Rotomould 2013

Coloured Powder What Every Moulder Should Know

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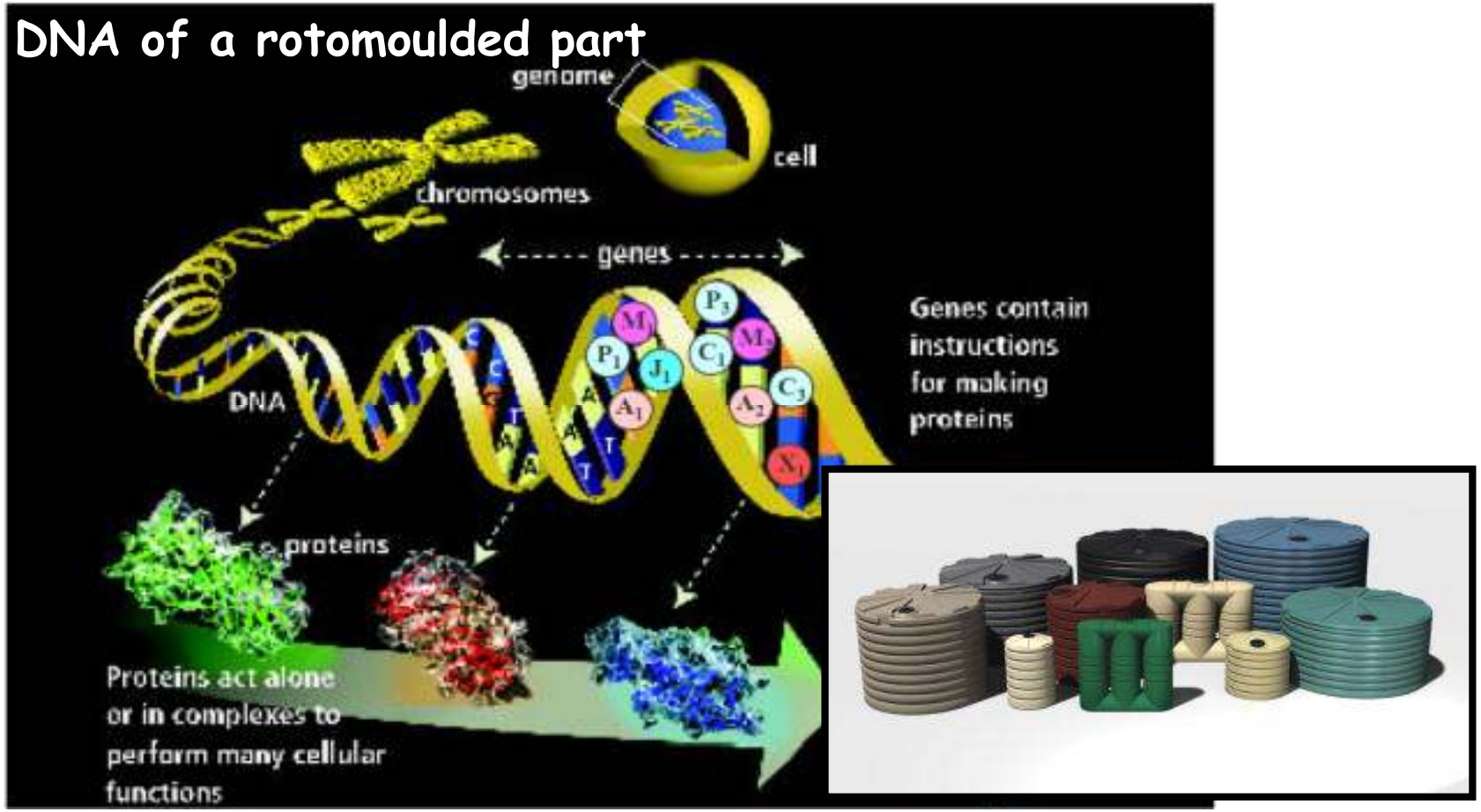
Bushmans

Coloured Powder - What Every Moulder Should Know

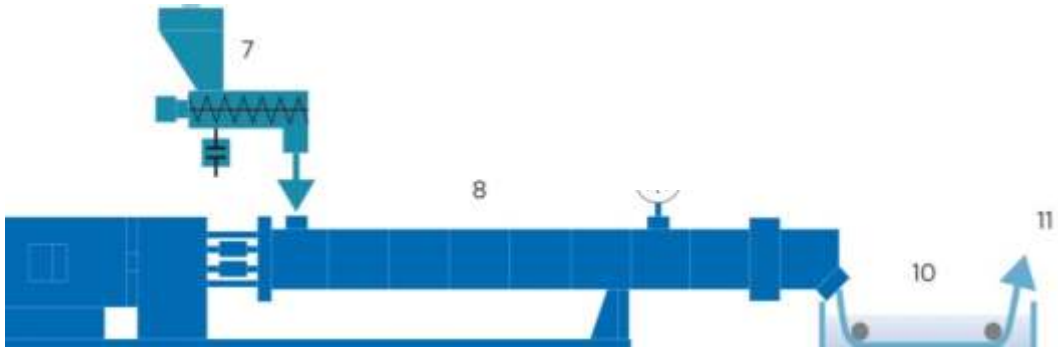


DNA – part only as strong as the weakest link

Presentation Outline

- Colour methods — Dry Blend versus Melt Compounds
- Compound Process — Overview with Text and Images
  - Pre-mixing of colours — Batch and Continuous
  - Screw and barrel
  - Equipment control processes
  - Pelletising
- Potential deficiencies — Colour and dispersion
- Examples of what the moulder can see when it goes wrong
- Examples of quality control - compounder
- Examples of process controls – compounder

- Summary



Colouring methods - blending

In the rotomoulding industry there are three commonly used methods to incorporate the pigment with the base polymer

1) **Tumble blending.**
2) **High speed blending.**
3) Melt compounding.

- Tumble blending or dry blending typically involves some low intensity mixing of powder with pigments outside of the mould.
- High Speed blending or Turbo mixing is an improved method of dry blending.
- The disadvantages of dry blending are that the pigment is not homogenized. Pigment remains in large agglomerates sitting between the powder particles.
- The physical performance of moulded parts are reduced.
- The colour tends to be weak and speckled.
- As you increase the amount of pigment, (to improve opacity), there is a substantial negative effect on performance.

Colouring methods - compounding

In the rotomoulding industry there are three commonly used methods to incorporate the pigment with the base polymer

1) Tumble blending.
2) High speed blending.
3) **Melt compounding.**

Melt compounding enables excellent mixing of the pigment and the polymer which results in a homogeneous compound.

(Compound definition : *To combine so as to form a whole*)

The pigment is combined within the powder particles, not between the particles.

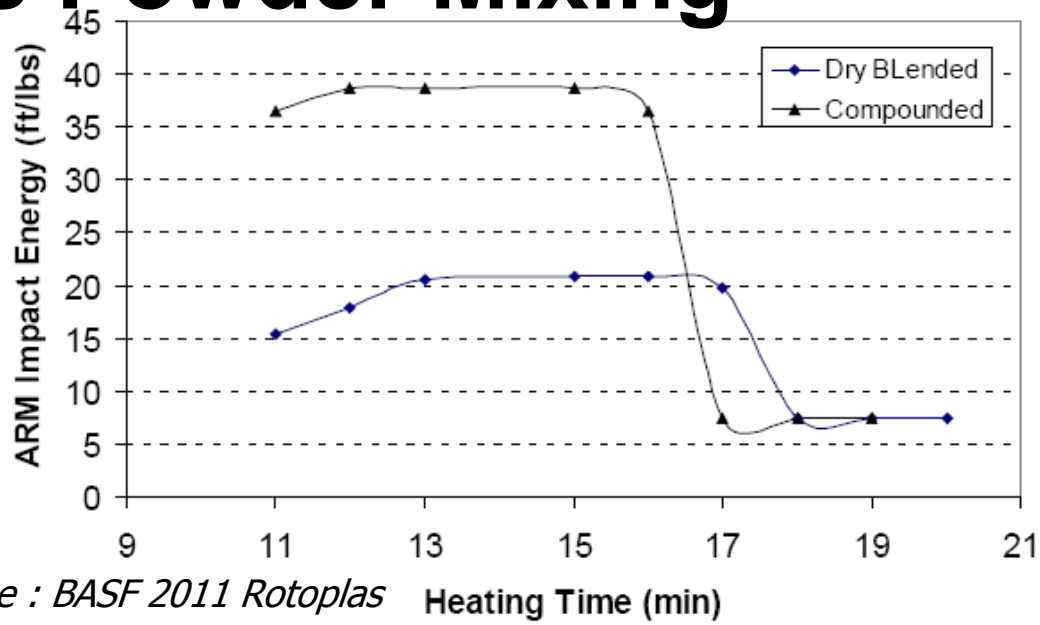
Compounding colours results in better physical properties of a moulded part than any other blending method.

The disadvantages of compounding are that is more expensive to produce because of higher equipment costs.

Compound Vs Powder Mixing

No significant reduction of impact strength of parts made from melt compounds,

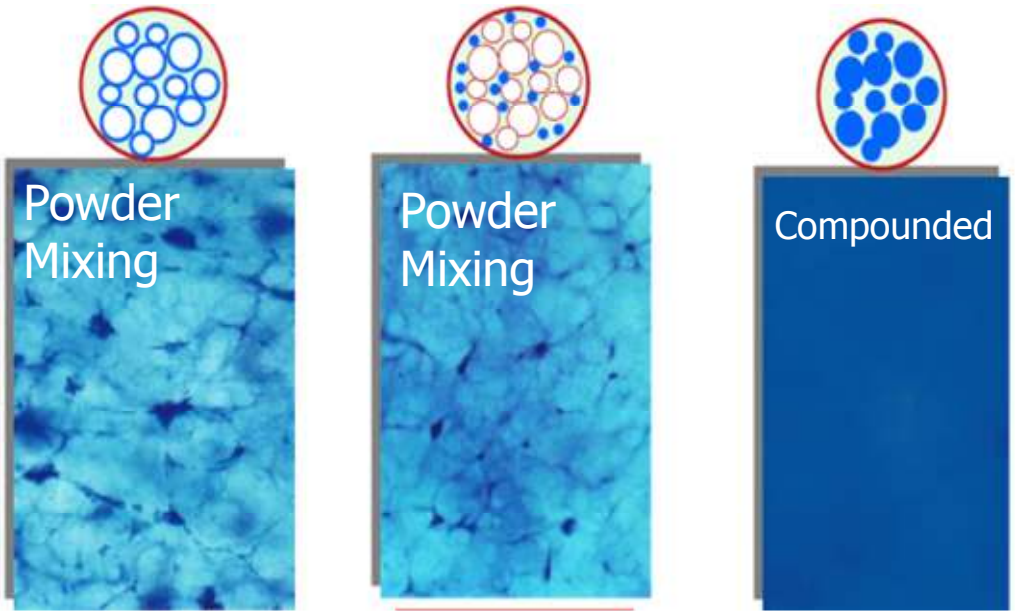
due to the superior distributive and dispersive mixing of the pigment within the polymer matrix



Source : BASF 2011 Rotoplas

Impact strength decreased for powder mixing,

which was a consequence of poor distribution of the pigment agglomerates in the polymer matrix leading to stress concentration points



Source : QUB 2006 ARMSA

Liquid Colour | Dry Blend | Compound

Compound Vs Powder Mixing

SUBJECT	Compound	Dry Blend	Explanation
Colours Range	Wide	Narrow 0.15% Pigments maximum	Compound allows higher pigment level as fully dispersed pigments in compound have little negative effect on physical properties. Dry blend limited to weaker less opaque colours.
Colour Consistency	Excellent Compound locks in colour development.	Variable	Compound supplier achieves consistent colour using sophisticated colour measurement & process control. Dry blend requires investment in precision weighing, blending and colour measurement equipment.
Part Toughness	Excellent	Fair/Poor	Refer to previous slide
Outdoor Life	Excellent	Fair	Compounds improve UV protection to polymer
Colour uniformity	Excellent	Fair/Good Swirls, lines and dark spots	Melt Compounding locks pigment dispersion. In dry blends much smaller and chemically dissimilar pigments powders separate by static electrical charge or gravity during storage and rotomoulding. High intensity blends reduce colour swirls.
Powder Shelf Life	Stable	Variable	
Mould Staining (Plate-out)	No	Sometimes	Red, Orange and Yellow worst In Dry blends very small size pigment particle may stick in porosity in mould surface. Stains require abrasive cleaning resulting in longer colour change and faster tool wear
Pigment Transfer from Part	No	Likely	Dry blend pigment concentrated at or on the surface and are easily transferred to other items such as clothing.
Powder Handling Costs	Lower	Higher	Dry blend: High dollar pigment spillage and dusting. Airborne pigment dust cause cross contamination. Some pigments have health, safety and environmental issues.
Lead Time Minimum Order	Requires planning	Shorter If pigment on hand?	Compound: Forward orders and mixed colour shipments shorten lead time and reduce minimum order quantity.
Material Cost	Higher	Lower	Purchase cost of Compound powder higher than cost of natural powder and pigments.

Plastics Compounding process colouring the plastic

- We use plastic raw material in the form of small beads that have no colour, and are called natural pellets.
- Plastic compounding is an operation that consists of preparing plastic formulations by blending, in a molten state, polymers with additives and pigments.
- The mixed material enters into the extruder feed throat at the rear of the barrel and comes into contact with the screw. The rotating screw forces the plastic beads forward into the barrel, which is progressively heated to the desired melt temperature of the molten plastic (200-240°C).
- After passing through the breaker plate, the molten plastic enters the die to produce various strand like shapes, about 2-3mm in diameter, which are then feed into a pelletizing unit which cuts the plastic to length, 2-3mm.(like original pellet)
- The small pellets are typically cooled in water, then dried, to remove any moisture from the surface of the coloured pellet.

What you should already know

Selection of correct grade of polyethylene raw material is critical.
In this presentation it is assumed that you have undertaken this selection process and the material you are using is ‘fit for purpose’.

We will be concentrating on the colour compounding process itself.


Bulk storage silo for
natural pellets

Pellets sucked out of silo

Pellets distributed to different compounding lines


Natural pellets can be received in 1Mt bulk bags or 25kg bags
HYSTER

Pre-Mixing

The compounding process combines different materials to form a whole. The initial mixing of the raw materials is the first step in the process. There are two common methods of mixing the colour pigment with the natural polyethylene.

1) blend pigment powders with pellets, using low or high intensity tumble mixing, which is then feed into the extruder on a batch process.

2) blend pre-compounded colour masterbatches. The masterbatch is a compound of pigments and polyethylene.

Colour masterbatches are more expensive to use than dry pigments, however, colour masterbatches will provide more consistent and better quality results. This is especially important when a single screw extruder is used, as they are good for high volume output rather than high intensity mixing.

Our industry uses single screw extruders.

Colour masterbatches are typically produced using twin screw extruders.

Compounders can blend masterbatch with natural pellets using volumetric or gravimetric dosing unit. Gravimetric dosing units are much better at mixing pellets of different geometries and different specific gravities.

Pre Mixing

We start with natural un-pigmented granules

Then add concentrated colour

Typically pre-mixed together

Batch versus Continuous mixing

The natural polyethylene can be pre-mixed with pigments (and other additives) in two basic processes.

Batch mixing

Tumble mixing or dry blending typically involves some low intensity mixing of powder with pigments outside of the mould. On a small scale this can involve rotating 200litre drums, and on a larger scale can involve large capacity ribbon blenders. This is a low intensity process which if undertaken correctly can achieve reasonable distribution of the pigment throughout the natural pellets. High Speed blending or Turbo mixing is an improved method of tumble mixing. A paddle or blade is rotated at very high speeds resulting in a temperature increase. The powder becomes tacky and the pigment particles adhere to the pellets.

The primary reason why compounders chose batch mixing is because the equipment costs are lower than continuous mixing and they can colour their natural pellets at the cheapest cost. It is a simple low shear, low cost technique

Continuous mixing

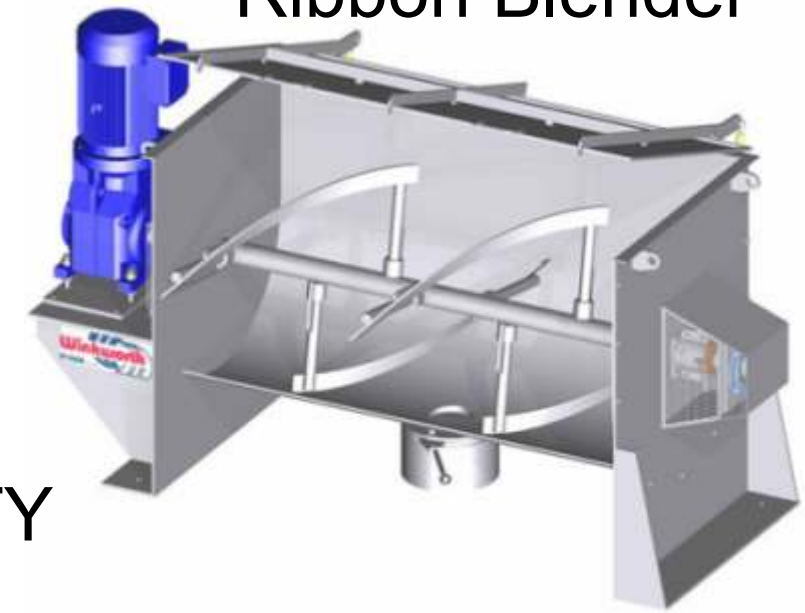
There are two commonly used processes, Volumetric or Gravimetric. Both will achieve better control than batch process

Batch mixing

High Intensity Mixer

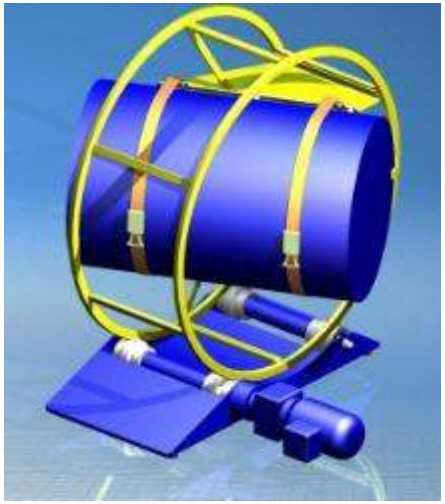
LOW INTENSITY

Ribbon Blender

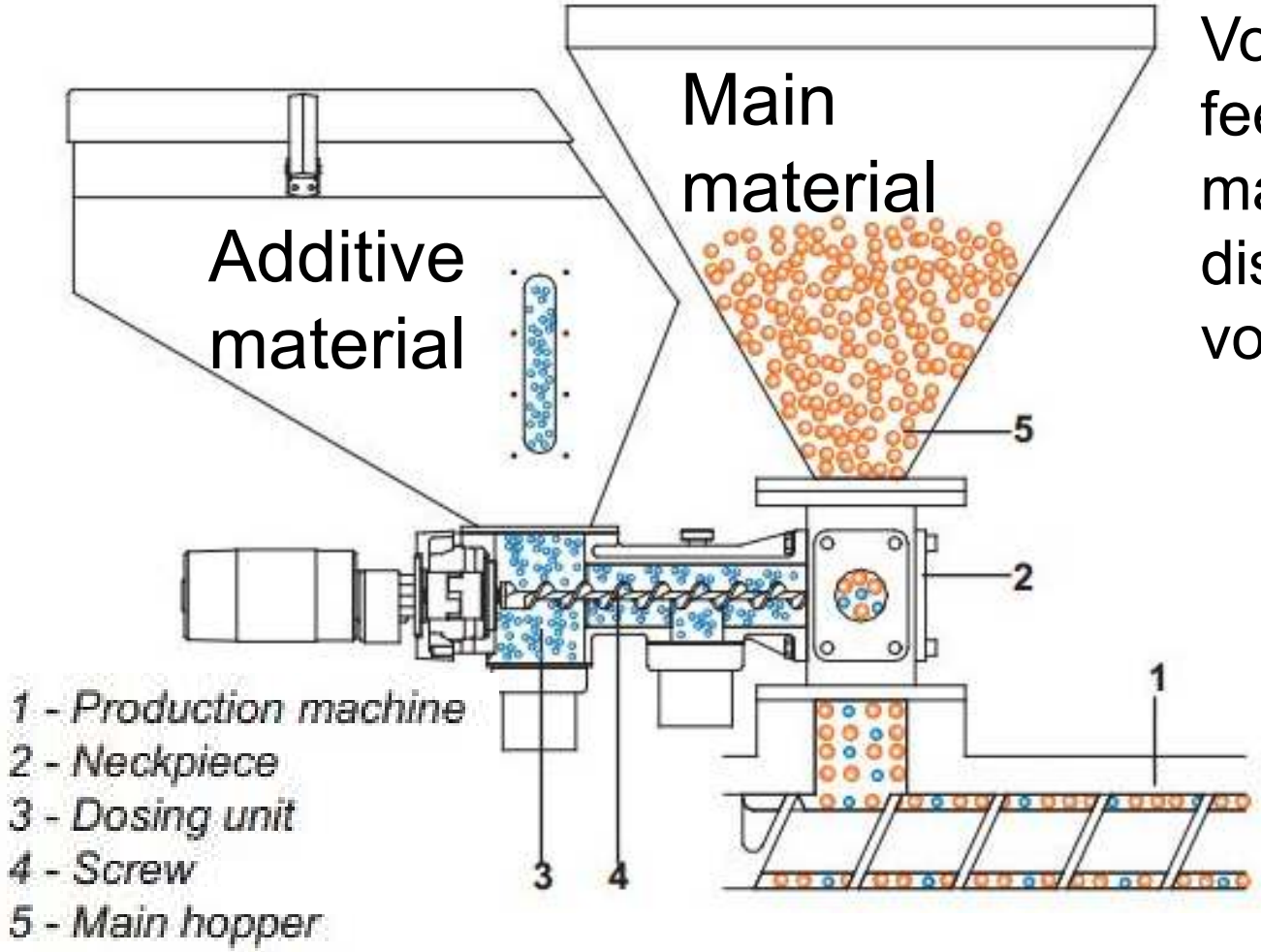


Conical Mixer

Drum Mixer



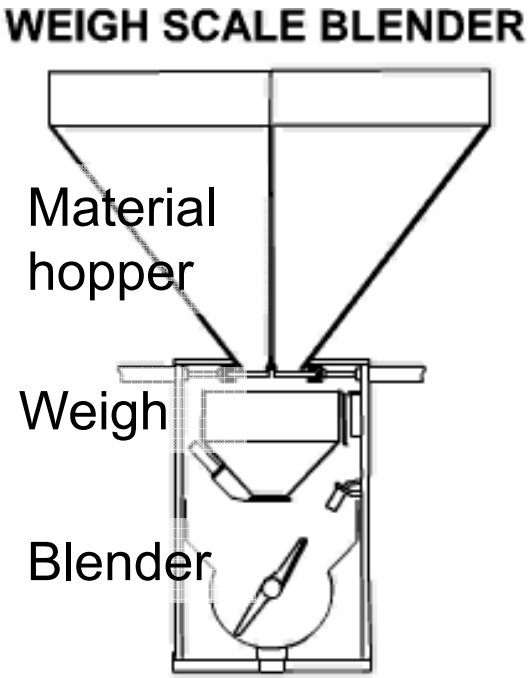
Volumetric Dosing

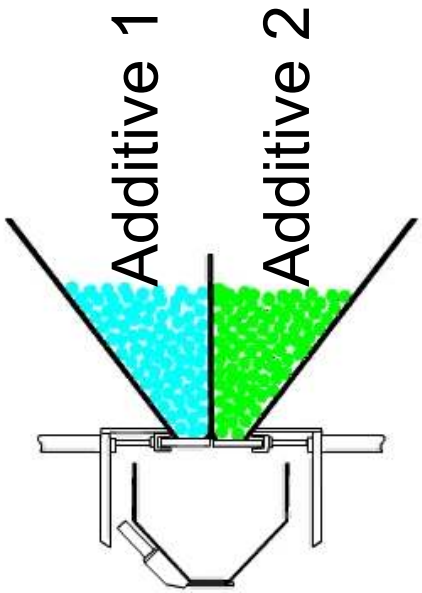


Volumetric screw feeders convey material by displacing a certain volume of material.

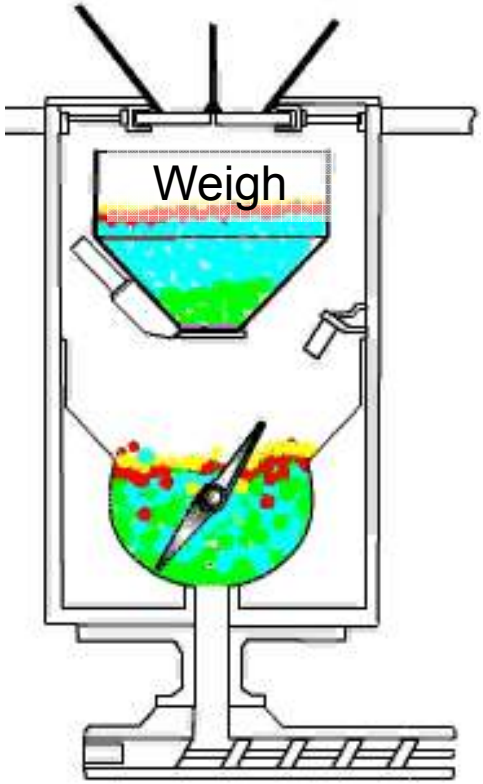
Gravimetric

Weigh scales mix the additives at correct ratios





Blender



Mixture dropped directly into extruder

Volumetric versus Gravimetric Dosing

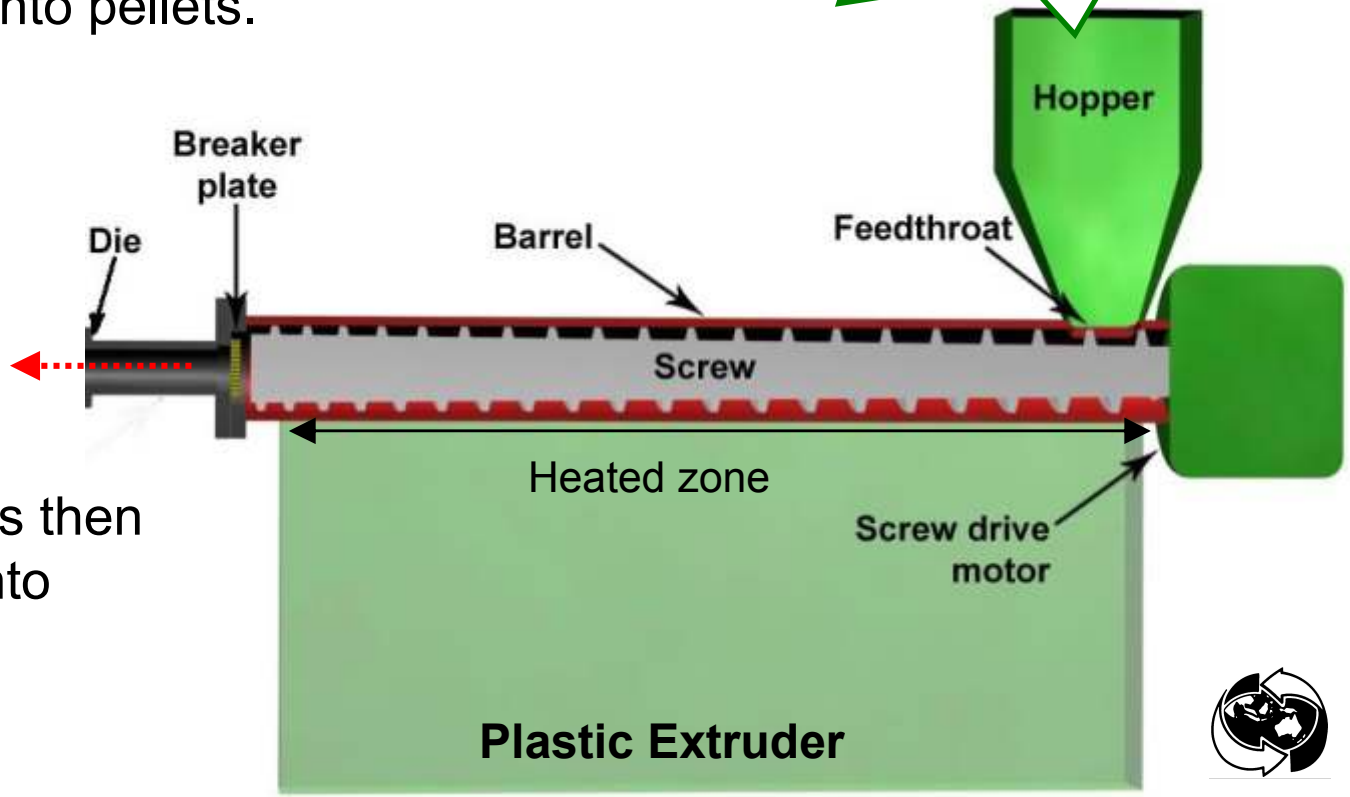
Volumetric screw feeders convey by displacing a certain volume of material. If a known weight has to be added at a fixed rate, changes in bulk density and particle size and shape affects the final outcome. In most cases calibrated volumetric feeders will give **accuracy of 2-5%** by weight due to bulk density variations in the hopper and flow characteristics of the material.

Gravimetric systems will be the best. They also need to be regularly calibrated and checked to confirm the raw materials are being feed to the extruder at the correct ratios. While good quality systems should give **accuracy within 0.2%** and not malfunction, a simple validation should include weighing raw materials, like the colour masterbatch, at the start and end of production run to make sure a sensible amount remains

Gravimetric systems require higher capital investment but they are more robust, give better reproducibility and are less sensitive to variations.
Good dosing accuracy and consistency improves the quality of the coloured powder, saves money by using less colour masterbatch and reduces scrap.

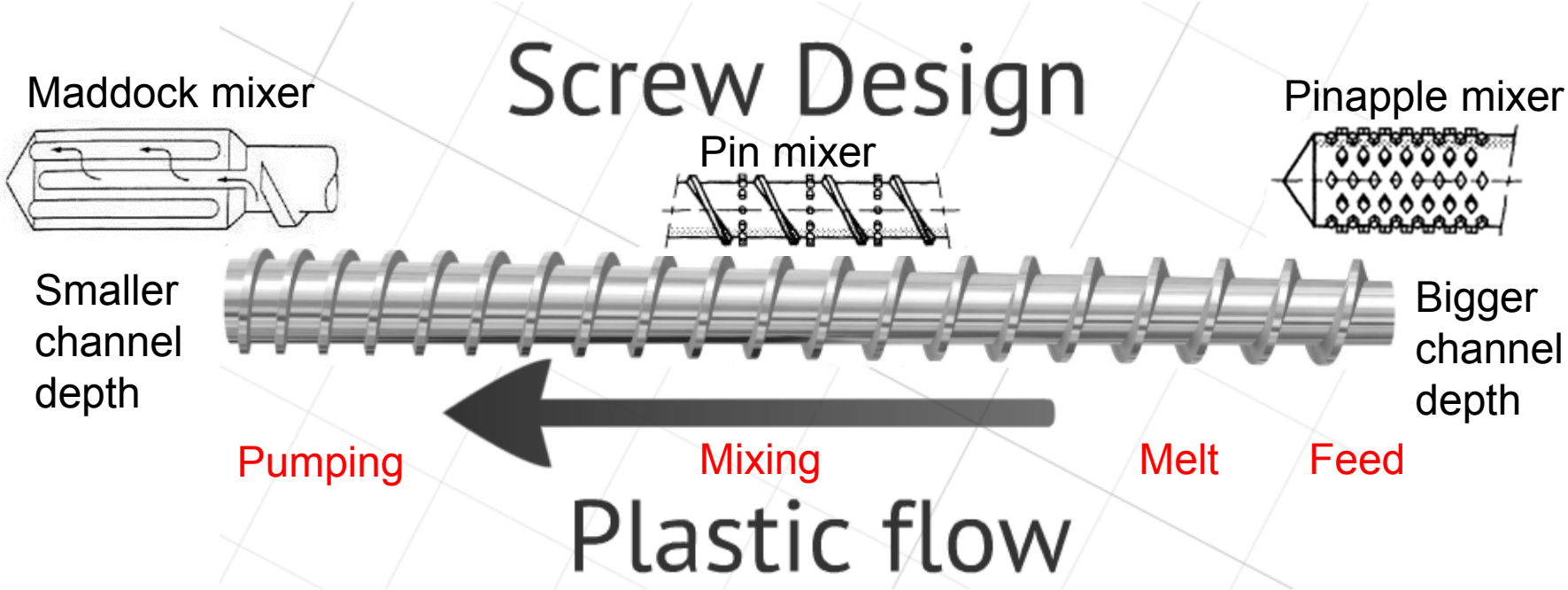
Plastic Compounding process
colouring the plastic

Natural plastic is mixed with a small amount of masterbatch (concentrated colour), then melted and mixed in an extruder to make into a uniformly coloured compound, and converted back into pellets.

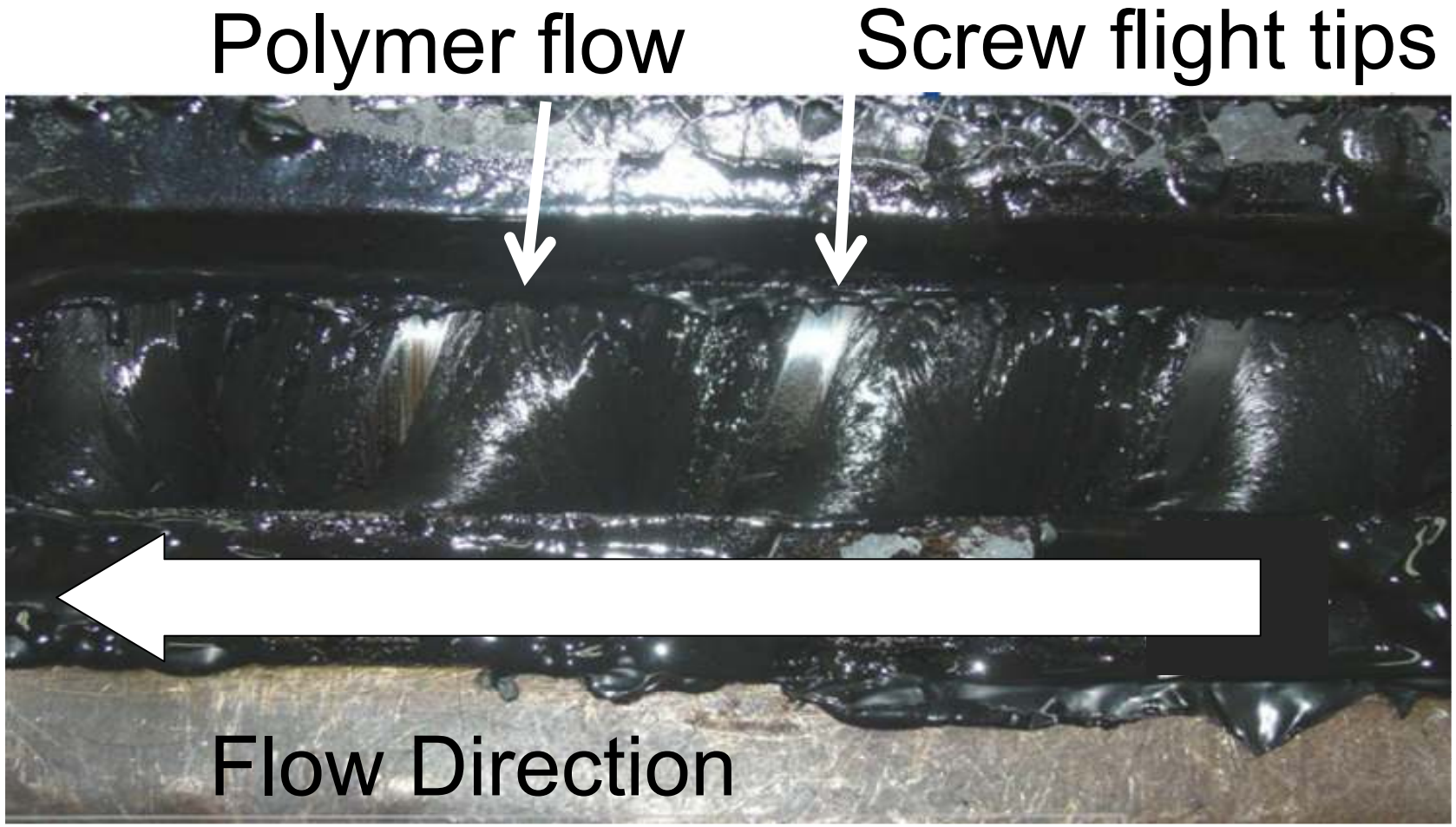


Pelletised material is then ready for grinding into powder.

Compounding extrusion is made up of 3Ms – Melting, Mixing and Metering. With a special emphasis on mixing.
Screw designs have tended to be variations on decades-old designs like the Maddock mixer (a fluted cylinder), and the "pin" or "pineapple" mixer, among others.



While screw designs are always being improved, single screws continue to have limited ability for dispersive mixing, which typically involves breaking up agglomerates of fine particles (like pigments).
This is why using pre-dispersed colour masterbatch results in better quality outcomes than using powdered pigments for single screw.


Polymer flow
Screw flight tips
Flow Direction

Screw/Barrel measurement for wear

Regular measurement required to determine the replacement of screw, and barrel, or both :

- 0.35mm plus the original screw/barrel clearance is indicative of wear, but condition is not critical.
- 0.75mm plus the original screw/barrel clearance is indicative of wear and consideration should be given to replacing the extrusion screw, the barrel, or both.
- 1.0mm plus the original screw/barrel clearance is indicative of severe wear and it is imperative that the extrusion screw be replaced, the extruder barrel be replaced, or both be replaced.

Single Screw versus Twin screw

Twin screw will always give better results than single screw due to better mixing

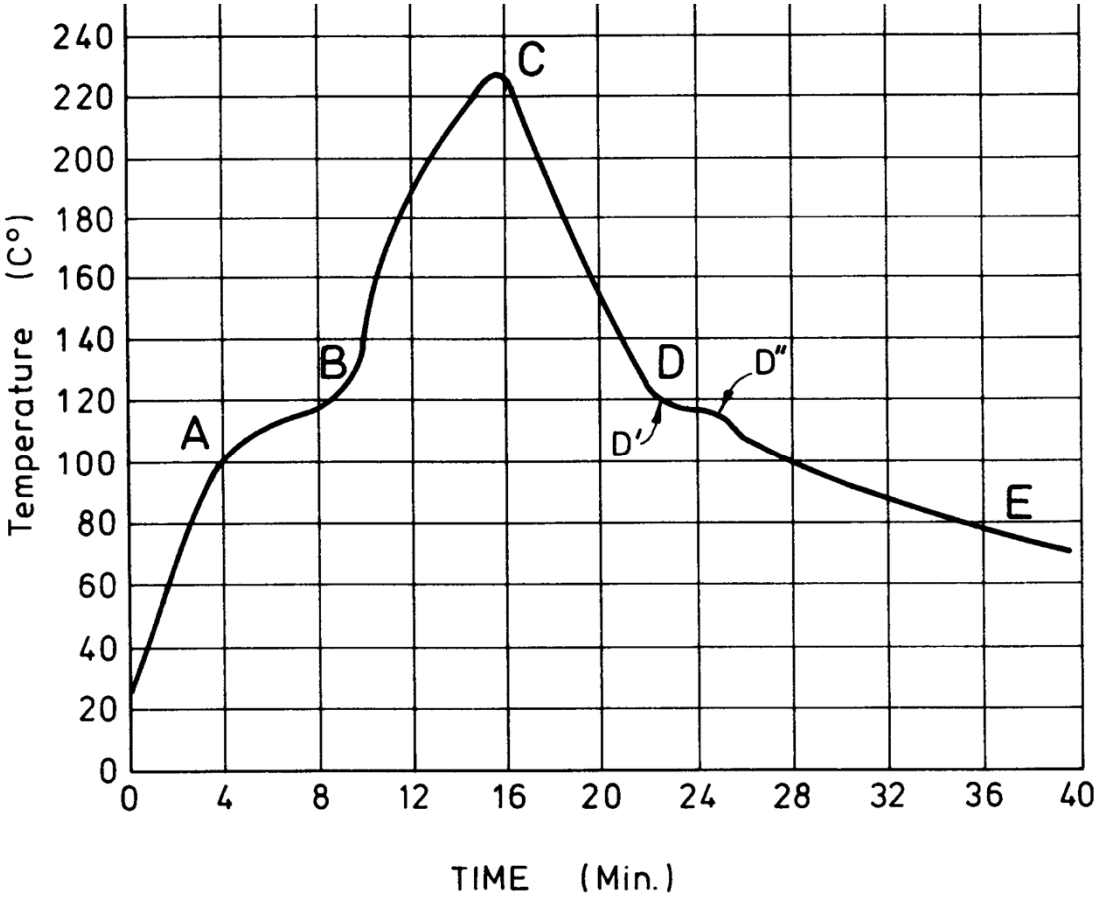
- break-up of the pigments agglomerates,
- better mixing,
- better dispersion,
- better control of shear,
- less temperature degradation due to heat build up from shearing in single-screw.

Twin screw extruder more expensive than single screw

Extruder barrel

Usually for single screw compounders there is a need for at least a 30 to1 Length to Diameter.
This means, if the screw is 90mm in diameter, the length of the screw must be 2700mm

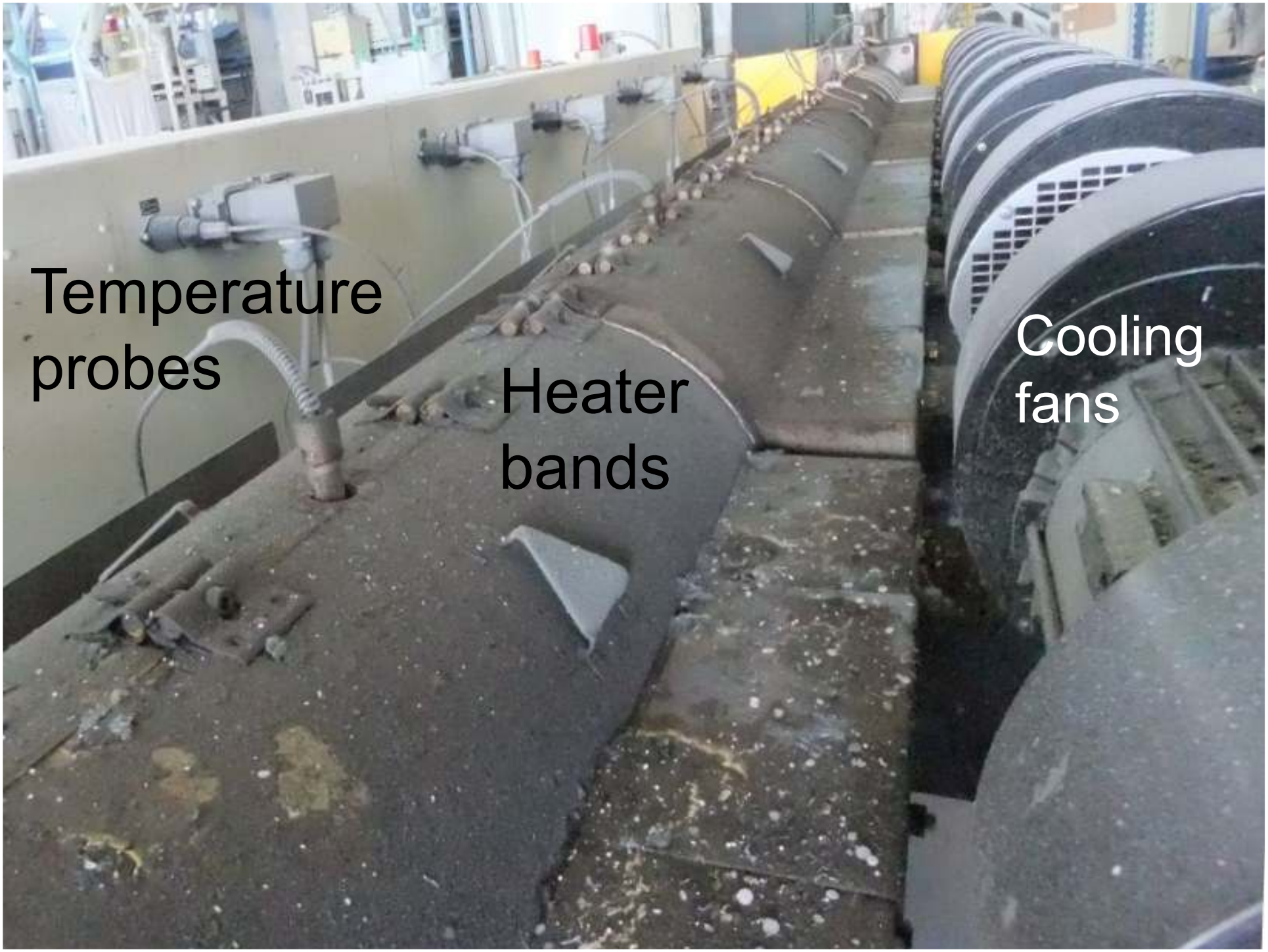
Temperature Control



Rotolog Internal air trace

If you have a problem with your product, your supplier will probably ask about your temperature control.

ASK YOUR SUPPLIER THE SAME QUESTION


Temperature probes
Heater bands
Cooling fans

Machine Control - temperature

Close control of temperature through the different zones of the extruder including melt temperature, amperage or power being consumed, head pressure, and the output rate, should all be monitored.

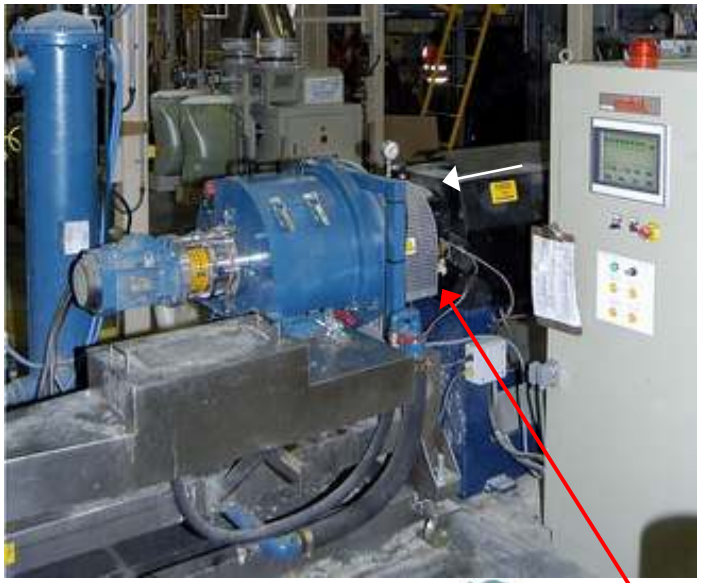
Temperature Controls MUST be accurate and calibrated regularly to operate within +/-5 degrees of set temperature.

The ideal temperatures for the polyethylene being processed should have been established. Any significant deviation from the established values will indicate a potential problem.

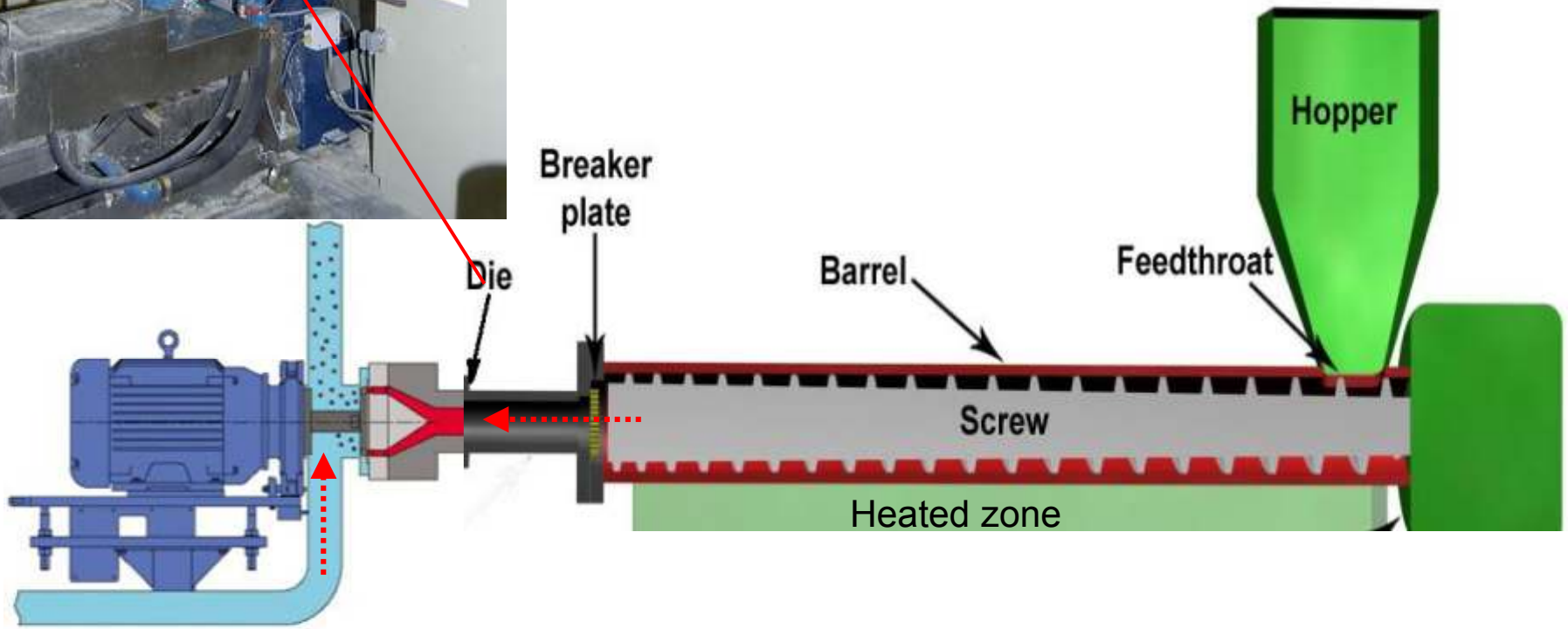
Two of the key quality control checks are for

- **thermal degradation (too much heat) and**
- **distributive mixing of the colour, which results in effective colour dispersion.**

Pelletising process



Coloured material is converted back into pellets for grinding.



Pelletising unit **Compounding Extruder**

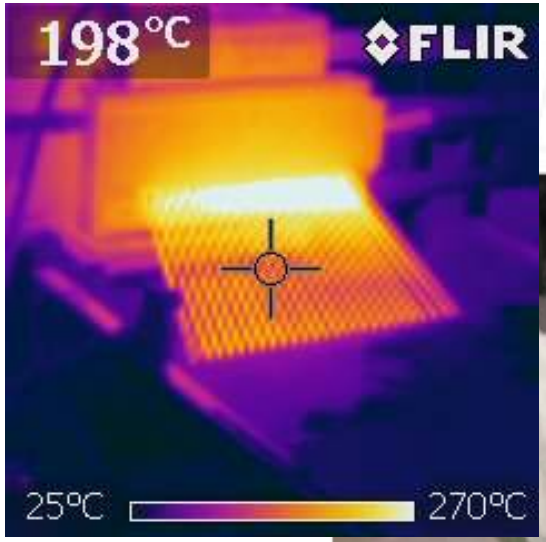
Pelletising process

Strand-cut systems

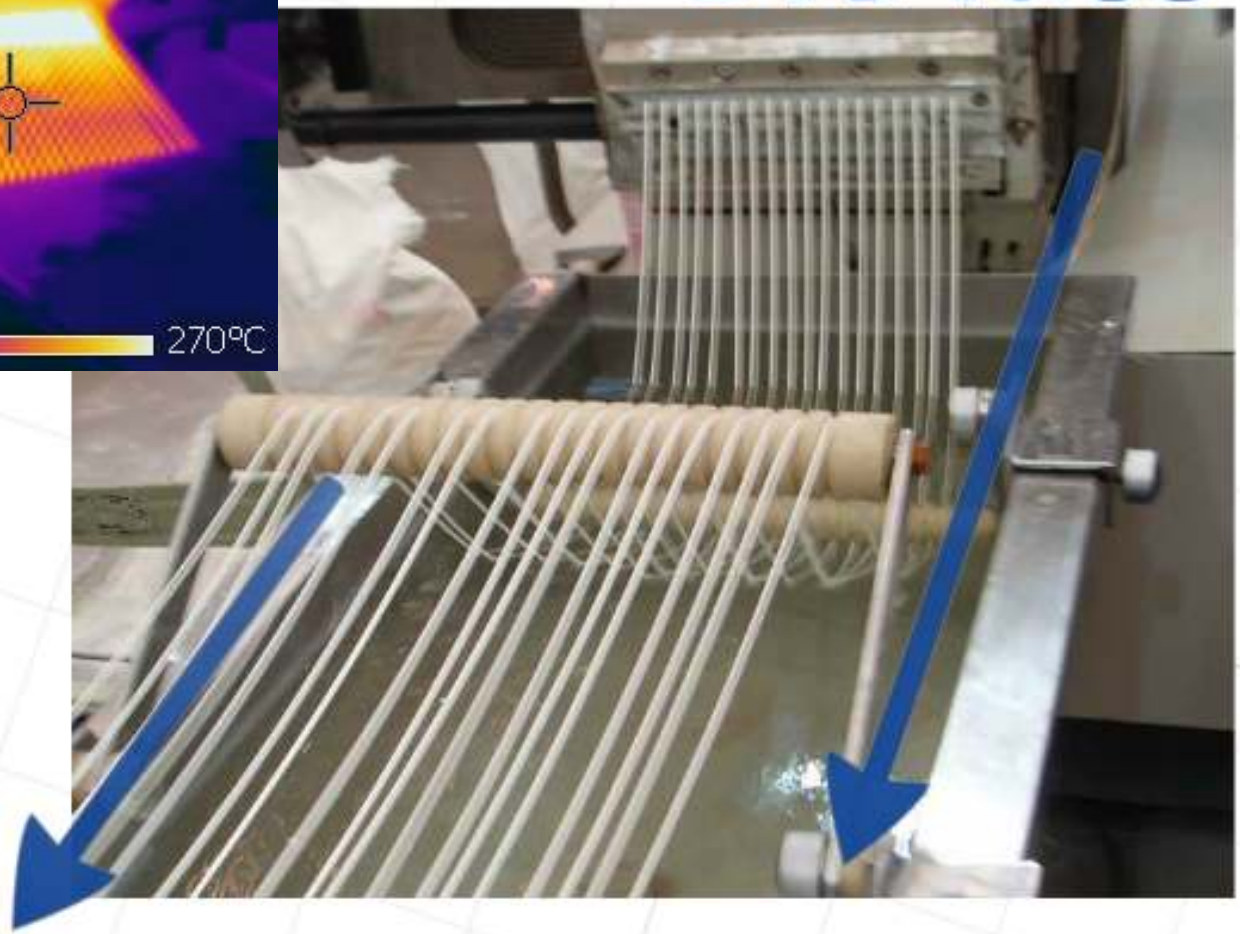
Molten strands are cooled in a water trough and pulled through an air blower into a helical cutter.

Die-face cutters

Underwater or water-ring pelletisers cut the strands on or near the die face with high-speed knives. The pellets are then conveyed into a water slurry discharge, which is pumped into a dryer where the pellets are separated from the water.



Die face



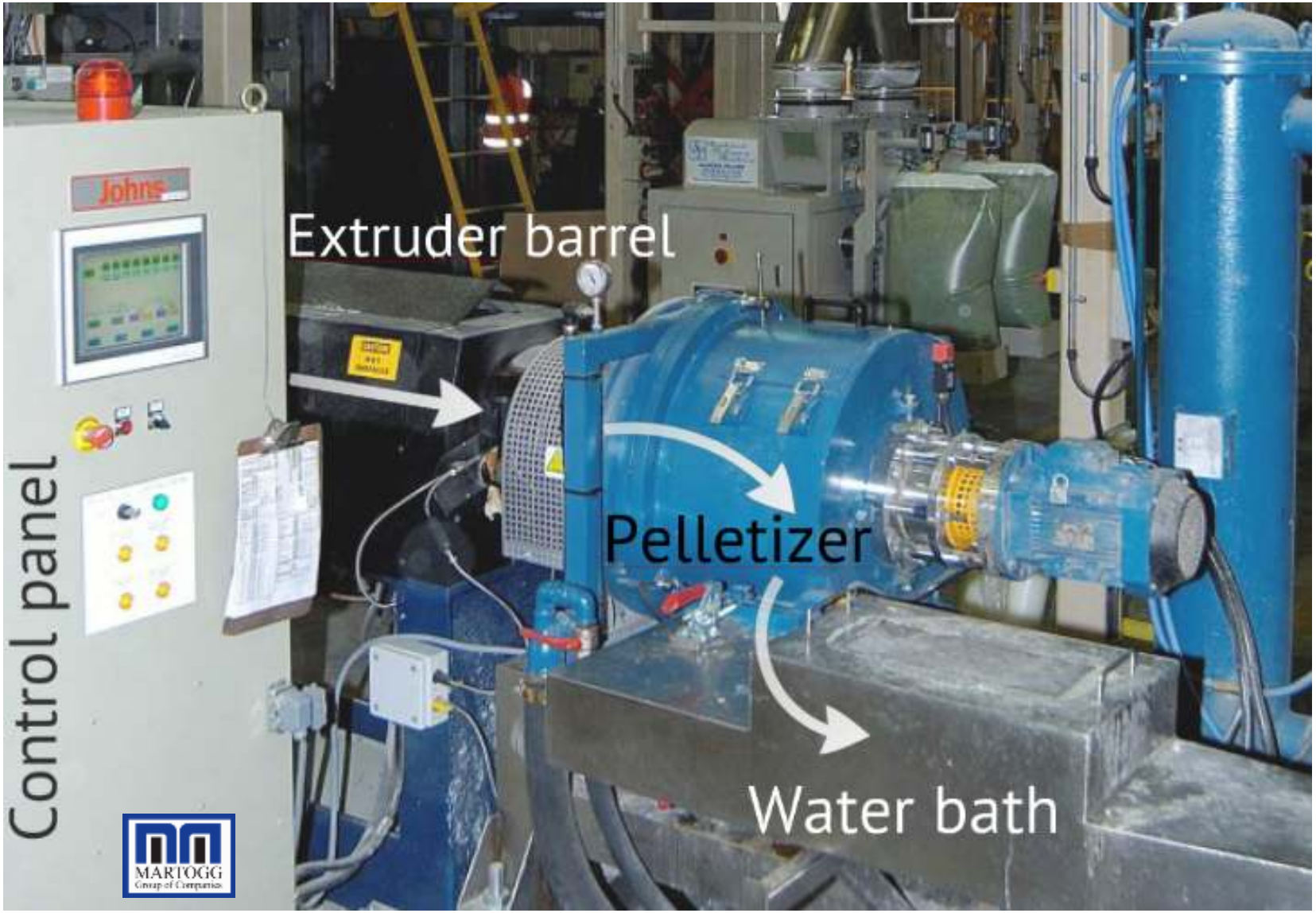
Strand profiles in water bath

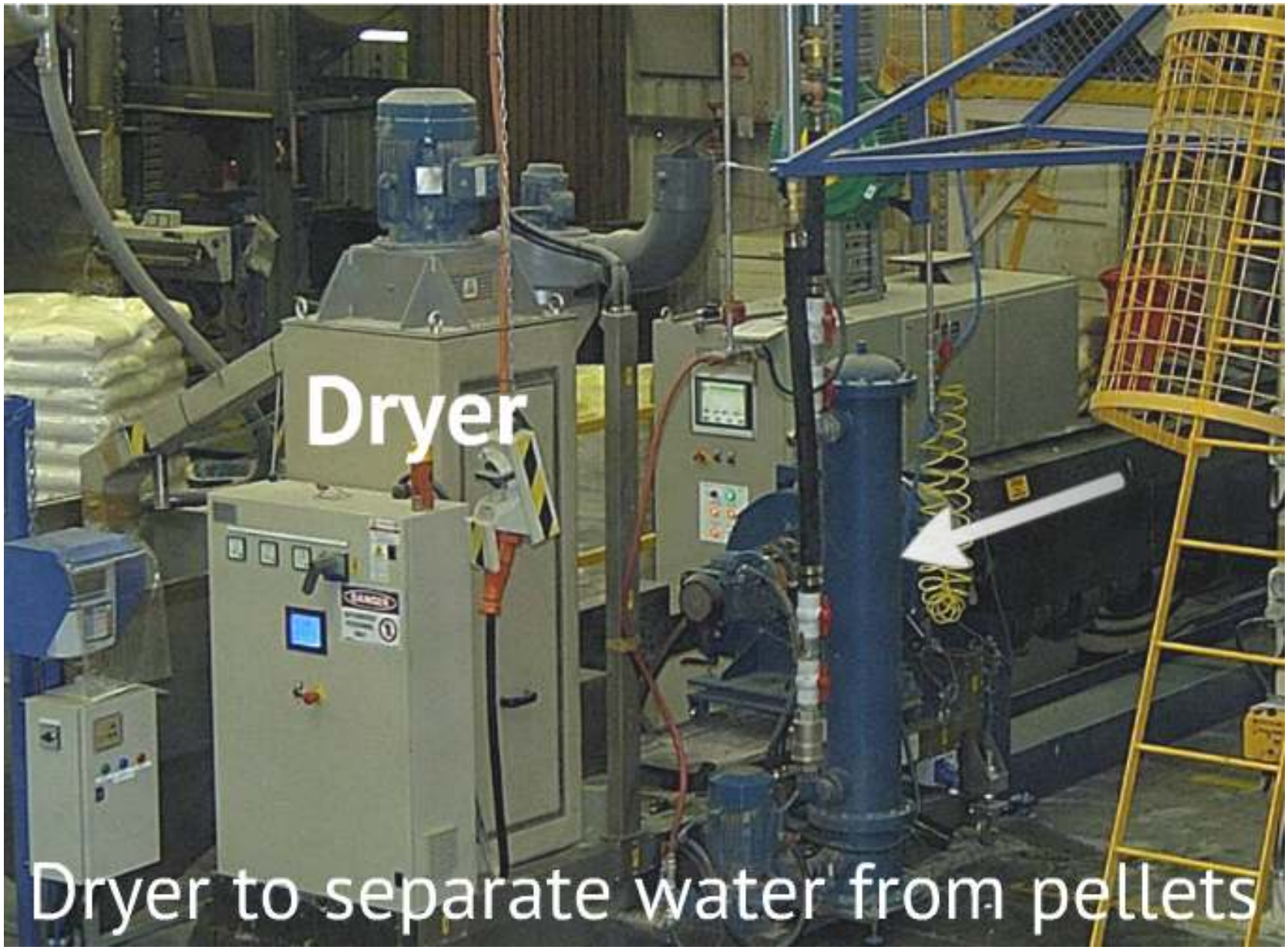
Conventional strand pelletisers are among the oldest types of pelletisers and are generally considered to be the simplest.

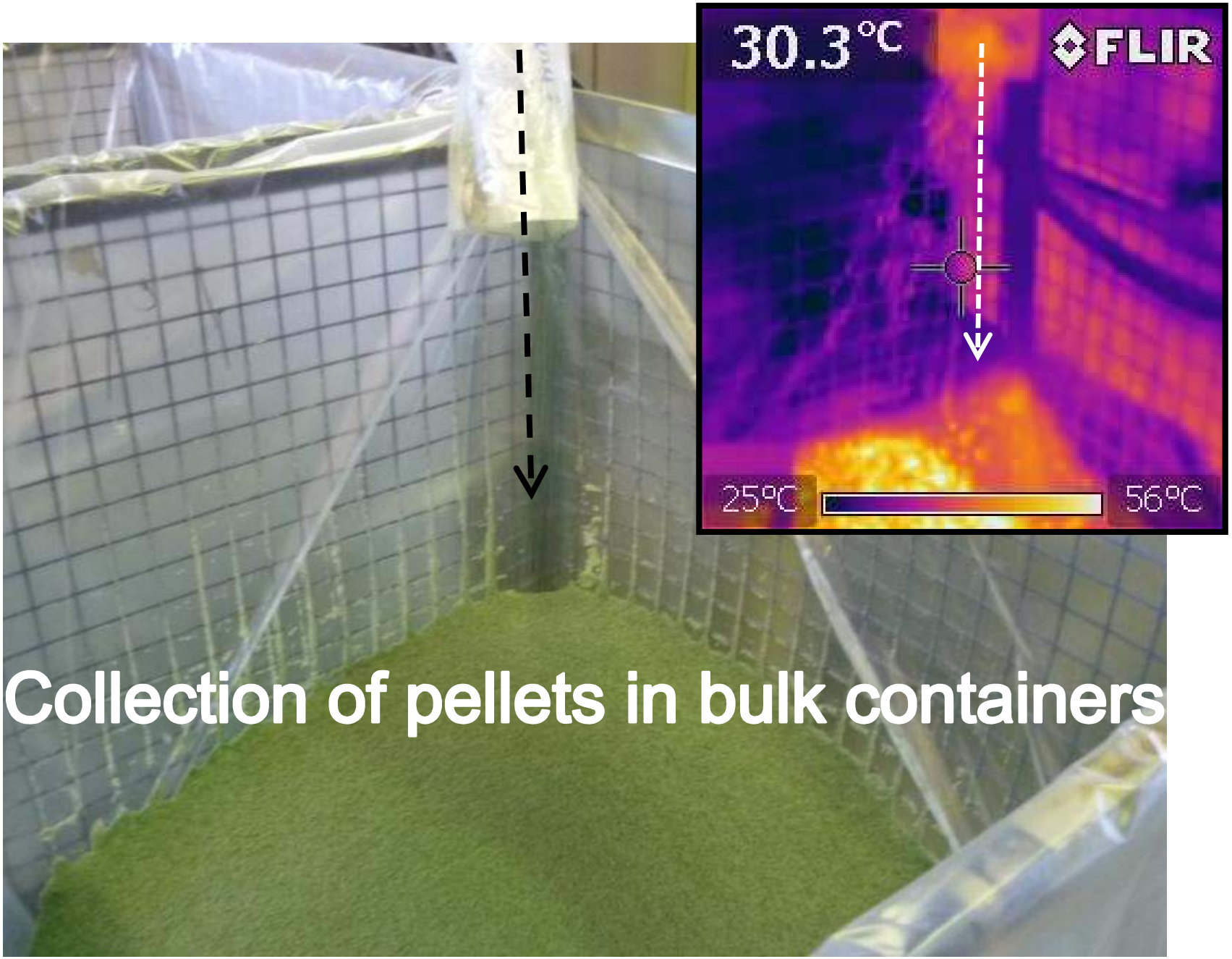
Pellets dropped into water bath

Die face cutters are complex, however, once up and running, performance is generally unattended, unless the line is stopped

Pelletizer / Die Face


Extruder barrel
Control panel
Pelletizer
Water bath
Johns
MARTOGG
Group of Companies


Dryer
Dryer to separate water from pellets



Collection of pellets in bulk containers

Pellet size and shape


CONSISTENCY = CONTROL

Potential deficiencies - Colour

Once the compound is pelletised the colour quality can be reviewed.

While the use of the good quality systems described previously should not result in any malfunction, a simple validation should include making a 2-3mm thick compression press-out from the pelletised material upon start-up of a new production batch to verify the correct colour shade, check dispersion of pigment within the polyethylene and check for contamination.

Colour verification can be undertaken both visually and on a colorimeter – computer colour measurement.
Visual verification requires the use for a light box to provide a standard light source.
If you don't standardize the light source the same sample of plastic can appear different.

Stormedge
Blue Batch 1

Stormedge
Blue Batch 2

Same supplier of colour – different batch

Potential deficiencies - Dispersion

In order to check dispersion a press-out must be made thin enough (approx 1mm) to allow light transmission to highlight uneven distribution of pigment. This typically indicates dosing problems or compounding/machine issues.
Recall that single screw extruders are trying to uniformly distribute the components (colour masterbatch). Single screw extruders are not suited to high intensity mixing, which is why using additives in masterbatch form will assist in achieving the best dispersion.

Moulder

What do you see when compounding is not quite right

Examples from 5 different compounding companies

Workmanship AS/NZS:4766

At the time of manufacture, the finished tank surface shall be free, as practicable, from visual defects such as foreign inclusions, air bubbles, pinholes, crazing and cracking that will impair the serviceability of the tank.
The surfaces shall be **smooth** and have a **homogeneous appearance**.

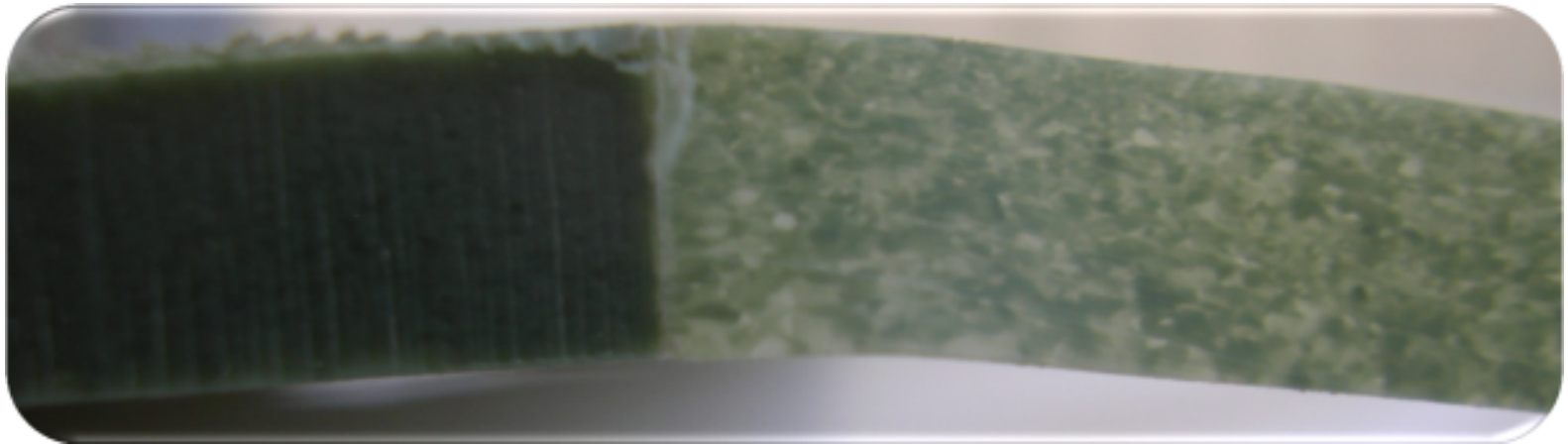
Smooth surface

Do you look?

Crazing surface or Orange peel

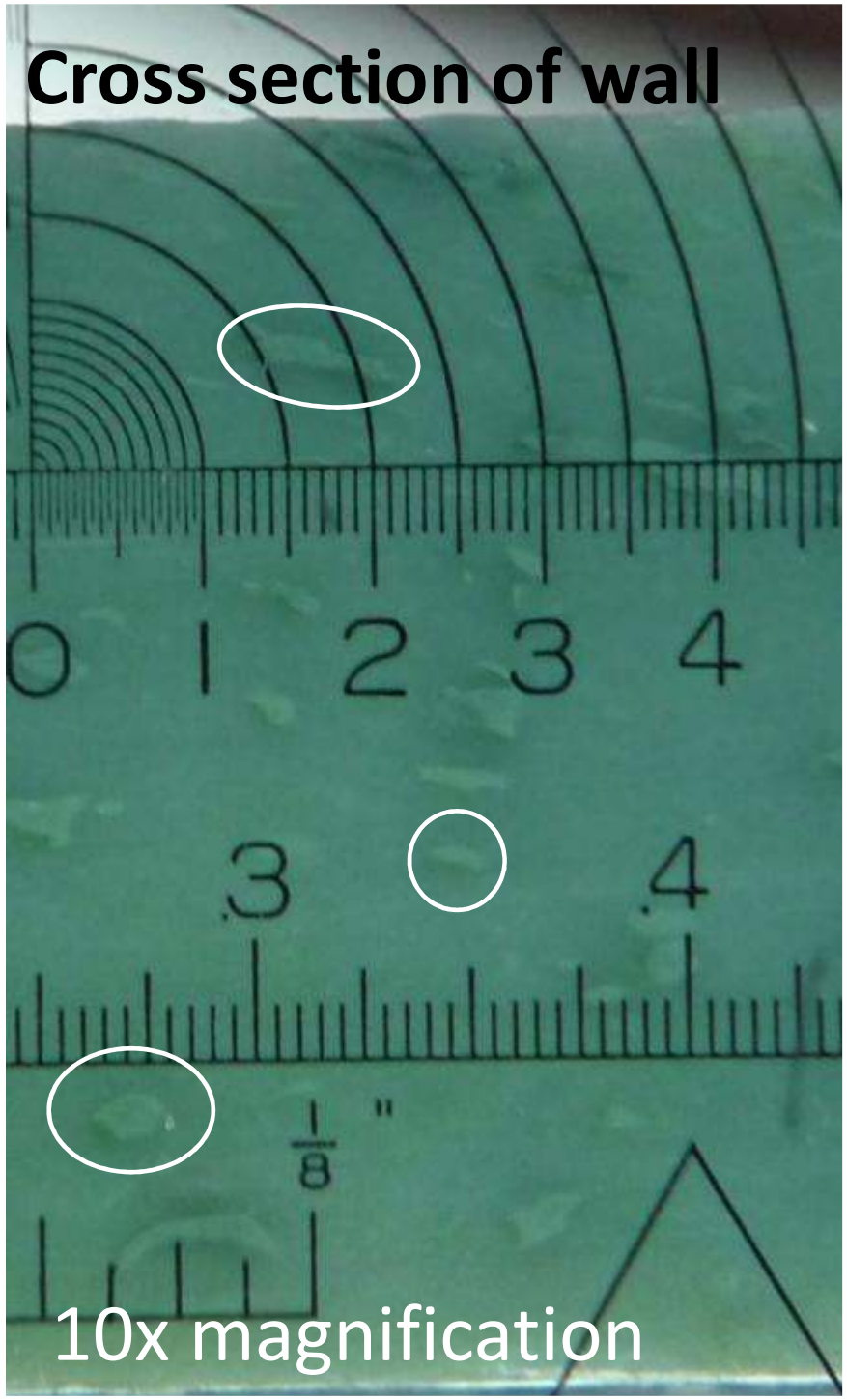
Inspection piece cut out of moulded part

You can undertake visual quality assessment



OPTICAL COMPARATOR

A traditional method to obtain enlarged images is to use a 10X optical comparator, which comes with a range of photo etched glass lenses, which are placed in actual contact with the measured object, thus obtaining simultaneous enlarged and measured objects.



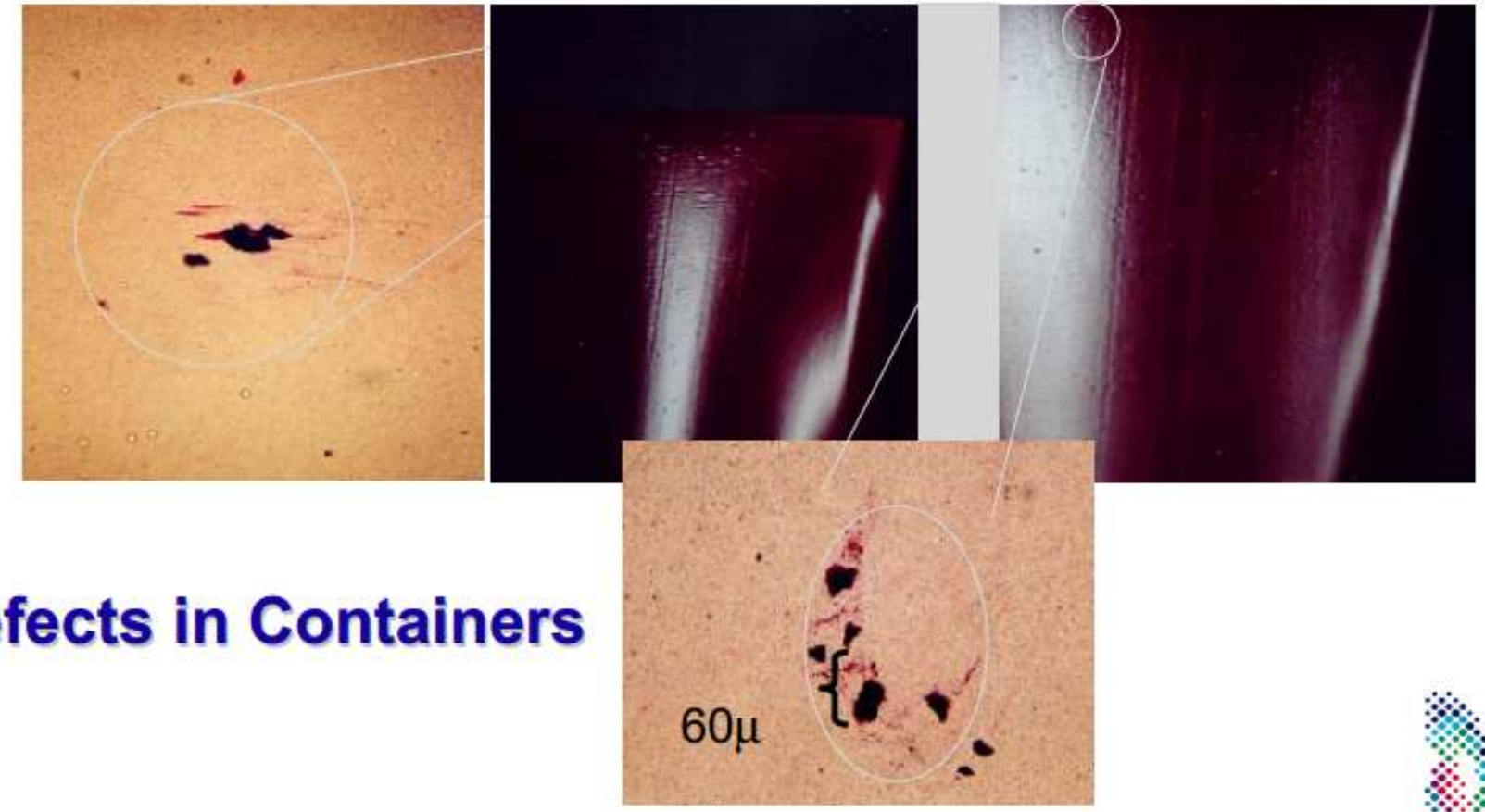
Reasons for concern

Apart from the obvious aesthetic problem caused by poor dispersion, the critical concern is that heterogeneous (non uniform) pigment dispersion will in all cases reduce mechanical properties,

- lower elongation,
- lower impact
- increased notch sensitivity,

compared to parts moulded with optimum (homogeneous) material characteristics

Pigment agglomerate



Defects in Containers

ROTOMOULD 2003

60 microns = 0.06mm

Ciba

Material Extenders

To reduce raw material costs, some compounders may replace some of the polyethylene in a formulation (typically the masterbatch) with cheaper calcium carbonate.

The savings comes at a price, however. The greater the amount of calcium carbonate used, the greater the *negative* impact on the physical properties of the moulded product, such as lower stress crack resistance and drop impact resistance.

Incoming raw materials

Inspection and testing of incoming raw materials is an obvious control.
Often take the form of Inspection Certificates or Certificate of Analysis.
Additives like colour would have visual inspections *prior* to melt compounding.

Certificate and *colour chip*

Incoming raw materials

Additives like UV and AO can be tested, but typically are accepted based on supplier certificates.

If a compounder purchases polyethylene without UV additives they can only incorporate UV in a colour masterbatch.
Most compounders can only check if the UV additive has been added in the final compound by visually inspecting the colour compound.
The assumption is made that if the colour looks is correct, the UV additive addition rate is correct.

Colour pigments - masterbatch

Quality of pre-dispersed colour masterbatch is essential to ensure good quality outcomes are achieved on single screw extruders. Some key quality considerations are:-

1.Heat stability

Ensure pigments are chosen that can handle the thermal history of both the compounding and rotomolding step.

2.Light Stability

Lightfastness is the chemical stability of the pigment under long exposure to light.(Indoors)

3.Weatherability

The weathering of the pigments (outside) is important. This is exposure to light, temperature and moisture.

More expensive that just light stable pigments.

BLUE WOOL SCALE

(top) unexposed;
(bottom) exposed to sunlight for 800+ hours

Colour pigments - masterbatch

Masterbatch percentage is critical - high level master batches may not disperse well if a low level of pigment is required in product.

Dispersion is very important for colour consistency. It may have a negative influence on impact strength.

Amount of pigment can have negative influence

1) Smooth Cream 2.0% pigment content in powder
   Masterbatch 65% pigment
2) Rivergum 0.4% pigment content in powder
   Masterbatch 40% pigment

Process Control

Many compound operators, (like many rotomoulders), want to be like old-time pilots, preferring to fly by the seat of their pants.

And many of them have excellent instincts for knowing when the process is running right, and when it is not.

However, it is much better to have some kind of quantitative way of assessing how the equipment is operating.

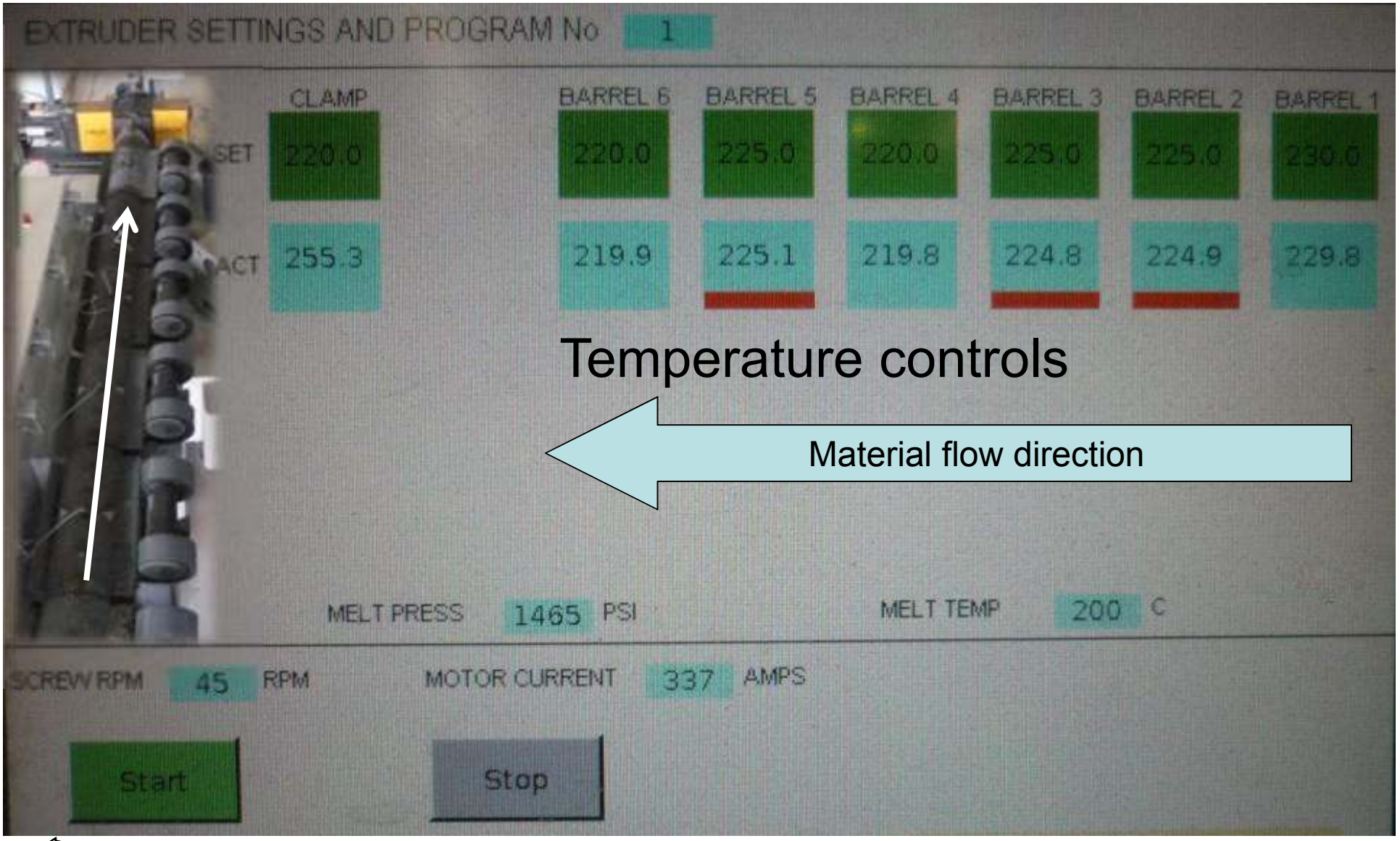
Process Control

A common example is when the operator is convinced something is different about the material.
The extruder (or mould) is just not running the same.

If the material supplier is contacted, they will probably say their QC records show that the material is the same as it's always been.

Without some real numbers, how can you prove to the material supplier, and to yourself, that the material is indeed different?

Extruder Controls



Process Control – collect real numbers

Operator Name			
Time of check			
		Set Point	Tolerance
Screw Speed	RPM	120	+/- 5
Motor Current	AMP	400	+- 40
Barrel Zone 1	^{o}C	225	+- 40
Barrel Zone 2	^{o}C	245	+- 15
Barrel Zone 3	^{o}C	245	+- 10
Barrel Zone 4	^{o}C	240	+- 10
Barrel Zone 5	^{o}C	235	+- 10
Barrel Zone 6	^{o}C	225	+- 10
Die Zone	^{o}C	220	+- 10
Melt Temperature	^{o}C	220	+- 15
Melt Pressure	BAR	120	Max
Output rate	Kg/Hr	750	+- 75

Process problems

Too High Temperature

- degradation of polymer and MFI goes up
- additives can be used up like Anti-oxidants
- discolouration - change colour shade

Too Low Temperature

- inefficient mixing of colour and additives
- strand breaks
- blocking up die head

Wrong screw geometry can create far too much shear, increasing risk of degradation and burning of colour

Wrong Dosing of additives and colour will result in colour shifts - also very expensive

Process control /consistency

Selection of CORRECT Masterbatch supplier is CRITICAL

Incoming natural polyethylene

- Certificates of Conformance (COC)

Incoming Masterbatch

- Master Samples and COCs - know what is in your Masterbatch - heavy metals - cadmium pigments - concentrations

Dosing units are critical and must be calibrated regularly (even auto calibrating systems).

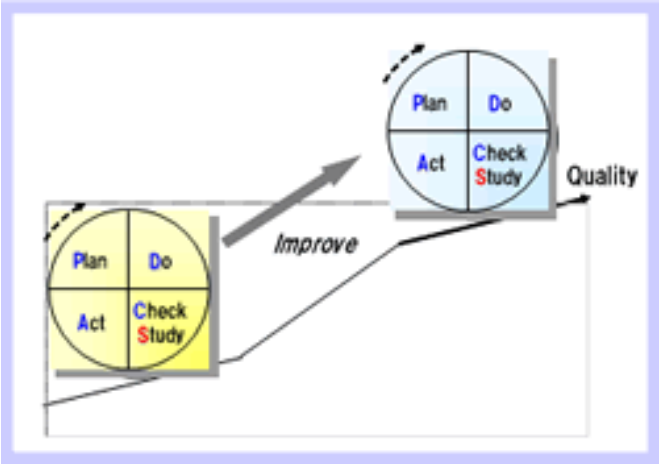
Colour and dispersion checking and monitoring from very 1st kg out of extruder

Proper QA system MUST be in place – just in case something goes wrong.

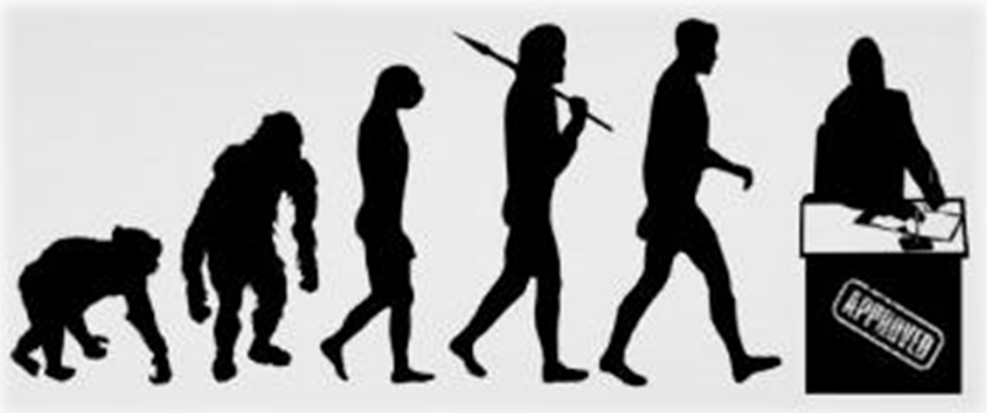
Process control equals consistency

When you have CORRECT processing equipment running within your standard operating parameters - monitoring is vital.

CORRECT materials in correct proportions = correct physical properties



Process control = Quality control



Summary

When different colouring methods are compared :

DRY BLENDING

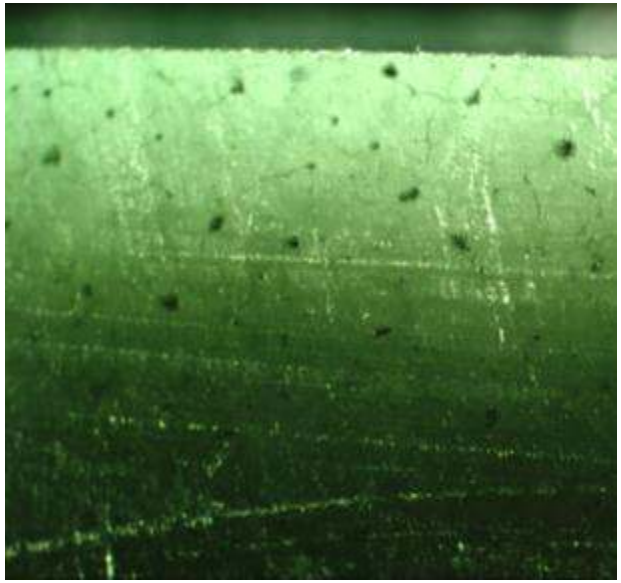
- impact strength decreases for powder mixing, which was a consequence of poor distribution of the pigment agglomerates

MELT COMPOUNDING

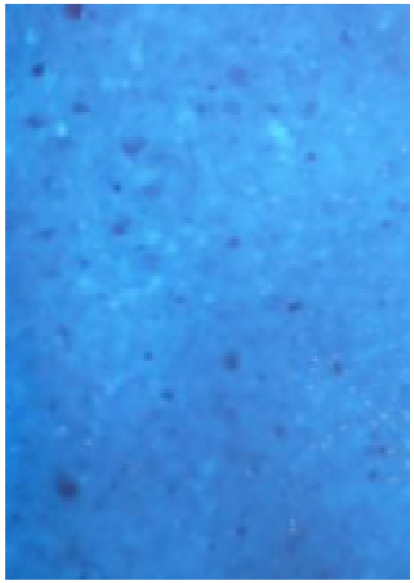
- Impact strength is maintained for compounded powder, due to the superior distributive and dispersive mixing of the pigment within the polymer matrix.

Bad dispersion of pigments equals
reduced impact strength
quicker crack propagation
reduced long term service life

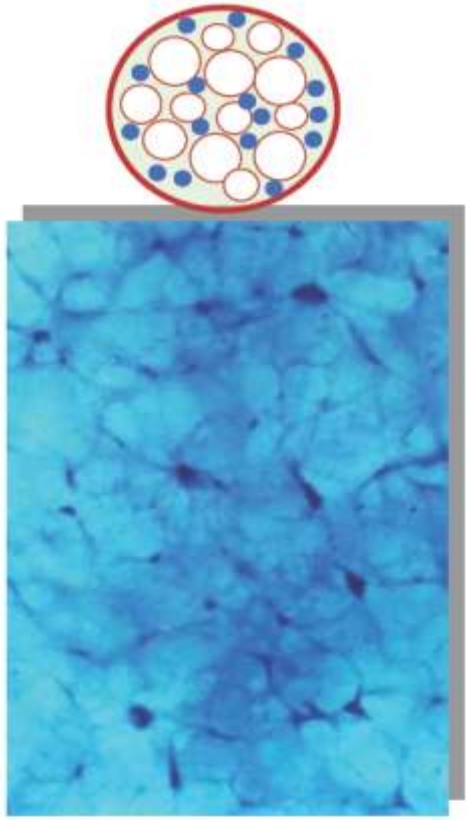
– **regardless of colouring method.**



Dry Blended



Compound



Dry Blended

Summary

When you inspect your rotomoulded parts make sure you check for visual defects such as crazing and 'motley' appearance.

Not just air bubbles and pinholes

Provide feedback to your supplier so they can improve their process.

Work with your supplier, not against them.

Thank you

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