CERTIFIED CCT COMPOSITES
TECHNICIAN
COMPRESSION MOLDING

Re-Certification Workbook

for renewal of CCT-CM credentials

Version 1.0 - 2008

CCT-Compression Molding Re-Certification

In the ongoing process of keeping abreast of developments in the the composites industry, Certified Composites Technicians must re-certify their credentials on a three year cycle. The CCT-CM Re-Certification Workbook is a self-study course designed to facilitate the revalidation of your CCT credentials. The articles presented in the workbook include a review of selected CCT-CM information; an introduction to composites processing technologies not discussed in the original study guide; and information on selected plant safety issues. Successful completion of the workbook test is the basis for renewal of your CCT-CM credentials.

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Defining Composites

What are thermoset composites?

What are composites? As elementary as the question may seem to those in the "composites" business, the exact definition of composites is somewhat elusive.

The term "composite" is used in a number of contexts within the English language. For example, there is the field of *composite photography,* where two or more photographs are joined to form a single image. The Air Force operates *composite wings,* which are units made up of various types of aircraft. And of course, there are *composite materials.*

Defining composites as an engineering material requires a progressive definition, which begins with the general and moves to the specific. The broad general definition of a composite is: *"Two or more dissimilar materials which when combined are stronger than the individual materials"*[2]

This definition draws attention to the synergistic effects of combining materials that have different properties, to create a new material with superior properties to the individual components. This definition can apply to both natural and synthetic (manmade) composites: Wood is an example of a natural composite that falls into the broadest definition of composites. Wood is a combination of cellulose fiber and lignin. The cellulose fiber provides strength and the lignin is the "glue" that bonds and stabilizes the fiber.

Manmade composites can be constructed using natural materials. Adobe bricks are a perfect example of a composite material; the combination of mud and straw forms a material that is stronger than either the mud or the straw.

There are many forms of synthetic composites. Steel and concrete combine to create structures that are strong and rigid. In this case the synergy results from the high stiffness and compression strength of the concrete, and the high tensile strength of steel, creating a structure that is strong and stiff. A very different composite is automobile tires. A steel belted radial tire uses rubber as a strong but flexible matrix to encapsulate steel strands which have high tensile strength.

This broad definition, however, is too general to describe the specialized form of materials from which the composites industry takes its name. A definition is required that adequately segregates these structural materials from other engineering materials. Brent Strong uses this definition in his book, "Fundamentals of Composites Manufacturing" - *The combination of a reinforcement material (such as a particle or fiber) in a matrix or binder material.*[3] Dr. Strong points out, "That the term composite also implies that the materials are macroscopically identifiable, that is, the materials are not merely different at the molecular level but have distinctive component properties and they are generally mechanically separable. This definition excludes many mate rials that form a composite. Considering that a composite is a combination of reinforcement in a matrix, it becomes necessary to define the terms *reinforcement* and *matrix.*

rials, which might have been included in the broader definition such as: metal alloys, plastic copolymers, minerals, glasses, and wood."
To hone a finer edge, the definition must be developed to the next level. One must examine the engineering properties of the component mate-

In engineering terms, one of the functions of a reinforcement in a composite is to take up the load strain transferred through the matrix. The load must then be distributed throughout the matrix and reinforcements.

Particles generally have a low aspect ratio (a comparison of length to width) and are roughly spherical in shape. Generally referred to as *fillers*, particles consist of both organic and inorganic materials. The most common particles found in plastic materials are, calcium carbonate (limestone), calcium sulfate, and alumina trihydrate. Additionally, hollow and solid spheres of glass or other materials may be used as fillers.

Particles in a matrix (such as a resin) produce isotropic properties. That is, the material will have the same tensile, compression and elongation properties in the X, Y and Z-axis. In other words, a particle filled matrix will be homogenous (the same throughout), as are metals. Particles however, are *not* effective as reinforcements. By virtue of having low aspect geometry (rough spherical shapes), they do not effectively transfer loads from particle to particle, and they produce a homogenous structure. *Therefore, particles are not considered, or referred to, as reinforcements in composites materials.*

Fibers are reinforcements having one long axis compared to one short axis – a high aspect ratio. In the matrix, fibers overlap to a degree that strain within the matrix is transferred to a series of fibers. Where fibers overlap, the load is distributed to adjacent reinforcements, with the matrix holding the fibers in place and transferring the strain from fiber to fiber. By nature of having a high aspect ratio (long and narrow), fibers may be oriented in a specific direction and have the capability to produce a material with anisotropic properties; a material that is stronger in one direction than the other. Fibers can be used to produce a non-homogeneous structure, which has different properties in different directions. This is a distinct advantage in an engineering material.

Defining Thermoset Composites

Broad General Definition:
"Two or more dissimilar materials which when combined are stronger than the individual materials."

This definition includes a wide range of materials combinations, such as; wood, adobe bricks, steel and concrete, rubber and steel (tires), concrete, and of course the combination of polymer resins and fibers.

Intermediate Definition:
"The combination of a reinforcement material in a matrix or binder material."

This more focused definition narrows the range of materials to a reinforcement and a matrix. In this case reinforcements could include fibers or particles, and the matrix may be a polymer resin, ceramic, or metal. Examples include: metal and ceramic matrix materials, reinforced thermoplastics, and reinforced thermoset polymer resins.

Precise Definition:
"Composites are a combination of a reinforcement fiber in a thermoset polymer resin matrix, where the reinforcement has an aspect ratio that enables the transfer of loads between fibers, and the fibers are chemically bonded to the resin matrix."

The precise definition of thermoset composites as an engineering material is based on the physical property characteristics of these materials. The synergy created by load transfer between fibers, and the chemical bonding of the reinforcement to the matrix, are the defining terms of this description.

The function of the matrix in a composite is to provide a relatively rigid media that is capable of transferring loads to the fiber components of the material. The matrix encapsulates the reinforcement creating the physical properties synergy between the two materials. In forming "composites" a critical aspect in the amalgamation of the matrix and the reinforcement is that a chemical bond is formed between matrix and the reinforcement.

To explore this concept further, consider the combination of a thermoplastic resin (such as polypropylene) and glass fiber; in this case the reinforcement fiber is merely encapsulated by the resin matrix but not molecularly bonded to the resin. Whereas, the combination of glass fiber and thermoset polyester resin produces a chemical bond at the interface of the fiber and the resin. Therefore, we arrive at one of the distinctive characteristics of a composite engineering material – the reinforcement is not merely encapsulated by the matrix, but is molecularly bonded to the matrix. The bonding of reinforcement and matrix produces the superior physical properties, chemical resistance and fatigue endurance, which characterize composite materials.

Now, having the technical aspects of composites characterization in hand, the definition of these materials can move to the final step of refinement.

> "Composites are a combination of a reinforcement fiber in a polymer resin matrix, where the reinforcement has an aspect ratio that enables the transfer of loads between fibers, and the fibers are chemically bonded to the resin matrix." [4]

This precise definition accounts for the attributes of thermoset composites as an engineering material, and differentiates them from a host of *combined* materials having lesser degrees of synergy between the individual components.

References:
[1] "College Dictionary", Houghton Mifflin Company, 1986
[2] "Certified Composites Technician Study Guide", Lacovara, CFA, 1999
[3] "Fundamentals of Composites Manufacturing", Strong, SME, 1989
[4] "Defining Composites", Lacovara, CFA 2000

Other References:
"Certified Composites Technician Instructors Guide", Lacovara, CFA, 2000
"Industrial Plastics", Richardson and Lokensgard, Delmar
Publishers, 1996
"Introduction to Composites", SPI, 1992
"Composite Basics", Marshall, Marshall Publishing, 1994
"Reinforced Plastics Handbook", Murphy, Elsevier Science
Publishers, 1994
"Composite Materials", Schwartz, Prentice Hall Inc., 1997

Understanding Materials

In the compression molding process, there are three main areas: material, mold and equipment. Each has a very important function in producing a high quality, consistent part.

It is important for the compression molding technician to understand what these materials are, and why they are important to the compression molding process. A basic knowledge of how these materials are checked and why; what the functions of the materials bring to the final part; and finally, an understanding of how and why they are combined is also of importance.

If materials, from the raw stage to the molding stage, are not understood and controlled, there is little chance of producing consistent, high quality parts at a profit.

Raw Materials

The definition of raw material will vary depending upon the size, scope and complexity of the compression molding plant. Some molders purchase basic raw materials (resins, fillers, initiators, monomers, pigments, release agents, additives, thickeners and reinforcements). These facilities do all their own formulation and compounding.

There are plants that only purchase and use compounds (Bulk Molding Compound, Sheet Molding Compound) that have been produced by specialized compounders. To them, SMC and BMC are raw materials.

Defining Raw Materials

Resin - an unsaturated polyester or vinyl ester (thermoset)
Filler – inert material, typically calcium carbonate, alumina silicate, or hydrated alumina, used to increase volume of the matrix and enhance certain physical properties
Initiator – a reactive peroxide that causes the unsaturated polyester to polymerize (cure).
Monomer – a major additive to a resin that both reduces initial viscosity and provides the cross-linking sites necessary for polymerization (referred to as a reactive diluent. Styrene is the most commonly used.
Pigments – colorants added to matrix for cosmetic purposes
Release agents – an additive that forms a barrier between the molded part and the mold surface allowing the part to separate after being cured
Thickeners – an additive that increases the viscosity of a molding compound, that tranforms it from a low viscosity to a high viscosity paste
Reinforcements – a fiber that imparts additional strength to the matrix;glass fiber is the most common type used
SMC (Sheet Molding Compound)– Both a process and a material. Refers to the SMC compression molding process and a sheet molding compound as a molding material
BMC (Bulk Molding Compound) – A form of molding compound that is in a mass rather than sheet
GMT (Glass Mat Thermoplastic) – a molding material that has a thermoplastic polymer

The above two classifications deal with unsaturated polyesters, and are classified as thermoset compounds.

There are also compression molders that purchase glass mat thermoplastic sheet materials (GMT) from suppliers, that they then compression mold. This GMT is also considered a raw material.

The decision as to which path to follow is determined by many factors. The size of the company; the available resources, the volumes of materials required, the technical expertise within the company; and economies of scale all play a role in determining which path to follow.

It is not uncommon to see a plant that may purchase and utilize all three types of materials. Each type of material purchase and use requires different methods of testing and control.

Compounding

Compression molding differs from other processes in that in compression molding the resin is combined (compounded) with the various other ingredients or additives long before the actual molding operation. This compounding is very critical to the compression molding process.

Whether your shop starts with the basic raw materials defined above, or purchases compounds, the starting point is the same – the formulation.

These formulations are developed by experienced technical people with a background in polymers and compounding, and they are developed after a careful review of the desired properties of the finished product. These properties are dependent upon the types and ratios of the basic raw materials. For example, if the molded part is going to be exposed to strong chemicals, the formulator will probably use either an isophthalic or vinyl ester resin. The filler may be an aluminum silicate rather than calcium carbonate, a general filler used throughout the industry.

In compression molding the flow, or movement of the material (compound) within the mold, is critical. This flow is dependent upon the viscosity of the material during the various stages of the molding cycle. There are definite relationships between the compound viscosity and (1) time, (2) temperature, and (3) pressure within the molding cycle.

The use of initiators in developing flow and cure within the matrix is very important in establishing this relationship. Depending upon part size and thickness, initiator systems may require the use of two or more initiators, each with a specific function in the overall cure of the part.

Once these formulations are developed they enter the process as a liquid matrix. This matrix will either go directly to the molding press, there to be combined with some type of fiber reinforcement, or to either the BMC or SMC compounding area. These operations will be discussed in more detail later.

Raw Material Control

The control of raw materials is very important to the compression molder. The control of materials begins with purchasing. Sufficient materials must be ordered to arrive as needed. Too much inventory affects the material cost just as much as running out of material.

Inventory should be run on a first in, first out basis. Some materials have short shelf lives (the amount of time that the material remains in warranty). It is very important to see that the oldest material is being used first. There is a tendency in some shops to use the fresher, newer material first, but this is never recommended.

Incoming material checks or tests are very important to controlling the process. These checks may be very simplistic visual inspections, or they may be more complex laboratory tests. The type of inspection used is directly related to the type of raw materials (basic or compounds) being received. Typically, receiving tests for compounds are more simplistic. In addition, certificates of analysis as provided by the supplier of compounds may be requested. A certificate of analysis is a report of certain tests that the supplier performed prior to shipping the compound. It lists the material, date produced, batch number, test results and the general specifications.

If a company is purchasing and receiving basic raw materials it probably has a test laboratory where it will check certain characteristics of the specific material. Some typical tests that may be used :

- Unsaturated polyester resins:
  - Cure
  - Viscosity
  - Specific gravity
  - Acid Number
  - Monomer Content
  - Thickening rate
- Fillers:
  - Particle size distribution
  - Percent moisture
- Thickeners
  - Viscosity
  - Specific Gravity
  - Thickening rate
- Pigments
  - Color draw down

These tests can be used to accept or reject material shipments. It is important that these tests or checks are made, that the results are recorded, and a history maintained. These reports should be one of the first things that a technician checks when investigating a process problem.

References:
"Plastics:Materials and Processing", A.Brent Strong, Pearson, 2006
"Thermosets and Composites", Biron, Elsevier, 2004
"Reinforced Plastics Handbook"Murrphy,Elsevier, 1998

Molding Compounds

SMC (Sheet Molding Compound)

SMC is a thermosetting polyester or vinyl-ester resin based compound which has the fillers, pigments, initiators, inhibitors, low profile additives, mold releases, thickener, and glass reinforcement combined together in a sheet form. The sheet may be anywhere between 0.0625 to 0.250 inches thick and is covered on both sides with a multi-layer film containing nylon to prevent the loss of styrene. It has been thickened chemically to a viscosity of 15 –30 million centipoises. This is about the stiffness of wet cardboard.

A typical formulation with quantity ranges is shown below:

Material	Parts Per Hundred (pph)
Resin	60-70
Low Profile Additive	20-40
Styrene Monomer	0-10
Initiators	0.8-2.0
Inhibitors	0.001-0.01
Pigments	0-5
Mold Releases	1-3
Fillers	100-200
Thickeners	2.8-4.9
1”-2” long glass fibers	75-125

The above formulation would give glass contents ranging from 20-30% by weight.

SMC thickening is achieved by the reaction of various earth oxides or earth hydroxides (usually magnesium oxide or hydroxide). There is an electronic attraction due to the ending acid groups in the resin, which gives a great increase in the viscosity of the material. This reaction is greatly affected by moisture levels in the resin paste. The viscosity of the SMC continues to increase over time so there is definite shelf life of the material. When subjected to the heat of the mold, the viscosity breaks down to a lower level.

SMC is produced on a machine with two (2) belts that each carry nylon film. The lower belt passes under a doctor box containing the resin paste and gets a measured coating of resin. This belt then passes under a glass chopper where glass rovings are chopped to preset lengths and are deposited on the paste. The upper belt is running in the opposite direction and also passes under a doctor box containing the resin paste. This belt then goes over a roller so that it changes direction by 180 degrees and is now running in the same direction as the lower belt. These belts now join forming a sandwich of: belt – nylon film – resin paste – glass – resin paste – nylon film – belt. The belts then go through a compaction section where the glass is thoroughly wet out. The SMC then is either collected as rolls or festooned into containers and stored in a hot room (80 degrees F minimum) until molding viscosity is reached. At that point it is removed from the hot room and stored at a lower temperature until molded. Release viscosities are in the15-20 million centipoises range and the SMC should be molded before it goes above 40 million centipoises.

The basic control checks for SMC are:

- ✓ Molding viscosity should be 20 million centipoises when received. It should be between 20 and 40 million centipoises when used.
- ✓ A panel should be molded to check the gel and cure characteristics, release from the mold, surface smoothness, shrinkage, and the specific gravity.

SMC is used where a smooth surface is desired in a uniform thickness panel and in panels of varying thicknesses with bosses, ribs and/or inserts.

BMC (Bulk Molding Compound)

BMC is a thermosetting polyester or vinyl-ester resin based compound which has the fillers, pigments, initiators, inhibitors, low profile additives, mold releases, thickener, and glass reinforcement combined together in a bulk form. BMC is usually extruded into a log for ease of handling and cut to a prescribed length for charging to the mold. BMC may be thickened for ease of handling, but it is thickened to a much lower level than SMC.

A typical formulation with quantity ranges is shown below:

Material	Parts Per Hundred (pph)
Resin	60-70
Low Profile Additive	20-40
Styrene Monomer	0-10
Initiators	0.8-2.0
Inhibitors	0.001-0.01
Pigments	0-5
Mold Releases	1-3
Fillers	150-250
Thickener	0-1.5
¼”-½”long glass fibers	40-65

The above formulation would give glass contents ranging from 10-15% by weight.

BMC thickening is achieved by the reaction of various earth oxides or earth hydroxides (usually magnesium oxide or hydroxide). There is an electronic attraction due to the ending acid groups in the resin, which gives a great increase in the viscosity of the material. This reaction is greatly affected by moisture levels in the resin paste. The viscosity of the BMC continues to increase over time so there is definite shelf life of the material. When subjected to the heat of the mold, the viscosity breaks down to a lower level.

BMC is produced in “dough” mixers such as a double arm sigma blade mixer, where the arms throw the material together and then tear it apart. Glass is added at the end of the mixing cycle at a controlled rate and minimum mix time to reduce glass degradation. The blade to barrel clearance of the mixer is relieved to reduce glass degradation. After mixing the BMC is run through an extruder where it is sized to a cross section and then cut to length. If it is to be boxed for shipping it is cut to box length. If being used internally it is cut to a mold charge length. The amount of thickening of BMC is much less than SMC and is done more for ease of handling than for flow in the mold.

The basic control checks for BMC are:

- ✓ Molding viscosity should be 8-10 million centipoises when received.
- ✓ A panel should be molded to check the gel and cure characteristics, release from the mold, surface smoothness, shrinkage, and the specific gravity.

BMC is used where dimensional stability is desired in moldings with bosses, ribs and/or inserts.

LCM (Liquid Composite Molding)

LCM is a thermosetting polyester or vinyl-ester resin based paste which has the fillers, pigments, initiators, inhibitors, low profile additives, and mold releases combined together in a paste. This paste is weighed onto fiberglass mat or a fiberglass preform and placed in a compression mold. Fiberglass mat is used for relatively flat or shallow draw parts. A preform that reproduces the male mold surface on its underside is produced on a vacuum screen or by a water mixture of fiberglass pumped through a shaped screen. A fiberglass preform contains 93-96% glass held together by 4-7% binder.

A typical LCM paste formulation with quantity ranges is shown below:

Material	Parts Per Hundred (pph)
Resin	60-70
Low Profile Additive	20-40
Styrene Monomer	0-10
Initiators	0.8-2.0
Inhibitors	0.001-0.01
Pigments	0-5
Mold Releases	1-3
Fillers	100-175

The glass contents of LCM moldings can have a range of 15 – 30% by weight depending on the properties required. The glass does not move during molding. This allows the use of localized reinforcement where needed for part performance.

The basic control checks for LCM are:

- ✓ Paste viscosity should be checked against a standard.
- ✓ A panel should be molded at the same glass level to check the gel and cure characteristics, release from the mold, surface smoothness, shrinkage, and the specific gravity.

LCM is used where a smooth surface and uniform strength is desired. LCM is best used in a single thickness molding. It is not recommended in panels of varying thicknesses or containing bosses, ribs and/or inserts.

GMT (Glass Mat Thermoplastic)

The following thermoplastic polymers are available with fiberglass reinforcements:

PBT (Poly Butylene Terephthalate)
PET (Poly Ethylene Terephthalate
PP (Polypropylene)

Polypropylene and polyamide account for the largest usage.

GMT is produced by running a stitched fiberglass mat between two (2) thermoplastic extruders. The extruders deposit the melted thermoplastic on the top and bottom of the mat. The mat then enters a heated consolidation unit where heat and pressure are applied
to distribute the thermoplastic through the mat uniformly. The GMT is then cooled and is sold as board stock or can be die cut to the customer's dimensions.

The molder heats the charge blank (usually in a conveyor oven) and then places the heated charge in a compression die that is below the melt temperature of the thermoplastic. GMT has also been thermoformed.

The basic control checks for GMT are:

- ✓ A certificate of analysis from the material supplier
- ✓ Confirm the weight per square foot

GMT is used in structural applications such as automotive underbody shields, seat structures, and front ends. It also finds applications in electrical and mechanical structures. It is not suitable for products requiring a smooth surface finish.

Controlling the Process

Consistent, high quality products require control. First the raw materials must be controlled from receipt through storage and finally conversion during the molding process. The dies and tooling required to convert the materials must be controlled from design through machining and initial tryout, and finally the press and auxiliary equipment must be controlled. In the majority of compression molding plants there are specialized process/quality engineers that do most of the quality and process control and trouble shooting must follow prescribed procedures and be

A job first enters the floor after a lot of advanced planning to insure that the process will provide a part that will meet or exceed the customer expectations. It has gone through a rather extensive program of product design and engineering. The basic steps to this planning are:

- Product planning
- Parts development
- Process planning
- Production planning

The engineers (design, process, manufacturing, and quality) are highly involved during these phases. It is their responsibility to review all areas, coordinating with the customer to be assured that the job launches without excessive problems. There are certain quality procedures, or tools, that they will use in their tasks.

Design for Manufacture and Assembly (DFMA) is a procedure that is used to identify potential production problems. The identified potential problem might be as simple as a part with varying thickness that will cause cure problems restricting production, or it might be as complex as a design problem that will prevent final assembly. Another tool, Failure Mode and Effect Analysis (FMEA) is used to identify possible failure modes of a product, or a process. Once the the potential failures are ientified, then actions or plans are developed to eliminate or reduce the chance of these failures from occurring.

It is important for a CCT-Compression Molding to have a basic understanding of these quality programs. A working knowledge of how these programs are implemented is not within the scope of this program. In the molding environment, your role will be in serving on “quality deployment” teams that brainstorm under the leadership of the process and quality engineers.

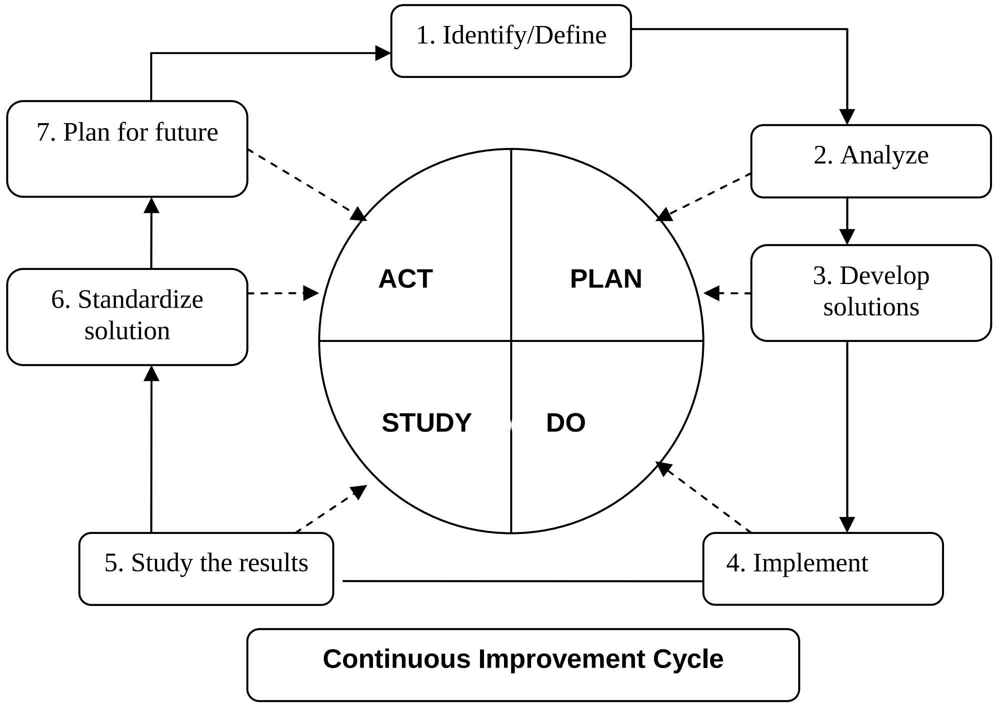
Problem-solving

As a CCT, your role in the troubleshooting and problem solving process will vary. You may be put in charge of a team to investigate and suggest possible solutions to a problem, or you may be asked to serve on a team. In some cases, you may be the first line, observing a problem and being in the position to continue or shut down the operation.

It is important for the CCT to be familiar with common problem-solving techniques. The basic problem solving cycle has four basic phases:

- **PLAN**
- **DO**
- **STUDY**
- **ACT**

As a CCT you should be familiar with this cycle and understand that this same four phase cycle is used to develop continuous improvement. In today’s manufacturing environment, where we are facing competition from alternative materials, and foreign companies, it is not acceptable merely to meet current customer expectations. A compression molder must strive to exceed these expectations. One of the ways of doing this is through continual improvement. The attached chart depicts the various steps in this cycle.



Common Quality Tools

As we look at the problem-solving steps depicted in the chart, there are some very basic tools that will assist the quality or process engineer in the taks required.

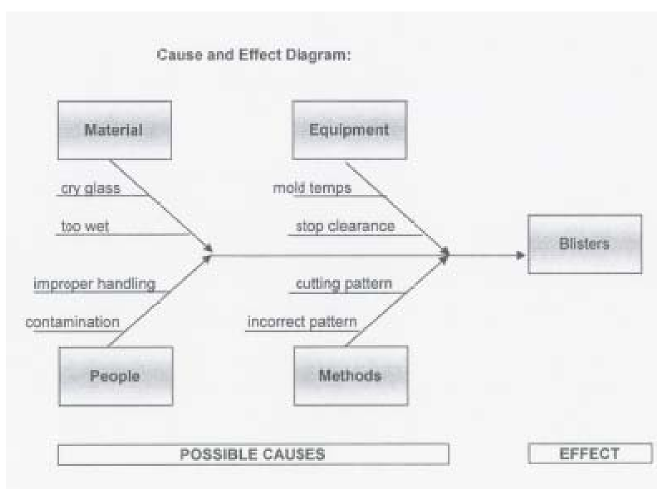
There are seven basic tools that the quality engineer uses in problem-solving:

- Cause-and-effect diagram (Fishbone, Ishikawa diagram)
- Check sheet
- Control chart
- Flow chart
- Histogram
- Pareto chart
- Scatter diagram

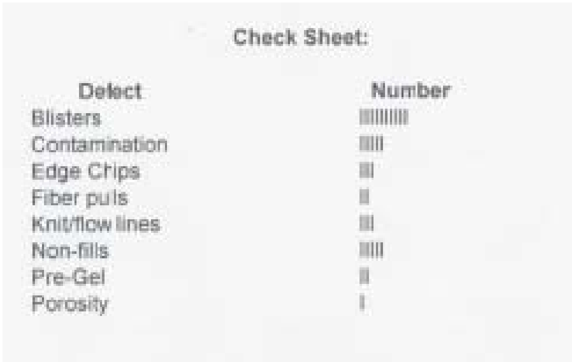
The CCT should be familiar with these names and have a brief understanding that they are all used in problem-solving quality problems.

Brainstorming is a technique that is used frequently in defining the problem. This technique is used by teams to generate ideas. Each person in the team provides as many ideas as they can contribute. This is the questioning phase: who, what, why, when, where, how questions are repeatedly asked, and all possible answers are considered. The above tools are used during "brain-storming sessions" to help define, analyze, and develop solutions to solve the problem.

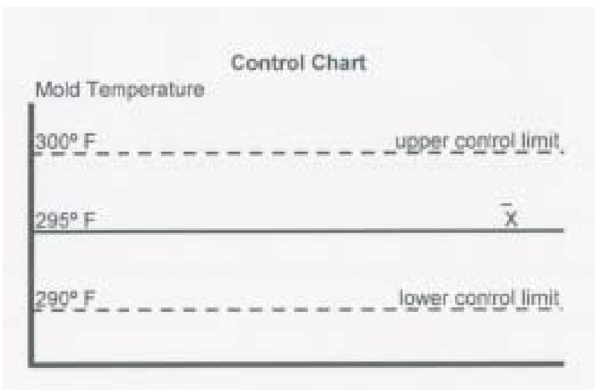
Cause-and-Effect Diagram: This diagram is sometimes referred to as the fishbone diagram, because when finished it resembles a fish skeleton. This diagram lists main causes and sub-causes leading to an effect (in this case, the problem the team is trying to fix).



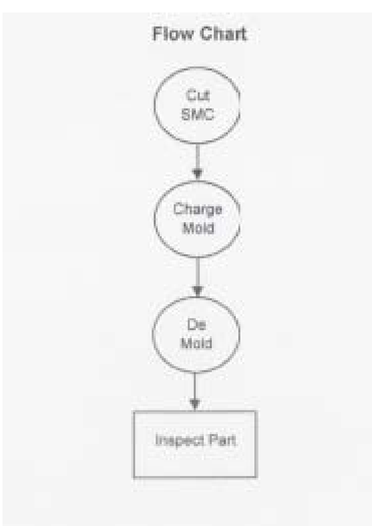
Check sheet: A custom made sheet used to record data.



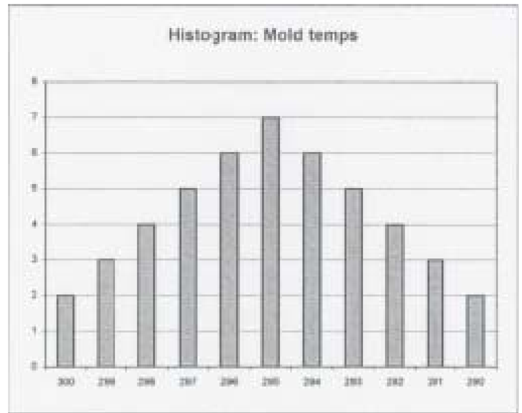
Control chart: A chart with statistical limits used to plot data, showing trends



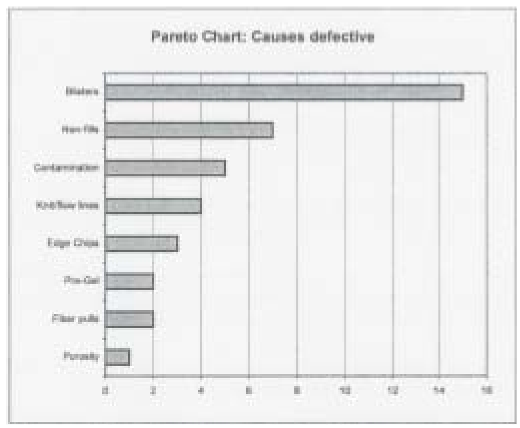
Flow chart: A graphical representation of the steps in a process



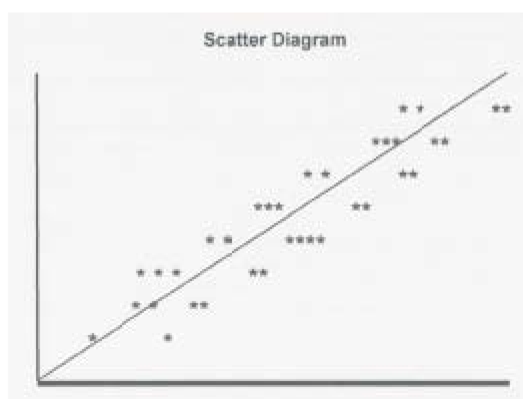
Histogram: A graphic summary of the variation in a set of data.



Pareto chart: A chart that graphically ranks causes from least to most significant



Scatter diagram: A graph that shows the relationship between two variables, plotted on the x&y axes.



MACT and the Compression Molder

What is MACT?[i]

When Congress amended the Clean Air Act in 1990, it directed EPA to require major sources of hazardous air pollutants to achieve MACT (Maximum Achievable Control technology). A major source is a facility with the *potential* to emit 10 tons per year (tpy) of any *single* HAP (hazardous air pollutant); or 25 tpy of any combination of HAP. Hazardous air pollutants were listed by Congress in the amended Act, and include styrene and methyl methacrylate.

EPA sets MACT for an industry by ranking industry plants by control effectiveness. MACT for existing sources is an emission limit that is at least as stringent as that achieved by the average of the best 12 percent of facilities in EPA's database of industry plants. MACT for *new* sources is an emission limit that is at least as stringent as that achieved by the best single facility in EPA's database.

EPA published the MACT rule for reinforced plastics composites production in the Federal Register on April 21, 2003. The composites MACT also is called "Subpart WWWW" or "the composites NESHAP". EPA published revisions to the composites MACT in mid-2005, to correct technical errors and clarify requirements.

The MACT rule is complicated, but in general:

- Open molding, pultrusion, centrifugal casting and continuous lamination operations must achieve the emission limits shown in Table 3 of the MACT rule.
- Compression molding (Closed Molding), compounding, mixing, materials storage and cleaning operations must comply with the *workpractice standards* in Table 4 of the MACT rule.
- New sources with total emissions exceeding 100 tpy are required to employ capture and control to achieve 95 percent emission reduction.

MACT Misconceptions[ii]

Misconception #1 –
MACT is an emissions limit:
MACT is not a facility emissions limit. The MACT Standard specifies technology that limits emissions on a per unit basis, but it does not specify how many units you can use. MACT does not limit the overall quantity of emissions from a facility. The emissions limit for a molding facility is a function of a negotiated State operating permit. A company can apply for an operating permit for any level of emissions. Assuming a successful negotiation and acceptance by the State regulatory agency, emissions permits can be any size required.

MACT does not place a cap on the gross quantity of emissions but rather requires that certain technology be in place for compliance. An analogy is EPA fuel mileage requirements for automobiles. The agency requires an average specified fuel mileage from an automaker's fleet, but there is no limit on how many miles you may drive your car.

Misconception #2 –
MACT is an emissions factor:
The Standard includes emissions factors for compliance, but MACT is not an emissions factor per se. There is a difference between MACT compliance factors and the factors used to report emissions for other purposes. Operating permit compliance and Federal or State emissions reporting may use similar but different emissions factors. These emissions factors are based on the Unified Emissions Factors (UEF) but contain different elements. For example, controlled spraying is not a compliance option under MACT. However, the emissions factors for controlled spraying may be used for either permit compliance or emissions reporting.

Misconception #3 –
MACT will limit production:
The MACT Standard in no way limits production. In most cases, based on a company's State operating permit, production is limited by the permitted emissions cap. If emissions can be reduced, more product units can be produced. Assuming the plant is using traditional materials and application equipment, moving into compliance with MACT will reduce overall emissions. This will actually allow more units to be produced while staying within the State permit requirements.

MACT and the Compression Molder

Initially EPA's AP-42 Emission Factors for Composites was used to provide the basis of emissions from all composite manufacturing processes.

EPA has withdrawn the AP-42 factors *for open molding*, replacing them with the ACMA ANS UEF-1-2004 for Estimating Emission Factors for Open Molding.

However, the AP-42 is still the basis for estimating emissions for compression molding.

[i] CM Magazine, "Regulatory Perspectives", John Schweitzer, July 2005
[ii] "MACT Misconceptions", Bob Lacovara, July 2004