Aluminum Pigments for Powder Coatings

SILBERLINE®

The Global Supplier of Effect Pigments℠

Metallic Effects in Powder Coatings

Introduction

Powder coatings may be defined as solventless paint systems composed of finely divided pigmented polymer particles. They are applied to the substrate using air as the transporting medium, where they deposit and form a protective and aesthetic film when subjected to elevated temperatures or radiation. Since their development in the 1960's, powder coatings have grown strongly as a class of coating systems and in 2006 the worldwide market was over 1 million metric tons, with Europe being, by far, the largest user.

Geographic Market Share (%)	Generic Share (%)	Areas of Use
Europe - 45	Thermoset - 95	Construction - Facades/Extrusions
Asia Pacific - 25	Thermoplastic - 05	Automotives
Americas - 25		Domestic Appliance
Others - 05		Office Equipment
		General Industry Exterior Application
		General Industry Interior Application
		Electrical Insulation
		Pipe/Rebar

The majority of powder coatings are applied onto metal substrates, such as steel and aluminum alloys, which can withstand the general curing temperature regimen of 140-200°C. More recent developments in low temperature cure systems and UV cure systems have allowed markets to be opened for less heat tolerant substrates such as wood, MDF composites and plastics. It is estimated that powder coatings represent 15-20% of industrial coatings and over 50% share of those sectors where they can compete effectively with liquid coatings. It is further estimated that approximately 10% of all powder coatings have a metallic effect and strong growth is evident here due to developments in higher performance metallic pigments and market trends in color and aesthetics.

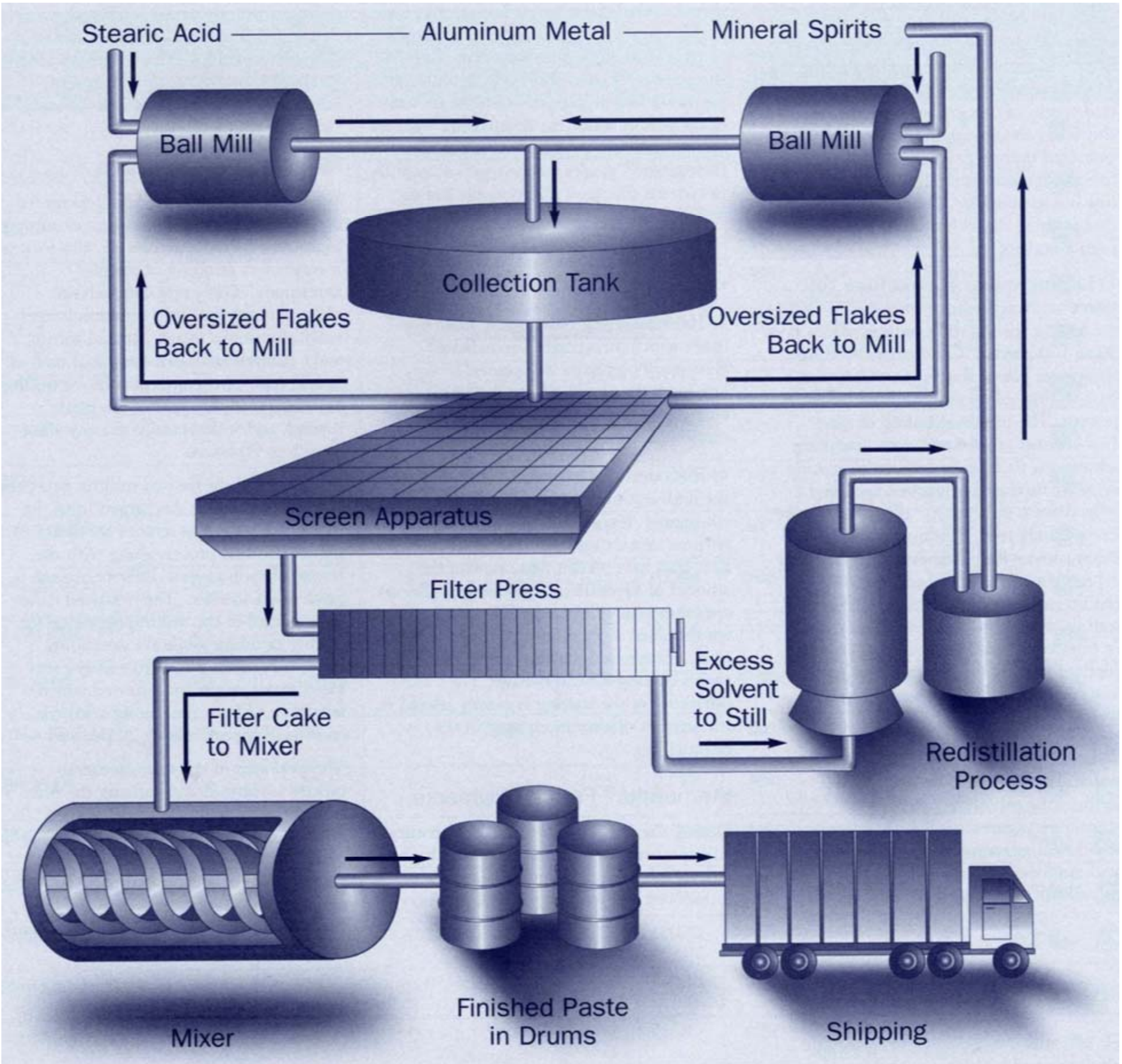
Metallic Pigments

By far, the largest class of metallic pigments used in powder coatings is based on high purity aluminum. For the purposes of this paper, we shall focus on this class. Other metallic pigment types in use are copper, bronze, stainless steel and zinc. In general, four effects can be achieved with aluminum pigments.

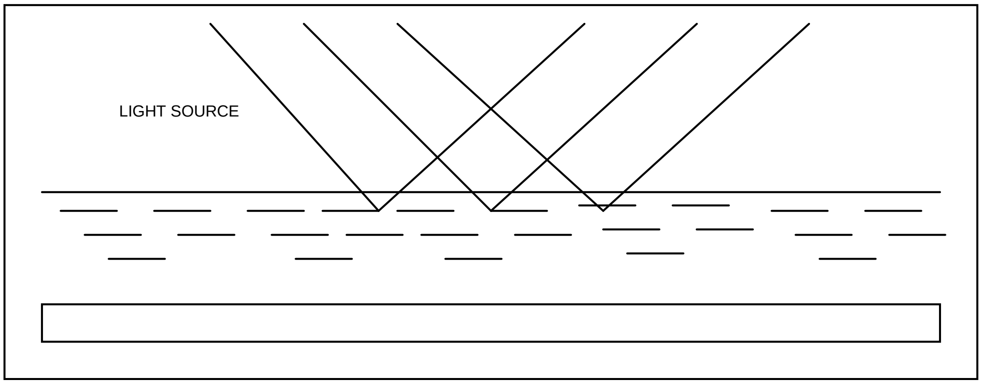
Leafing	Non-Leafing
Bright silver	Bright silver Chromatic silver Hammer finish

The manufacture of aluminum pigments involves a specialized ball-milling process as the first stage. Here the atomized aluminum is ball-milled in the presence of solvent and a lubricant for a period of five to 40 hours. The lubricant is employed to prevent "cold welding" of the aluminum particles and thus avoid agglomerates. The choice of lubricant determines whether the effect will be leafing or non-leafing.

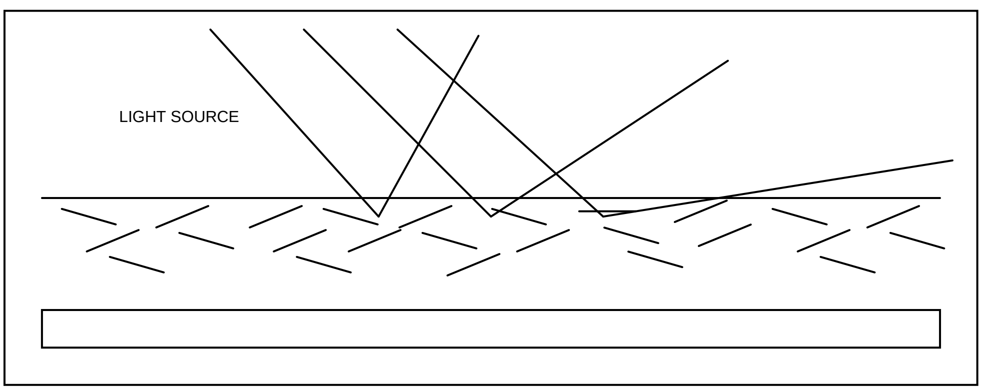
Flow Diagram for Production of Aluminum Flakes



Leafing aluminum pigments are produced using stearic acid, a saturated carboxylic acid, as the lubricant, which is absorbed onto the surface of the aluminum pigment. Since stearic acid is incompatible with powder coating polymer chemistries, the metallic pigment migrates to the upper surface of the coating during the cure cycle, where it will orient parallel to the surface. Very bright, reflective finishes are achieved using leafing grade pigments.



Non-leafing aluminum pigments generally use oleic acid, an unsaturated carboxylic acid, as the lubricant, and again this is absorbed onto the surface of the aluminum pigment. Oleic acid is compatible with powder coating polymer chemistries and, for this reason, the metallic pigment is oriented in a random manner throughout the bulk of the film. Very bright silver, chromatic silver and hammer finishes are achieved using non-leafing grade pigments.



In the case of leafing effects, as mentioned, the pigment is orienting parallel to and on the upper surface of the film. For this reason, such effects are easily marked by contact with fingers or by abrasion. To prevent this problem, the leafing effect coating can be over-coated with a clear-coat. However, since stearic acid is saturated, inter-coat adhesion may be jeopardized at the base-coat to clear-coat interface. Generally, if the clear-coat is cured at a temperature in excess of 190°C, the inter-coat adhesion problem is eliminated. Therefore, to obtain a very reflective metallic effect with good mark resistance, a base-coat/clear-coat system is recommended. This however, virtually doubles the cost and film thickness, which limits their usage.

Conversely, non-leafing pigments are randomly oriented throughout the film and have excellent resistance to finger marking and abrasion as a one-coat system. It is due to this combination of performance and economics that non-leafing effects form the majority of applications, from silver to polychromatic and hammer finishes. Although very bright, non-leafing effects can be achieved, they are generally less reflective than leafing effects.

In the ball-milling stage, control of the process variables determines the particle size and particle size distribution. The aspect ratio is defined as the ratio of the largest pigmentary dimension to the smallest, with typical aluminum pigment ratios ranging from 10/1 to 200/1. The importance of aspect ratio on sheer resistance in powder coating extruders will be reviewed later. Additional stages of sieving and classification are employed to achieve products with tighter distribution. Further stages of solvent addition, solvent replacement or solvent removal determine the physical form of the final product, which is presented as a paste, polymer carried granule or powder.

In powder coatings, the majority of aluminum pigments used are available with particle sizes of seven microns (for a very fine appearance) to 90 microns (for coarse glitter appearance).

The growth of metallic effects in powder coatings may be attributed to:

- Market Trends - Over 50% of automotive passenger cars have a metallic effect achieved by solventborne or waterborne base-coats. Strong growth in metallic effects is witnessed in coil coating applications, for facades and other transport sectors. Sporting equipment and bicycles/motorcycles have shown the same trends.
- Development - Metallic pigments have high performance and are user-friendly.
- Added Value - A combination of over-capacity and acquisition activity in the Powder Coating market has led to fierce price pressure.

Manufacture of Metallic Effect Powder Coatings

There are four particular methods by which a variety of metallic effects can be produced:

- Post blend with uncoated aluminum flake
- Post blend with coated aluminum flake
- Co-extrusion
- Bonding process

Post Blend with Uncoated Aluminum Flake

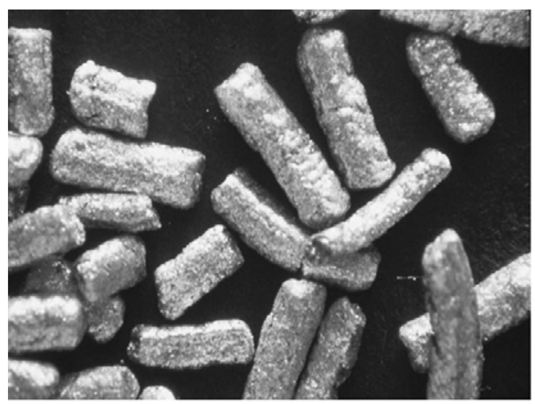
This method involves the mixing or tumbling of the pre-compounded micronized powder coating with dry, uncoated aluminum flakes. The main advantages are low cost and the retention of flake integrity due to the low energy involved in mixing. Great care should be taken in this method due to the high risk of explosion. Additionally, since aluminum is a conductor and the powder coating acts as an insulator, the electrostatic behavior during spray application will be different. The aluminum pigment will tend to migrate to the edges of the coated article resulting in an unsightly “picture frame” effect. A further problem results in the poor recycling aspects of this type of powder coating. Partially due to the wide difference in specific gravity between aluminum (2.7 g/cc) and the powder coating (1.2-1.6 g/cc), some phase separation occurs during the recycling of over-spray material. This, therefore, leads to the recycled material having a different composition and appearance compared to the virgin material. The low cost and less bright appearance of the aluminum flakes used in this process are due, in part, to their lower purity (<99.7%), which results in potential problems with humidity resistance or exterior durability. Leafing and non-leafing types may be produced this way.

Post Blend with Coated Aluminum Flake

In order to improve upon the problems of explosion risk, spray application, recycling, aesthetics and durability associated with uncoated aluminum flakes, new developments have been commercialized where the aluminum flake is coated. Essentially, the flake is coated either with an organic or inorganic coating, which has the combined effect of reducing the specific gravity of the pigment and making the pigment less conductive in an electrostatic field. Since higher purity aluminum is used (<99.7% or >99.97%), better resistance to humidity and exterior environment results. The base pigments used for coated aluminum are brighter, more sophisticated types than those found in uncoated aluminum and, for that reason, much brighter effects are achieved. Generally, only non-leafing effects are produced by this method.

Co-Extrusion Process

In this method, the aluminum pigment is generally supplied in a granule form, wherein the proportion of aluminum pigment is around 70-80%. The remainder is a polymer selected for compatibility with those polymer types used in powder coatings. The following photos illustrate aluminum pigment granules.



The pigment granule is added to the other raw material at the pre-mix stage. A homogeneous blend is achieved using a tumble blender or under low shear using a low speed (~100 rpm) inverted mixer. The typical time required during the pre-mix stage is around five to seven minutes. The homogeneous blend then passes to the extruder and onward to the chill roll, kibbling, micronizing, sieving and packing stages. Ten to 15 years ago, attempts to produce bright, sparkling metallic effects by this route were not successful. Generally at that time, rather gray luster finishes resulted. It must be kept in mind that high purity aluminum is a rather soft, malleable metal and under conditions of high shear, the pigment particles can be fractured. These fractured particles are smaller in particle size, which result in a darker appearance with increased opacity.

Damage to the aluminum flake will occur during the powder coating manufacture process that imparts the highest shear density, namely in the extruder. If we look at the extrusion stage, whether for single screw reciprocating or twin screw co-rotating types, both temperature gradients and shear gradients exist. The time taken from the pre-mix entering the extruder at ambient temperature until it exists at around 120ºC is approximately 20-90 seconds, depending upon the extruder type. During this time, the polymers must melt, pigment disagglomeration must be achieved and all raw materials must be homogeneously distributed. If we compare this with liquid coating manufacture by ball-milling, high speed dispersion or sand-milling, which involves hours of dispersion time to achieve disagglomeration and wetting, it is obvious that powder coating extruders act at high shear.

Single Screw Reciprocating Extruders

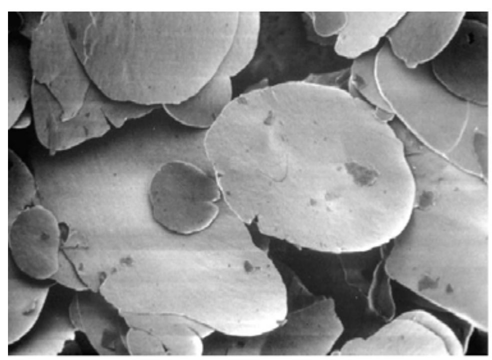
The screw has interrupted flights and in the barrel there are stationary "teeth." As the screw rotates, it also oscillates, which leads to axial rather than radial shear. The maximum shear gradient exists between the flight tip and the barrel wall, or tooth, where the clearance gap is between 0.5-1.6 millimeters. Since there is effectively a channel between each of the flights, a velocity/shear gradient of around 50% exists during the process. Both dispensive mixing and distributive mixing occur during extrusion and residence time is around 90 seconds.

Twin Screw Co-Rotating Extruders

Here, each screw consists of a shaft fitted with a suitable sequence of "paddle" and screw elements. The number and angular positioning of the paddles can be varied. In twin screw extruders, only rotation of the screws occurs and this leads to radial shear. The clearance gap between the tip of the paddle and the barrel wall is of the order 0.2-0.6 millimeter and this leads to a higher shear gradient than is found in single screw extruders. The residence time in twin screw is approximately 20 seconds or less. As mentioned before, high shear caused traditional aluminum pigments to be fractured and led to poor color or brightness.

Three developments have been introduced that have resulted in brighter metallic effects by the co-extrusion route:

- Low Aspect Ratio Pigments - So called degradation resistant pigments with aspects ratios of around 20/1 are much more shear resistant than traditional pigments whose aspect ratios are typically 150/1.
- Tailored Distribution - Classification techniques remove very fine particles from the aluminum pigment distribution and enhance the brightness.



In the co-extrusion process, the aluminum pigment becomes completely encapsulated by the powder coating polymer. This results in powder coatings which:

- Are very suitable for electrostatic applications
- Are free of picture frame defects
- Have improved penetration into recess areas
- Give homogeneous recycle over-spray

Bonding Process

In the bonding process, the aluminum flake is physically attached to the exterior surface of the powder coating. A variety of patents and licenses are evident in this technique. Good color effects are achieved by the 'bonding' process and, in addition, the over-spray material has a composition that is not significantly different from that of the virgin material. The main disadvantage has been that of cost - the bonding process is the highest cost method of manufacture.

SILBERCOTE® PC X Series for Powder Coatings

SILBERLINE®

The Global Supplier of Effect Pigments℠

The SILBERCOTE PC X series represents a generation of high performance aluminum pigments for use in powder coatings.

SILBERCOTE PC X can be incorporated into powder coatings by dry blending or bonding and is conveniently packaged in two kilogram bags for ease of handling and safety. The composite package for the SILBERCOTE PC X is a 16 kilogram drum that contains eight-by-two kilogram bags.

Using an advanced inorganic treatment, SILBERCOTE PC X combines improved chemical resistance with reduced Faraday Cage defects and superior recyclability. Very bright, tarnish resistant effects are possible in a one-coat application. A clear -coat is recommended for high performance, exterior durable applications.

Typical addition levels are up to five percent depending upon the desired effect. SILBERCOTE PC X should be dispersed into the powder by tumble blending or bonding or under conditions of low speed agitation.

FEATURES

- **Free flowing powder**
- **Unique packaging**
- **Advanced passivation**

BENEFITS

- **Ease of dispersion**
- **Superior economics and safety**
- **Excellent brightness**
- **Excellent chemical resistance**
- **Excellent damage resistance**
- **Electrostatic compatible**

SILBERCOTE PC X Series	* (µm)	Appearance
SILBERCOTE PC 8153X	14	Bright, smooth, excellent opacity
SILBERCOTE PC 8602X	16	Very bright, smooth, very good opacity
SILBERCOTE PC 6222X	20	Bright, very good opacity
SILBERCOTE PC 6792X	25	Very bright, good opacity
SILBERCOTE PC 4852X	33	Very bright, sparkle, good opacity
SILBERCOTE PC 3101X	36	Bright, high sparkle
SILBERCOTE PC 3331X	36	Bright, high sparkle
SILBERCOTE PC 1291X	47	Bright, high sparkle
* Before conversion		

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SILBERCOTE® PC X Display Panels

SILBERCOTE PC 3101X

SILBERCOTE PC 8602X

SILBERCOTE PC 4852X

SILBERCOTE PC 8153X

SILBERCOTE PC 6792X

SILBERCOTE PC 6222X

SILBERCOTE PC 3331X

SILBERCOTE PC 1291X

SILVET® Technology For Powder Coatings

SILVET is designed to provide improved ease of handling, dispersion and compatibility in the manufacturing of extrudable metallic powder coatings. SILVET is supplied as a metallic masterbatch in a granule form with typically 70% or 80% aluminum pigment. SILVET is added at the pre-mix stage along with other raw materials of the formulation. After pre-mixing, the blend is extruded below its cure temperature through single or twin screw extruders. This is then followed by micronizing the blend into the finished metallic powder coating.

For powder coatings, SILVET products are manufactured by two different processes. Each process results in a product with distinct characteristics. One process generates a product with a highly compacted pellet. These products have the suffix "E" in the product name. The second process generates a less compacted pellet or granule. These granules are manufactured by a low shear process and are identified by the suffix "J", "E1", and "P".

SILVET "E" pellets are carried in a low molecular weight polyolefin as are the SILVET "E1" granules. SILVET "J" granules are carried in an aldehyde resin and SILVET "P" granules are carried in an acrylic resin.

Typical addition levels are one to five percent depending upon the desired effect. High purity aluminum pigments are malleable and may be damaged under certain circumstances that will reduce their size and brightness.

Features

- High metal content
- Wide range of effects
- Polymer carrier
- Low addition level

Benefits

- Non-dusting
- Ease of dispersion
- Ease of handling
- No picture frame effect
- Excellent compatibility
- Excellent recyclability
- Improved penetration into recessed areas

Conditions to Avoid or Reduce

- High speed dispersers
- High viscosity in the extruder
- High shear rate in extrusion
- Long residence time in extruder
- Abrasive extenders in the formulation

Aldehyde “J” Granules	Median Particle Size *(µm)	Effect		
		Luster	Hammer	Sparkle
SILVET 210-20-J	15	X	X	
SPARKLE SILVET® 790-20-J	47			X
SPARKLE SILVET 797-20-J	35			X
SPARKLE SILVET 880-20-J	27			X
SPARKLE SILVET 960-20-J	14	X	X	

Modified Polyolefin “E” Pellets	Median Particle Size *(µm)	Effect		
		Luster	Hammer	Sparkle
SILVET 220-20-E	9	X	X	
SILVET 620-20-E	21			X
SPARKLE SILVET 760-20-E	55			X
SPARKLE SILVET 790-20-E	35			X
SPARKLE SILVET 880-20-E	27			X
SPARKLE SILVET 960-25-E	15	X	X	

SILVET “E1” Granules	Median Particle Size *(µm)	Effect		
		Luster	Hammer	Sparkle
SPARKLE SILVET Premier 950-30-E1	16	X	X	
SPARKLE SILVET Premier 890-30-E1	20			X
SPARKLE SILVET 790-30-E1	47			X
SPARKLE SILVET 755-30-E1	64			X
SPARKLE SILVET 764-30-E1	80			X
SILVET 440-30-E1	83			X

SILVET “P” Granules	Median Particle Size *(µm)	Effect		
		Luster	Hammer	Sparkle
SPARKLE SILVET 960-20-P	14	X	X	
SPARKLE SILVET Premier 860-20-P	24			X
SPARKLE SILVET 790-20-P	47			X
SPARKLE SILVET 760-20-P	55			X

* Before conversion

SPARKLE SILVET® Display Panels

SPARKLE SILVET
880-20-J

SPARKLE SILVET
960-25-E

SPARKLE SILVET
880-20-E

SPARKLE SILVET
960-20-J

SPARKLE SILVET
790-20-J

SPARKLE SILVET
790-20-E

SPARKLE SILVET
760-20-E

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This 2012 edition supersedes all previous editions.

Revised Aug 2012