

A primer on the evolution and fabrication methods of

# Game Counters and Casino Chips

Keywords: Engraving; Nacre tokens; Celluloid chips; Paranoid; Galalith; Decalcomania; Crest & Seal; Bakelite chips; Urea; Pyralin; Plaskon; Paper chips; Catalin chips; Beetle; Scarab; Plastic; Dies; Extrusion; Calendering; Compression moulding; Mould designs; Edge-spots;

By George Melas, European and Chartered Engineer

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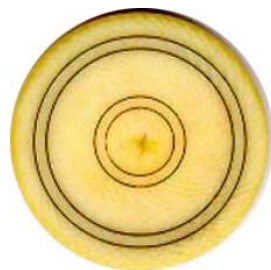
The concept of representing currency by means of game counters or tokens offers the advantages of exclusivity, speed of gaming and portability for both the operator and the player. For the operator it also provides the means to issue a personalized currency the denomination of which reflects the quality of the clientele and the financial resources of the [house](#).

The concept is not new. Archaeology offers numerous examples of Greek and Roman tokens used not only for admitting spectators to games but also for home entertainment.

## Early Gaming Chips

The early [tokens](#) were made of bone, [ivory](#) and metal. Advances in technology and manufacturing processes brought with them the introduction of materials such as glass, [porcelain](#), metallurgical compounds and [polymer](#).

Nowadays, there are many types of gaming chips in casinos worldwide whether in the form of wheel checks, cash chips, [plaques](#) or tokens,



Ivory

for slots, chip sorting machines and tables; whatever the choice the chips have become more intricate in appearance, construction and use. In the latter part of the sixteenth century, gaming chips that had been traditionally made of [bone](#) were outclassed by ones fashioned from materials less prone to [counterfeiting](#), such as the smoother and denser ivory or [Mother of Pearl](#).

Even [porcelain](#) was used, allowing a choice of spectacular designs whether in terms of shape (circular, square and [polygonal](#)) or by the detailed work of the hand-carved surface.

By the late 1880's, chip manufacturers were offering various styles of engraved, [embossed](#), [inlaid](#), decal and plain chips. Within a short time embossing superseded the labour intensive engraving method, until the inlaid chips with a wide range of colours and designs became part of the standard table float. The concept of the inlaid chips has remained the same over the decades; numerous combinations of colour are realised through the inlay of an inset of one colour design into the body of a chip of a contrasting colour.



Porcelain

The technology advanced rapidly after World War II and by the late 1960's French [jetons](#) and inlaid chips were in use worldwide.

### **Nacre tokens (1800s)**

Nacre, also known as Mother of Pearl, is an organic-inorganic composite material produced by some [molluscs](#) as an inner [shell](#) layer; it is also what makes up [pearls](#). It is very strong, resilient, and [iridescent](#). Nacre is found in some ancient lineages of [bivalve gastropod](#) and [cephalopod](#). The inner layer in the great majority of mollusc shells is [porcellaneous](#), not nacreous, frequently resulting in a non-iridescent shine or less commonly in non-nacreous iridescence such as *flame structure* (e.g. [conch](#) pearl); widely used for pearl buttons especially during the 1900s.

**1839:** American, [Charles Goodyear](#) invents rubber vulcanization and [Eduard Simon](#) discovers [Polystyrene](#) (PS).

**1856:** Alfred Critchlow and Samuel Peck invent [Shellac](#). Francois Charles Lepag invents [Bois Durci](#) - A plastic moulding material based on cellulose and made to imitate the expensive black wood ebony; mixed with a binder e.g. sawdust, water and animal blood.

### **Florence compound (1857)**

Alfred Critchlow (1813 – 1881) developed Florence compound, one of several new plastics invented in the mid-19th century. Critchlow was born in Nottingham, England and was in the horn button business in Birmingham, England. He met Josiah Hayden, who convinced him to move to Haydenville, Massachusetts, to start a horn [push] button business there. Critchlow arrived in America in 1843. After several years he moved to Florence, Massachusetts, and started his own wooden (wild laurel) button manufacture. In Florence Critchlow invented "Florence compound," - a shellac and sawdust-based moulding composite that he used mostly for making buttons, revolver cases, and decorated cases. In 1858 he bought an old woolen mill in Leeds, Massachusetts, where he manufactured the first vegetable ivory buttons in the United States.

**1863:** John Wesley Hyatt invents Cellulose Nitrate or [Celluloid](#). It was first created as [Parkesine](#) in 1862 and as Xylonite in 1869, before being registered as Celluloid in 1870.

### **Decalomania (1865)**

The term '[decal](#)' is an abbreviation of [decalomania](#), from the French *décalquer*, 'to transfer', and *manie*, 'mania', or *décalcomanie*, which refers to a process of transferring designs from specially prepared paper to another surface. It was invented in England by a Frenchman named *Simon François Ravenet* about 1750 and imported into the United States at least as early as 1865. Chip manufacturers



have spent much time and energy in their efforts to stop people from trying to remove (or swap) the decals. Current designs allow for very secure fixing, destruct-when-removed decals, graphic sublimation and invisible bar coding, progressing to more elaborate diffraction grating and holographic decals.

**1872:** Eugen Baumann first created [Polyvinyl Chloride](#) or PVC.

### Celluloid and Paranoid chips (1880s)

Celluloid, the oldest of the synthetic plastics, is made of cellulose nitrate compounded with a plasticizer, usually [camphor](#) - a resin obtained from the camphor tree. It dates back to the work of the French chemist Braconnet in 1833; it was not until 1869, however, that John Wesley patented the use of cellulose nitrate as a solid mass, forming the basis of the plastics moulding industry.



Celluloid

Celluloid gaming chips (also known as 'French ivory' because of a grain that resembled ivory) were fairly solid and non-flammable, but proved hard to work on, were brittle and cracked when heated to higher temperatures.



Celluloid

The emergence of Celluloid and the Celluloid compounds containing ivory particles presaged the demise of the carving of pure ivory chips -much to the relief of the elephant. The term 'Paranoid' is the trade-name for a plastic material which resembles celluloid, often used for dominoes and poker chips.

In the early 1880's a new 'composition' chip made from clay and [shellac](#) featured in the Will & Finck catalogue as 'Compressed Ivory'; the chips were available at very low cost, were moulded in steel moulds and baked for a few minutes at high temperature. The chips were then removed from the moulds, like cookies, scraped, polished and packed.



Inlaid



Inlaid Clay

The early clay chips were widely available, but limited to very few colours, insufficient to identify more than just a handful of players at any one time. Some players took advantage of the manufacturing restrictions and resorted into 'pushing' their own chips during gaming action. There have been stories of operators finding at the close of play nearly twice as many chips as they had when they started gaming.

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[embossing](#) superseded the labour intensive engraving method, until the inlaid chips with a wide range of colours and designs became part of the standard table float. The concept of the inlaid chips has remained the same over the decades; numerous combinations of colour are realised through the inlay of an inset of one colour design into the body of a chip of a contrasting colour.

**1894:** Charles Frederick Cross and Edward John Bevan discover [Viscose Rayon](#) - a manufactured regenerated [cellulose fiber](#).

**Galalith chips (1897)** Galalith (Erinoid in the United Kingdom), is a synthetic plastic material manufactured by the interaction of [casein](#) and [formaldehyde](#). Given a commercial name derived from the Greek words *gala* (milk) and *lithos* (stone), it is odourless, insoluble in water, biodegradable, antiallergenic, antistatic and virtually nonflammable.



Galalith



Galalith

Although it could not be moulded once set, and was hence produced in sheets, it was inexpensive to produce due to its simple manufacture. Galalith could be cut, drilled, embossed and dyed without difficulty, and its structure manipulated to create a series of effects. No other plastic at the time could compete on price, and with ivory, horn and bone products becoming far more expensive, it found a natural home in the fashion industry and adapted to gaming. Although Galalith was historically cheap, the fact it could not be moulded led to its demise by commercial end users.



### **Crest & Seal chips (1907)**

Crest & Seal chips were originally made by the United States Playing Card Co. (U.S.P.C.), in Cincinnati, OH. The process involved the translation of customers' sketches,



Clay chip and decal

drawings, initials, monograms and trade marks on to a final design; the design was then printed on a white opaque material (the 'crest') and laminated with a thin layer of transparent material to protect (and 'seal') the printing from wear.



Galalith

They were available in square edge, dull linen finish or supplied in a round edge and polished.

There are chips presently being made by the [Bud Jones Company](#) (now part of [Gaming Partners International](#)), mostly wheel checks,



Decal Removed

that are similar to Crest & Seal, except that there is no “seal.” One can feel the edge of the inlay by running one’s fingernail across the chip surface. A thin layer of transparent film that seals the decal would confirm that the chip is of ‘Crest & Seal’



Crest & Seal

construction.

It can be seen above that ‘ordinary’ decals can be removed from the mouldings with ease.

**1908:** Jacques E. Brandenberger discovered [Cellophane](#) ®

**1909:** [Leo Baekeland](#) invented the first true thermosetting plastic Phenol-Formaldehyde trade named [Bakelite](#).

### Bakelite chips (1909)

Scientists recognized that many natural resins and fibers were [polymers](#), and in an effort to find a replacement for shellac (a natural polymer resin secreted from the "[laccifer lacca](#)", a small beetle bug in India), Dr. [Leo Hendrik Baekeland](#), a Belgian chemist, investigated the reactions of phenol and formaldehyde and found that if he applied sufficient pressure and temperature to phenol and formaldehyde he could produce a hard *mouldable* plastic: *polyoxybenzylmethylen-glycolanhydride* or Bakelite; a thermosetting phenol formaldehyde viscous resin - the world’s first synthetic plastic.



Bakelite



Bakelite

When this material was allowed to cool it would harden and in this way could be moulded into shapes. Unfortunately, the new product was brittle and would break and crumble with minimal pressure. At some stage Dr. Baekeland increased both temperature and pressure thus permanently ‘setting’ or bonding the molecules of the two chemicals into a stable and hard material. This process became known as [thermosetting](#).



Inlaid Bakelite

The result was a powder that could easily be put into moulds to create products e.g. chips. In 1909, Dr. Baekeland patented this new material and formed a company called Bakelite. The company kept

experimenting with the new material and quickly found that they could use "fillers" to make their product stronger, more durable and cheaper. The filler material was usually rags, cotton, wood flour or carbon. Even when these fillers were incorporated into the original material during curing, the intense heat and pressure would produce a range of opaque colours e.g. dark brown.

The variations of colour (mainly browns), mottling and even [swirling](#) often observed in Bakelite chips are from the different fillers used.

### **Urea chips (1921)**

Following the work of Dr. Baekeland, Austrian chemists discovered that when the chemical [urea](#) was mixed with formaldehyde it created a gooey "plastic" compound and when wood flour was used as filler and allowed to cure, the end product was white in colour. Another difference was that the heat and pressure need to cure the material was only a small portion of that needed to create Bakelite; the white base color and lower curing temperatures allowed the use of dyes to be added to create an end product with a variety of colours.

Ironically, the lower temperature setting manifests itself today in an unfavorable way: cracks. The cracks commonly referred to as "stress lines" which seemingly begin and end anywhere on the chips are caused by time – as the curing process completes over the years.

### **Pyralin chips (1925)**

Pyralin polyimide (PI) was Du Pont's answer to a synthetic Mother of Pearl, or nacre. Essentially celluloid, it evolved from nitrocellulose and the explosives industry in the early part of the 20th century. Naming cellulose *Pyralin* was an attempt to portray it as a more natural, not manmade material.



DuPont promoted Pyralin in the early 1930s and has been used for both actual chips and inlays in an attempt to imitate the limited and expensive real Mother of Pearl. It is still used for knife handles, mainly to imitate natural materials, and to create a visual interest with a wide range of colours and patterns.

**1926:** [Waldo Semon](#) invented a plasticized PVC - [Vinyl or PVC](#).

**1927:** [Cellulose Acetate](#) - the American Cellulose & Chemical Manufacturing Company changed its name to Celanese Corporation of America.

**1930:** [Wallace Carothers](#) and [DuPont](#) Labs invent [neoprene](#).

### **Plaskon chips (1931)**

[Plaskon](#) was developed and introduced in 1931 by the Toledo Scale Company; they began with the urea compound and used cellulose as

filler. Plaskon soon became the plastic of choice when a manufacturer wanted an end product to be a colour other than the standard Bakelite brown and black. Nearly all of the pre-war plastic chips found today that do not fit into the Bakelite or [Catalin](#) genre are made from plaskon.

### **Paper chips (1933)**

Paper chips probably existed because they were a cheap alternative to the clay composition chips. In addition if the game was to be kept secret, quiet chips were ideal. In the early 1930's, the Dyment Company of Cleveland Ohio manufactured plain paper poker chips, that were quite popular during the Depression days. The photo depicts a set of vintage poker chips in their original box (dated circa 1940's).



The chips are described as "noiseless and unbreakable", are well-made, heavy duty, thick, sturdy, square-edged and made of pressed paper. In 1933, Dyment hired the famous H.T. Webster (the New Yorker Magazine cartoonist) to promote their chips by producing poker-specific cartoons. The cartoons were randomly printed on one side of each chip – but not on all chips.



It can be seen that the box is torn in a couple of the seams; each box contained 60 chips -- 20 red, 20 white and 20 blue. The box advertised them as "noiseless" (never described as paper) and "the most economical poker chips sold".

**1933:** Ralph Wiley, a [Dow Chemical](#) lab worker discovered [Polyvinylidene chloride](#) or Saran also called PVDC.

**1935:** [Wallace Carothers](#) and DuPont Labs invent [nylon](#).

**1936:** [Poly\(methyl methacrylate\)](#) (PMMA) was first brought to market in 1933 by [Rohm and Haas Company](#), under the trademark **Plexiglas**.

### **Catalin chips (1937)**

Catalin is trade name for the same family of thermosetting plastics made of phenol and formaldehyde – a [cast plastic](#). When the patent for Bakelite ran out in 1927, the Catalin Corporation, among others, began making their own variation of cast phenol, [melamine](#) or urea formaldehyde plastic that contained no fillers.

By maintaining the initial resin liquid, dyed the desired colour, and poured into moulds to cure and by mixing different batches together, they could produce pieces with swirled or marbled patterns of lighter colour and translucent; over time it can shrink, warp, crack and yellow when exposed to sunlight.



Catalin was introduced to the public in 1930 and disappeared from the scene by the late 1940's due to the prohibitively high production costs and high [toxicity](#) of the lead moulds used for cast during manufacture.

Chemists around the world experimented for several years trying to find dyes that would hold colour under the conditions needed to cure the material. Finally, a group of German chemists devised a way to make dyes directly from [coal tar](#). Combined with varying amounts of water the dyes could be added to the resin to create a range of colours from clear to opaque.



The new dye-laden resin still couldn't stand the moulding process, so instead they used a method called "[casting](#)". Casting differed from moulding in several ways; the most important being that when the casting process was completed, the product still required much more work to render the piece into its final shape. Milling, sanding, [buffing](#) and tumbling were the usual steps to a finished product.

Around 1937, the Rohm & Haas Chemical Company patented an acrylic resin they named "[Plexiglas](#)". At the same time the DuPont Corporation developed an identical compound they called "[Lucite](#)"; it became popular from about 1940 to 1953. This new plastic was produced in an array of colours ranging from jewel-like transparent to shiny opaque and the production of vintage Catalin chips and tokens effectively ceased in the 1960s.



**1938:** [Roy J. Plunkett](#) invented polytetrafluoroethylene (PTFE) well known by the [DuPont](#) brand name [Teflon](#).

**1939:** Nylon and [Neoprene or polychloroprene](#) invented.

**1939:** [World War II](#) begins.

### **Beetle and Scarab chips (1940)**

Beetle, a direct descendent of urea, was developed initially for the tableware industry during the late 1920s and was manufactured

using various compounds as fillers and dyes. With Catalin gaining in popularity, chemists began experimenting with urea-based compounds and using some of the same processes developed for Catalin. Although Beetle is a moulded plastic and its compounds set, the resulting product was somewhat similar in appearance to Catalin but much more stable. As with Catalin, Beetle could be created in many colours, mostly pastels and even swirled to give it a marbling effect.

As with urea and plaskon, we see the same problems arise in Beetle chips. The lower temperatures used to cure the compound did not completely vulcanize Beetle and therefore it was prone to frequent stress lines. Another problem we find today is that constant low heat (from tubes, sunshine, lamps) over a period of time will cause separation in some of the swirls.

**1941:** Whinfield and Dickson invented [Polyethylene Terephthalate](#) or Pet- patented in 1941 by the Calico Printers' Association of [Manchester](#).

**1942:** Low Density Polyethylene discovered; [John Rex Whinfield and James Tennant Dickson](#) patented [Unsaturated Polyester](#) also called UPR.

**1943:** [Synthetic rubber](#) invented.

**1945:** [World War II](#) ends.

**1951:** [Paul Hogan](#) and [Robert Banks](#) invented [High-density polyethylene](#) or HDPE trade marked [Marlex](#).

## Plastic chips

The word [plastic](#) is derived from the Greek [πλαστικός](#) (plastikos) meaning capable of being shaped or moulded, from [πλαστός](#) (plastos) meaning moulded and refers to their malleability or plasticity during manufacture that allows them to be cast, pressed, or extruded into a variety of shapes. Plastic materials have come a long way since Bakelite, but the way in which plastic is moulded and produced has remained basically unchanged.



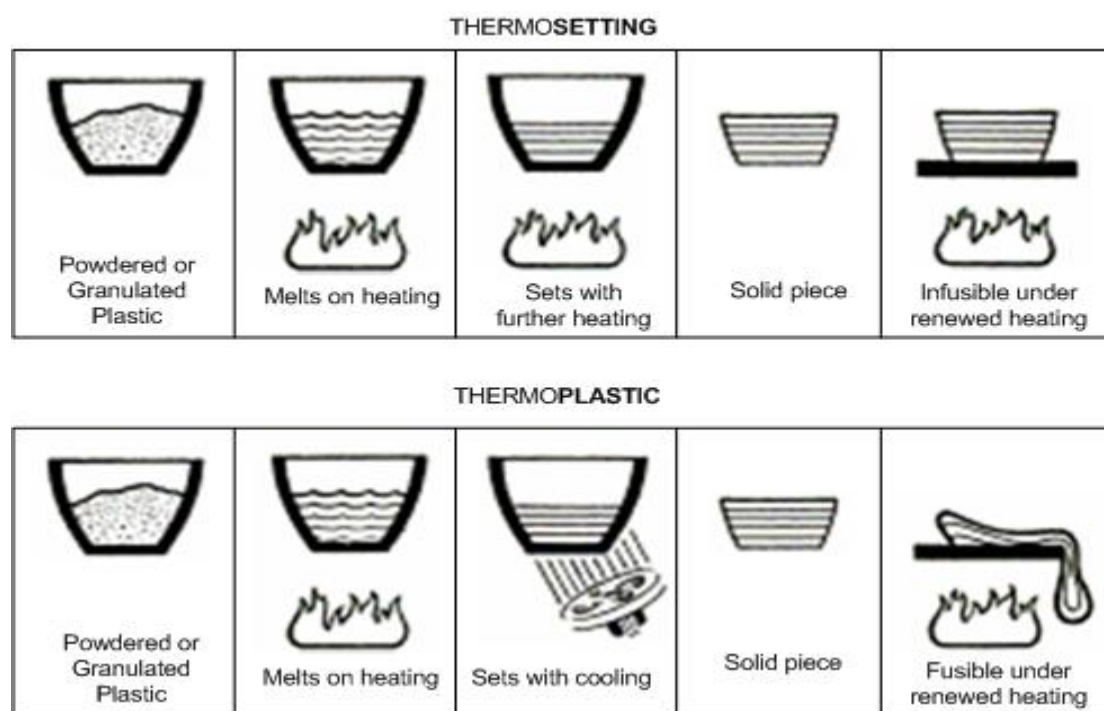
[Compression moulding](#) and [injection moulding](#) are the two main systems typically used to fashion chips from plastic moulding compounds. Compression moulding is generally used for [thermosetting](#) materials, and injection moulding is used for [thermoplastic](#) materials.

Plastics are typically polymers of high molecular mass, and may contain other substances to improve performance and/or reduce production costs.

### Compression moulded ‘clay’ chips

With increasing demands for more chips it became evident that a cheaper and simpler alternative, more suited to mass production, was needed – the ‘clay’ chip; the result of compression moulding of clay with shellac.

A plastic material is any of a wide group of [organic](#) compounds or resins largely synthetic, which, under suitable conditions of heat and pressure can be made to flow and in that condition, can be moulded or cast into various shapes. Plastics are of two types – [Thermosetting](#) and [Thermoplastic](#). The distinction is the way they react to heat. Both melt when first heated but on further heating the thermosetting materials harden permanently. Thermoplastics, on the other hand, are hardened by cooling and if heat is applied again they will melt. These properties determine how they are manufactured.



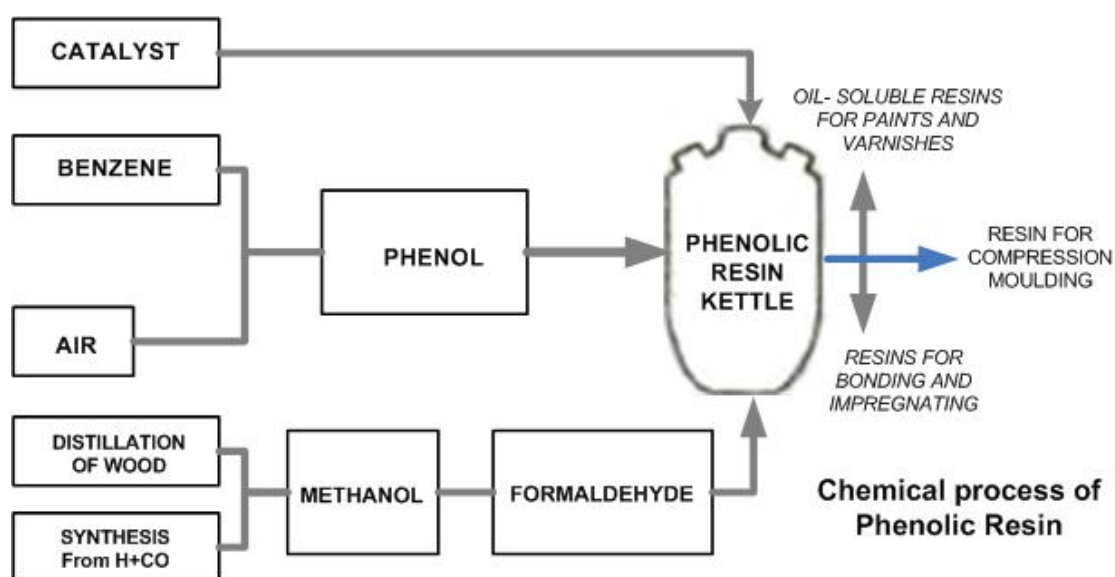
### Early moulding materials

The principal thermosetting materials are the [phenol-formaldehydes](#), such as [Bakelite](#), and the [Urea-formaldehydes](#), which are much used in bonding plywood whereas the thermoplastics include [celluloid](#), [cellulose acetates](#) and [acrylics](#).

The first compression moulds were handmade. In the 1800s, plastic products like buttons, handles and gaming counters were made from handmade compression moulds. The manufacturing process, known then as "[compression moulding](#)," was suitable for the production of simple, small geometric-shaped items.

The first automatic compression machine patent was secured in the 1930s. Soon after, hundreds of them were sold to plastic companies. [Alfred Critchlow](#) is said to be the founder of the first plastic moulding company, the Pro Corporation. Companies later began using large-scale compression moulding machines.

Compression moulding, just before World War II, was mainly confined to thermosetting plastics. A compression mould is basically a press into which a plastic material is fed; when the mould has been filled, it closes, heat and pressure are applied, and the material flows and takes the shape of the cavity. The mould remains closed until curing takes effect. When the material is fully set or 'cured' it is ejected and the cycle begins all over again.



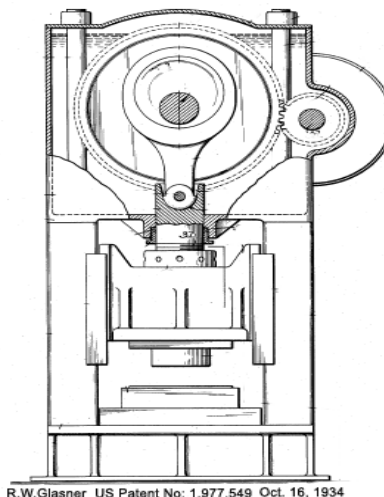
It can be seen from the left hand side of the diagram above that the first phenol or [carbolic acid](#) ( $C_6H_5OH$ ) is evolved from benzene and air, or from coal tar, and reacted with formaldehyde ( $HCHO$ ) in a resin kettle under heat and pressure in the presence of a [catalyser](#) – a chemical which facilitates reaction without undergoing any change itself. Oil-soluble resins for coatings are taken off, also resins for coating and impregnating. The remainder, with the consistency of [molasses](#), is poured out on to a floor and allowed to cool. Then it is broken into lumps, crushed and ground into powders, and mixed with a filler such as wood flour (ground wood or sawdust), or in some cases walnut shell flour. Subsequently it is heated and rolled, ground again, screened and blended with other batches to ensure a uniform product, and finally we have the plastic powder which is fed into the hopper of the moulding machine.

Clearly there are numerous modifications of this process. Rather than phenol other related compounds, like [cresol](#), may be used. Another alternative material is [furfural](#), obtained from waste farm products like [corncoobs](#), soybeans and [rice hulls](#). As an 'extender' a relatively small percentage of phenolic resin mixed with ground [lignin](#) pulp

makes a usable plastic – however the moulding cycle is longer. Cellulose materials continue to be important and include nitrocellulose and cellulose acetate.

## Moulds, dies and tooling

The first compression moulds were handmade. In the 1800s, plastic products like buttons, handles and gaming counters were made from handmade compression moulds. The manufacturing process, known then as "[compression moulding](#)," was suitable for the production of simple, small geometric-shaped items. The first automatic compression moulding machine patent was secured in the 1930s and soon afterwards similar machines were used for large-scale moulding production. Compression moulding, just before World War II, was mainly confined to thermosetting plastics.

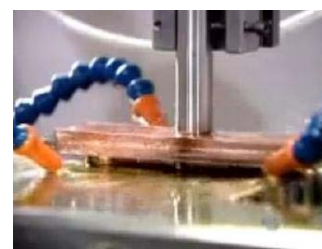


R.W.Glasner US Patent No: 1,977,549 Oct. 16, 1934

Production moulds are usually made from steel for pressure moulding that requires heating or cooling channels, strength to resist the forming forces, and wear resistance to withstand the wear due to plastic melts, particularly that which has glass and other abrasive fillers. The design and construction of a mould plays a significant role in the dimensional integrity of its product. The cavity that forms the final product can be shaped using a variety of steel removal methods from jig grinding to wire-feed electrical discharge machining.

## Die cutting

Once the chip design is finalized [and legally protected by a patent or a registered design] the moulds and tools are made to manufacture the chips. Most mould-making and tooling department build moulds that are precise to within 1/1000th (.001") of an inch. Before World War II the work was done by machinists on lathes, mills and other machinery; it is now done by computer-controlled machines. This allows the mould-maker to instruct the computer to operate the CNC tools that make the mould that will produce the chip. The result is a more precise mould and a more exact part.



Spark machining



Web mould die

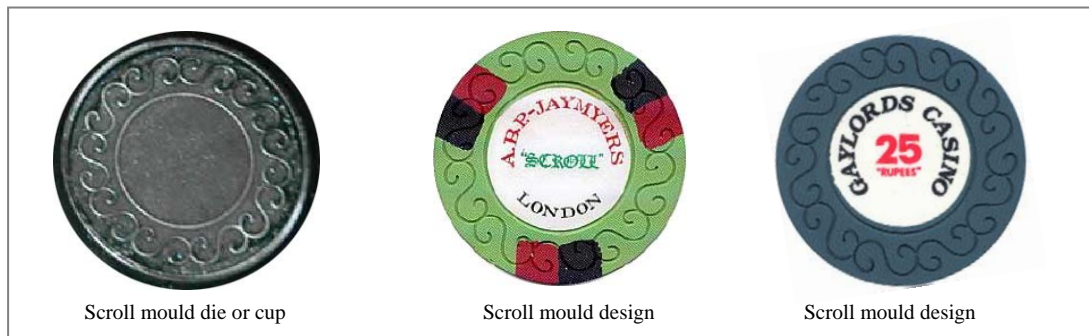


Web mould design

A die is a specialized [tool](#) used in [manufacturing industries](#) to [cut](#) or shape [material](#) using a [press](#). Like [moulds](#), dies are generally customized to the item they are used to create. Products made with dies range from simple [paper clips](#) to complex pieces used in advanced technology. Forming dies are

typically made by [tool and die makers](#) and put into production after mounting into a [press](#). The die is a metal block that is used for forming materials like sheet [metal](#) and [plastic](#).

For the creation of steel dies for producing mould designs an electric discharge machining (EDM) process is often used and is sometimes colloquially referred to as spark machining or spark eroding. The

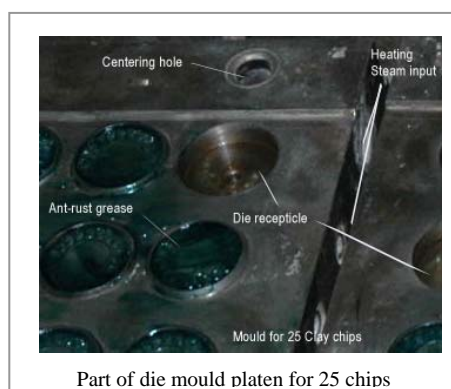
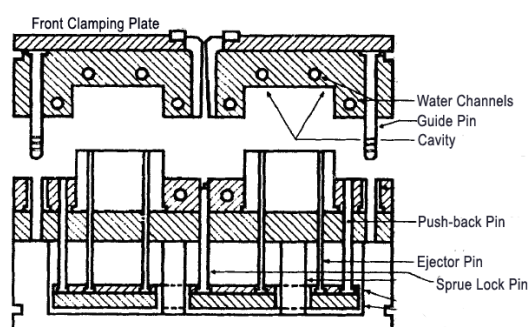


desired shape is obtained using electrical discharges (sparks) whereby material is removed from the work piece by a series of rapidly recurring current discharges between two [electrodes](#).

When the distance between the two electrodes is reduced, the intensity of the [electric field](#) in the volume between the electrodes becomes greater than the strength of the dielectric, which breaks, allowing current to flow between the two electrodes. This phenomenon is the same as the [breakdown of a capacitor](#) (see also [breakdown voltage](#)). As a result, material is removed from both the electrodes. Once the current flow stops, new liquid dielectric is usually conveyed into the inter-electrode volume enabling the solid particles (debris) to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as flushing.

## Moulds

The moulds are heated using steam rather than hot oil or electricity. Mould materials include cast or forged steel, cast iron, and cast aluminium. Tooling is usually machined (P20) steel, steel with hardened tooled-steel inserts or cast alloy moulds that can be in either single or multiple-cavity configurations. Steel moulds are



hardened and sometimes chrome plated for enhanced durability. Matched metal moulds and tooling can cost in the region of £40,000.

Like the moulding process itself, compression moulding machinery is relatively simple. Most compression presses consist of two platens that close together, applying heat and pressure to the material inside a

mould. The majority of the presses are hydraulically operated the platens exert pressures ranging from 6 up to 10,000 tons. Virtually all compression moulding presses are of vertical design. Most presses having tonnages less than 1000 are upward-acting, while most over



Weight: 50 lbs per 25-cavity steel shoe or 100lbs for both moulds including the dies or cups

1,000 tons act downwards.

### **Moulding process**

Compression moulding was the main method of manufacturing plastics during the first half of the last century because of the development and extensive use of phenolic plastics in 1909.

By the 1940s this situation began to change with the development and use of thermoplastics in extrusion and injection moulding processes. Compression moulding originally processed about 70% of all plastics, but by the 1950s its share of total production was below 25%, and now that figure is close to 3% of all plastic products produced worldwide.

This change does not suggest that compression moulding is not a viable process; it just does not provide the much needed lower cost-to-performance benefit of thermoplastics, particularly at high production rates. In the early 1900s plastics were almost entirely thermosetting (95%), but that proportion had fallen to about 40% by the mid-1940s and now is close to 10%. Thermosetting has experienced an extremely low total growth rate, whereas thermoplastics have expanded at an unbelievably high rate.

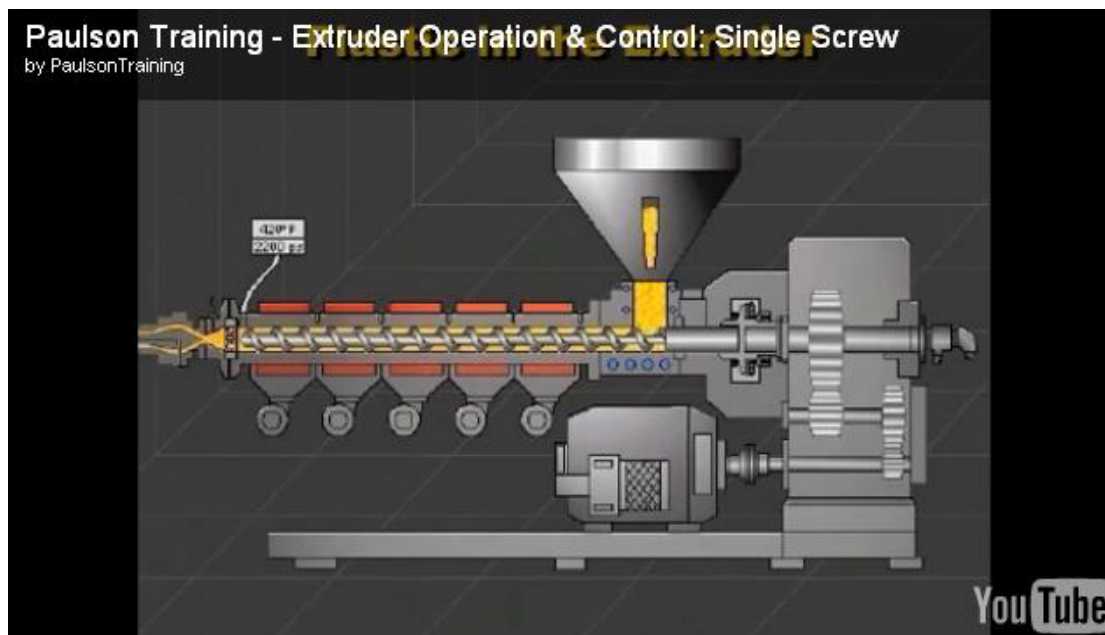
Compression moulding is the most common method of moulding thermosetting materials. In this process, material is compressed into the desired shape using a press containing usually a two-part closed mould and is cured with heat and pressure. This process is not generally used with thermoplastic materials.

A compression mould is basically a press into which a plastic material is fed; when the mould has been filled, it closes, heat and pressure are applied, and the material flows and takes the shape of the cavity. The mould remains closed until curing takes effect. When the material is fully set or 'cured' it is ejected and the cycle begins all over again.

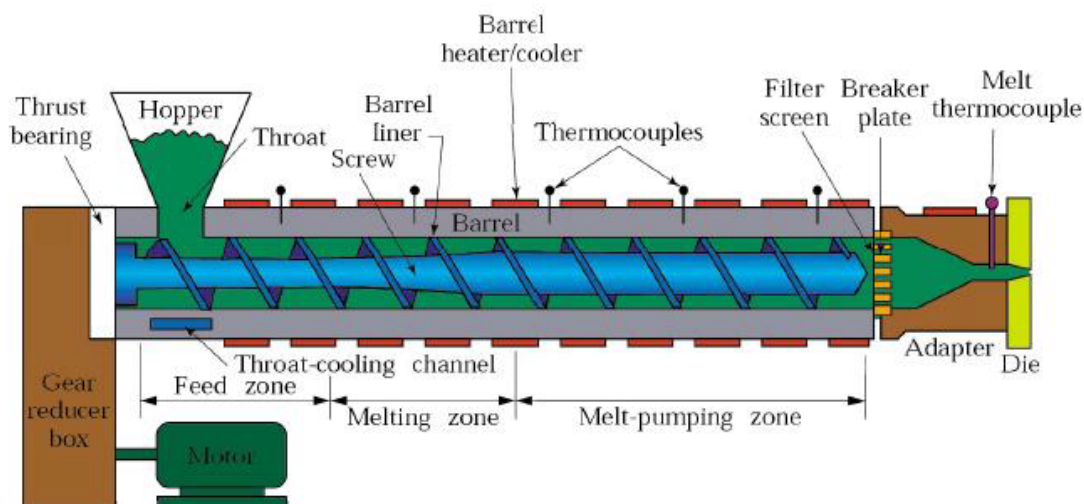
### **Extrusion stage**

The first stage is the [extrusion](#) stage; in this stage, the raw thermosetting material in the form of small beads or pellets is gravity

fed from a top mounted [hopper](#) into the barrel of the extruder. Additives such as colorants are often used and can be mixed into the resin prior to arriving at the hopper.



This action is illustrated by the Paulson Training video clip on YouTube (above). For convenience, the following drawing gives a detailed account of the various stages.



The material enters through the feed **throat** of the **hopper** (the opening near the rear of the barrel) and comes into contact with the **screw**. The rotating Archimedes screw (normally turning at up to 120 rpm) forces the plastic pellets forward into the **barrel** which is heated to the desired melt temperature of the molten plastic (which can range from 200 °C (392 °F) to 275 °C (527 °F) depending on the polymer).

In most processes, a heating profile is set for the barrel in which three or more independent [PID](#) controlled heater zones gradually increase the temperature of the barrel from the rear (where the plastic enters) to the front. This allows the plastic pellets to melt gradually as they

are pushed through the barrel towards the **Melt-pumping** zone (the [metering](#) zone is often used to control the pressure and temperature of a plastic melt material) and lowers the risk of overheating which may cause degradation in the polymer.

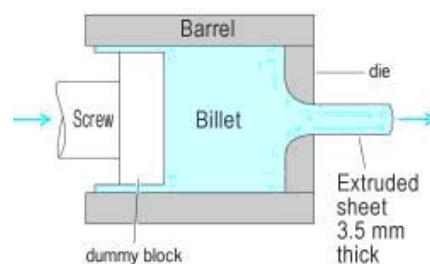
Extra heat is contributed by the intense pressure and friction taking place inside the barrel. In fact, if an extrusion line is running a certain material fast enough, the heaters can be shut off and the melt temperature maintained by pressure and friction alone inside the barrel.

In most extruders, cooling fans are present to keep the temperature below a set value if too much heat is generated.

At the front of the barrel, the molten plastic leaves the screw and travels through a **filter screen** pack to remove any contaminants in the melt.

The screens are reinforced by a **breaker plate** (a thick metal puck with many holes drilled through it) since the pressure at this point can exceed 5000 [psi](#) (34 [MPa](#)).

The filter screen pack/breaker plate assembly also serves to create back pressure in the barrel. Back pressure is required for uniform melting and proper mixing of the polymer, and how much pressure is generated can be 'tweaked' by varying screen pack composition.



This breaker plate and screen pack combination also does the function of converting "rotational memory" of the molten plastic into "longitudinal memory".

After passing through the breaker plate molten plastic enters the **die**. The die is what gives the final product its profile and must be designed so that the molten plastic evenly flows from a cylindrical profile, to the product's profile shape. Uneven flow at this stage would produce a product with unwanted stresses at certain points in the profile. These stresses can cause warping upon cooling. Almost any shape imaginable can be created so long as it is a continuous profile.

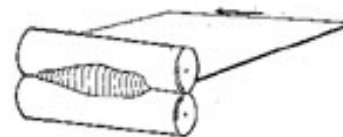
Heat control is crucial as uncontrolled reheating of the material results in reaching the decomposition temperature before the melting point is obtained. Therefore, a thermoset material cannot be [melted](#) and re-shaped after it is cured. This implies that thermosets cannot be recycled, except as filler material.

Plastics are very good thermal insulators and are, therefore, difficult to cool quickly. Compared with steel, plastic conducts its heat away 2000 times more slowly.

The product must now be cooled; for products such as plastic sheeting, the cooling is achieved by pulling through a set of cooling rolls.

## Calendering stage

Basically the calendering process is used in the production of plastic films and **sheets**. It converts plastic into a melt and then passes the paste-like mass through roll nips of a series of heated and rotating speed-controlled rolls into webs of specific thickness and width.

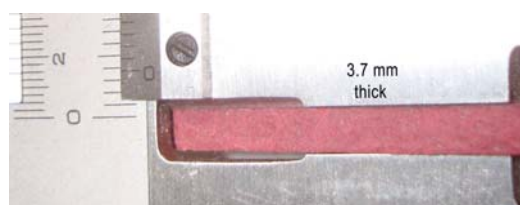


The hot mass of polymer is fashioned into a continuous sheet by passage through a system of heated rolls, known as [calender](#). The



Polymer sheet: 3.7 mm thick

sheet is cooled, cut to size and stacked. The process is used to manufacture sheets that can be rigid, transparent or coloured opaque. The calendar machine comprises of a stack arrangement of rolls mounted on bearings, supported by side frames with roll drives and heating arrangements. The relatively small compounded polymer sheets emerging out of the two-roll mill are then fed into a metering extruder or a strainer. The function of a strainer is to continuously feed the calender at a controlled rate and to filter out foreign particles. The material entering from the nip gets transformed into a continuous sheet. This sheet is progressively pulled through a series of rolls to resurface each of the two sides of the sheet.



Polymer sheet: 3.7 mm thick

## Blanking die

A blanking die produces a flat piece of material by cutting the desired shape diameter in one operation. The 'chip' is referred to as a blank. Generally a blanking die may only cut the outside contour of the chip, often used for chips with no internal features. While many dies perform complex procedures simultaneously, a 'pancake' die may only perform one simple procedure with the finished product being removed by hand.



39 mm diameter punch

The use of blanking dies offers the following benefits:

*Accuracy.* A properly sharpened die, with the correct amount of clearance between the punch and die, will produce a blank that holds close dimensional tolerances in relationship to the blank's edges.

*Appearance.* Since the moulding is blanked in one operation, the finish edges of the blank produce a uniform appearance rather than varying degrees of burnishing from multiple operations.



Punch with decal outline

*Flatness.* Due to the even compression of the blanking process, the end result is a flat moulding that may retain a specific level of flatness for additional manufacturing operations. While composite clay chips were made as early as the [1880s](#), the standard clay chip as we know it today was made starting in the late '40s and early '50s. It has several parts to its basic anatomy: the base, the inserts, the mould, and the inlay.



39 mm diameter blank

The base of a chip is the colour of the main piece of clay. If thermosetting resin is moulded, the mould may be open in hot state – cured thermosets maintain their shape and dimensions even in hot state. If thermoplastic is moulded, the mould and the moulded part are cooled down before opening. The blank can be used to produce a single colour chip or it may have several other pieces of clay of different colours inserted into it.

The mould determines whether the chip has shapes embossed or incused into it, or ridges around the edge. The inlay is the center of the chip with the casino logo and denomination—it could be a solid piece that goes all the way through the chip or just a piece of plastic



39 mm Plain chip

or a paper decal that's glued to the surface. The form of the chip created during this compression-moulding process is determined by the shape of the mould cavity.



39 mm Plain chip

Most casinos have their own proprietary moulds, originally used as a security feature, but used more today for branding and style. Some have the casino's name depressed into the outer track of the chip. Others have unique geometric designs around the track of the mould. The inlay area can be deeply depressed from the rest of the surface of the chip.

### **Mould designs**

The design moulded into the rim or outer edge of a poker chip is called the mould design. This design is unique often proprietary and offers chips some protection against counterfeiting, exclusivity, styling and branding.

There are numerous popular and unique designs; some contain a suction-inducing cavity inlay feature which keeps the poker chips stacked in place and some with a fine textured surface that prevents the chips from slipping.

**Table 2: Mould designs**

The following selection of mould designs is not an all-inclusive list but rather a sample of 65 different examples.

|   |   |   |  |   |
|---|---|---|--|---|
|    |    |    |    |    |
| Cord  | Crown (Large)   | Crown (Small)   | Harp   | Hat (no cane)   |
|    |    |    |    |    |
| Hat & Long Cane   | Hat & Short Cane  | Hat & Cane (Alt Dir)  | Hat & Cane Inverted  | Hat & Cane C-Jones  |
|  |  |  |  |  |
| Horseshoes  | Hourglass   | Hourglass (New)   | Roman Border   | Scroll  |
|  |  |  |  |  |
| Stakis - Candelabra   | Greek Small Key   | Greek Large Key   | Web  | Arrow   |
|  |  |  |  |  |
| Aztec Pyramid   | Braid   | C   | Courts & Numerals  | Crown & Dice  |
|  |  |  |  |  |
| Diamond Square  | Dice & Card   | Dice  | Dice Swirl   | D/L Broken Circle   |

|   |   |   |  |   |
|---|---|---|--|---|
|    |    |    |    |    |
| Dragons   | House: Dunes  | Ewing   | Flame - Shell  | Flame - Shell   |
|    |    |    |    |    |
| Fleur-de-Lis  | Horse Head  | H   | Hub  | Jokey (JPL)   |
|    |    |    |    |    |
| Lazy diamonds   | L   | Lazy N  | Lazy S   | Lucky Bee   |
|   |   |   |   |   |
| House: MGM  | Paradise  | Pineapple   | Ridge  | Cigar & Snifter   |
|  |  |  |  |  |
| Rope  | Roulette  | Scrimshawed   | Dollar   | Square  |
|  |  |  |  |  |
| Triangles & Clubs   | T's   | Unicorn   | Wave crests  | Zigzag  |
|  |  |   |  |   |
| Zigzag Circles  | Square / Circle   |   |  |   |

## Plain 'A - Mould' chip

Once the moulds are 'plumbed in' and secured, compression moulding is the most common method by which thermosetting plastics are moulded. In this method the plastic, in the form of a blank disc, is dried by heating and then further heated to near the curing temperature; this heated blank is loaded directly into the mould cavity. The temperature of the mould cavity is held at 150°C, depending on the material.



American Mould: letter A in 4 places separated by a design around the rim

The mould is then partially closed, and the plastic, which is liquefied by the heat and the exerted pressure, flows into the recess of the mould. A pressure of 2,250 psi (158 kg/cm<sup>2</sup>) would be suitable for phenolic materials, whereas for moulding urea and melamine materials pressures of approximately one and one-half times of that needed for phenolic material is necessary.



American 'A' mould chip

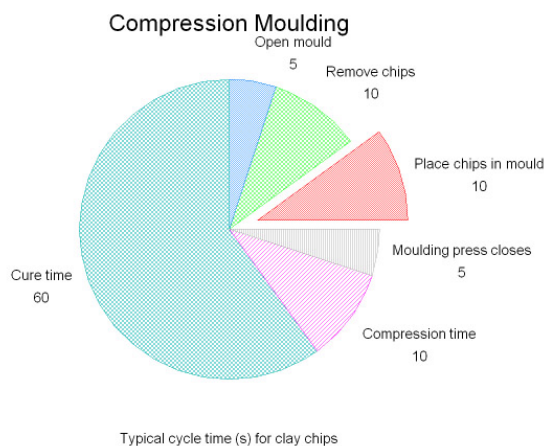
At this stage the mould is fully closed, and the flow and cure of the plastic are complete. Finally, the mould is opened, and the mould block removed. The chips are removed from their moulds placed on a v-shaped rack, 20 at a time, and their edges scraped with a steel rule to remove any excess material. The stack height is then measured with a vernier for consistency and quality control.

## Cycle Time for SMC

The schematic below shows a typical cycle time for compression moulding of [sheet moulding compound](#) (SMC). The total time is from 80 to 120 depending on the material used. Notice that most of the cycle time (60 seconds in this example) is spent curing the resin.

Thus, attempts to reduce the cycle time should focus attention on the cure characteristics of the moulding compound.

The graph below shows typical temperature and pressure profiles for SMC compression moulding. The graph depicts the same events as were shown on the compression moulding time cycle above.



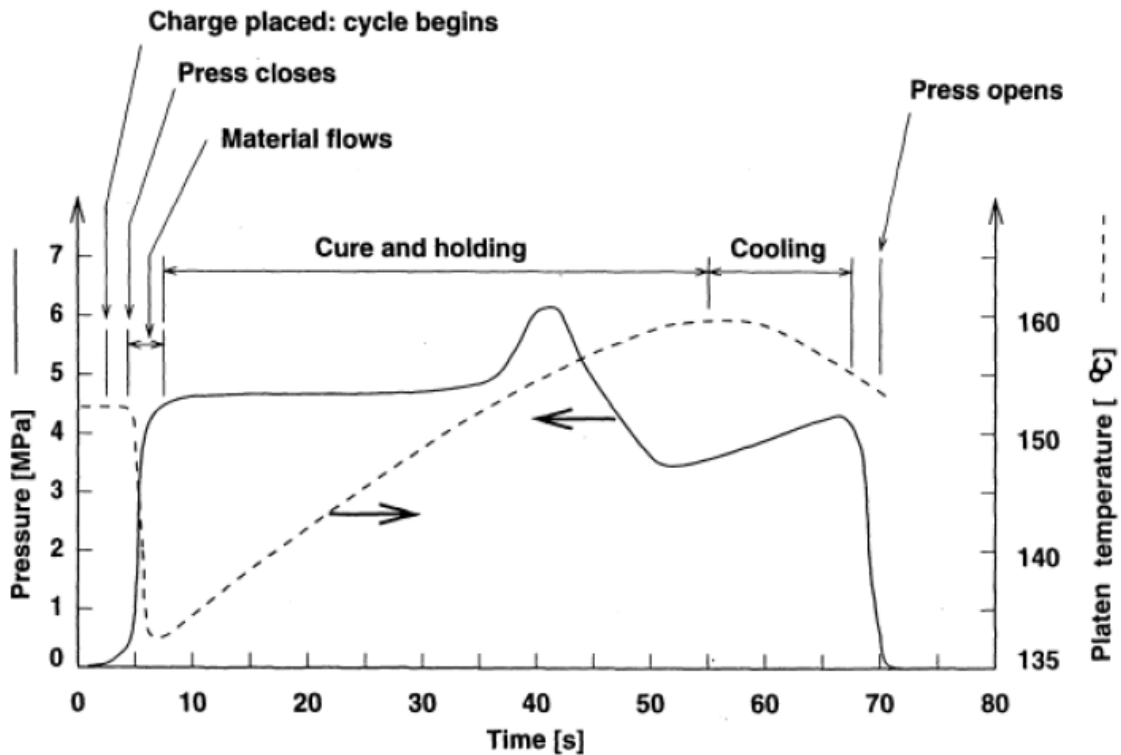


Table 3

|                             |   |
|-----------------------------|---|
| Cost of mould               | Approximately \$2,000 (1950);<br>\$15,000 (2005).   |
| Time taken to change moulds | 60 to 90 minutes to remove a set of moulds and as long to change and connect to plumbing.   |
| Production rate             | Single colour: On average 1, 850 per day per moulding machine. Six compression moulding machines could produce on average 11,000 chips per day. |
| Price per single chip       | \$0.94 (2006).  |

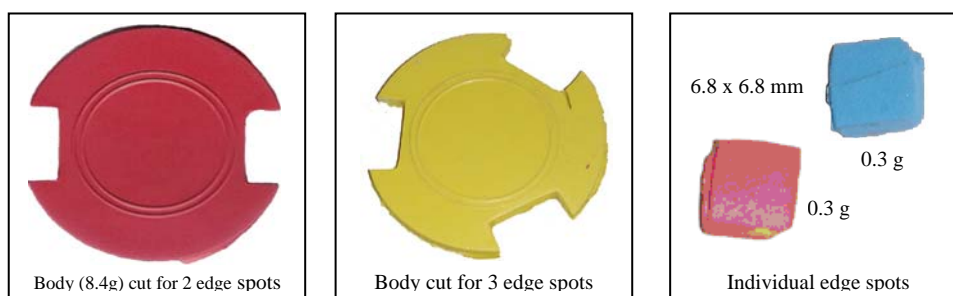
Chip construction: The original 'clay' chips were compression moulded and did not contain metallic cores.

### Edge Spots

The edge-spots are cut from the same material and used with materials of contrasting colours; the colour combination would depend on customer requirements. Assuming that a casino operator requires a yellow chip with three two-colour edge spots; different organic dyes are used to produce a range of colours.

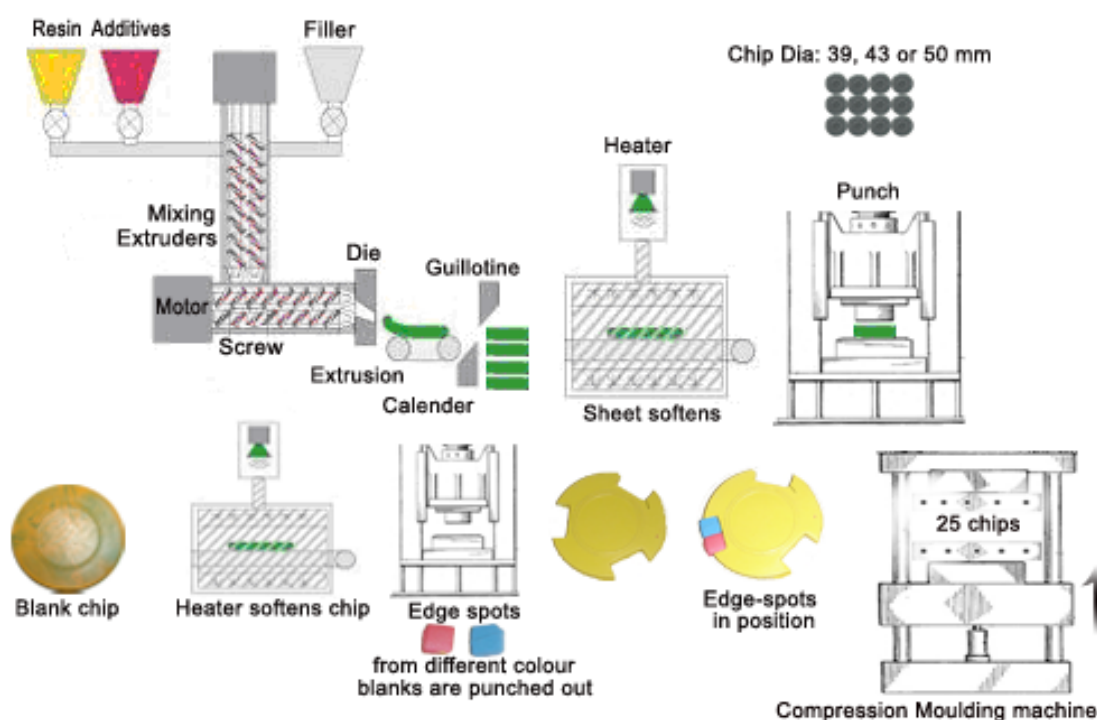
The body of the chip is heated up to avoid cracks and punched at low pressure e.g. 15 to 80 bars according to requirements. The gaps are filled with the edge inserts of contrasting colour to make up the desired colour combination and orientation.

The body and inserts are then put back into the mould, are compression moulded and fused during the moulding cycle thus becoming an integral part of the chip.



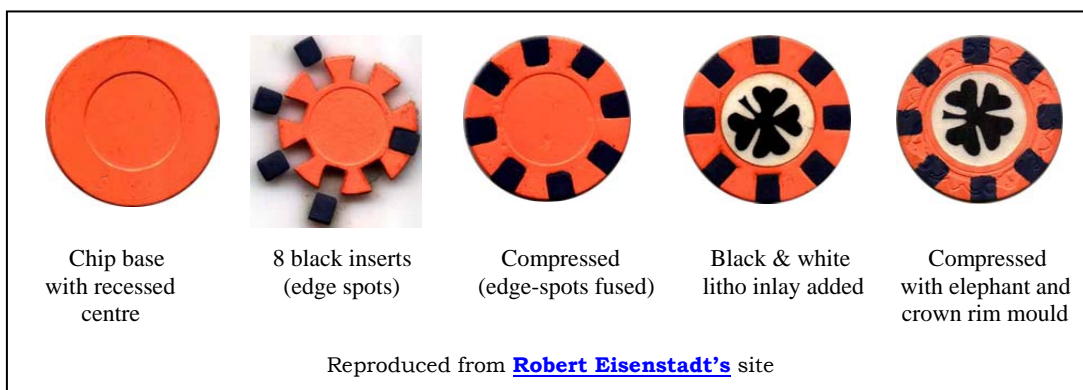
When the chips are removed from the moulds, their edges are rough; this is overcome by placing the chips on a v-shaped jig and scraping the edges with a hard brush or in some cases putting the stack of chips between the jaws of a lathe and turning them down to their final size.

The chips may now be embossed with a casino name and [denomination](#).



For the Crest & Seal type there is an additional process. This process involves the creation of a [cavity](#) at the centre of the chip and this is achieved by means of a centre insert that produces the required cavity depth for the decals which are then heat sealed into position.

Decals are normally 0.6 mm thick and are processed separately from the same type of material, using a similar method.



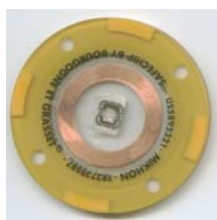
In 1975, chip manufacturer Christy & Jones Co. (the first company of Bud Jones, who still makes chips today) patented a chip with a metal inlay, usually of aluminum or brass, with the details stamped into them.

These chips, known as brass core, are made by a plastic injection mould over a metal core—collectors should note that [counterfeit](#) brass core chips have been discovered.



Other *Roulette Research* documents on Casino Chips

1. [History of the Casino Chip](#)
2. Counterfeiting Casino Chips;
3. [Chemical Analysis](#) of Casino Chips;
4. History of Casino Chip [Security](#);



5. The [Injection Moulding](#) process of Casino Chips.



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