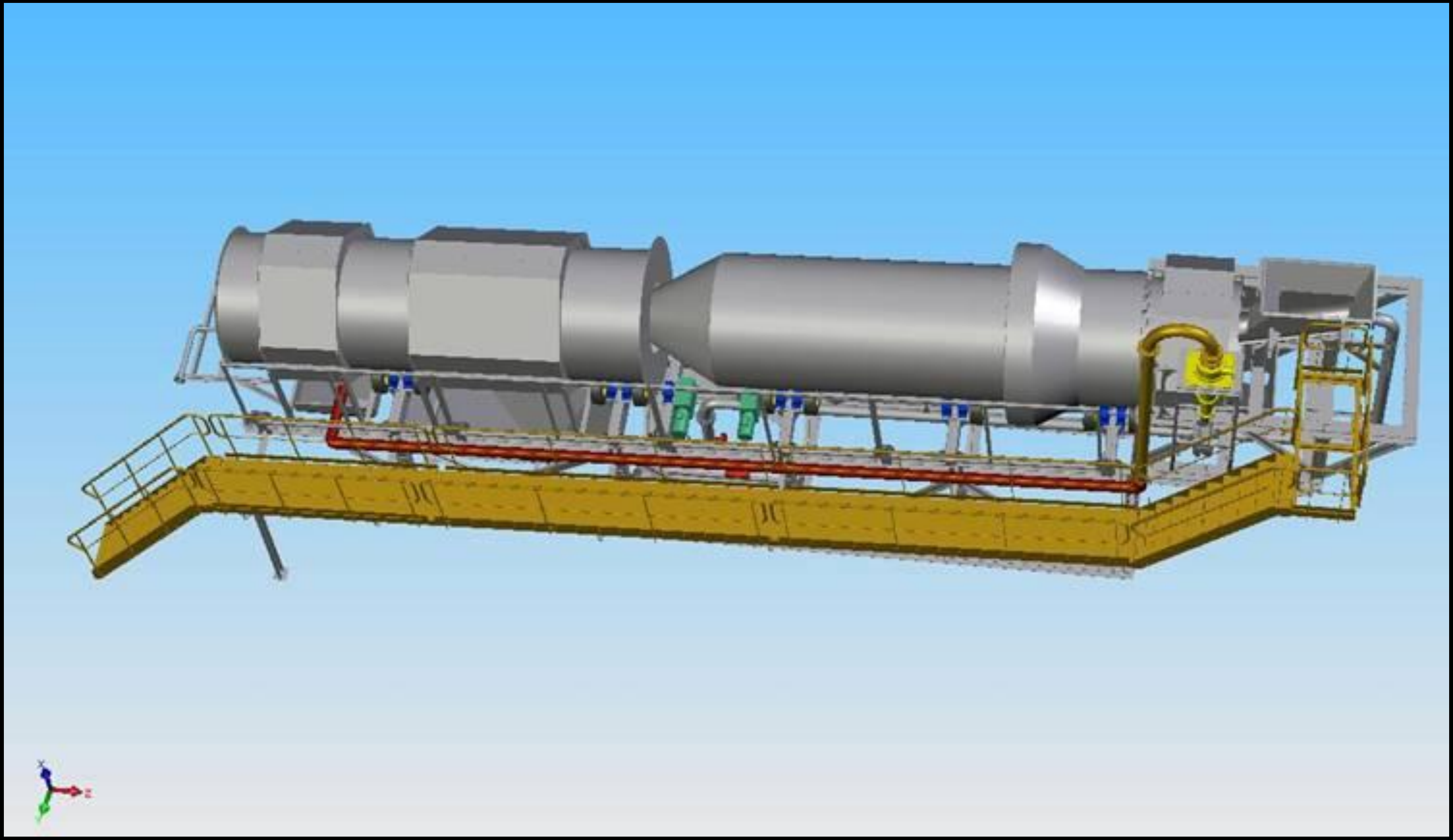
Sixteen vegetable separators were sold in Belgium and France. The food giant, Nestle, bought two 60 TPH potato separators which were installed at its dehydrating facility in Rossiere, France. The leading vegetable processor in Europe, Bonduelle, with a 30% market share, bought five separators. Their fifth separator, installed in August 2004 in

Bonduelle

Renescure, France, is the first vegetable separator designed by ESR LLC that does not employ vibratory screens. The following are drawings and pictures of the latest Bonduelle separator.

60 TPH Carrot Separator

60 TPH Carrot Separator



60 TPH Carrot Separator

Sink Side

Float Side

Dewatering Scrubbing Draining

Dense Medium Drum

Main Medium Pump

Fine Sand

Just about all soils in which root vegetables are cultivated contain ultra-fine sand between 10 and 60 microns. This sand constitutes an excellent suspension creating material, and by means of the same two stages of classifying cyclones discussed previously, this fine sand can be isolated and reclaimed from the scrub and rinse water of a root vegetable line.

Fine Sand

Due to the presence of dioxins in quarry clay (e.g. M^{c}Cains in Holland) and heavy metals in commercially processed sand (e.g. Sibelco in Belgium), the French government has recently banned the use of all suspension fines not derived from the same field in which the root vegetables are harvested.

From Vegetables to Metals

In 1990 this vegetable separation technology was transferred to the separation of automobile and industrial waste. Initially four of the largest recycling centers in Europe were set up in Belgium and France with the Galloo Group.
In 1997 a fifth recycling was set up at Chaparral Steel in Midlothian, Texas.

The Galloo Success

Back in 1990 the Galloo Group began receiving eddy current reject throughout Belgium, Holland, Germany and France. At times this eddy current reject had a non-ferrous metal content as high as 15%. On one particular site in France, Galloo operated an ESR separator that extracted up to 40 TPH of non-ferrous metals, at a value of $1,000 per ton, all from materials destined for

The Galloo Success

landfill. This equated to $40,000 per hour of metals, and based on such a revenue stream from landfill waste, Galloo eventually become one of the largest recycling companies in Europe.

In 2004, the largest recycling company in Europe, CFF Recycling of France, set up its first recycling center employing ESR dense medium technology.

Galloo Recyval

CFF Recycling

CFF Recycling

CFF Recycling

CFF Recycling

CFF Recycling

GDE & Galloo

In 2006 the second largest processor of non-ferrous metals in France, Guy Dauphin Environnement, bought its first ESR separator.

Also in 2006 the Galloo Group in Belgium bought a similar separator for non-ferrous metals.

Scrubber-Rinser

After separation, the dewatering and rinsing of metals pose a problem. Here the use of vibratory dewatering screens is far from ideal. Vibrating screens are difficult to maintain, they have limited material transfer capacity, they blind up with copper wire, and they presuppose large volumes of rinse water emanating from spray nozzles that often only

Scrubber-Rinser

impact the surface of a bed of metals. ESR LLC therefore developed a unique dewatering and rinsing device called a scrubber-rinser.

A scrubber-rinser is a counter-flow vessel consisting of two or more stages of scrubbing and draining. Solids are scrolled and scrubbed in one direction, while rinse water is pumped from

Scrubber-Rinser

from stage to stage in the opposite direction. Since in the scrub stage the material is totally immersed in water, the rinsing efficiency is far higher than what we typically see in the case of a vibratory screen equipped with multiple banks of spray nozzles. Twisted metals have an interior that can only be penetrated by repeated underwater scrubbing and tumbling.

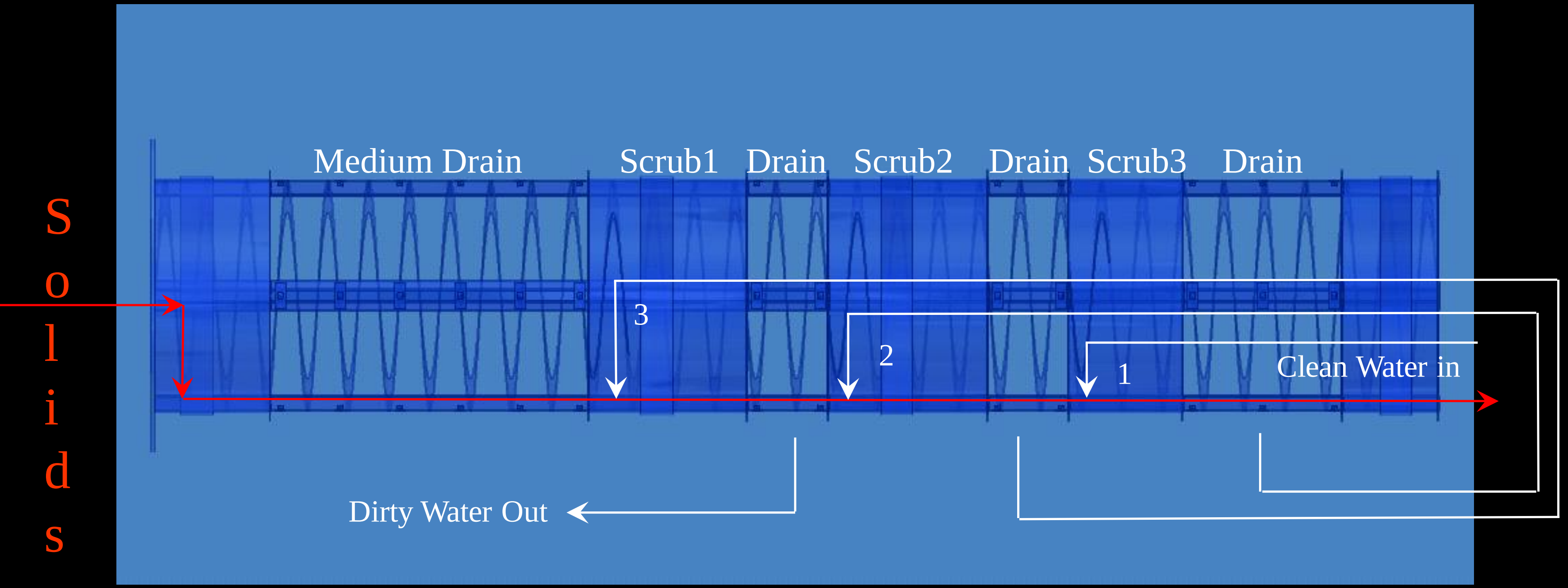
$ Savings $

Only in this way are inhering magnetics released. With scrubber-rinsers replacing vibratory screens, ferrosilicon losses in metal applications typically drop from over 7 kgs/ton of metals to less than 300 grams. Since atomized ferrosilcon easily sells for over $1,000 per ton, the savings here are substantial.

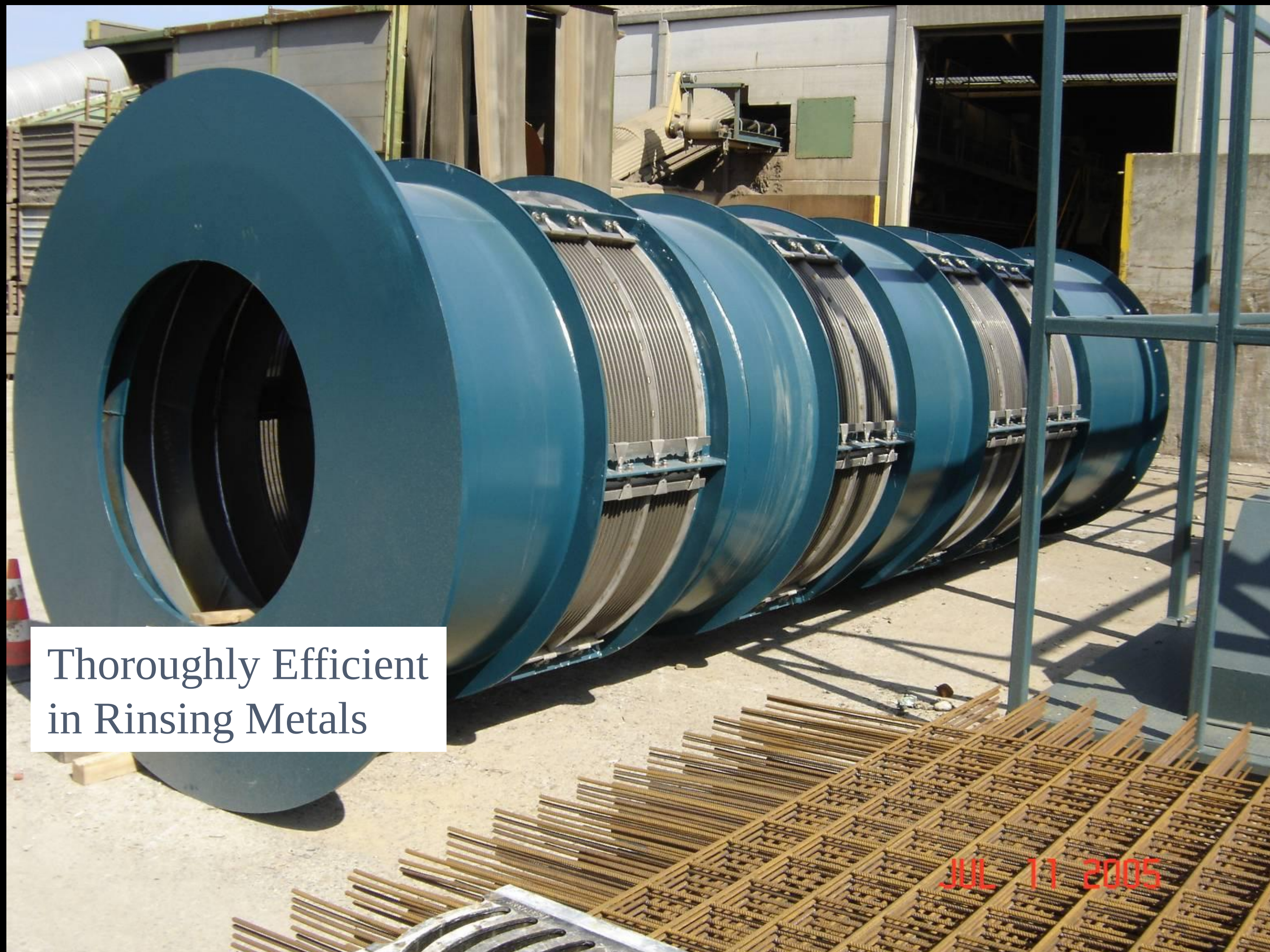
Five-fold Decrease in Water

Since rinse water in a scrubber-rinser is used multiple times, the amount of clean water required often drops by a factor of four or five. Since large objects continually scrape the surface of the wedge wire, copper wire does not blind up panels. The device is, for the most part, self-cleaning. Let us review the logic of a 3-stage scrubber-rinser.

3-Stage Scrubber-Rinser



The Scrubber-Rinser



Thoroughly Efficient
in Rinsing Metals

The Scrubber-Rinser

Panels never blind up and are easy to service and replace.

Advantages of Scrubber-Rinsers

- very little wear, maintenance, breakdown,
- easy panel fixation,
- with no vibration, there is very little noise,
- SSWW panels are not hammered shut,
- panels do not blind up with copper wire,
- rinsing takes place with an amazing efficiency,
- very little water is used.

1.6 Separator

After 1.0 separation, the next separation usually takes place at a density of 1.6. This separates organic from inorganic. The floats of this 1.6 separation can report to another separator at a 1.25 density. The sinks of this 1.25 separator represents an organic rich in PVC, and this sinks fraction is ideal for the Vinyl–Loop process that recovers PVC. Further separations at densities < 1.25 target

1.6 Separator

the recycling of plastic. But all attempts to recycle plastic as plastic fall short, and the residues from these processes, together with rubber, can be used as an alternative fuel in cement kilns or as a reductant and fuel in blast furnaces or electric arc furnaces. For over 15 years the floats of the 1.25 separator were supplied to cement kilns in Belgium and France.

Cement Kilns & Blast Furnaces

This greatly reduces the amount of fossil fuel needed to make cement, and in burning this alternative fuel, cement kilns are able, at times, to produce cement at a negative energy cost. The ash from the burning of this alternative fuel is vitrified and becomes part of the finished product. Even the slag from an electric arc furnace can be disposed of in a cement kiln and actually enhances the

Cement Kilns & Blast Furnaces

cement-making process, as in the CemStar process patented by Texas Industries (TXI) and marketed by Hatch of Canada. It is hard to imagine a landfill avoidance strategy that does not work in conjunction with the steel and cement industries. But in the absence of steel and cement ovens, the gasification of non-recyclable organics is an exciting option.

Floats of the 1.25 Separator

Sinks of the 1.25 Separator

Note the Huge Amount of Copper present in this concentrate

3.2 Separator

The sinks of the 1.6 then report to the 3.2, isolating a broad range of heavy metals:

- Zamac (6.6sg) – totally recovered
- Zinc (7.1sg) – totally recovered
- Stainless steel (8.5sg) – totally recovered
- Nickel (8.8sg) – totally recovered
- Copper (8.9sg) – totally recovered
- Lead (11.3sg) – totally recovered

3.2 Separator

Galloo in Belgium boasts of a heavy metal fraction containing less than 0.1% aluminum. By means of sizing screens and eddy current separators, most of the copper can be removed from this heavy metal fraction. Copper constitutes as much as 1% of the weight of an automobile, and it is very important to recycle 100% of this valuable metal.

3.2 Separator

Not only does the ESR process recover all of the copper present in this residue, but also all free copper reports entirely to the sinks of the 3.2 separator. Not even the smallest free copper wire is misplaced in the floats of the 3.2 separator.

2.2 Separator

The floats of the 3.2 report to the 2.2, to separate magnesium (1.7sg) from aluminum (2.7sg). The maximum allowable magnesium in aluminum is 0.4%. The actual magnesium after ESR separation typically stands at about 0.1%. But even this is not a separation error. This represents unliberated or alloyed magnesium which in theory cannot be separated.

The 2.2 and 3.2 Separators

Sinks of the 2.2 Separator

The sinks of the 2.2 separator consists of aluminum, insulated copper wire, glass and stones. Aluminum is separated from wire, glass and stone by means of an eddy current separator, and wire is separated from glass and stone either by means of a nail belt, or by means of a combination of a jaw crusher that pulverizes the inorganics and an accordion screen that screens

Low-Grade Aggregate

out the fines. All non-metallic inorganic material that exits the ESR process does not have to end up in landfill. The Gallo Group has undertaken a very successful program of selling this material as a low-grade aggregate.

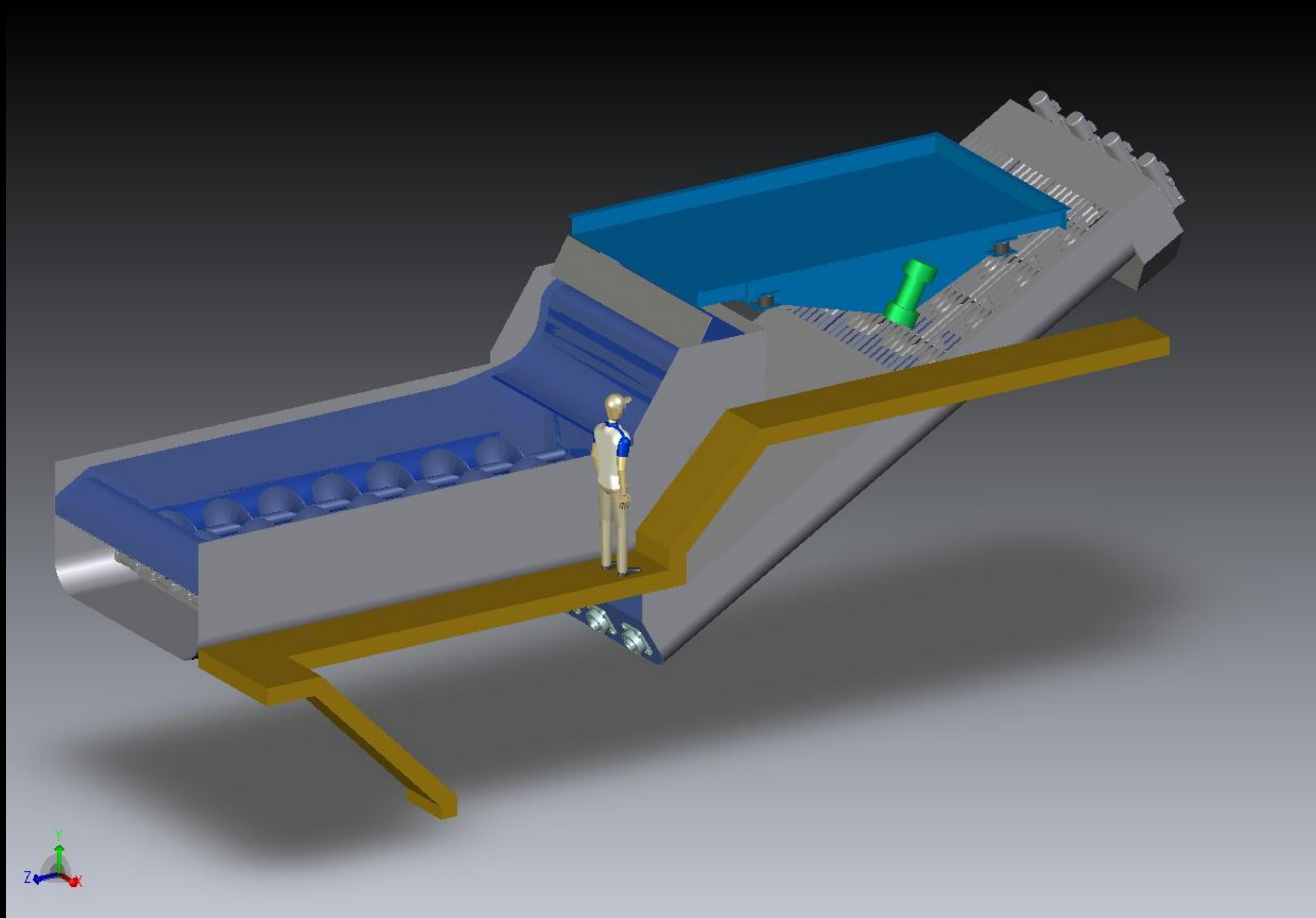
Plastic Separation

New regulations issued by the European Community dictate that it is not enough to make alternative fuels from ASR. ASR processing must include the recycling of part of the organics, and here the attention of ESR shifted to the recycling of plastics. But to separate one plastic from another, even the bi-directional dense medium drum is not adequate.

The New ESR Dense Medium Separator

ESR has designed and is patenting a new dense medium separator that employs in large measure the same fluid dynamics as the bi-directional drum - but is not a drum. This new separator is also a horizontal bi-directional vessel, but it fulfills the four first principles of a good dense medium separator in a more efficient manner than the drum, and it does so at about half the price.

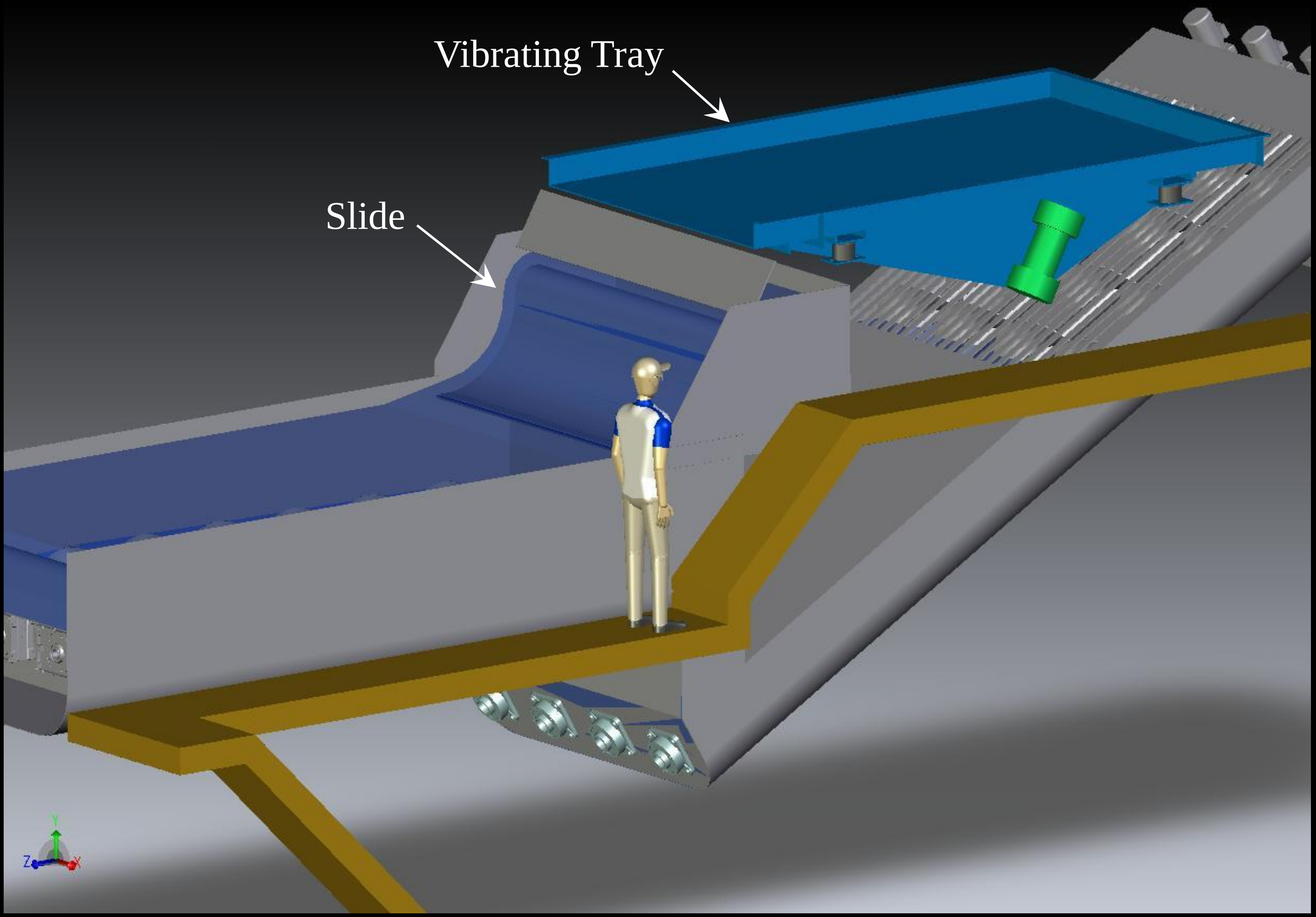
The New ESR Dense Medium Separator



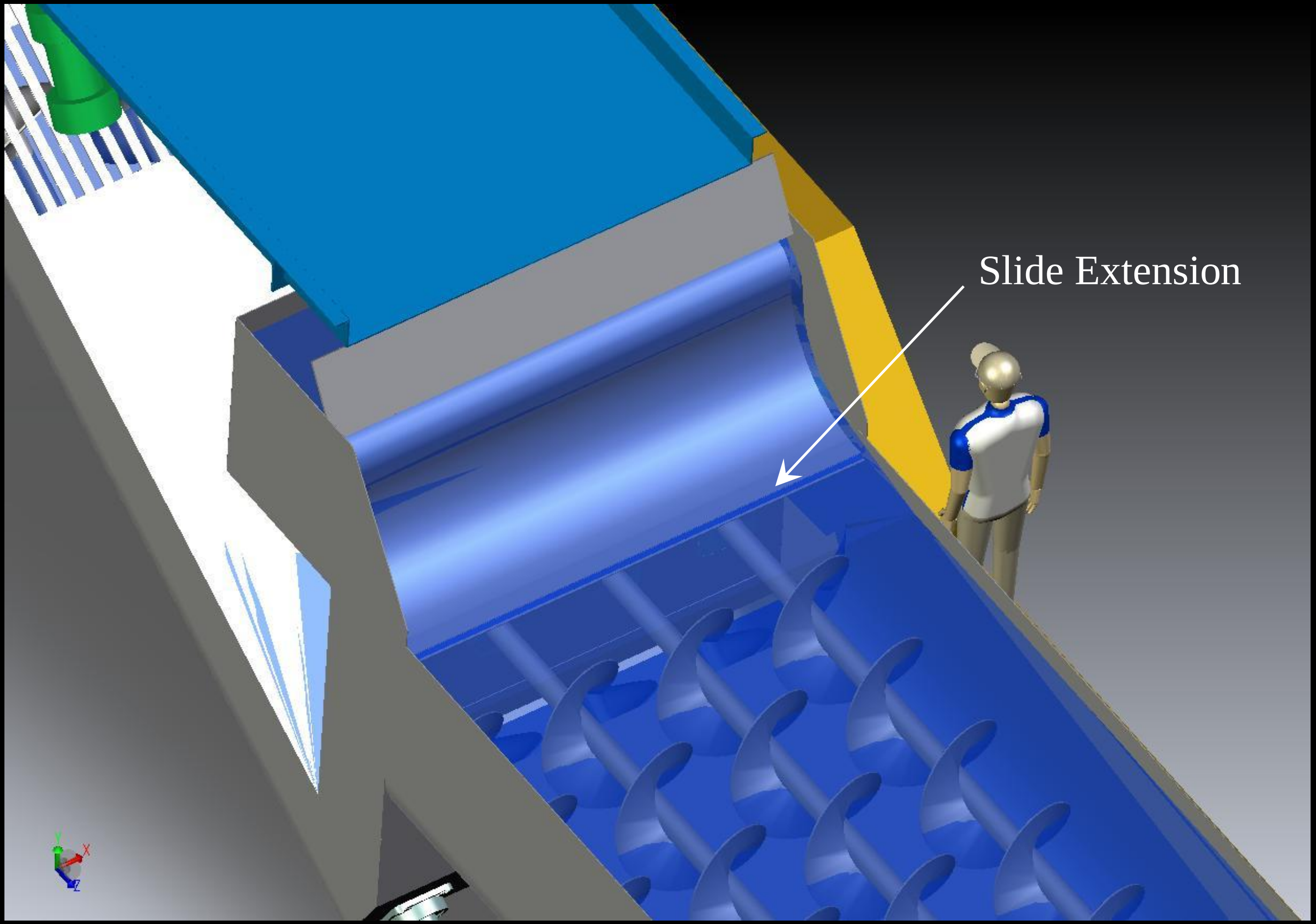
The Four First Principles

1) Unlike the barrel, the injector of this new separator has the same width as the bath itself. The injector consists of a header-box that overflows medium onto a slide. Solids are evenly distributed over the full width of the slide by means of a vibrating tray. The bottom of the slide is extended horizontally and situates at the same height as the bottom of the weir.

The New ESR Dense Medium Separator



The New ESR Dense Medium Separator



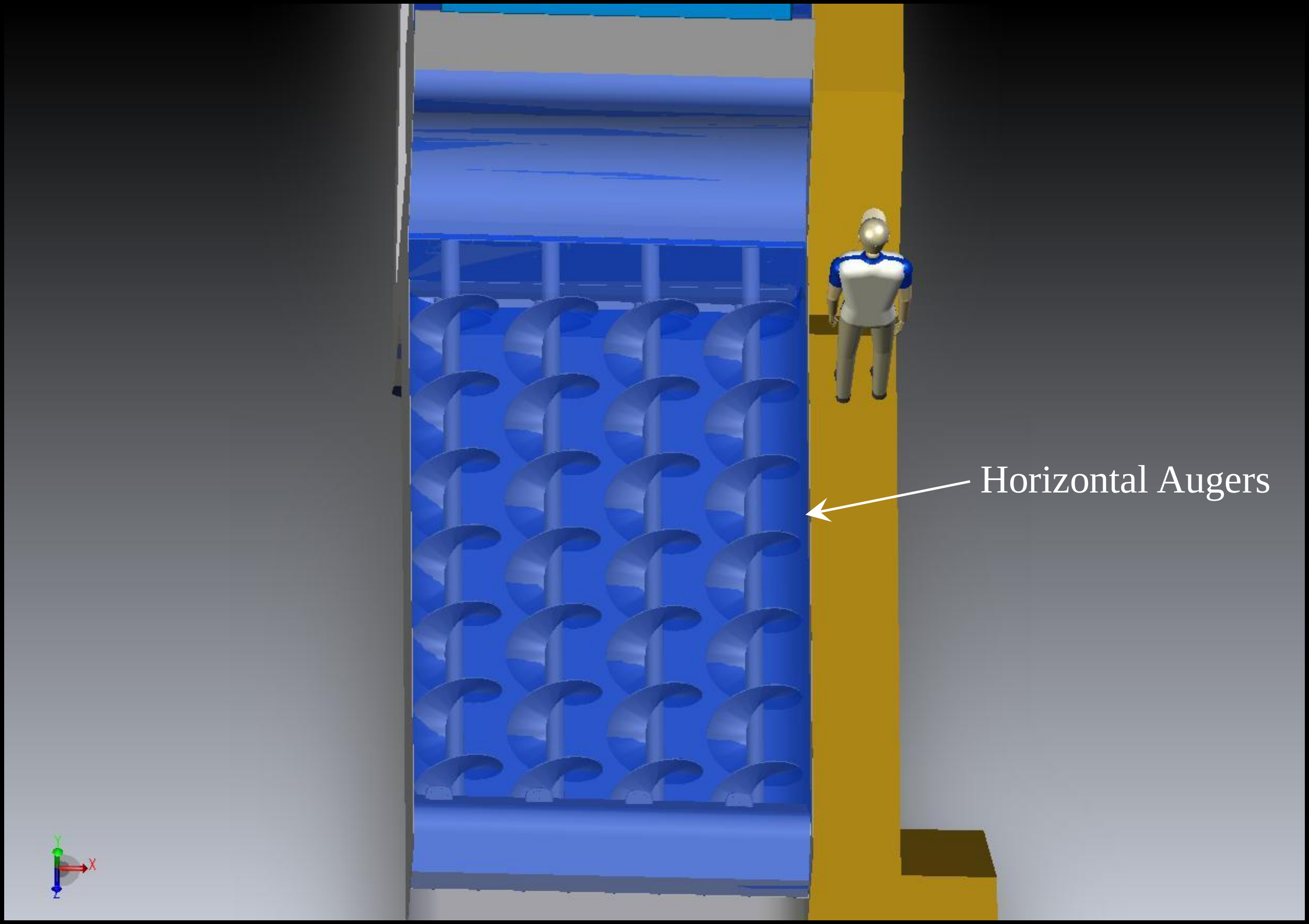
The Four First Principles

2) The bath remains a shallow bath, but, unlike the barrel, it has a uniform depth throughout its length. Sinks are conveyed along the bottom of the bath by means of augers. At a simple turn of a button, the operator can control the speed of these augers to impart just the right amount of turbulence needed to assure the stability of the medium. The augers here are horizontal, and they

The Four First Principles

can transport a greater volume of solids than their flights can contain. In this case, solids may rise above the top of the flights, and the augers begin to function as a walking floor. Therefore auger speed is more a function of stability than sinks evacuation. Medium depth from the top of the flights to the bottom of the weir is set to no more than about 400 mm or less than 16 inches.

The New ESR Dense Medium Separator



The Four First Principles

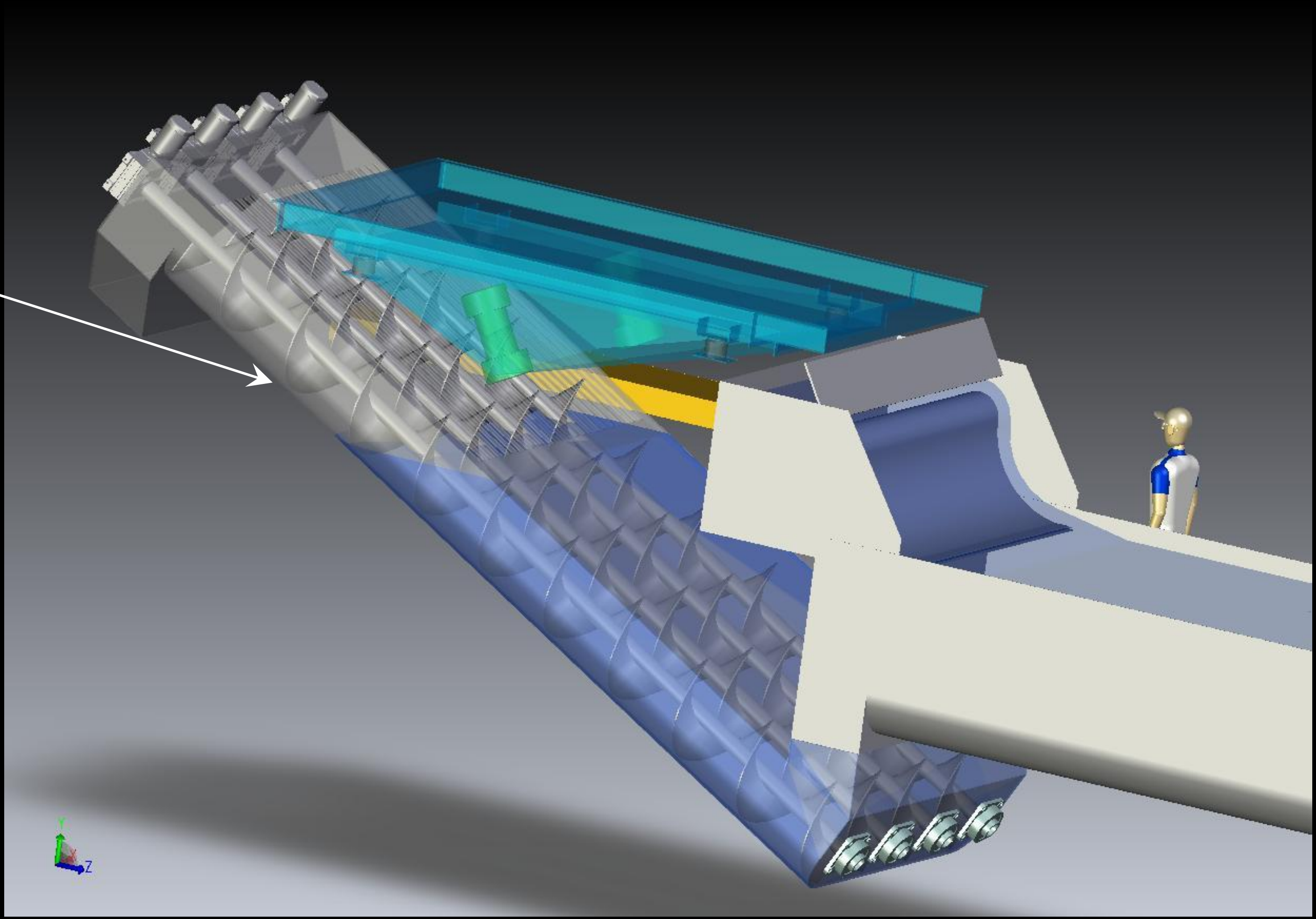
3) The length of the separation zone can be easily and economically extended to 4 or even 5 meters.

4) Since the new separator is not a scrolled barrel, the curtain to prevent floats from crossing over with sinks is not required. This new separator, like the drum, does not lift up sinks while they are in the separation zone. The actual lifting of sinks out of the bath is accomplished by a second set

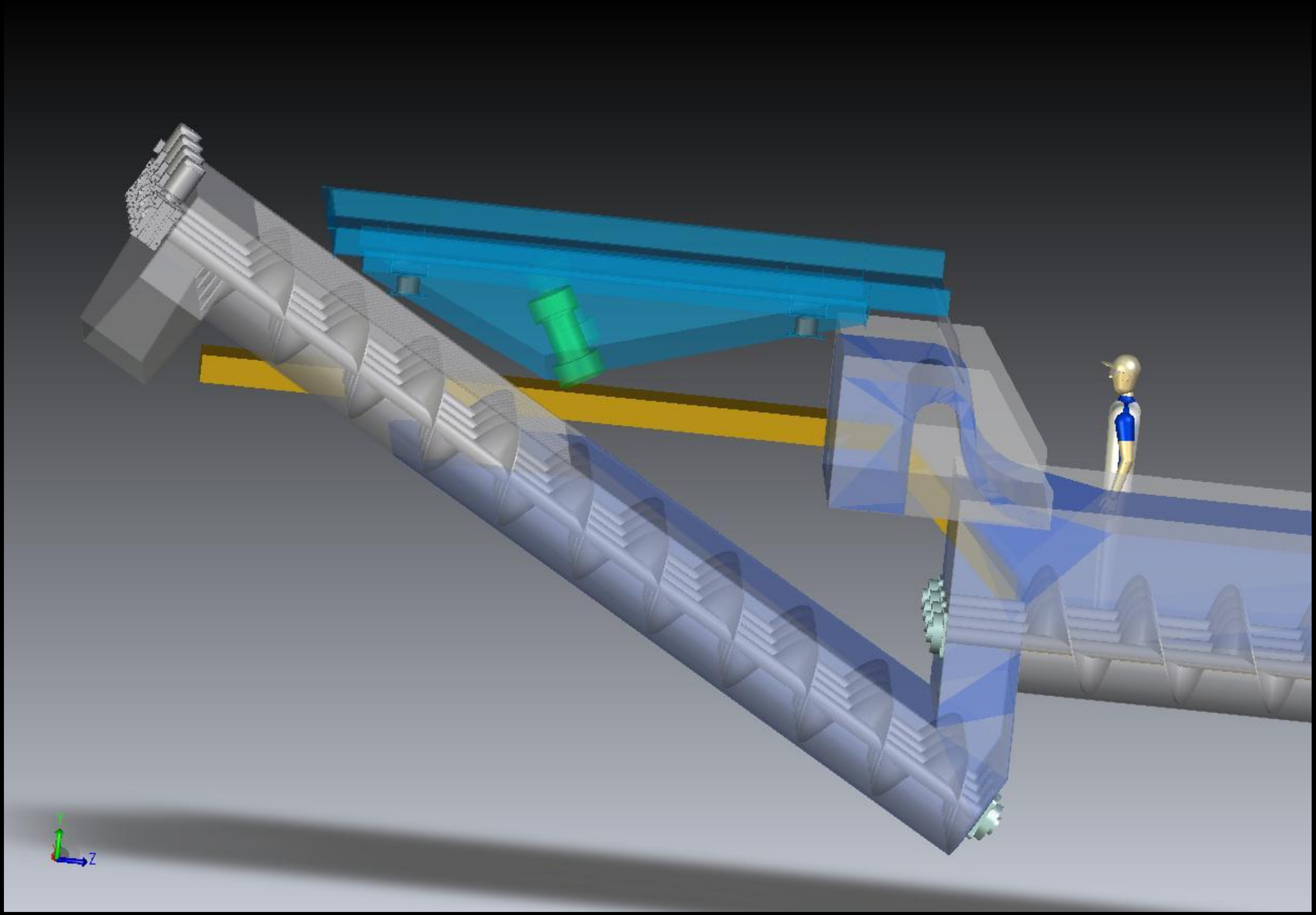
Sinks Evacuation

of augers situated completely outside the separation zone. These inclined augers may be operated at a speed different from that of the first set of augers. Even at a relatively high speed, they will not influence the fluids dynamics of the separation zone. In the case of a small quantity of sinks, a single inclined augur may be positioned at a right angle to the horizontal augers.

High Capacity



Sinks Evacuation



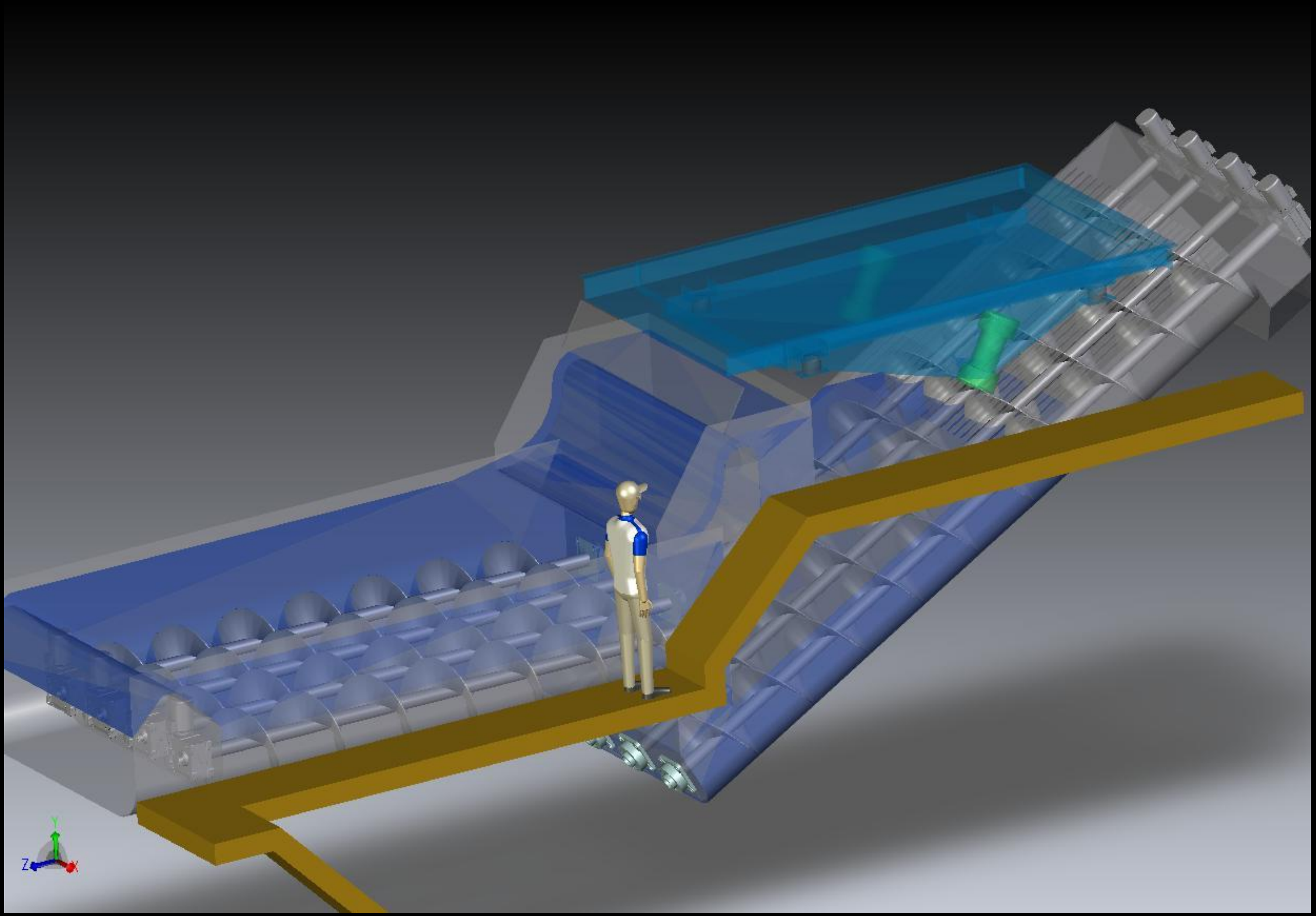
Other Features

Since this new separator is not a drum, it is not necessary to reduce the width of the bath on the float and sink sides by means of cones. Therefore the width of the overflow weir is the width of the bath itself. Since the width of the weir is the same as the width of the bath, cascading static sieve bends can be used to dewater and rinse fine floats and sinks. If no vibratory screens or rotating

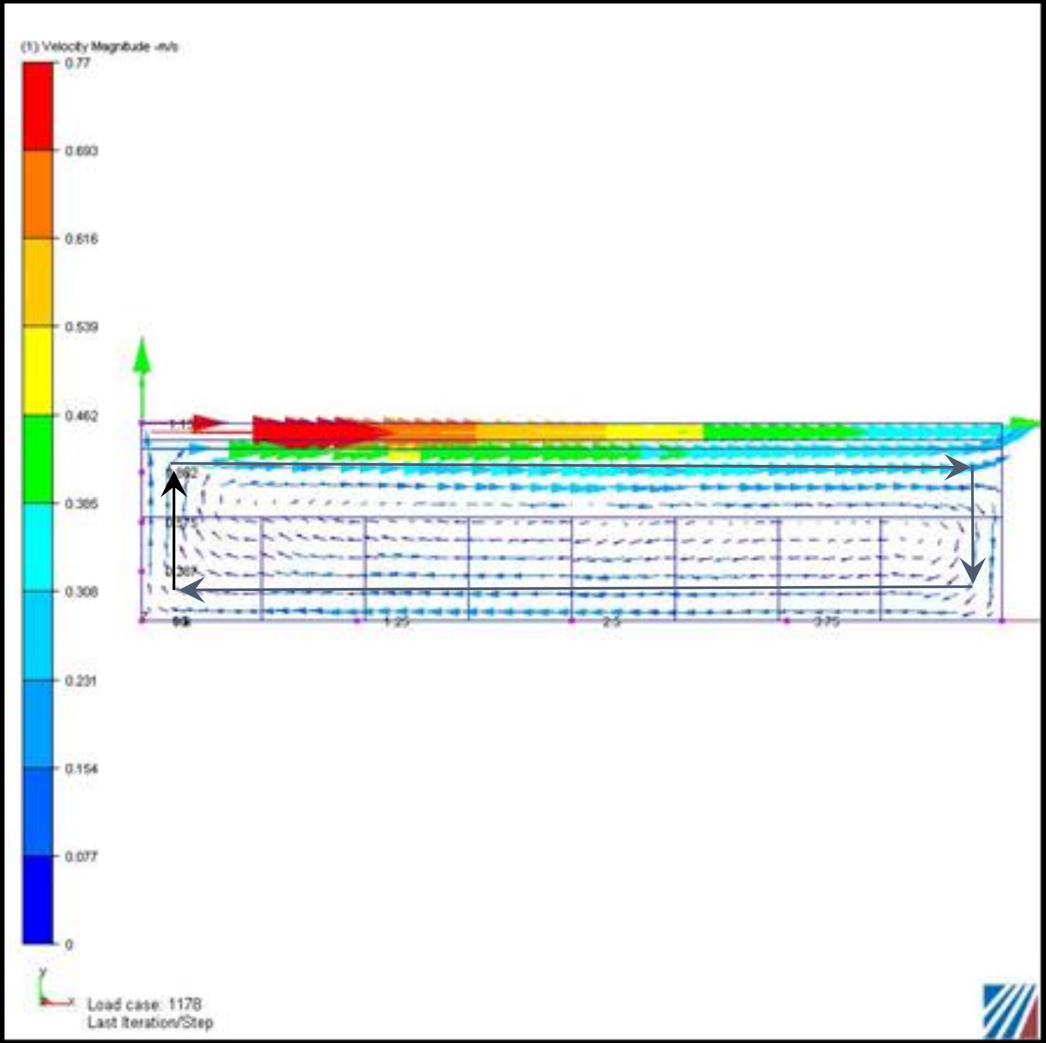
Other Features

scrubber-rinsers are required, the price of the separator is reduced even further. This new dense medium bath is ideal for the separation of plastics and fines materials having a large percentage of near-gravity material.

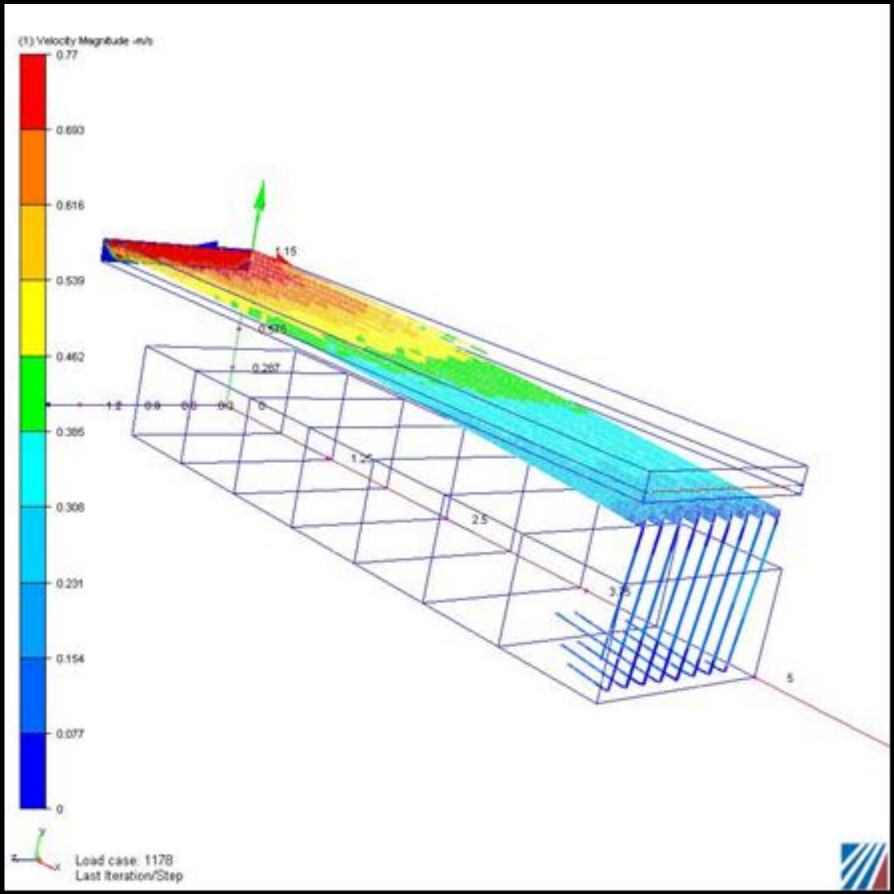
The New ESR Separator



Elliptical Fluid Flow

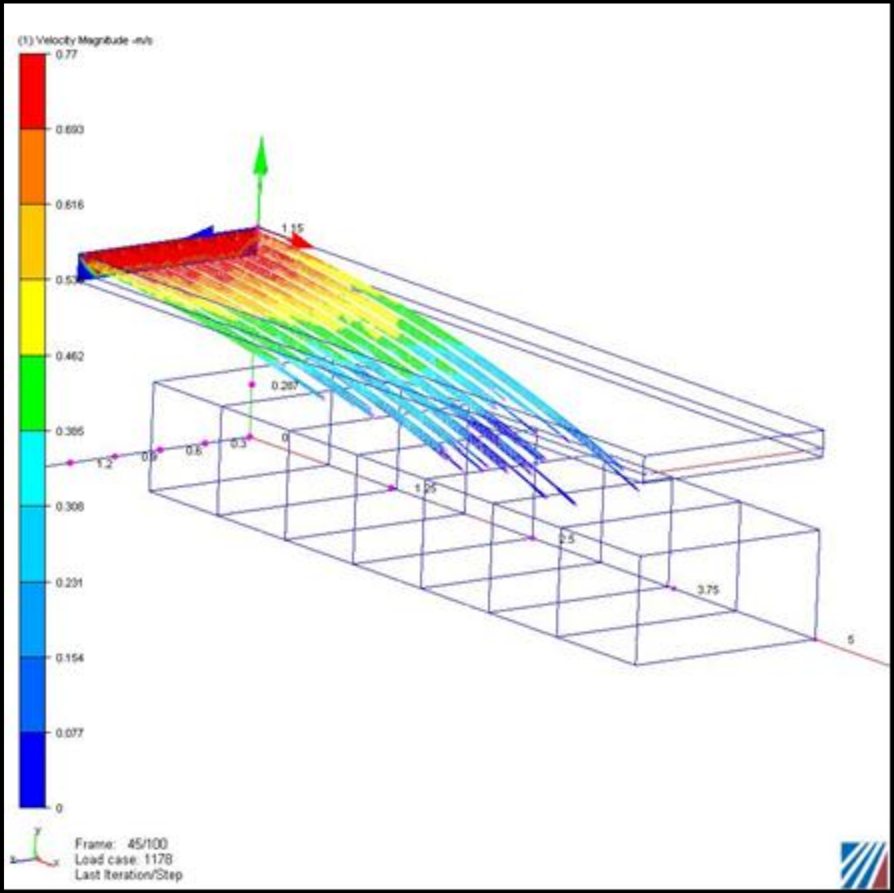


Precise Separation



Path of 50 mm diameter particles of a 1.001 density in water

Fluid Dynamics

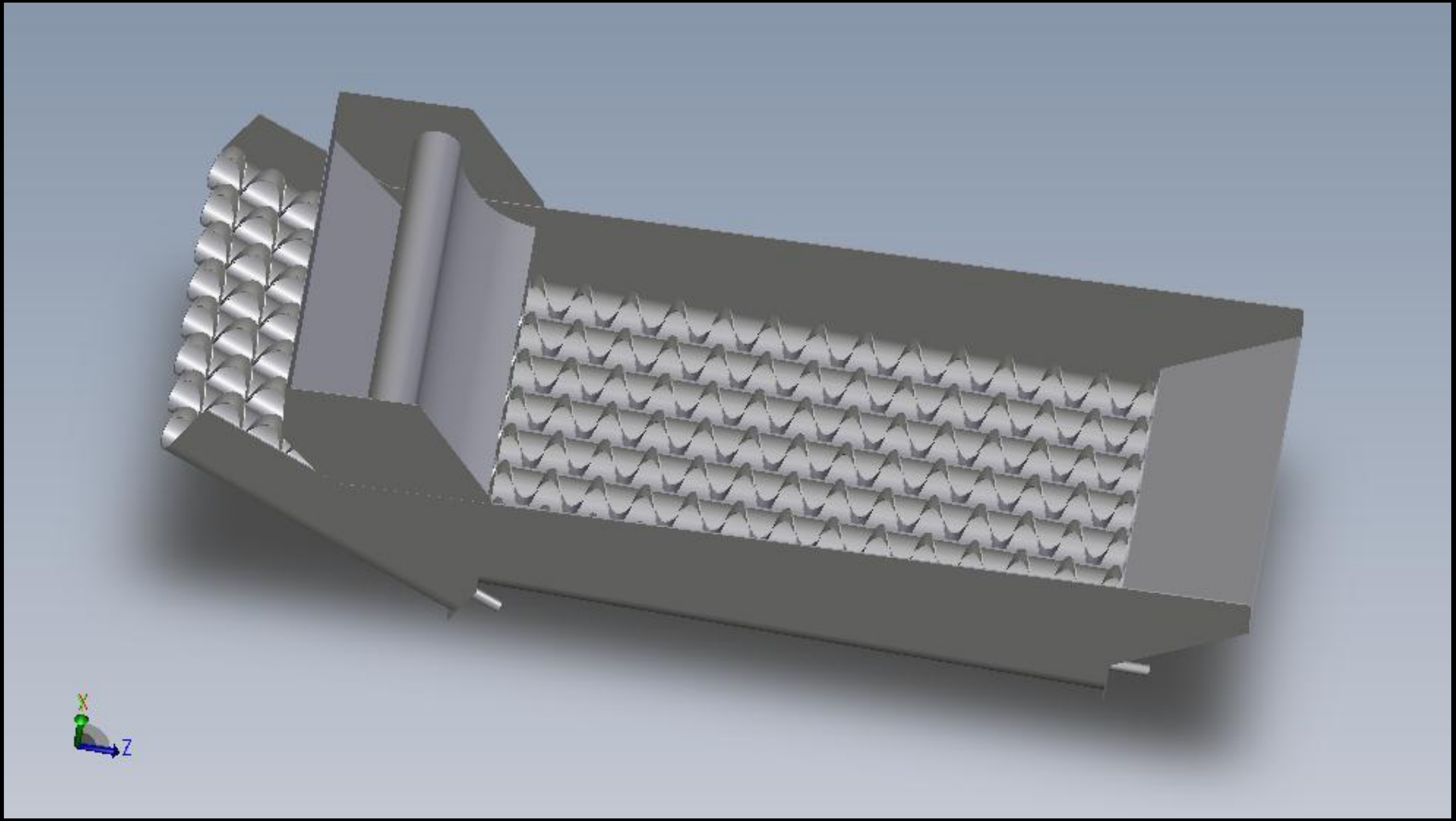


Path of 50 mm diameter particles of a 1.005 density in water

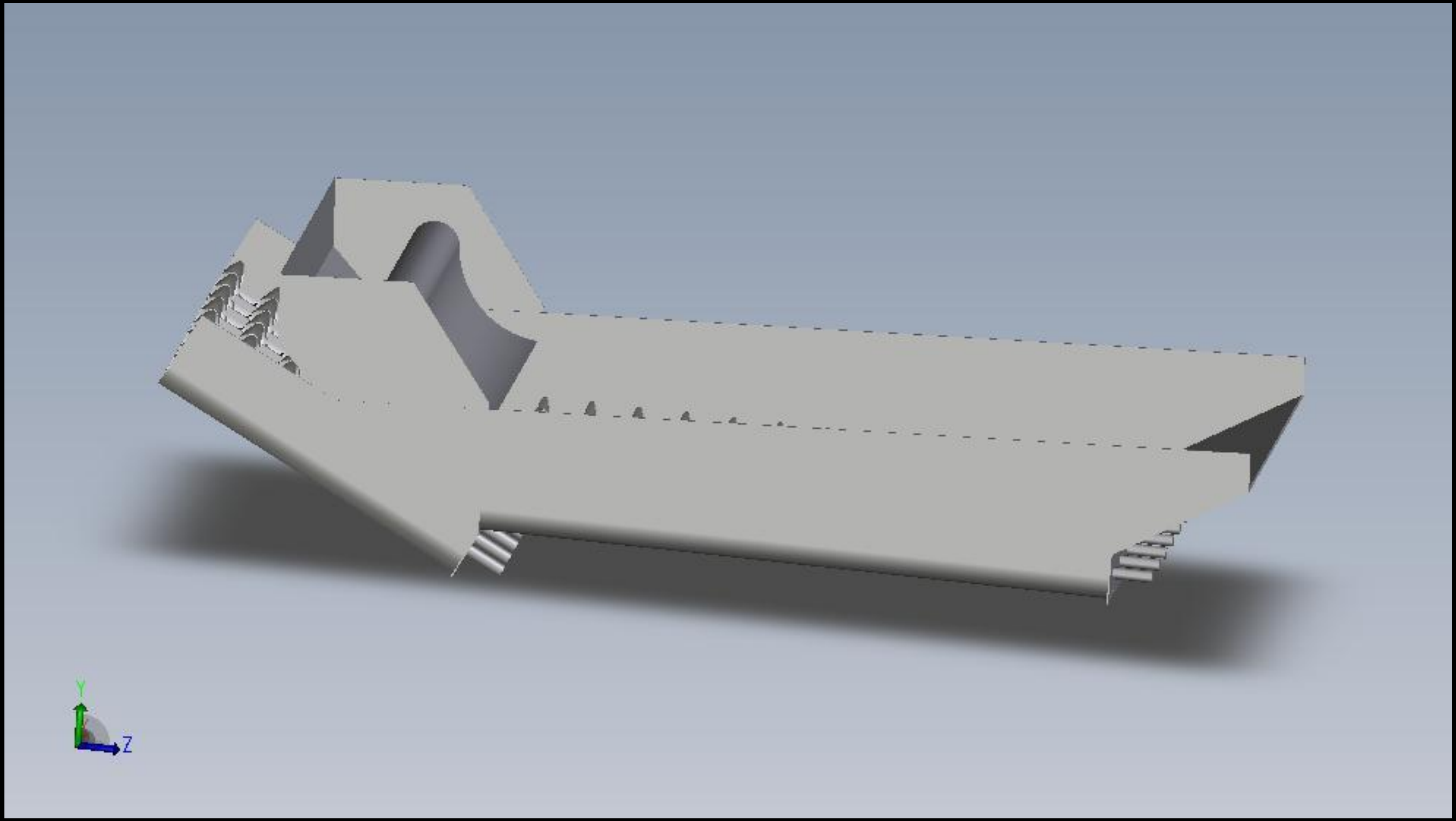
Another Auger Configuration

Another way to configure augers would be to use shaftless augers fixed on only one side. This creates a far more compact separator, and it gives bath depths similar to those in the bi-directional drum.

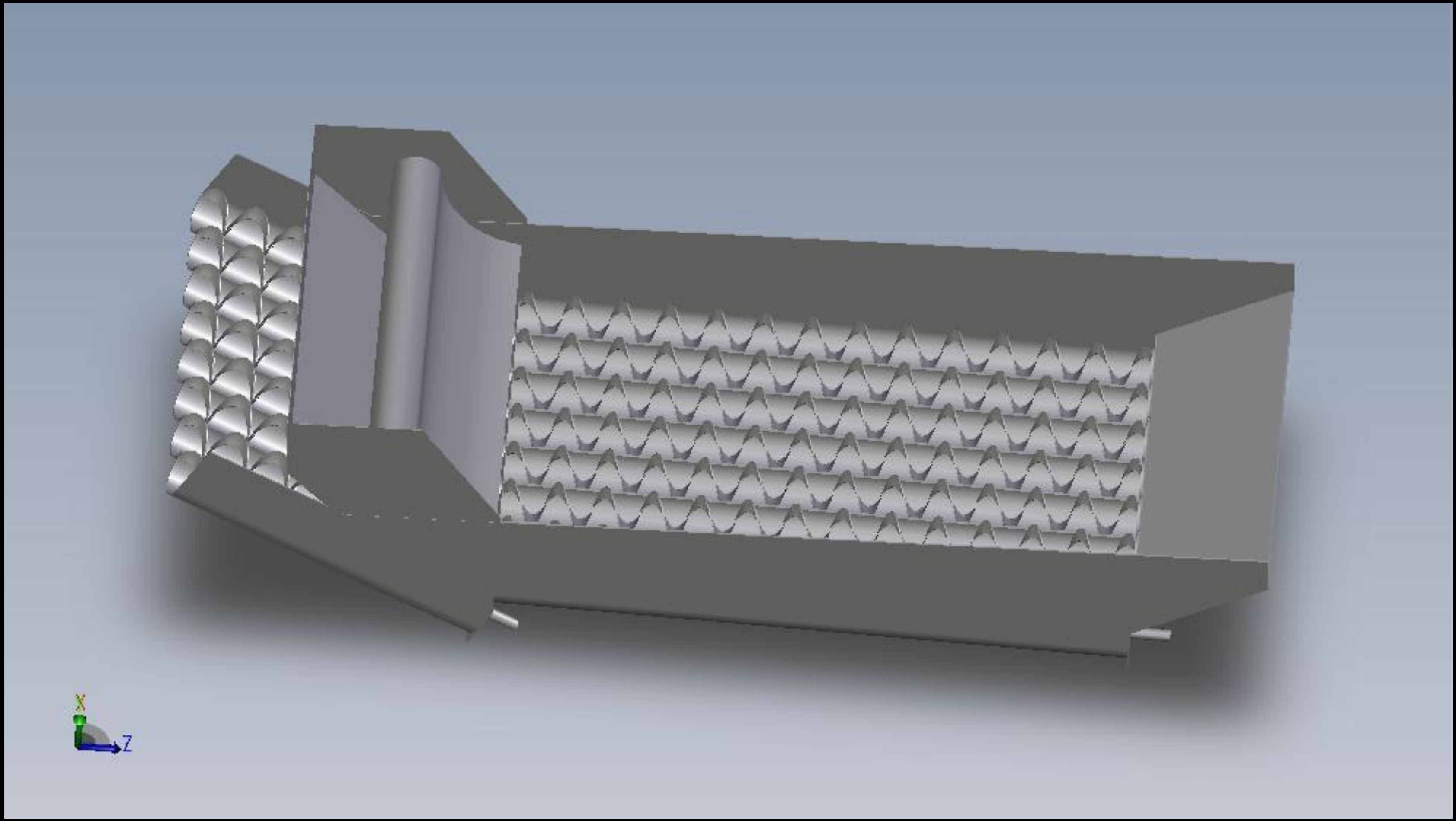
Another Auger Configuration



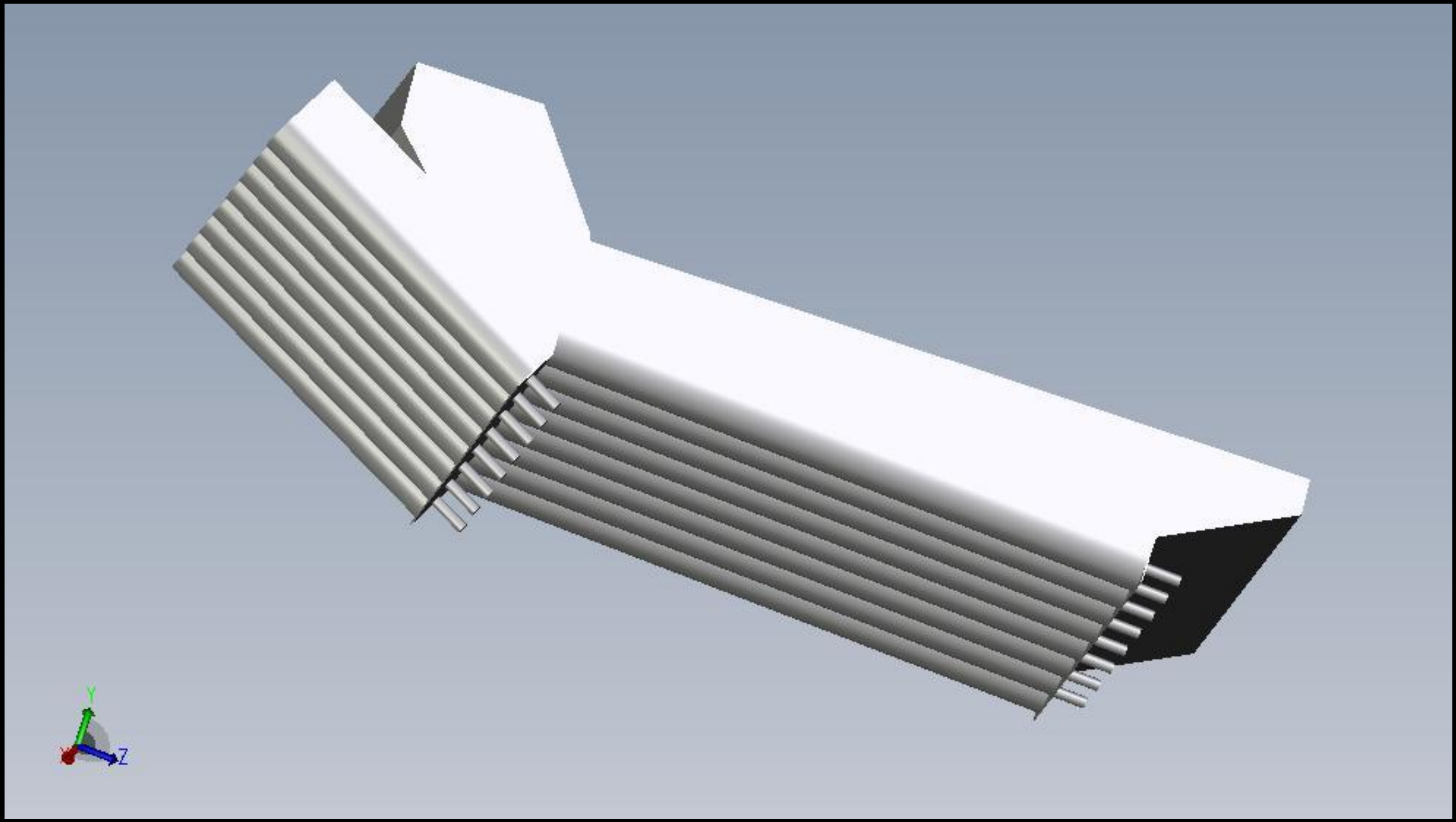
Another Auger Configuration



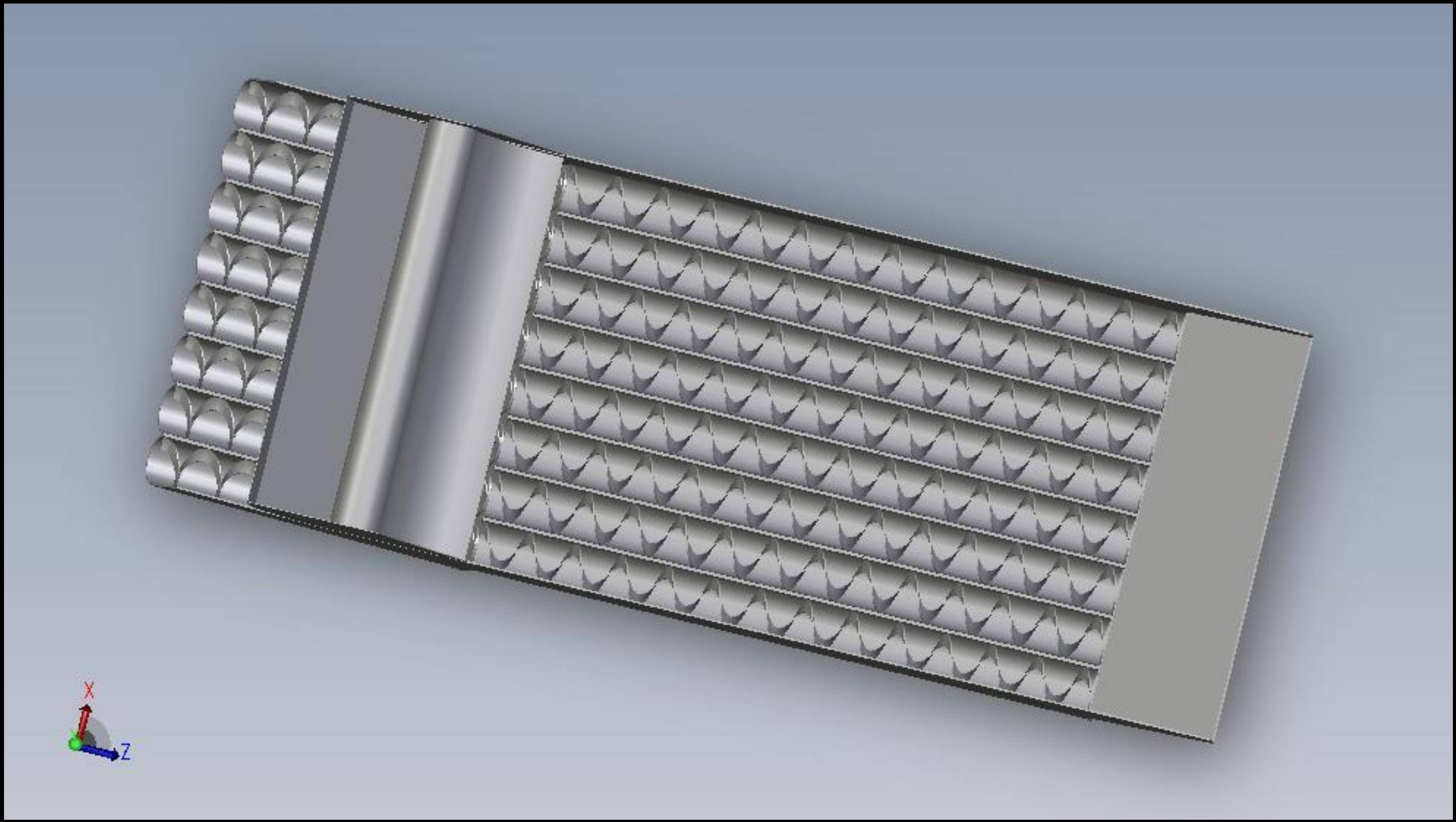
Another Auger Configuration



Another Auger Configuration



Another Auger Configuration



How to Design a Dense Medium Separator?

The design of this new separator is flexible and modular, and it begins with the determination of the surface density of the material to be separated.

Surface Density

Surface density is the measurement of the maximum weight of solids that can be situated in a given area without stacking one particle on top of the other (we express it in terms of kgs/m$^{2)}$. Surface density will vary according to true density and average grain size: surface density increases as either the true density or average grain size increases.

Surface Density

The surface density of a solid represents the maximum weight that can be fed to a dense medium bath. Any attempt to crowd more weight into a bath leads to particle interference and separation error. The surface density of a plastic is determined by taking a representative sample and laying it out over a surface in the tightest manner possible without stacking. The procedure is

Maximum Particle Diameter

is repeated until a high degree of statistical uniformity is reached. Once we have determined the surface density of a plastic, we must then determine the maximum particle diameter of that plastic as it presents itself to a weir. This in turn will determine the weir height required to overflow the largest particles. In general, the weir must have a height at least two thirds that of the

Maximum Particle Diameter

diameter of the largest particle in a floating position, otherwise that particle will not overflow the weir. However in the design of a separator, it is best that the maximum particle diameter and the height of the weir be the same. Once we have determined surface density and weir height, we can apply computational fluid dynamic formulas to determine the surface speed of the medium through the bath.

Surface Speed/Capacity

If we know surface density and surface speed, we can then calculate the capacity per meter width of separator. According to the tonnage to be processed per hour, we can then select an appropriate separator width. For example, in the case of a plastic of a surface density of 3 kgs/m^2 traveling in a bath at a surface speed of roughly 0.18 meters/second, the capacity per meter width

Width = Quantity

is roughly 1.93 tons/hour. If the separator must process, for example, about 5 TPH of plastics, then the separator must have a width of about 2.44 meters. This 8-foot width represents a maximum separator width, since the transport and assembly of anything wider would be problematic. If more capacity is needed, more units are installed.

Quantity and Quality

Now that we have determined the width of a separator, how do we determine its length? The former relates more to quantity, while the latter relates more to quality.

Length = Quality

The calculation of separator length is based upon the residence time in the bath required for the smallest near-gravity particles. We must determine the rise rates and settling rates of these difficult particles and allot to them the residence time they require. If, for example, we determine that a residence time of 22 seconds is required for the most difficult particles, then the

Length = Quality

a separator with a surface speed of 0.18 meters/second must have a length of at least 4 meters. As the maximum particle diameter of a particle decreases, the height requirement of the weir also decreases, and as the weir height decreases, so too the speed of the flow of medium on the surface of the separator. Even though a relatively small particle does not float and sink as

Length = Quality

rapidly as a large particle, it still can separate with a high degree of precision if the bath is long enough. Since small particles traveling at low speeds in long baths might separate with the same precision as large particles traveling at high speeds in long baths, it may be advisable to size a plastic into at least two fractions and present each size to its own dense medium vessel.

Optimal Bath Configuration

So as we follow the logic of surface density, weir height, surface speed and residence time, not only can we design separators that are perfectly adapted to the most difficult plastics, but we end up with a circuit that is far less complicated than the static separators used today on plastics. Instead of feeding material at right angles to the flow of medium, the new ESR separator gently

Problems with Static Baths

introduces the feed over the full width of the bath in line with the flow of medium. Since a static bath is equipped with surface scrappers to propel the material along the surface, the surface of a static bath is anything but static. Instead of allowing the material to flow gently and slowly from one side of the bath to the other, the surface of the bath is subjected to violent agitation.

Problems with Static Baths

Because static baths are relatively deep and do not have a uniform depth throughout their length, they must work with clays or salts to obtain medium stability. But such materials are far from ideal. Clays provoke viscosity, salts are corrosive, and both clays and salts are expensive and difficult to recycle and reclaim. Here ESR truly excels with the use of ultra-fine sand between 10 and 30

Problems with Static Baths

microns. This sand is obtained free-of-charge from the inorganic fines generated from the shredding of the larger waste stream from which the plastics are derived. These fines are not viscous or corrosive, in suspension they are exceedingly stabile, and they are easily recycled and reclaimed.

Problems with Baths

It is easy to understand why dense medium baths have been so problematic in the separation of metals and plastics. Because solids were poorly introduced, floats were buried with sinks. Because baths were deep and fluid dynamics within baths were not uniform, operators struggled to maintain the stability of the medium. Because baths were short (oftentimes only 4 or 5 feet in length) and

Problems with Baths

because fluid dynamics were oftentimes violent and turbulent, separation efficiencies were poor. Because bath designs were complicated and encumbered with a lot of high-maintenance moving parts, they were exceedingly difficult to operate. Because baths were seldom configured correctly in terms of width and length to match the quantity and quality requirement of the material

Problems with Baths

to be processed, they often performed in an unsatisfactory manner. Whether it be a Drewboy, a Wemco, a Peter’s or a Daniel’s bath, or even the most advanced static bath, we find innumerable reasons why each falls short in fulfilling the requirements of a sophisticated and demanding recycling industry. In addition to the problems associated with baths, there are many problems

Problems with Dry Separation

associated with the dewatering and rinsing of materials, as well problems relating to frothing and water treatment. In the end, it is easy to understand why the non-ferrous metal recycling industry turned to dry separatory techniques such as eddy current separators and optical sorters. But none of these dry techniques can truly clean the residue and concentrate pollutants, can classify organics and

Problems with Dry Separation

inorganics down to the micron level, can sort with efficiency a complex blend of the tiniest copper wire alongside large pieces of foam rubber, can sort with efficiency various types of plastics that differ in density by only one or two points to the second decimal place, or can recover virtually all the metals present in both the light and heavy fractions from the shredder.

Superior Performance

If a dense medium bath is correctly designed, it is by far the preeminent separating instrument in almost all waste applications. The rapid movement of a particle through a Newtonian liquid, where gravity is the predominant force and the influence of particle shape and size is greatly minimized, offers a simplicity and precision that cannot be matched by any other separatory technique.

Electronic Waste

But the technology outlined in this presentation can be used to process a lot more than automobile and industrial waste. Electronic waste runs through the ESR process with an amazing efficiency. The isolation of fine and ultra-fine inorganics makes it possible to recover all of the precious metals present in this waste.

Residential Waste

But ESR technology does not stop at electronic waste. It is also possible to do a 1.0 separation on shredded residential waste. Normally the food waste present in residential waste would destroy the quality of water within this separator and make this an impossible task. However if the water flowing through this separator would not be cycled back after the initial dewatering of solids but

Residential Waste

would be routed in its entirety to a water treatment process employing of methanogens, then it would be possible to do a relatively precise separation on shredded residential waste. The methane from this water treatment process could be recovered and utilized, and clean water would be returned to the 1.0 separator allowing it to function as efficiently as it does in the case of ASR. The floats of this

Residential Waste

1.0 separator would then be routed to another anaerobic digester where methanogens would be suppressed and where mixed alcohols would be produced. The sinks of the 1.0 separator would be routed to a 1.6 separator to separate the remaining non-putrescent organics from inorganics. The residue of the mixed alcohol process and the floats of this 1.6 separator would then be routed to

Residential Waste

an oxy-fuel gasifier, and the synthesis gas from this gasifier would report to a steam reformation process and converted into methanol and/or ammonia. The methane from the 1.0 water treatment process could also be reformed and converted into methane and/or ammonia. The sinks of the 1.6 separator would be routed to a 3.2 separator to isolate heavy metals, as in the

Residential Waste

processing of ASR. The floats of the 3.2 separator would then be routed to an eddy current separator to isolate aluminum from non-metallic inorganics such as glass and stone. These inorganics could be crushed and sold as a low-grade aggregate.

At this point, there remains now only one type of residential waste that demands our attention: lawn and garden waste.

Residential Waste

The softer, more biodegradable portion of this waste can be composted, and the harder, more recalcitrant portion of this waste (woody biomass) can also be gasified and converted into methanol and/or ammonia. So in the end, is there any fraction of residential waste that we should we dump in landfills? The answer here is clear.

Total Landfill Avoidance

No, there is nothing, nothing at all.