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PET bottles recycling.

This is what everybody is after these days.

And, because of this let's see what it exactly means; lots of people out there have only a rough idea of what this means so let me try to explain what's good, and what's not.

The good part, it is always better to start from the good part, is the fact raw material is "a bottle" and even a kid can recognize it.

Second good part, and it depends by the first one, is the fact collection becomes "easy" and the right translation for this means "low cost".

End of the good part of it, not much folks.

Because transport of empty, loose, bottles is practically impossible, PET bottles need baling to increase the bulk density and to be handled more easily.

In some location, pre-sorting is done right after the baling process not because the people doing it like it but because sorting means to sell PET bottles at a higher price and to bale some HDPE bottles scrap as well and make some more money out of them.

This, unfortunately, doesn't apply to PVC bottles but this something we'll be talking about later on. So, a certain day you see a lot of these bales piled up and together with the fact you are environmental conscious, and have some money, you start thinking about recycling PET bottles.

Well, this is a day you're going to remember.

Here's why:

PET is an engineering material and the final product needs precise characteristics to be used and, always remember, you're starting from a bunch of bottles collected on the street from somebody that doesn't know what PET is, and never will, plus the fact that many of them carry a label where's written "water" but has been used to store "?????" you name it, and think to the worse.

And here we go.

As said before, the final product needs to be 100% (actually 99,99995% or 50 PPM, parts per million residues allowed) clean, out of garbage.

Now, from now on, keep this in mind and don't ask any more why a washing line cost so much; we'll go into it step by step explaining the reasons there are so many machines.

You get bottles in bales and, according to production rate, and the country you are in, you may want to use a bales breaker to open them up and have all bottles single.

This is required, doesn't matter if you'll go with manual or automatic sorting, bottles need to be single for people, or machines, to be recognized and sorted.

Bottles will go on a conveyor belt, always sized according to the number of bottles that will go on it, and further step, pretty important, is to "stabilize" the flow of bottles going to sorting.

The best, easy, and inexpensive way to do it is a trommel.

Most of everybody thinks trommel is used to remove glass, stones, some caps etc; it is somehow true but the main reason for a trommel to be there is the fact it delivers a very steady flow that's required by people but, mainly, by automatic sorting devices.

We'll not be talking about the single devices here, there are some other pages for that, but only why that particular machine or device needs to be there.

So, from the trommel, bottles will go onto a conveyor belt, or a set of conveyors according to the sorting method that has been chosen.

Let's talk a little more about sorting because our opinion is this makes the difference.

Even with the very best, sophisticated washing line, will give you a nice, shiny clean, perfectly dry garbage in form flakes at the end, if you feed garbage.

Let me try to make this a little more clear:

As said before PET bottles from kerbside collection will be out of , about, 96 / 97 % of PET bottles while the rest will be PVC first (average 1,5 %) some PS, normally in form of clear trays, some aluminium cans and “something else”.

Let’s talk about PVC contamination:

The maximum content allowed at the end is in the range of 10 PPM and most of everybody will start from that 1,5 %, that’s equal to 15.000 PPM.

In simple words, this means the amount of PVC needs to be less than 0,7 ‰ of what it is at the beginning or, if you’re not in mathematics, less than one bottles of thousands coming are allowed to the washing line.

Of course there are ways to sort them out and get to this purity but let’s keep an eye on costs.

Fortunately NIR and X-ray detectors are going down as far as price, so it is kind of affordable now or, at least, it can be evaluated.

Go to the “automatic sorting” page if you like to know more about this.

The rest is kind of easy to sorted and removed from main stream of PET bottles.

It can be a can, a Polystyrene tray or a pair of cotton socks but none of these look like a bottle so anybody is in position to sort tem out.

Don’t laugh too much about the socks because this is the least of what it’s going to come on the sorting conveyor and, always as an example, there is no automatic device that can sort out cotton from PET so, even with the most technologically advanced device, you’ll need somebody on the conveyor for final check before going to granulation.

And now, let’s talk a bit about granulation.

What’s the deal with granulation ?

Well, again, doing something wrong before going into washing line, means to have problems into it. Granulator should therefore have some specific characteristics:

First it needs to be strong, no not the one you’re thinking about, stronger.

Second, it needs to be run with sharpen blades all the time otherwise size of flakes will increase, bulk density of flakes will be a lot less and, most important, running a granulator with dull blades means many flakes will “open up” like it was a multi-layer material and this traps air when going into water making them to float together with PE.

Last, but not least, dull blades create lots of fines, that’s good material thrown away. (read it money thrown away).

PET is a very abrasive material and dirt and paper don’t make things better so you should expect the blades to wear out in very little time.

Choices are therefore two; or you should consider to stop the line once every, let’s say, a day or two maximum or go with two granulators having one running and the other on maintenance, stand by.

You may argue this is an expensive choice, and this is true, but how much it costs to keep a million dollars line stopped 4 or 5 hours every two days or less ?

If you run some numbers, you’ll find out you get your money back in a very short time indeed and after this, cost of downtime, that’s the most expensive item in the costs list, will decrease a lot.

When it goes to operating costs in fact, you better pay a lot of attention to “hidden” costs rather than the ones very clear to everybody.

How much is maintenance cost for example ?

Does anybody tells you this when sending an offer of the PET bottles washing line ?

You better ask about it, together with energy costs to heat water up, filtering water and so on.

Back to granulators, there is another choice to make.

It is better a dry or wet (running together with water) granulator ?

Dry granulation has the advantage to work together with a blower and this increases a little bit the capacity of the machine, labels can be easily removed afterwards with a simple air separator, that works only with dry flakes, and bearings will never have a problem running dry.

The wet one instead, is better because rotor and blade will always stay cool, blades life will be surely longer, it performs like a pre-washing machine removing most of the surface dirt, it converts most of paper labels to pulp and it is less noisy than dry one.

Wet granulator is equipped with a screw conveyor running on a screen for dewatering purposes and flakes will come out with a 30/40% water content, according with paper content.

If you choose to go with the wet system, you should consider a dryer just after granulator to separate remaining loose dirt and paper pulp.

With a good dryer you can even think to have an air separator after it to remove plastic labels and, at this point, PET flakes will have only some PP and PE contamination (labels still glued on the bottle, caps and rings and glue of course), very little dirt, paper and other contamination.

So, first one is simpler from operating point of view and delivers a material just ground while second, is effectively more expensive but, in the long run makes you to save a lot as far as cleaning, starting from a pre-washed material, and blades life is longer (maintenance cost is less).

I personally suggest to go with the wet one but, of course, the matter is open for further discussion.

In case of dry granulation I suggest a pre-washing machine to get flakes clean, at least from paper and most of dirt because of something we'll be talking later on, very important part of the system, that's water filtration that has a chapter by its own.

In both cases at this point we have semi-clean flakes, and here the washing line starts.

The very beginning of the line is a buffer silo where flakes went after pre-washing system, doesn't matter which one; every washing line, for any kind of scrap, likes very much to have a steady amount of material going through.

There are many reasons for this and main ones are the fact that residence time of flakes for the washing stage will be pre-set, and constant, second because centrifugal dryers will perform much better if material comes at the same flow rate all the time.

Washing is not the first step of the washing line anyway.

Our flakes are semi-clean it is true but still have caps and rings, few labels left by air separator(s) that we better remove prior going into the washing stage.

So, from buffer silo extracting flakes at a constant rate, set by the operator, flakes we'll go into a sink-float tank where separation of olefins occur.

Once more I would like to point out that a tank doesn't wash anything so call them "washing tanks" doesn't sound right to me.

Anyway, let's go head with the washing line.

After pre-washing and olefins separation our flakes are ready to be completely washed out from remaining dirt, whichever it is.

One of main concern everybody has is glue washing so, let's talk about glue removing and various technologies available to get rid of it.

The oldest one, still used very much, is to put flakes into a hot water tank, together with a caustic solution, and leave flakes into for a certain period of time with the help of a steering, agitation, friction shaft, call the way you like it the most, to detach (not remove) glue from the surface.

Together with glue, of course, the rest of paper, dirt etc, will be detached as well and go into water.

It normally is a "batch process" in order to control the residence time because, according to the "solution" and temperature to which the solution is set, time can vary.

Now you may think "the longer, the better" but this is not quite right due to the fact caustic starts a process called "saponification" that is the opposite of "esterification" that in simple words means caustic will start breaking the Polyester chain with two main effects:

First is to have a very porous surface of flakes, that's ideal to trap dirt and stuff like that, and second it degrades the polymer itself adding oxygen to the open radicals of the chain with the effect to turn the polymer yellow first time you'll heat it up (read it extrusion process).

To avoid this, in nowadays, some special chemical solution compounds are used and results are pretty good in terms of quality.

I'm not a chemist so I leave this to the right people; I just know what in reality happens to PET flakes out of post-consumer PET bottles.

We do use a completely different approach to the problem, for quite many reasons.

First, as I said before, is the fact residence time should be as less as possible to avoid the starting of chemical reaction, that will degrade the polymer.

Second was to find a way to save money as far as energy concern, because the heating of water by steam, electric gas, diesel and anything like this is too expensive.

To achieve the result, we do use something very new, not big indeed, running with self-heating water, not by miracles or anything like this but by the friction created by the rotor itself.

As it should be easy to understand, friction is what's needed by washing, meaning scrubbing the flakes with the highest possible energy, in presence of water (caustic solution).

Of course this friction is adjustable and it can go from less than a minute to 4/5 minutes at the most, time required by the glue and dirt to come off the surface of flakes.

The process is faster than other system because a small trick that, knowing the machine, is pretty easy to understand.

And by what I told you before you should understand why by yourself anyway.

I give you a small tip to get to the point. (if you like mathematics)

Effect of temperature on reaction rates using the Arrhenius equation.

$$k = A \cdot \exp\left(\frac{-E_a}{R \cdot T}\right)$$

where k is the rate coefficient, A is a constant, E_a is the activation energy, R is the universal gas constant, and T is the temperature (in degrees Kelvin).

R has the value of $8.314 \times 10^{-3} \text{ kJ mol}^{-1} \text{ K}^{-1}$

And, because of this, caustic consumption will be a lot less than any other system, and this has many advantages; rinsing will be a lot easier and water filtration and treatment sized accordingly.

Another point to make clear is the fact glue doesn't dissolve because of caustic or, in other words, caustic doesn't make saponification of glue but reacts only with Polyester.

At this point, the presence of a wetting agent is compulsory to trap the glue particles and carry them out of the machine.

Yes, of course, our machine has a continuous water (solution) inlet and outlet so glue, dirt, paper etc, will come out immediately after being removed from surface of flakes.

After this washing process, rinsing is compulsory for quite many reasons:

First is the fact flakes should arrive at the end of the line with practically no chemical contamination of any kind and second because caustic and other chemicals should stay in the close loop filtration system that is normally installed for this part of the system.

To carry this job out, we do install a very powerful centrifugal dryer that delivers flakes with a residual moisture content of less than 0.7% .

Because the "solution" is used at about 1%, after the dryer caustic residues will be $7/1000 \cdot 1/100$ equal to 70 PPM, that's not bad indeed as first step.

A second sink-float tank is installed on the system we suggest because at this stage there are still plastic labels detached by the washing machine but still, in loose form, together with PET flakes.

So, one more separation in water is compulsory to get rid of them.

The tank is also very helpful for rinsing purposes because some of residues coming from previous stage are still around and we don't want them with clean flakes.

The tank has a continuous extraction screw carrying flakes to a rinsing machine, meaning a machine that does nothing but removing the last traces of chemicals still sticking on the surface.

Of course, using de-mineralized water at this stage will be a lot helpful.

A final mechanical dryer will dry flakes down to a mere 0.7% moisture and everything goes to a storage silo.

End of the system.

Not quite.

Let's talk a bit about water filtration.

As very easy to understand, washing with dirty water doesn't make sense much.

But before talking about filtration systems let's make some considerations about the dirt (the average expected dirt in solid form) coming with scrap bottles:

Dust, sand, paper and not much else, always talking about solid stuff; the rest will be the residue content of the bottles that nobody will ever know what will be.

And we don't either. (Remember this for later considerations)

Not to mention we're going to put some chemicals ourselves to complete the mess.

Aren't we ?

Let's be serious about this because here is where most of problems can arise from.

We should make another consideration about it, valid in most of countries and in a short while compulsory all around the world.

Waste is categorized according to what it is into, so if you like to save money, this waste, meaning the most of solid contamination of bottles, shouldn't go together with caustic for no reasons whatsoever, otherwise will be in serious problems.

So we should have one filtration system dedicated to the very first part of the system taking care of surface dirt, paper and all these good stuff.

To do a better job, you may like to have a briquetting machine to squeeze water out (of course if you pay to dump waste by weight).

At this point you may start to understand why a pre-washing section of the plant is required and, if you have the patience to read it all, there is another even more important reason for that.

Filtration of solid particles is normally done with a mechanical filter, many available on the market.

Also in this case, the more you spend, the better you are, and this is why:

With a simple inexpensive 100 micron screen water filter you will have a certain amount of dirt/paper pulp going back to granulator and, as you can imagine, dirt and paper don't help to keep blades sharpened so, if you get a better system to go down to 50 microns or less, a lower amount of dirt will go back to the system and, blades will last longer, pumps will run better, dewatering system will never jam, just to mention a few.

Now let's talk about the most important, most difficult part of the system that has nothing to do with the washing line itself, and is the filtering system of hot caustic solution.

There are quite many systems available and well running; all of them have one thing in common:

Very Expensive

How do you like it ?

Once again, with "expensive" we mean mainly as far as operating cost.

Osmosis, membranes of any kind, fossil flour vacuum systems, you name it, can represent a high % of total running costs, for quite many different reasons but all of them are expensive.

And if you're running a system already and are laughing right this moment because you found the way to bypass the problem, you better think it over again because your 600.000 plus Kcal. steam generator doesn't run for free. Isn't it ?

Honestly, I'm not to the easy solution of the problem yet, but some lab trials show good results and an industrial set up will be running soon.

The investment cost will be equal to other system and as far as operating cost we'll be close to nothing.

I understand most of everybody is looking at the very end of the offer, where prices are, but this is not the right way to save money.

Check out all data about energy consumption, including the hidden ones, and multiply the difference for whichever is the cost of energy in your country, times 7000 hours/years and see how much it is and if you can buy a brand new SL Mercedes with this difference.

It may be more than one.

So, back to plastic recycling, energy consumption is an issue, together with maintenance, downtime, material lost (fines), waste handling and disposal.

Let's see each one of them one at the time.

We were talking about energy consumption.

Energy is consumption of electricity, gas, steam, diesel or whatever else you need to create motion and/or heat, required for the proper washing of flakes.

This should include both washing line and water/solution filtering system(s).

Washing line needs to be complete in all aspects but try to skip useless steps with energy eating, high maintenance machinery doing almost nothing. (I saw very many around)

This because each piece of equipment has a cost, consume energy, needs maintenance and, main reason it can break, like any machine in this world.

And when this happens you are in damn troubles.

Unfortunately any system is a complex of a certain number of machines one after the other, every machine should care about material coming from the previous one and should deliver it the right way and right amount to the next one, 24 hours a day.

This simply means that if the stupid 0,18 kW lubrication pump stops, your one million plus beautiful washing line is down and you can do just nothing about it. And nobody can.

This means, to make a long story short, you should count downtime expenses when running your numbers, and you'll see that profit decreases quite a bit but, at least, you know it.

Specially when talking about PET recycling, maintenance, because of wearing, is an everyday issue and you can do very little about it, just deal with it.

A plastic recycling line means handling dirty scrap material, in a wet environment, pretty noisy and so on.

No big deal, as long as you know what you're doing.