GPEC 2004 Paper Abstract #5:

Title: **"VacuRema" and Bottle Recycling**

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EREMA®

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The EREMA system , the "VacuRema" . *TV* and food grade .

EREMA have produced lines for recycling PET since early in the 1980's. The original EREMA concept was to make the recycling of light and thin materials such as film and fibres more production/operator friendly and reduce the cost of recycling. Conventional recycling systems were based on pre-cutting of recyclate, often with intermediate storage, followed by stuffing and cramming systems feeding into a standard extruder.

In this conventional type of system, energy is used and then lost during transport or storage at each stage of the preparation of the material, it can be seen as labour intensive and a good production flow can be difficult to achieve. EREMA designed their system to alleviate some of the problems they felt were common to many conventional processes.

The concept behind the "classic" EREMA system is that material is fed directly via a conveyor into a large drum (cutter/compactor) containing cutting knives. The cutting knives are mounted on a high speed-rotating disc. In the cutter/compactor the material is cut and pre-heated. The heat is created simply by friction. The cutter/compactor is mounted directly onto the extruder and the preheated material is fed, continuously, direct onto the extruder screw. Feeding onto the screw is very efficient as it is forced onto the screw intake by the high speed rotation created by the cutting disc and knives within the cutter/compactor. As material is taken out of the cutter/compactor new material is fed into the cutter/compactor in order to maintain the level and thus the frictional heat. This is done automatically.

The majority of the energy used in cutting and heating created through friction is then used in the extrusion process.

The material is constantly flowing within the cutter/compactor drum allowing for the exposure of a large surface area to heat and drying.

This allows the EREMA system to be based on short extruders, often with no shear which then can result in less heat history on the recyclate.

There have been some 2000 " Classic" EREMA systems delivered world-wide.

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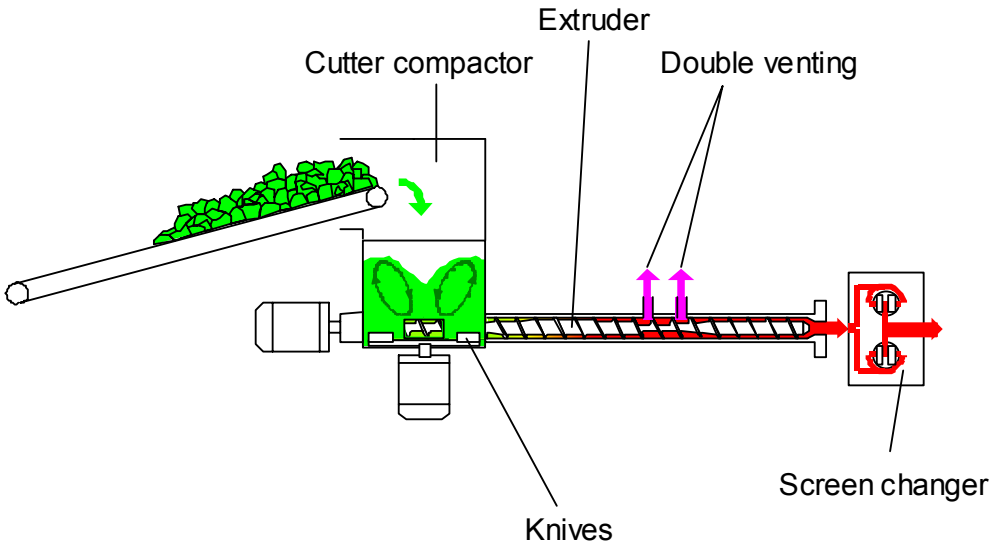
The "Classic" EREMA



EREMA and PET

EREMA were looking at the potential source of "high value" recyclate which appeared undervalued compared to its virgin price, could be highly valued and was readily available. PET bottles offered this.

Like all extrusion processes the classic EREMA will reprocess PET with an average of 10-12% IV loss This IV loss occurs even in standard extruders and it effects the quality of pellet produced and this, in turn, were this recycled pellet can be used.
Often due to loss of quality the RPET may only be considered for applications were lower IV can be accepted such as fibres etc.

IV loss is caused because PET is hydroscopic, even a short time in atmosphere will allow it to absorb moisture .PET is also sensitive to thermal degradation. It discolors easily due to an increase in Acetaldehyde levels, which occurs in every thermal/extrusion stage.

In order to optimise the value of PET recylcate and encourage its use in markets other than lower IV markets EREMA looked at PET in a logical manner asking themselves what would be required to achieve this. Their interest was increase the use of RPET and thus increase the market for their product.

Of course there is the conventional drying/crystalisation route but having the EREMA system available this seemed to be a waste of energy.

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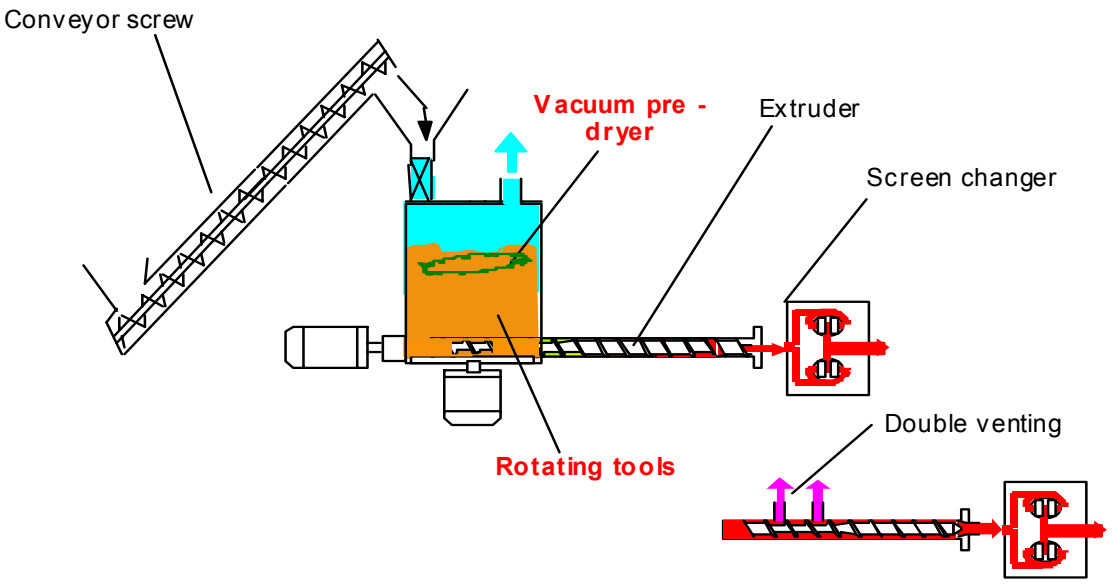
It seemed EREMA needed to look at methods of drawing the moisture from the PET chemical chains to reduce IV loss and reduce dwell time under extrusion heat to reduce Acetaldehyde levels.

It had been noticed during start up of an “In Line” pellet crystalisation process that when the (extremely large) dust extraction over the EREMA cutter/compactor was switched on the IV of the pellet loss seemed lower.

EREMA also achieved this effect in their Teknicum putting the classic system cutter/compactor under Vacuum. The results showed that IV loss could be kept below 10 %.

The next stage was to increase dwell time from the standard 10-15 minutes
In the " classic " system by slowing down the rotating cutter system thus reducing friction. This then gave a loss of below 5%.



The final stage was the “ VacuRema" in which the drum was equipped with a higher vacuum capacity, replacing the rotating cutter with a rotating mixer system and was larger to allow for increased dwell time. This gave an IV loss of less than 3%.

In addition to this it was proven that conventional vented extruders were not needed because of the venting effect in the drum. The standard vented EREMA at approx.35D could be replaced by an unvented system of approx.24 D. This resulted in a reduction in the creation of Acetaldehyde

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At this stage that EREMA had achieved what they had set out to do. It also became very obvious that this " VacuRema " system could be used for direct production of finished products rather than going through the more conventional pelletising stage.

EREMA delivered (and are still delivering) these "VacuRema" machines for the direct production of fibres, sheet, pallets, monofilaments and strapping.

However as always happens some customer demand dictated that we needed to see more . They wanted to see IV increase. The target was being sought by the strapping manufacturers were increases to .85 were required in order to be able to achieve the properties required of the strapping.

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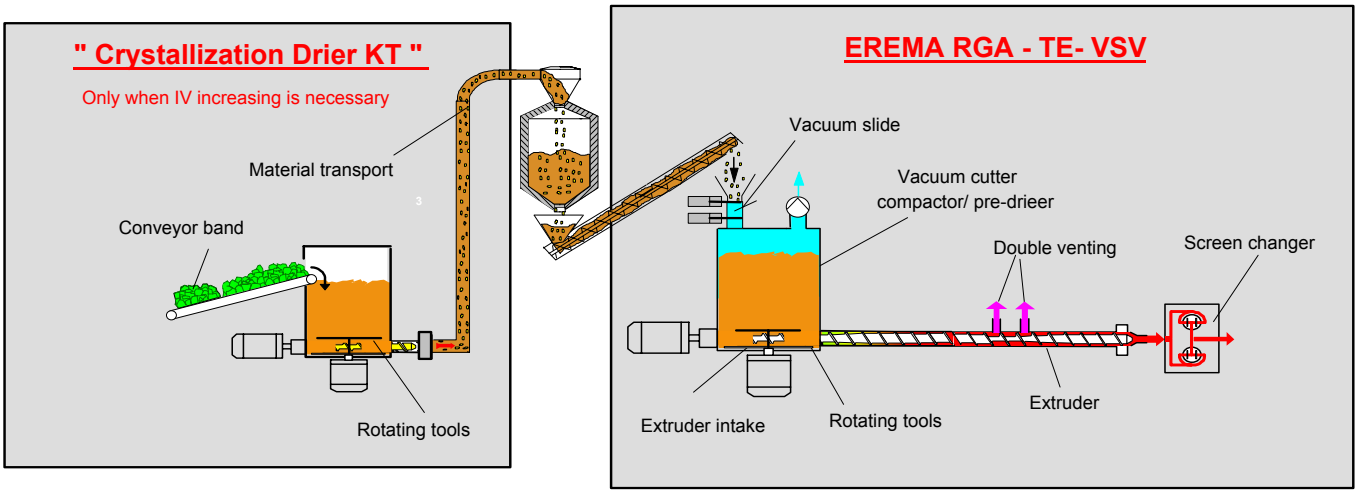
EREMA had seen occasional IV increases in the "VacuRema" system but to satisfy production conditions it needed to be regular and reliable.

EREMA addressed this issue by increasing dwell time , they chose to use a two stage " VacuRema" system introducing the KT before the "VacuRema" and then finally also putting the KT under vacuum.
This had the effect of doubling the time at which the PET is under vacuum and heat.
Using the two-stage process IV could be reliably increased and trials showed the increases required to take the IV to O.85 were the input material was suitable.



This was still not good enough though. Customers were also asking for IV increase from .75 to over 1.0!
It is now worth looking at the chemical effect, as this will be important on IV increase. (Much of the following information / theory is not from EREMA, although the IV results are).

The PET chemical chain allows moisture to migrate from atmosphere to between the chains and it is this moisture which causes IV loss if it in not removed.

In the "VacuRema" drum (reactor) the PET is exposed to heat , dwell time and vacuum. If the heat and dwell times are sufficient then the PET chains will open up allowing the moisture to migrate from/to within the chains. If you then introduce vacuum to this process then a) the migration speed is increased and b) moisture in the atmosphere is removed (migration can be in both directions !)
This means the levels of moisture in the chains must reduce , in turn allowing IV loss to be controlled.

This chemical reaction is what allows the "VacuRema" to achieve such results.
It is also the same process which allows the use of the "VacuRema" for processing post consumer RPET for food grade applications because the effect on contaminants is (on the whole) the same which I will explain later .

Now to high IV increases.
In order to achieve increase in IV to over 1.0 the choices were to increase dwell time again, which was beginning to be become impractical, or to use chemicals/additives.
EREMA have, so far, taken an IV enhancer added it to the RPET. Their aim was to take .75/. 8 material above 1.0 The IV enhancer is said to be a regrader and repolymerization agent which is used to increase viscosity, improve mechanical properties and increase pressure on the die. (This is a yellow compound so its suitability for use in clear/natural materials needs to be examined)

Using a conventional PET extrusion process processing RPET this enhancer would be required to be dosed at up to approx. 3-4%. Using the 2 stage VacuRema process similar results were achieved with just 03. to 0.6 %
This is a considerable saving in additive costs and is probably possible because of the very effect which the "VacuRema" creates. This may be because the chemical chains may be more receptive under "VacuRema" running conditions of heat , dwell time and vacuum.

This is were EREMA stand at the moment, however other people are looking at new projects to take care of the coloured PET flake.

In Germany a company called Remaplan were recently developing machinery to manufacture PET pallets, boxes and other large transport items. They have claimed that improved properties can be achieved using a blend of PET and PE together with their own brand" additives which it seems may be based on recycled materials rather than more expensive " virgin" additives.

In the UK a recycler has been working with EREMA on a similar additive project with a view to achieving similar results at a much lower additive cost in order to make a technical compound with the high value properties of PET but by adding PE it has flexibility and appears to be able to be handled in a similar way to PE , PP or PS i.e. without pre-drying of crystalization .
A UK pipe producer has , with the help of EREMA , produced a corrugated PET/PE blend pipe which appears to out perform similar existing PE of PVC pipes but up to 5 times. This has an additive to compatibilise and an impact modifier. However using washed coloured post consumer PET and post consumer HDPE thus reducing material costs while still improving properties.
In the UK EREMA customers have also now taken a PET/PE blend compound pellet and injection moulded it without the need for pre-drying.
This PET/PE blend not only has very high technical properties but it also cools in half the time PE or PP materials would thus allowing a potential doubling of production.

As you can see there is a lot more to these recent developments than may at first appear, EREMA continue to lead the field.

EREMA and food grade

The next step was to provide a system, which could produce a melt, or a pellet that was suitable for use in food grade applications.
Over a period of time EREMA worked with the Fraunhofer Institute of Friesing who evaluated the VacuRema process according to the FDA's "threshold of regulation".

In order to come to a result which could be submitted to the FDA two different tests were conducted 1) A challenge test and 2) A migration test.

The challenge test was a "worst case" scenario were various "control" chemical contaminants were added to a sample of bottle flake. These "contaminated" flakes were left for a period of time under controlled temperatures. These flakes were then run on the VacuRema system in a controlled test.
During this production samples were taken for testing at different stages of the process. At the same time a "head space" analysis of the atmosphere of the cutter/compactor was carried out.

The pellets produced were then used for the **migration test**. Bottles were blown and filled with different food contents. These filled bottles were stored under controlled conditions and later the food contents were analysed. **The level of trace allowed in the food according to FDA standards is 10 ppb. The migration levels in the food were found to be below 0.1 ppb.**

On this basis EREMA were given the US FDA letter of no objection on 17th November of 2000. This has now been extended with a statement from the Fraunhofer

that the EREMA system is inside the European ILSI Document, which is inside the German BGB1. They also approval from Switzerland.
Further letters of none object have been issued by the US FDA

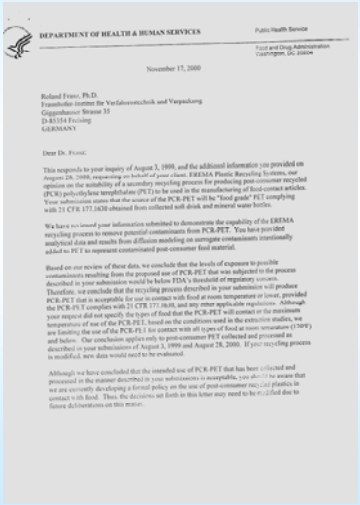
This letters of no objection allow for use of washed post use mineral and csd bottles from all curbside/collect systems for the production of a melt or a pellet which could be used for all kinds of foods for both hot and cold fill applications.

The first letter of none object

EREMA PLASTIC RECYCLING SYSTEMS

Status for Direct Food contact

- FDA: No objection letter 17.11.2000
- Proved by the BAG for Switzerland Jan. 2001
- Statement from Fraunhofer, that EREMA is inside European ILSI Document
- Inside the German BGBl Nov.2000


DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Food and Drug Administration

November 17, 2000

Roland Franz, Ph.D.
Fraunhofer-Institut für Verfahrenstechnik und Verpackung
Giggenhauser Strasse 35
D-85354 Freising
GERMANY

Dear Dr. Franz:

This responds to your inquiry of August 3, 1999, and the additional information you provided on August 28, 2000, requesting on behalf of your client, EREMA Plastic Recycling Systems, our opinion on the suitability of a secondary recycling process for producing post-consumer recycled (PCR) polyethylene terephthalate (PET) to be used in the manufacturing of food-contact articles. Your submission states that the source of the PCR-PET will be "food grade" PET complying with 21 CFR 177.1630 obtained from collected soft drink and mineral water bottles.

We have reviewed your information submitted to demonstrate the capability of the EREMA recycling process to remove potential contaminants from PCR-PET. You have provided analytical data and results from diffusion modeling on surrogate contaminants intentionally added to PET to represent contaminated post-consumer food material.

Based on our review of these data, we conclude that the levels of exposure to possible contaminants resulting from the proposed use of PCR-PET that was subjected to the process described in your submission would be below FDA's threshold of regulatory concern. Therefore, we conclude that the recycling process described in your submission will produce PCR-PET that is acceptable for use in contact with food at room temperature or lower, provided the PCR-PET complies with 21 CFR 177.1630, and any other applicable regulations. Although your request did not specify the types of food that the PCR-PET will contact or the maximum temperature of use of the PCR-PET, based on the conditions used in the extraction studies, we are limiting the use of the PCR-PET for contact with all types of food at room temperature (70°F) and below. Our conclusion applies only to post-consumer PET collected and processed as described in your submissions of August 3, 1999 and August 28, 2000. If your recycling process is modified, new data would need to be evaluated.

Although we have concluded that the intended use of PCR-PET that has been collected and processed in the manner described in your submissions is acceptable, you should be aware that we are currently developing a formal policy on the use of post-consumer recycled plastics in contact with food. Thus, the decisions set forth in this letter may need to be modified due to future deliberations on this matter.

Processing Quality Control / Monitoring

In order to supply a system which can be relied upon for a manufacturer EREMA can supply the VacuRema with monitoring systems.

a) Input material - EREMA can supply an "electronic nose " headspace analysis system on the VacuRema that looks for volatile substances, and with this it is possible to establish a "good/bad" characterisation of input materials. This analytical device provides a simple spot check quality control of the input material.
b) Processed material IV monitoring can be carried out using EREMA's "in line" Viscometer.
c) The PET VacuRema's have computer controlled touch screen technology, which allows for the constant monitoring and collection of line data.

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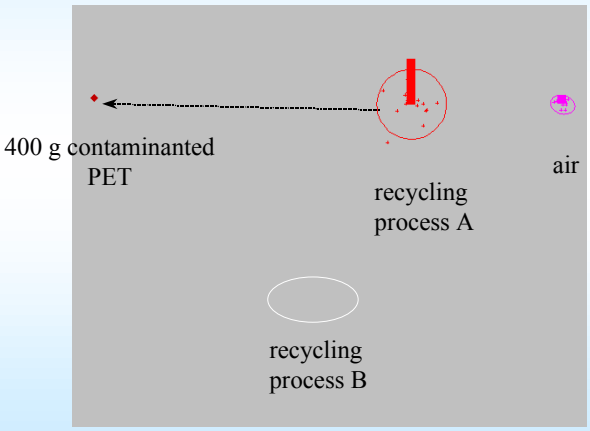
Continuous Quality Control "Electronic noses"

- Suitable for fast online analysis of volatile substances
- Integrated into the EREMA system
- Six sensitive chemical sensors
- A quick "good - bad" characterisation is possible

⇨ **By using this analytic device the manufacturer has a simple spot check quality control of the input material.**

Continuous Quality Control "Electronic noses"



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This technology remains an adaptation of a simple idea 20 years ago but it is being applied to an increasingly demanding market and to much more demanding applications.

Thank you for listening!

In Line production of " food grade" PET sheet using the "VacuRema"