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Historical Contribution

# THE HISTORY AND DEVELOPMENTS OF THE IMPACT TREATMENT PROCESSES

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## Industrial Summary

This paper presents a chronological account of the major steps in the development of impact treatment processes, from their inception prior to 1870 up to the present day, identifying the contributions of the many individuals concerned. The wide range of application of such processes is illustrated, as is the scale of application, and the place and importance of impact treatment processes in manufacturing industry is emphasised.

The observation of a natural phenomenon resulted in the foundation of a World Wide Industry: the observer was B.C. Tilghman, who appreciated the effect of sand blown by wind against glass windows covered by wire mesh screens, where the etching effect of the sand was pronounced by the unaffected glass which was protected by the wire of the screens. This was alleged to have been observed in the Arizona desert over 100 years ago. True or not, it was Tilghman whose imagination and foresight resulted in the birth of blast cleaning and its associated processes and to whom the credit must go.

In 1870 Tilghman filed his first patent [1] for ". . . cutting, grinding, etc. . . ." by blasting with steam (Fig. 1), water, and compressed air. This patent included methods of using direct pressure, suction (syphon system) and partial vacuum. In the same year Tilghman filed a patent [2] covering projection of abrasives by means of centrifugal force. He visualised the use of a wheel in which the abrasive was thrown by a "slider" action and by a "batter" technique (Fig. 2).

All the methods outlined by Tilghman were to be subsequently put to use. His first company was formed as B.C. & R.A. Tilghman of Philadelphia. Later he moved to England and formed Tilghmans Patent Sand Blast Company, operating in Sheffield. An early catalogue dated July 1890 listed machines for "sharpening and scouring files (Fig. 3); decorating, perforating, and frosting glass and pottery; cleaning metallic surfaces and incising ornaments on granite and marble". Also in this catalogue reference is made to Tilghman

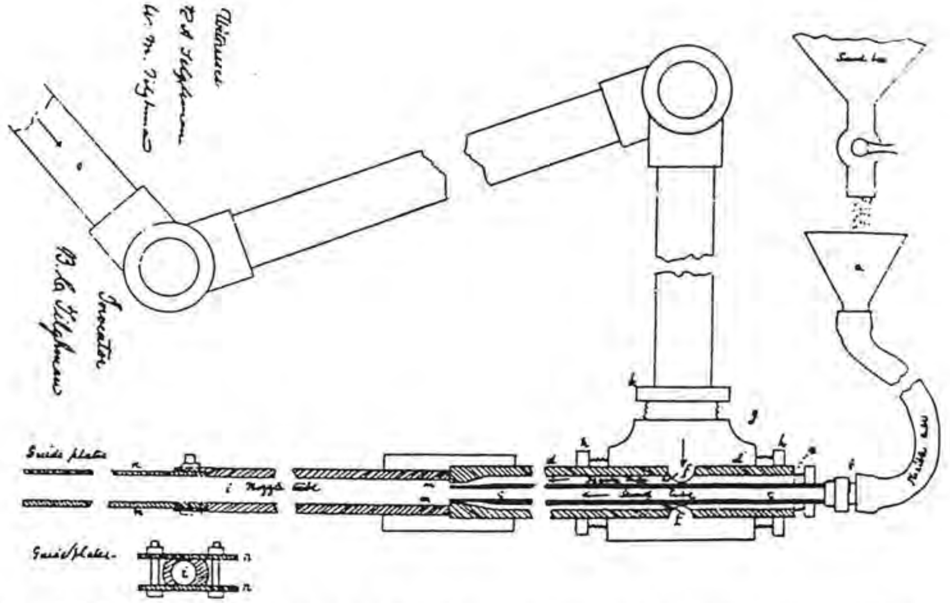

Fig. 1. Tilghman's first patent, for the projection of an abrasive by means of steam: 1870 (after ref. 1).

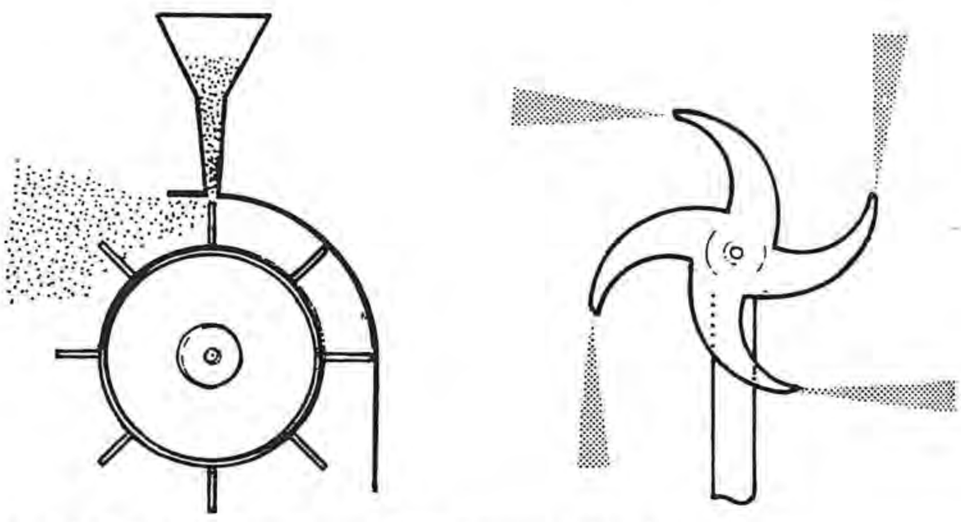

Fig. 2. The first blast wheels patented by Tilghman: 1970 (after ref. 2).

exhibiting his process in London in 1873. Mention is made also that "... in the United States, in 1875, 254,000 headstones in the National cemeteries were lettered by placing letters and figures of cast iron on to the stones and, by blasting away the surrounding area, the covered portions were left in relief ..."

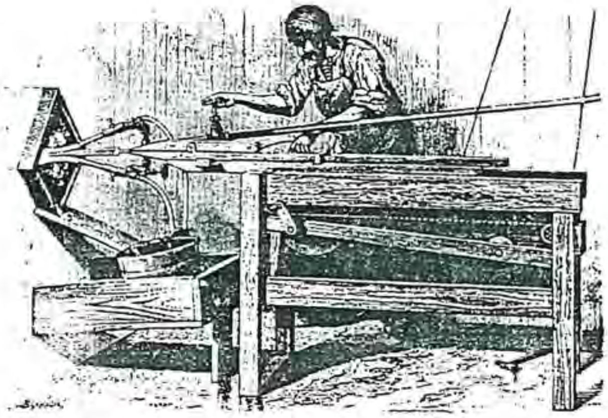

Fig. 3. File sharpening by means of sand projected by steam: 1879 (from La Nature, No. 297, February 8, 1879, p. 145).

In 1872 Tilghman filed a patent [3] for the manufacture of "Cast Iron Globules", by pouring the molten metal onto a revolving saucer shaped disc, projecting the metal in the form of drops which chilled and solidified in flight. The patent also states that Tilghman had used "grains made by cutting off short lengths of wire". Tilghman foresaw the use of chilled iron shot for use in the cutting of granite and marble when the cutting is considerably aided by feeding the shot into the teeth of the saw as the cut is made. This particular use of chilled iron shot constituted the principle demand of the next 50 years. It is, incidentally, still used for this purpose. Mention is made in this patent of ". . . Magnets used to help saving and separating of the iron shot from the mineral powder . . .".

Soon the Tilghman Company was to be joined by Mr. J.E. Mathewson, who by his skill and ingenuity added largely to the success of the company. Mathewsons first contribution was in 1877 for patented designs [4] of machines for "Operating upon the surface of Glass, Marble etc. by means of a blast of sand". The principle of his patent was in a machine using a partial vacuum to impel abrasive to etch the surface of plate glass. Mathewson realised the problems of exhausting sand-laden air by means of a fan and the ". . . considerable amount of power required . . ."; he therefore produced a design in which the air was to be moved by a mechanical vibrating motion. Mathewson also described a machine for drilling holes in glass. This machine was the basic design for units made for the old Weights and Measures Dept., for the Crown marking of glass tumblers. Very many were made and it is known that one such machine was in constant use for over 53 years. By 1893 Mathewson had established himself in the industry and his patent [5] for the design of a sand blast machine, based upon direct pressure, became the standard design for the next 50 years. Various modifications and improvements have been made, principally in moving the position of the mixing valve from the inside of the machine to the outside for easier maintenance.

The earliest recorded patent [6] for a blast wheel design for cleaning castings was registered by Hans Beeg in Germany in 1893. This was based upon a batter type wheel of both single- and dual-sided types and included a perforated working table with a recovery system for the sand.

A problem that has plagued industry for many years — that of descaling wire — was tackled by Mathewson in 1904. His patent [7] was based upon passing wire through the mixing chamber of a pressure vessel; the abrasive was accelerated along the wire to provide a scouring action.

One of the most important machines used today is known as the "Closed Circuit". It is interesting to note that in 1907 F.M. Wise filed a patent [8] with the same object of keeping the operation of blasting in an enclosed system. Before the success of the present day method other attempts were made, including a design for blasting ships decks*. In this case the surface of the deck became the back wall of the blast cabinet and the operator worked through arm holes as with a standard hand cabinet.

From this time onwards, very many inventions were patented, many of no great importance, but illustrating the activity in the industry. One invention of importance was that of Johnson [9] whose design of a rotary barrel is still in use today (Fig. 4). Johnson's design was for use with an air operation blast unit: modern machines are fitted with a blast wheel. One feature of interest is the door being hinged upon a side column, a feature employed only in recent years.

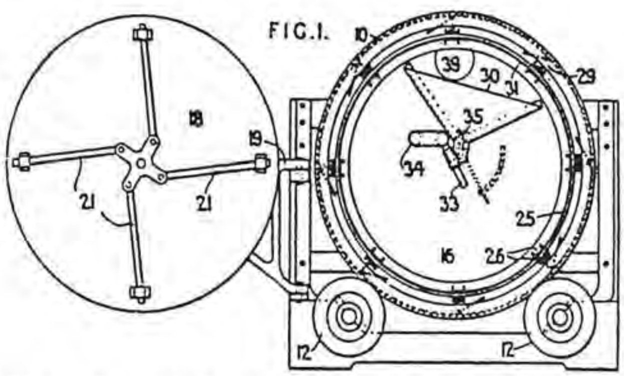


Fig. 4. The original rotary barrel patented by Johnson: 1909 (after ref. 9). Note the pillar-hung door.

Whilst Johnson's design was followed through the years, another interesting design was that of Ochs [10] where the barrel was cradled in an endless belt (Fig. 5). It was not the barrel which kept the interest of designers, but the method used of cradling the barrel. This was to form the basic element of the most popular of all blast machines — the reverse belt tumbling machine. In 1912 Bouillet [11] took out a patent for the blast cleaning of lithographic

*British Oxygen Company.

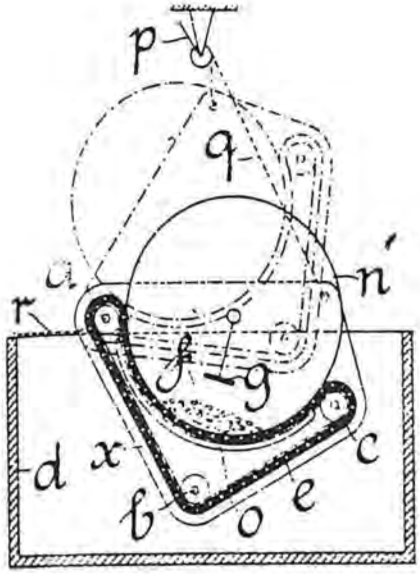


Fig. 5. Ochs' design of an endless reverse belt machine: 1911 (after ref. 10).

stones. This was a regularly recurring patent application and claims were made for the processing by both wet and dry blasting methods.

Activity was accelerated during the Great War and in 1916 Jackman filed a patent [12] for the interior blasting of artillery shells. A rotary indexing table was used upon which the inverted shells were placed. An air operated nozzle would blast the shell for a predetermined period before the next shell took its place.

About this time a book was issued by the United States Silica Company entitled "Little Journeys of The Flint Shot Man", in which the advantage of using flint shot was proclaimed. In this book the claim is made that "... Automobile bodies, whether made from steel or aluminium, not only hold the enamel better, but also present a much more uniform and beautiful appearance in the finished product ..." A statement no doubt which will be reiterated today. The argument against the use of "Steel Grits" was that it "... was apt to clog the nozzles ..." whilst flint shot is "... always ready to shoot ...". "... Steel grit, even though it might be obtained, would cost ten to forty times the price and would be doubtful economically ...".

In 1921, Wilson [13] wrote "... Coarse silver sand suitable for sandblasting, costs 30 shillings per ton on rail Leighton Buzzard. Chilled iron shot costs £25 per ton, delivered on rail Manchester, and crushed or cornered shot about 10% more, but as shot lasts 20 times as long as sand there appears little advantage in using sand ...". Wilson was no doubt correct in this but he did not highlight the logical reason for using metallic abrasive. This was brought to the fore by Merewether [14] whose work "The Risk of Silicosis in Sand Blasters" was of the utmost importance. The report was a shocking indictment of the industry and was most timely.

It may be coincidence, but about this time many technicians were deploying their minds to improved mechanical methods of throwing abrasive. This implies projecting the abrasive by means of a wheel. Very many attempts had already been made but none were entirely practical. One such wheel, designed by Peik [15], was basically correct in that the object was to throw the abrasive directionally.

It is to Minich [16] that the credit must go for achieving the practical operational design of blast wheel (Fig. 6). Minich obtained his success by gravity-feeding the abrasive into the core of the wheel, where it was picked up by a small impellor, connected, and related to the blades of the main wheel. By passing the abrasive through a slot in a stationary component the direction of the blast stream could be predetermined. This basic principle is now established practice throughout the industry.

In 1938, Keefer [17] designed an alternative wheel. Whilst the Minich wheel was arranged with two side plates, the Keefer wheel had a single side plate onto which the blades were fastened. This was the first real turning point in the blast cleaning process: a mechanical system that not only took the application away from a manual operation but also is probably 10 times as efficient, and opened up avenues hitherto unseen. Once the soundness of a directionally controlled wheel was established, designers turned their attention to the variables in the design of individual components: blades; control cages; impellors; all seeking to improve them, as a result of practical application.

It is interesting that whilst the Minich design became established from 1936 onwards, Wilson [18] had filed an invention in 1933 (though the complete specification was not accepted until 1940) for a blast wheel (Fig. 7). This was based upon the concept of the wheel acting as a fan, and as such being capable of aspirating the abrasive to the projection point of the blades. Wilson visualised the use of both curved blades and flat blades, and in addition blades of tubular form. Such blades could be inserted in the core of the wheel and held by a flange. He also foresaw the method of fastening blades by means of the spacer bar, a system which many manufacturers were to follow. Blount [19] also designed a blast wheel with tubular blades inserted through the core of the wheel.

It was about this time that Tirrel [20] filed patents for a wet blasting process which became widely known as the "Hydroblast". This found extensive use in foundries for removing cores of exceptional size, such as columns for vertical boring machines.

At this time Rosenberger published his valuable text book "Impact Cleaning" [21]. His coverage of all the various processes — both from the practical and theoretical angles — made a considerable contribution to the industry. As he stated, ". . . No individual can intelligently design, sell, purchase or use any mechanical device, without at least a fair fundamental knowledge of the principles involved . . .".

Wheel units continued to be modified, some with valuable improvements, April 20, 1937. V. E. MINICH 2,077,636

ABRASIVE THROWING MACHINE

Original Filed May 26, 1934 2 Sheets-Sheet 1

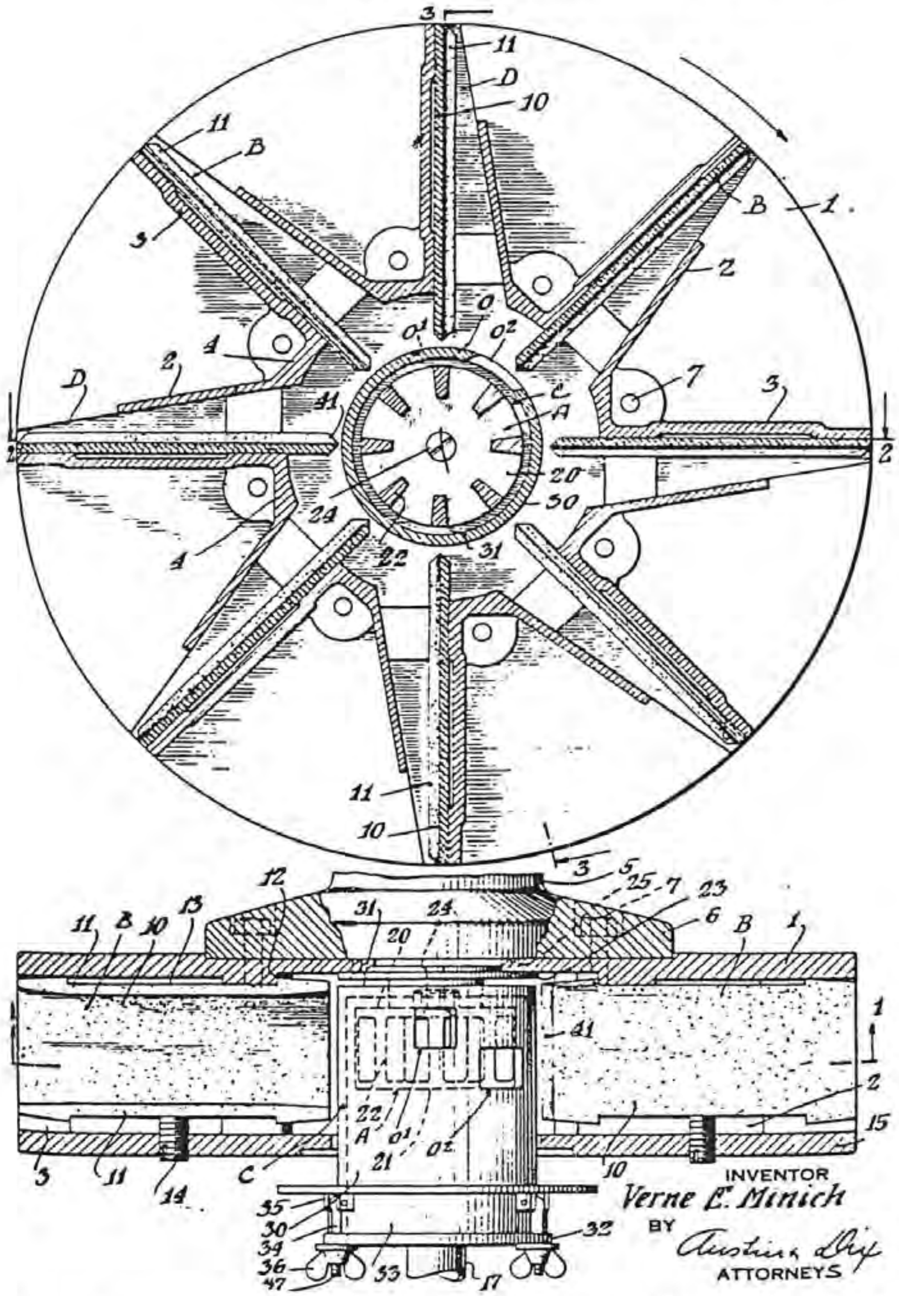


Fig. 6. The earliest directionally controlled blast wheel designed by Minich: 1933 (after ref. 16).

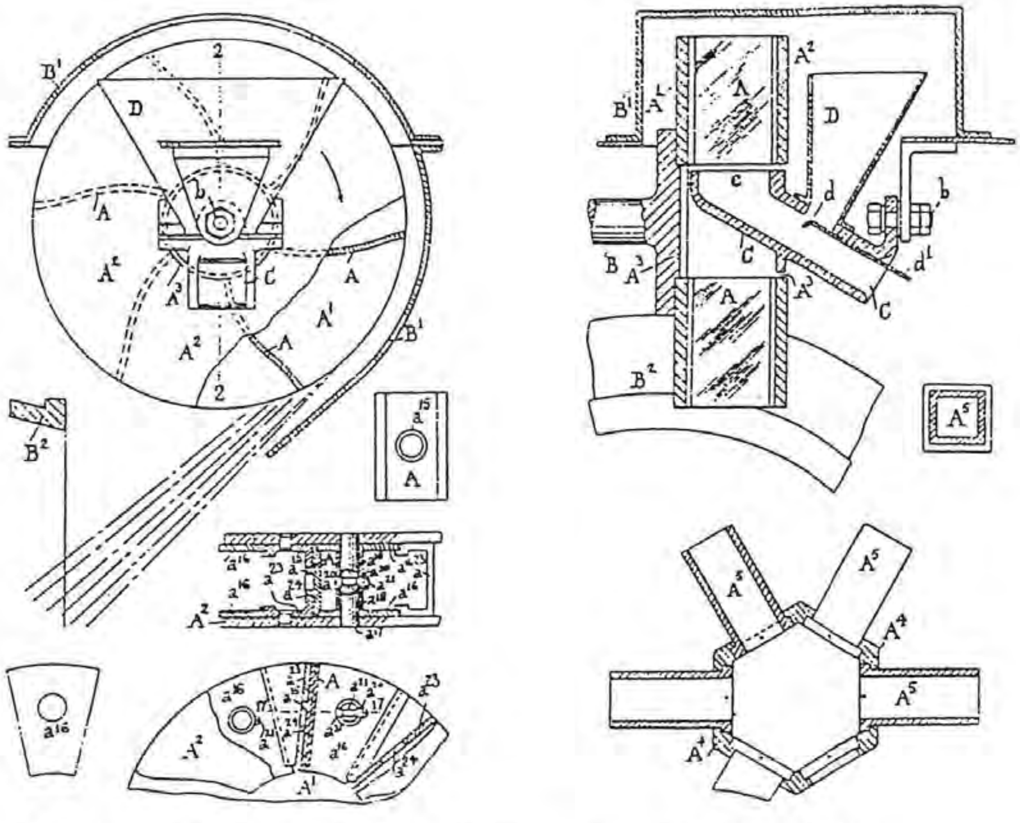

Fig. 7. An early variation of wheel design by Wilson: 1940 (after ref. 18).

but side by side with the progress in machine design. The development of Ochs' [10] design of the reverse belt machine fitted with the improved blast wheel was most notable: with the mill size made as small as 1½ cubic feet (0. m$^3$) and as large as 100 cubic feet (2.83 m$^3$) and with mechanical loading this became the "workhorse" of the foundry industry. From then on, particularly over the next ten years, there was an eager persuit to design a perfect blast wheel. Bladeless types were a particular aim, and even wheels of complex "batter" type were considered. Variations of the "slider" design wheel seeme to hold sway over all others and ultimately became the standard.

Blast machines are fundamentally the combination of an abrasive throwing device and a mechanical handling system. In respect of the latter, rotary tabl machines were designed as early as 1916; flat belt conveyor machines were designed mainly for the vitreous enamelling industry; mono-rail machines provided more flexibility; roller conveyor machines were designed for the structural steel trade and diabolo roller conveyors for tubes and drums. Thes and many others became established designs.

The growth of the process over the early years was fitful: mainly it was looked upon as a useful cleaning method. However, Herbert [22] published a work in 1927 on the hardening of steel by abrasion. He had designed a method which he named the "Cloudburst" which resulted from his crude but effective experiments, yet he had failed to recognise the true importance of his work in increasing fatigue resistance. In the early 1930s, manufacturers of leaf springs discovered that there was an improvement in the life quality of the springs when they had been cleaned by grit blasting. Many researchers — Foppl [23], Frye and Kehl [24], Weigand [25] and others — proved the effectiveness of shot-peening, but manufacturers were content with their grit blasting methods. It proved difficult to convince them that shot was preferable, especially as they knew the problems of using chilled iron shot, which broke down so readily. To these named in early connection with shot peening must be added Almen [26] whose influential work included the introduction of the "Almen Gauge System", so valuable to the shot-peening process.

The War years raised inevitably more problems in the impact treatment areas of production: the introduction of the jet engine, for example. Precision production required precision finishing, hence the introduction of the process of Vapour Blasting or Liquid Honing into this field. For example, the linishing and polishing of a jet-turbine air compressor unit could take up to 220 hours, but by the introduction of Vapour Blasting this was reduced to 22 hours. Ashworth [27] did a great deal to improve the design and methods of this process.

Again connected with the aircraft industry was the problem of aeroplane structural stability. Modern ultra high speeds imposed such phenomenal strain that new methods of construction were essential to replace the skeleton and skin method by a new technique. Borger [28] filed a patent of a design to achieve cold forming by the use of blast nozzles: it will be seen in Fig. 8 how the result is achieved. Carle [29] produced similar results by using blast wheels. In 1960 Fuchs [30] introduced a gantry type peen-forming machine wherein the workpiece remained stationary at an inclined angle and the nozzles reciprocated as the unit moved laterally.

In 1945 Mead [31] updated the concept of Wise [8] to produce a machine that could be used for blast cleaning without the need for a blast chamber and with the operator requiring no special clothing. This was patented in 1949 and could be classed as a revolutionary step. Made in various sizes, the machines are able to be operated in hitherto unacceptable places.

Possibly the most important introduction into blast cleaning was that of steel shot. Introduced in the 1950s, it was instrumental in reducing the costs of the process. The life of steel shot is many times that of chilled iron: maintenance costs are reduced, and the extra cost of the medium has been found well justified since its introduction. In the cases of shot-peening and peen-forming, both processes have reached a standard hitherto impossible with other media. Steel shot had, because of the lower operational cost, an immediate influence upon the industry. Ships plying in the most corrosive environment could be now constructed from blast-cleaned plates. New methods of construction were introduced and in some cases sub-assemblies were blast cleaned by machines using 32 blast wheels.

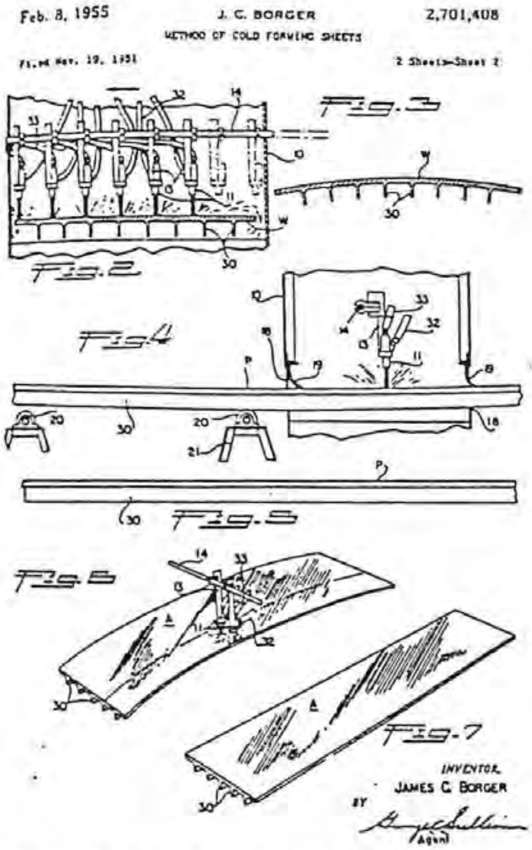


Fig. 8. Modern peen-forming machine by Borger: 1955 (after ref. 28).

In the post-war years, Ballotine (glass beads) [32] made an appearance in the blast cleaning field: this was an additional outlet for a medium which was produced originally to aid the reflectivity of night signs. Glass beads have had a considerable impact in shot peening, particularly in the aircraft industry.

One of the problems in the production of plastic or rubber articles is the removal of "flash" or "sprue". As an example, the removal of "flash" from "O" rings is a time consuming and tedius operation performed by hand by the use of scissors. In 1959 a patent [33] was issued for a method in which the blast machine is housed in a refrigerator and the flash removed from frozen rubber.

By now there became a conscious awareness of the need for standards of surface preparation. In 1963, the Swedish Standard [34] — a photographic comparison — was produced to judge or assess surface conditions. Whilst this standard is now used universally it is by no means a complete answer to the problem, but it had led the way to better standards.

There is always a continual search for higher efficiency. When blast wheels were introduced there was an immediate appreciation of their value. Unger [35] visualised the operation of such a wheel by direct manual control: this was a very early conception, much ahead of its time. Weight and torque are the problems and over the years designers increasingly controlled the movements of blast wheels, as the problems demanded. Perhaps the initial credit should go to Garforth [see 36] who designed the machine for blasting sections of the Forth Road Bridge wherein the wheels were panel mounted, raised and lowered mechanically, and balanced by water tanks. Following this, Oddie [37] introduced a remotely controlled wheel unit especially to deal with the problems related to structural steel. A patent [38] for pivoting blast wheels through a desired angle on a rotatable platform was introduced to aid the treatment of steel strip. More recent is the introduction by Carpenter [39] of an almost infinitely variably controlled wheel so that it may be remotely controlled to blast in almost any direction; this may lend itself to many uses, for example, shot peening in the aerospace industry [40]. Now development has reached the point where the control may be completely taken out of the hands of the operator using such advanced technology as computer-diagnostics [41].

The introduction of a new expendable abrasive in the form of a crushed copper slag was welcomed by the practitioners of "site blasting" [42]. To replace silica sand with a far less hazardous medium was a valuable step, but "site work" is a difficult operation with all the attendant problems, and efforts have been made to mechanise the operation whenever possible. Such a machine was introduced in 1968 [43], where rotary blast nozzles were housed in a sealed chamber that could be clamped to the side of a ships hull or gas holder. Later, a more elaborate design was made in which the operation was carried out by blast wheels [44] under the control of an operator seated adjacently, who could watch and control the whole operation in comparative comfort. In both cases, the machines used metallic abrasives which have the advantage of being much cleaner than crushed slag, and have an extended life.

The foregoing does not overlook the progress made in other complementary fields nor the refinements almost constantly being introduced: for instance, the more extensive use of high-pressure water cleaning in the area of site work, or the introduction of zinc-coated iron grit — involving complex machine design [45] — in which the object is the dual operation of blast cleaning and provision of a temporary protection in the same operation. There is also the field — not commonly known and appreciated — of the "etching" of fine plastic film, which latter has many uses, including sheet for drawing offices [46] (Fig. 9). This film — which measures 3 mils (0.003″ = 0.0762 mm) in thickness — is a tribute to the designers of the processing machine and serves to illustrate the extensive field of impact treatments.

Little has been said so far of the scale of the applications of impact treatments. It would be impossible to evaluate the enormous tonnage of iron and steel castings that have been blast cleaned over the last 100 years. Such an operation has little appeal when compared, for example, with whole railway coaches being prepared for painting by blast cleaning. There is more romance — if such a word may be used in this industry — in the blast cleaning of bridges, for example the Forth Bridge [47] and the Severn Bridge: both are

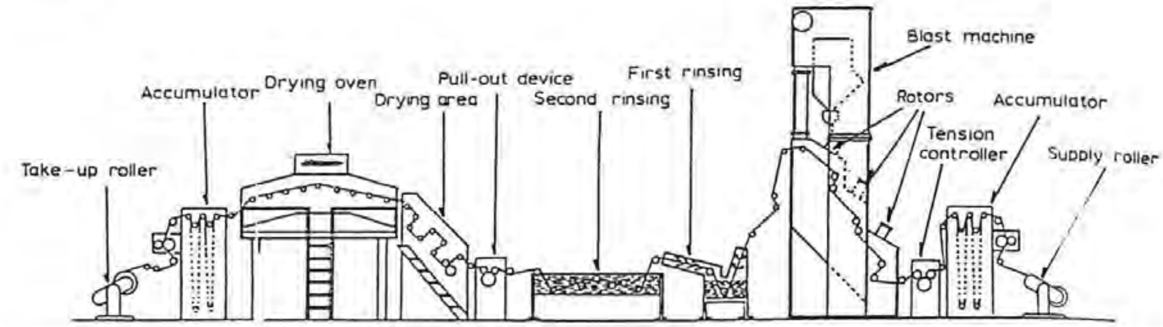


Fig. 9. In-line production system for producing etched or grained plastic film (after ref. 46).

landmarks with which to assess the value of the process. It is estimated that in the early 1950s 200,000 tons of structural steelwork was grit blasted [48] prior to the application of an anti-corrosion system. This work was carried out for new steelworks at Margam, Trostre, and Velindre in South Wales. Today it is common practice to construct ships from steel plate pre-cleaned before fabrication, and almost every shipyard has modern blast equipment capable of handling the largest and heaviest plate. Perhaps the most ubiquitous object is that of the low pressure gas cylinder used in the home, field and industry: there are estimated to be in excess of 20 million of these cylinders in use. Blast cleaning of new cylinders is part of a long term protection system [49] as well as a reconditioning system, a practice well established in most countries. These are but a few of what may be many hundreds of applications, some mundane, many interesting, and quite a large proportion critical and essential.

This is but a brief resume of an absorbing and versatile industry, that had a conspicuous beginning — due to a man of exceptional vision — a fitful growth, and now has an established position in almost every essential industry. Much effort has been due, in addition to those named in the text, to L.D. Peik, D.E. Turnbull, R. Maeda, C.E. Unger, H. Boardman, E.J. Hill, J.S. Straub, Werner Lawry, and R.S. Thomson. To these and many others unnamed, the industry is indebted.

## Acknowledgements

Illustration by courtesy of: Fig. 3 — La Nature, France; Fig. 9 — Sampoh Co. Limited, Japan.

## References

1 B.C. Tilghman, U.S. Patent No. 108,408, October 18, 1870.
2 B.C. Tilghman, U,K. Patent No. 2,900, November 3, 1870.
3 B.C. Tilghman, U.K. Patent No. 3,626, December 2, 1872.
4 J.E. Mathewson, U.K. Patent No. 1,584, April 23, 1877.
5 J.E. Mathewson, U.K. Patent No. 12,306, January 13, 1894.
6 H. Beeg, German Patent No. 71,824, January 7, 1893.
7 J.E. Mathewson, U.K. Patent No. 17,591, August 12, 1904.

8 F.M. Wise, U.K. Patent No. 4,239, February 20, 1907.
9 J.Y. Johnson, U.K. Patent No. 25,134, November 1, 1909.
10 K. Ochs, U.K. Patent No. 4,724, February 11, 1911.
11 J. Bouillet, U.K. Patent No. 24,498, January 12, 1912.
12 J.W. Jackman Co., U.K. Patent No. 109,147, November 3, 1916.
13 F.W. Wilson, Cleaning and dressing castings, Proc. The Manchester Association of Engineers, 28th February 1921, p.308.
14 E.R.A. Merewether, The risk of silicosis in sand blasters, Tubercle, (June 1936) 385–391.
15 L.D. Peik, The Wein Engineering Co., Warren, Ohio, U.S. Patent No. 1,953,566, April 3, 1934.
16 V.E. Minich, American Foundry and Equipment Co., U.S. Patent No. 2,049,466, July 5, 1930.
17 W.L. Keefer, Pangborn Corp., U.S. Patent No. 2,108,006, February 8, 1938.
18 F.W. Wilson, St. George's Engineering, U.K. Patent No. 518,803, March 7, 1940.
19 H.T. Blount, Mills Alloys Inc., U.S. Patent No. 2,301,508, November 10, 1942.
20 W.L. Tirrel, The Hydroblast, U.S. Patent No. 2,176,577, October 17, 1939.
21 W.A. Rosenberger, Impact Cleaning, The Penton Publishing Co., Cleveland, 1939.
22 E.G. Herbert, The work hardening of steel by abrasion, J. Iron Steel Inst., 116 (1927) 265–282.
23 O. Foppl, Compression of the surface of steel machine parts, Stahl & Eisen, 49 (1929) 575–577.
24 J.H. Frye and G.L. Kehl, Fatigue resistance of steels as affected by some cleaning methods, American Society of Metals, 26 (1938) 192.
25 H. Weigand, Effect of Surface Treatment on Fatigue Strength, B.M.W. Flumotorenbau, 1940.
26 J. Almen, Peened surfaces improve endurance of machine parts, Metal Progr., 270 (February 1943) 209–215.
27 N.I. Ashworth, U.K. Patent No. 658,270, October 3, 1951.
28 F.C. Borger, Lockheed Aircraft Corp., U.S. Patent No. 2,071,498, February 8, 1955.
29 J. Carle, Tilghmans Limited, U.K. Patent No. 857,027, December 29, 1960.
30 H.O. Fuchs, Metal Improvement Equipment Co., U.S. Patent No. 2,933,802, April 26, 1960.
31 W.H. Mead, U.K. Patent No. 617,161, February 2, 1945.
32 H.J. Plaster, Blast Cleaning and Allied Processes, Vol. 1, Industrial Newspapers Ltd., Redhill, Surrey, pp. 179–180.
33 R.M. Lilieart, Wheelabrator Corporation, U.S. Patent No. 2,996,846, August 14, 1959.
34 Swedish I.V.A. Corrosion Committee of the Swedish Standard Association, Stockholm, 1963.
35 C.E. Unger, American Foundry and Equipment Co., U.S. Patent No. 2,263,321, November 18, 1941.
36 H.J. Plaster, Blast Cleaning and Allied Processes, Vol. 11, Industrial Newspapers Ltd., Redhill, Surrey, p. 83.
37 W.M. Oddie, Spencer & Halstead Ltd., U.K. Patent No. 1,067,451, May 3, 1967.
38 George Fischer A.G., U.K. Patent No. 893,324, April 4, 1962.
39 J.H. Carpenter, The Carborundum Co., U.S. Patent No. 3,521,406, July 21, 1970.
40 D.L. Baughman, The evolution of centrifugal wheel shot peening in the aeroplane industry and recent applications, in: A. Niku-Lari (Ed.), Proc. First International Conference on Shot Peening, Paris, Sept. 1981, Pergamon, Oxford, 1981, pp. 101–108.
41 R.M. Lelieart, The application of computer-diagnostics to high production shot peening systems, Ibid., pp. 95–100.
42 P.J. Wharton, Historical development of blast-cleaning, in: Conf. Economics of Blast Cleaning, Manchester, U.K., Sept. 8, 1982.
43 M.A. Cardon, Vacu Blast Ltd., U.K. Patent No. 1,102,688, December 7, 1968.

44 D.R. Neeld, J.W. Fogle and J.R. Goff, Airless blast cleaning of ships hulls, The Wheelabrator Corporation, March 7, 1969.
45 Sampoh Co., Tokyo, Patented process.
46 Sampoh Co., Tokyo, Patented process.
47 W.R. Ballard, Metal Spraying and the Flame Deposition of Ceramics and Plastics, Charles Griffin & Co., London, 1963, pp. 475—476.
48 Corrosion under Control, 1962, 16 mm Film (25 min, sound) available from: Spencer & Halstead Ltd., Ossett Yorks; Charles Clifford Co., Birmingham; Metallisation Ltd., Dudley, West Midlands.
49 S.A. Meguid and H.J. Plaster, Comments on the energy and materials conservation aspects of impact treatment, J. Mech. Work. Tech., 6 (1982) 139—149.