INTERNATIONAL THERMAL SPRAY ASSOCIATION

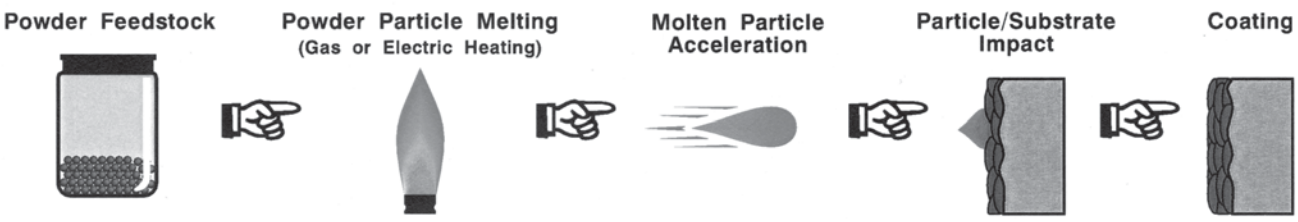
*Bringing Technology and Technique Together*

***Mission:*** *To strengthen the level of awareness in general industry and government on the increasing capabilities and advantages of thermal spray technology for surface engineering through business opportunities, technical support, and a social network that contributes to the growth and education of the thermal spray industry.*

# What is Thermal Spray ?

***thermal spraying***, a group of coating processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semimolten condition to form a coating. The coating material may be in the form of powder, ceramic-rod, wire, or molten materials. (1)

## Thermal Spray Coating Process




**Graphic courtesy of Westaim Ambeon**



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## THERMAL SPRAYING:
## *What it Was and What it Has Become*

**by Frank J. Hermanek**

On the eve of celebrating the one hundred anniversary of its discovery, thermal spraying looks back to its roots - early experiments in which liquids were broken up into fine particles by a stream of high-pressure gas. Efforts more directed at producing powders rather than constructing coatings. It fell to one Dr. Max Ulrick Schoop of Zurich who recognized the possibility that a stream of molten particles impinging upon themselves could create a coating. His work, and that of his collaborators, resulted in the establishment of the thermal spray process. This process has fostered a worldwide industry serving over thirty technology sectors and generating sales of over two billion dollars per year. This article traces the history and development of the principal flame and electrical thermal spray processes.

***thermal spraying****, a group of coating processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semimolten condition to form a coating. The coating material may be in the form of powder, ceramic-rod, wire, or molten materials.*[1]

In the early 1900s Dr. M. U. Schoop and his associates developed equipment and techniques for producing coatings using molten and powder metals. Several years later, in about 1912, their efforts produced the first instrument for the spraying of solid metal in wire form. This simple device was based on the principle that if a wire rod were fed into an intense, concentrated flame, (the burning of a fuel gas with oxygen), it would melt and, if the flame were surrounded by a stream of compressed gas, the molten metal would become atomized and readily propelled onto a surface to create a coating. This process was initially referred to as metallizing. Currently the technique is known as oxy-fuel or flame spraying. Other oxy-fuel methods include wire, powder (metallic and ceramic), molten metal, ceramic-rod, detonation and high velocity oxy-fuel (HVOF).

In addition to using chemical means to plasticize the input consumables electrical currents are also used. Typically, electrical energy is used to create a heat source into which powder, and more recently wires, are fed, melted/plasticized and conveyed onto the surface to be coated. Major, commercially employed electrical methods, used to construct coatings include non-transferred arc plasma, RF plasma, and wire arc. Based upon the two (2) heat sources a "family tree" of thermal spray methods can be constructed, Figure 1.

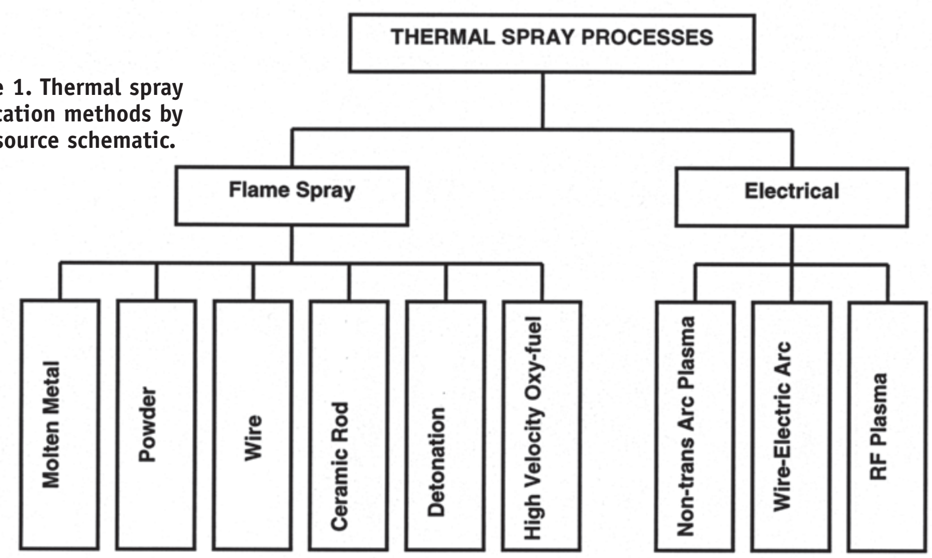



**Figure 1. Thermal spray application methods by heat source schematic.**

## THERMAL SPRAY METHODS

### Molten Metal FlameSpray

***molten metal flame spraying****, a thermal spraying process variation in which the metallic material to be sprayed is in the molten condition*[1]

It has long been recognized that fluids may be broken up into very fine particles by a stream of high velocity gas emanating from a nozzle. Early experiments using this atomizing approach appear to have been directed at producing metallic powders rather than coatings. It was left to Schoop to appreciate the possibility that a stream of metallic particles, formed from a molten source, could produce a coating. Myth has it that Schoop developed the concept when playing "soldiers" with his son and observing the deformation of lead pellets being fired from a toy cannon against a brick wall. Whatever the rationale, it can be stated that the pioneer work of Schoop resulted in the discovery and development of metal spraying and subsequently the "Thermal Spray Process".

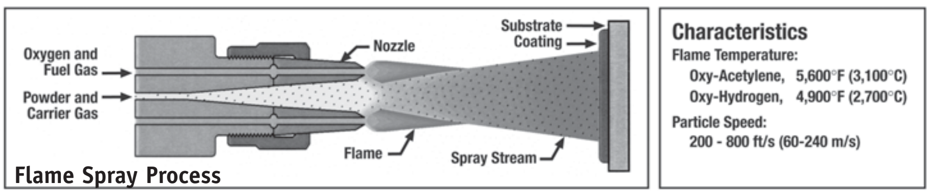
The first spray technique developed by Schoop was the outcome of experiments in which molten metal was poured into a stream of high velocity gases. Schoop's apparatus consisted of a compressor supplying air to a heated helical tube. The heated air was used to pressurize a crucible filled with molten metal and eject it out as a fine spray that would adhere to a suitable surface. This system was bulky, primitive and inefficient; however, the concept did lead to the development of portable and user friendly equipment. There are no further accounts of molten metal spraying by Schoop, it appears that his efforts were directed at developing and improving powder and wire flame spraying. However, work by others continued as a 1924 Dutch patent, describing equipment for spraying low melting point metals, was granted to Jung and Versteeg[2]. Mellowes Ltd commercialized the process in the UK. Their system consisted of a gun, a furnace, an air compressor and a fuel supply. The gun had many air and gas valves, a heating chamber (burner), nozzle, handle and a melting pot. The pot was bulky having the ability to store 1.8 kg (4 lb) of molten lead. The pot sat atop the heating chamber, which was similar in construction to a Bunsen burner. Compressed air, fed to the burner, intensified the flame. The handle jutted out and downward from the pot; it was insulated using wood and asbestos. Metal exited the pot through a front orifice where it was directed into a nozzle. Compressed air surrounded the nozzle, atomizing the molten metal and propelling it to the surface to be coated.

The molten metal process has advantages and disadvantages. Advantages include: cheap raw materials; use of inexpensive gases; and, gun design is very basic. Noteworthy disadvantages are: gun is cumbersome to use in the manual mode, can only be held in a horizontal plane; high maintenance due to high temperature oxidation and molten metal corrosion; and, useful only with low melting temperature metals.

Uses for the molten metal thermal spray process include the fabrication of molds, masks and forms for the plastics industry, using low melting point bismuth based alloys (the Cerro family of alloys); the deposition of solder alloys to joints that would be coalesced using torches or ovens; and, the production of metal powders.

## Powder Flame Spraying

***powder flame spraying****, a thermal spray process in which the material to be sprayed is in powder form.*[1]




Powder flame spraying is probably the simplest of all the spray processes to describe - feed a powder through the center bore of a nozzle where it melts and is carried by the escaping oxy-fuel gases to the work piece. Unfortunately, this approach yields coatings high in oxides and with void contents approaching 20 volume percent (v/o). However, coating quality can be improved by feeding air to the nozzle through a small jet, which reduces the pressure in a chamber behind the nozzle. This chamber is connected to the powder feed hopper. In this way a gentle stream of gas is sucked into the gun and carries powder with it. A typical gun is illustrated in Figure 2.

This concept was developed by Fritz Schori[2] in the early 1930s. However, the amount of powder that can be supported by a gas stream depends on many factors including powder characteristics. If air is not used then the density of the supporting gas influences the feed rate and, for any particular powder there is an optimum amount that can be carried in a gaseous stream. It depends upon the velocity and volume of the gases used. The usefulness and criticality of flowmeters and pressure gauges are governing factors.

## Wire Flame Spraying

***wire flame spraying****, spray process in which the feed stock is in wire or rod form.*[1]

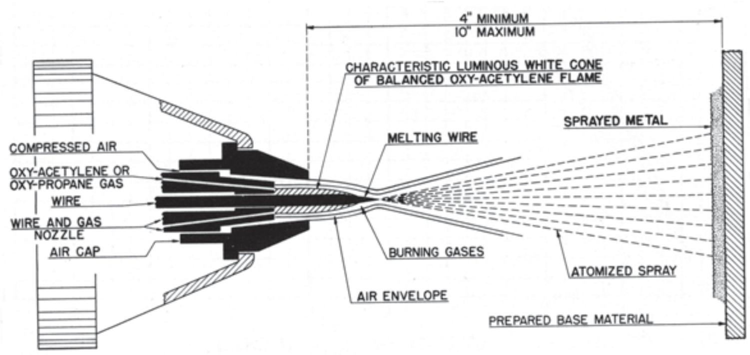



**Figure 3. Wire flame-spray. (Graphic from *Flame Spray Handbook*, Vol. 1 Wire Process, "Wire Nozzle and Air Cap Cross Section - METCO Metallizing Gun.", page A-64, copyright 1969 located in International Thermal Spray Association Historical Collection.)**

In about 1912 Schoop developed the first device for spraying metal wires. The apparatus consisted of a nozzle in which a fuel, probably acetylene or hydrogen, was mixed with oxygen and burned at the nozzle's face[3]. A stream of compressed air surrounding the flame atomized and propelled the liquefied metal. Process continuation depended on feeding the wire at a controllable rate so it melted and was propelled in a continuous stream. Schoop approached this problem by using a turbine to actuated gears and drive rolls that pulled the wire into the nozzle. This apparatus appeared to him to be similar to a pistol or gun, and because of this, he and we, refer to thermal spray devices as "guns" or "pistols" and never "torches". A typical wire spray gun is shown in Figure 3. Schoop' concepts of spraying solid metals has given rise to the thermal spray industry and for this reason it is sometimes referred to as the "Schoop Process". Regardless, the wire flame spray gun has not radically changed since the days of Schoop. While there have been changes in nozzle and air cap design, replacement of the air turbine with an electrical motor and even the use of barrel valves the basic principal, however, remains the same "push or pull a wire into a flame, melt and atomize it and deposit the molten droplets to form an adherent coating".

## Ceramic Rod Flame Spraying

***ceramic rod flame spraying****, a spraying process in which material to be sprayed is in ceramic rod form.*[1]

The spraying of ceramic rods dates back to the early 1950s when a demand arose for heat resistant refractory coatings. Plasma had not come into its own and flame sprayed powder

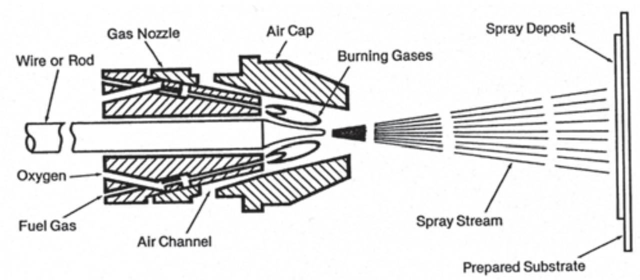



**Figure 4. Ceramic Rod, flame spray gun - schematic.**

coatings, due to their porous nature, lacked the integrity and protection required. The solution was rather simple - Coors Ceramic and Norton developed ceramic rods, referred to as Rokide, while the Metallizing Engineering Company (Mogul), modified a wire gun to spray rods. What differentiated the guns were the drive rolls. A wire gun had serrated steel rolls to grip and feed the wire while the Rokide gun employed "V" slotted fiber rolls that pinched the rods and fed them forward. The principle of operation in either gun is similar - the nozzle's flame is concentric to the wire or rod in order to maximize uniform heating. A coaxial sheath of compressed gas around the flame atomizes the molten material and accelerates it to the workpiece, Figure 4. Particle velocities in both the wire and rod process are approximately the same - 185 m/sec (600 ft/sec) while coating densities have been measured at approximately 95 v/o.

Ceramic rods are 61 cm (24 in.) in length and offered in three diameters 1/8, 3/16 and 1/4 in. Compositions include several stabilized zirconias, white and gray alumina, and a spinel.

## Detonation Flame Spraying

***detonation flame spraying****,a thermal spray process variation in which the controlled explosion of a mixture of fuel gas, oxygen and powdered coating material is utilized to melt and propel the material to the workpiece.*[1]

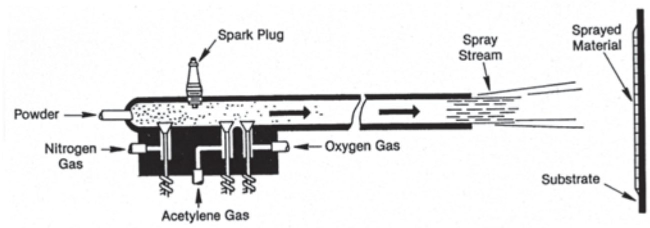



**Figure 5. Cross-section view of a detonation gun schematic.**

In the early 1950s Gfeller and Baiker[2], employees of Union Carbide Corporation, Linde Division, developed concepts of using explosions in a unique manner. Their concept was to introduce powdered materials into detonation or shock waves. The "waves" are produced by igniting a mixture of acetylene and oxygen into the detonation chamber which is opened to a one meter long tube two and one-half centimeters in diameter, Figure 5.

The system is complex. In operation, a mixture of spray material, acetylene and oxygen is injected into the detonation chamber. Combustion gases can be neutral, reducing or oxidizing and can have their temperature controlled by the addition of an inert gas, for cooling, or hydrogen to heat it. The procedure is initiated by a gas/powder metering system that measures and delivers the mixture to the chamber where it is ignited. The resulting shock wave accelerates the powder particles to over 731 m/sec (2,400 ft/sec) and produces temperatures in excess of 4,000°C (7,232°F). Pressures from the detonation close the controlling valves until the chamber pressure is equalized. When this occurs the cycle may be repeated either 4 or 8 times per second. There is a nitrogen purge between cycles. Each detonation deposits a dense and adherent layer several microns thick and about 2.54 centimeters (1in) in diameter. Repeating the cycle produces thicker coatings. Detonation coatings are designed for applying hard materials, especially carbides, on surfaces subject to aggressive wear. The Linde Division, Union Carbide Corporation (now Praxair Surface Technologies), referred to the process as "Flame Plating", this is no longer used. The term “D-gun” is currently used by Praxair Surface Technologies for this proces. Also, the equipment generates noise in excess of 150 dBA and must be acoustically housed confining noise emissions.

## High Velocity Oxy/Fuel Spraying (HVOF)

***high velocity oxy/fuel spraying (HVOF)****, a high velocity flame spray process*[1]

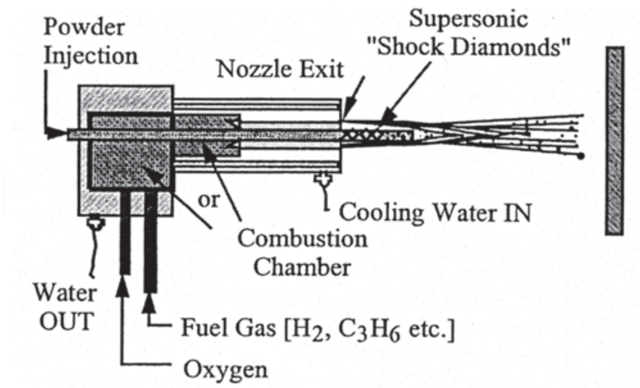
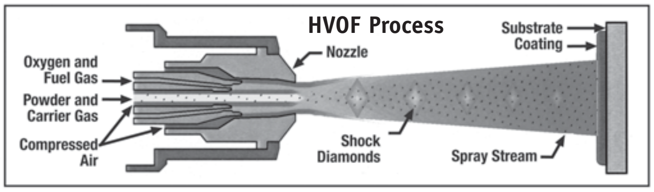



**Figure 6. HVOF combustion spray.**
**(graphic courtesy of Deloro Stellite Company, Inc.)**

In the early 1980s Browning and Witfield, using rocket engine technologies, introduced a unique method of spraying metal powders. The technique was referred to as High Velocity Oxy-Fuel (HVOF). The process utilizes a combination of oxygen with various fuel gases including hydrogen, propane, propylene, hydrogen and even kerosene. In the combustion chamber, burning by-products are expanded and expelled outward through an orifice where at very high velocities. Oft times they produce "shock diamonds" exiting the spray gun, Figure 6.

Powders to be sprayed via HVOF are injected axially into the expanding hot gases where they are propelled forward, heated and accelerated onto a surface to form a coating.




**Characteristics**
Flame Temperature:
Approximately 5,000°F (2,760°C)
Fuel Gases:
Propylene or Propane or Hydrogen
Particle Speed:
Up to 4,500 ft/s (1,400 m/s)

Gas velocities exceeding Mach 1 have been reported with temperatures approaching 2,300°C (4,172°F). The coupling of inertially driven/highly plasticized particles can achieve coatings approaching that of theoretical density. Disadvantages include low deposition rates and in-flight the oxidation of particles. Future efforts will focus on applying thick coatings and improvements in processes control including in-flight transit time and exposure to atmospheric oxygen.

## Cold Spray

***cold spray****, a kinetic spray process utilizing supersonic jets of compressed gas to accelerate near-room temperature powder particles at ultra high velocities. The unmelted particles, traveling at speeds between 500 to 1,500 m/sec plastically deform and consolidate on impact with their substrate to create a coating.* (1)

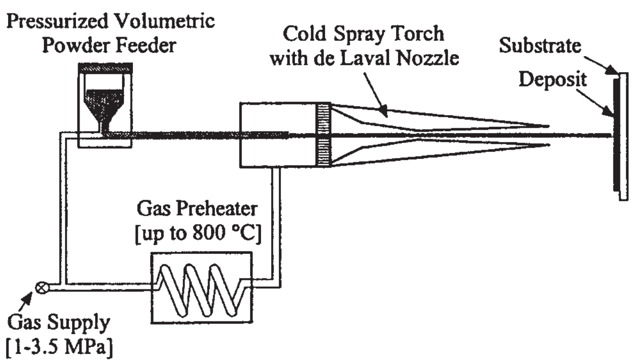



**Figure 7. Cold spray system developed for spraying ductile metals schematic.**

A mention is made of "Cold Spray" although the name seems to contradict the concept of "Thermal (heat) Spraying"; however, the method has garnered significant research interest over the last five years. Developed in the former Soviet Union in the mid 1980s by Papyrin (4), the process is, however, now being commercialized in both Europe and the United States. A typical system is shown in Figure 7.

The basis of the cold spray process is the gas-dynamic acceleration of particulates to supersonic velocities (300-1200 $m/sec^{-1}$), and hence high kinetic energies, so that solid-state plastic deformation and fusion occur on impact to produce dense coatings without the feedstock material being significantly heated. This is achieved using convergent-divergent, de Laval nozzles, high pressures (up to 500 psi [3.5 MPa]) and flow rates (up to 90 $m^3$/hr) of gases such as helium or nitrogen. The gases are pre-heated to about 800°C (1472°F), or below the melting point of many metals, to increase the velocity. Pre-heating also aids in particle deformation. The spray pattern is roughly 20 to 60 $mm^2$ (0.031 to 0.093 sq in.); spray rates - 3-5 kg/hr (6.5 to 11 lb/hr), with build ups of about 250 µm (10 mils) per pass and DEs of 70 wt %. Feedstock particle sizes are typically of the order of 1-50 µm.

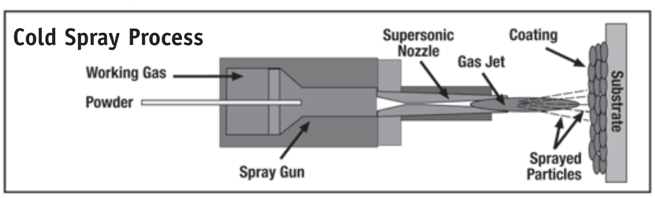
The advantage of cold spray versus the "hot" spray processes, which melt or soften the feedstock, is a significantly reduced level of coating oxidation. Electrical conductivity of cold sprayed copper has been reported at about 90% of wrought material - a significant increase over the <50% typical for other sprayed copper deposits.

Cold spray coatings also exhibit improved adhesion, reduced material loss by vaporization, low gas entrapment, insignificant grain growth and recrystallization, low residual stress, phase and compositional stability, reduced masking requirements and improved surface finishes (5) (6).

Cold spray, owing to its principle of impact-fusion coating build-up, is limited to the deposition of ductile metals and alloys (Zn, Sn, Ag, Cu, Al, Ti, Nb, Mo, NiCr, Cu-Al, nickel alloys and MCrAlYs) and polymers, or blends of >50 vol % ductile materials with brittle metals or ceramics. The absence of a heated jet also yields a low heat input to the substrate.

Obvious disadvantages to the cold spray process include the use of high gas flows, increased gas costs, especially in the case of helium, recycling would be needed. Consequently, lower cost gases as nitrogen are being investigated as alternatives. Also, high gas pressures have required the development and modification of powder feeders. Solid materials traveling at high velocities are abrasive, so the lifetime and dimensional stability of key components are emphasized. Nozzle lifetimes in excess of 100 hours have been reported (7).

Applications for cold spray coatings include corrosion protection, where the absence of process-induced oxidation may offer improved performance; deposition of electrical conductors and solders; and, the application of metallic coatings to ceramic and glass substrates.




**Characteristics**
Jet Temperature: 500 - 1250°F
Gases Used:
He,$N_2$
Particle Velocity:
2000 - 3,300 ft/s (600-1000 m/s)

Photo Courtesy of ASB Industries

## Spraying With Electricity

### Nontransferred Plasma Arc Spraying

***plasma spraying****, a thermal spray process in which a nontransterred arc is a source of heat that ionizes a gas which melts the coating material and propels it to the workpiece.* [1]

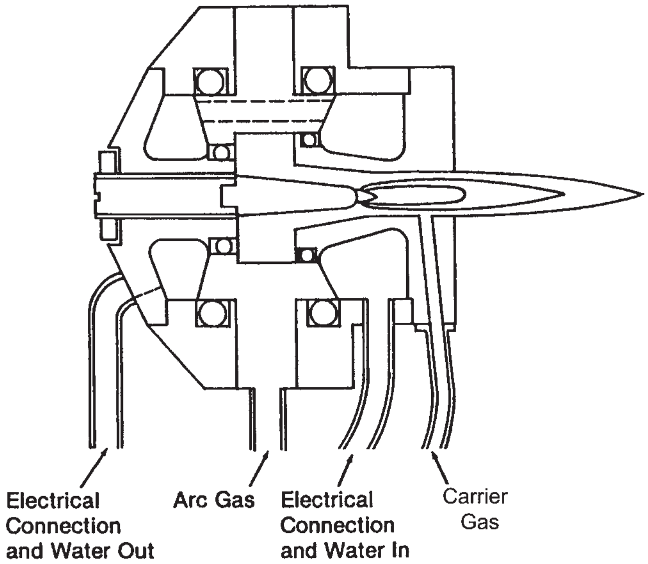
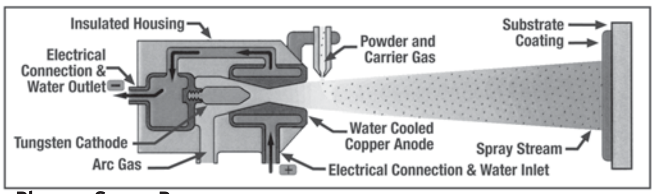



**Figure 8. Nontransferred arc plasma gun schematic.**

Plasma is an ionized gaseous cloud composed of free electrons, positive ions, neutral atoms and molecules. Because of its unique properties some have referred to it as the "fourth state of matter". Plasma is generated whenever sufficient energy is imparted to a gas to cause some of it to ionize.




**Plasma Spray Process**

**Characteristics**

Flame Temperature:
Approximately 12,000 - 20,000°F (6,000 - 11,100°C)

Gases Used:
$Ar/H_2$
$N2/H_2$

Particle Speed:
800 - 1,800 ft/s (240-550 m/s)

**Photo Courtesy of Westaim Ambeon**

If a gas is heated above 5,000°C (9,032°F) chemical bonds are broken down and its atoms undergo violent random movements. This results in atomic collisions that cause some electrons to become detached from their nuclei. Electrons are the negatively charged constituents of atoms; so having lost an electron the heavier nuclei, with any remaining electrons, become positively charged. When a gas undergoes this disruption it is said to be ionized and the cloud it has become is identified as plasma. Its behavior involves complex interactions between electromagnetic and mechanical forces. Plasma is present in any electrical discharge even one as in an ordinary arc or in a vacuum tube. It is cold plasma that excites the phosphors within a fluorescent tube.

Plasmas have been known for a considerable time. In commercial technology they are considered as hot streams of particles attaining temperatures greater than 10,000°C (18,032°F). Today's plasma spray guns are sufficiently robust to produce temperatures from 5,000°C (9,032°F) to 16,000°C (28,832°F) for long periods. These guns are referred to as "nontransferred arc plasma generators". The generator is essentially an electric arc working in a constricted space. Two electrodes, front (anode) and rear (cathode), are contained in a chamber, as is the arc through which the effluent (the operating gas) passes, a concept developed by H. Gerdien[2] of Germany in the1920s. However, at that time, it was afforded little interest, as there was no apparent need for such high temperatures. The advent of the space age changed this and workable systems were commercially introduced in the 1950s.

Plasma generators work on the concept that if sufficient voltage is applied to two electrodes, separated by a small gap, the difference in potential at that moment causes electrons to be extracted from the cathode. The electrons accelerate and speed toward the anode. If a gas is inserted in the gap between the two electrodes, its atoms will collide with the ensuing electrons and themselves, causing more electrons to detach and travel towards the anode. Meanwhile, the nuclei stripped of their electrons, and positively charged, move to the cathode. Thereby, the gas in the gap has been ionized, becoming electrically conductive - a plasma arc; it exits through an orifice in the anode as a plasma stream, containing only electrons and ionized gas is formed[7]. Meanwhile the issuing plasma stream, reaching temperatures exceeding 9,000°C (16,232°F), begins to cool and the once ionized gas begins to recombine.

Most commercial plasma guns are fundamentally simple in design, consisting of a chamber and front nozzle (anode) in which there is an orifice. The chamber and nozzle are water-cooled. At the rear of the chamber is another electrode, also water-cooled. This rear electrode is non-consumable and is fashioned from thoriated tungsten, Figure 8. A port, somewhere within the chamber, allows the high-pressure plasma forming gas, or gases, to enter. A high-frequency spark initiates operation and is discontinued upon ignition. It should be noted that the high-pressure gas cools the outer layer of the plasma arc so extreme heat is kept away from the nozzle bore.

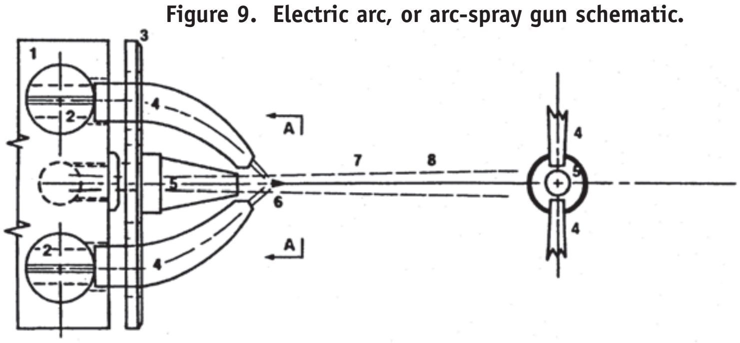
Typical plasma forming gases include argon, nitrogen, hydrogen and helium. They may be used either alone or in combination: viz, argon-hydrogen, argon-helium, nitrogen-hydrogen, etc. Argon and nitrogen are generally utilized as primary plasma gases and hydrogen is favored as a secondary as it aids in producing a "hotter" plasma. Nitrogen is less expensive than argon so, based on economics, is more widely used than argon. Helium tends to expand the plasma and when used in combination with argon produces a "high velocity plasma" that exits the nozzle at about 488 m/sec (1,600 ft/sec). Argon/hydrogen and nitrogen/hydrogen exit velocities have been measured at roughly 366 m/sec (1,200 ft/sec).

As most plasma guns are designed to spray powders, the powder is introduced through an external port at the nozzle orifice. Hardware is also available for injecting powder internally upstream into the nozzle bore. The primary plasma forming gas is usually used as a carrier to transport the powder to the plasma stream.

## Electric Arc Spraying

***electric arc spraying**, a thermal spray process in which an arc is struck between two consumable electrodes of a coating material. Compressed gas is used to atomize and propel the material to the substrate.* (1)

**Figure 9. Electric arc, or arc-spray gun schematic.**



**1. Insulated housing for contact piece; 2. Contact piece; 3. Heat resistant protective plate; 4. Wire guides; 5. Atomizing air nozzle; 6. Arc point; 7. Metal particles; 8. Atomizing air stream.**

The electric arc spray process utilizes metal in wire form. This process differs from other thermal spray processes in that there are no external heat sources as in any the combustion gas/flame spray processes. Heating and melting occur when two electrically opposed charged wires, comprising the spray material, are fed together in such a manner that a controlled arc occurs at their intersection. The molten metal is atomized and propelled onto the prepared workpiece by jets of compressed air or gas.

As early as 1914, Schoop in collaboration with Bauerlin (2), an electrical engineer, experimented with electrical heating for spraying. Initial attempts were unsuccessful as they attempted to tailor their spray apparatus on the lines of molten metal equipment rather than wire. One pole was a graphite crucible, loaded with the consumable, the other a carbon rod. An arc was struck between the crucible and the rod causing the metallic consumable to melt and flow through an orifice. On exiting, the molten metal was atomized by jets of compressed gas. Eventually, a device was built utilizing two wires, insulated from each other, made to advance and intersect at some point. Generally, the wires were given a difference of electrical potential of about 89 V that caused the wires to melt and; in the presence of a gas stream, spraying was produced. Later guns, developed by Schoop, do not radically differ from those used today.

The gun is relatively simple. Two guides direct the wires to an arcing point. Behind this point a nozzle directs a stream of high-pressure gas or air onto the arcing point where it atomizes the molten metal and carries it to the workpiece, Figure 9. Typically, power settings of about 450 A can spray over 50 kg/hr (110 lb/hr). Electric arc spray systems are offered that feed wire by either an air or electrical motor. Some units push the wire to the gun while others pull the wire into the arc. Controls include volt and ampere meters and air regulators.

Electric arc spraying has the advantage of not requiring the use of oxygen and/or a combustible gas; it has demonstrated the ability to process metals at high spray rates; and is, in many cases, less expensive to operate than either plasma and/or wire flame spraying. "Pseudo" alloy coatings, or those constructed by simultaneously feeding two different materials, are readily fabricated. An example would be copper-tin coatings constructed by feeding pure copper and tin wires into the arc to produce a heterogeneous mixture of each in the coating. Also, the introduction of cored wires has enabled the deposition of complex alloys (such as MCrAlYs) as well as carbide-containing metal alloys that were only attainable using powdered materials as feedstock. Some materials produce "self-bonding" coatings that are sprayed in a "superheated" condition. The overheated, hot particles tend to weld to many surfaces thereby increasing the coatings' adhesive strength.

## RF Plasma Spraying

***RF plasma**, a system in which the torch is a water-cooled, high frequency induction coil surrounding a gas stream. On ignition a conductive load is produced within the induction coil, which couples to the gas, ionizing it to produce a plasma.* (1)

Inducing electricity to flow through a conductor causes heating to occur. This occurs primarily as a result of resistance to the flow of the induced current and is proportional to the square of the current (I) and directly proportional to resistance (R) and time (t) or ($I^2Rt$) (8).

Induction occurs when a conductor is placed in an alternating magnetic field. When the effect is sufficient, great eddy currents are set up in the conductor, which rapidly gets hot or even melts, the magnetic linkages necessary being increased with the frequency. To be used for thermal spraying, a water cooled helix of several turns is fashioned from OFHC copper. It is wrapped around a quartz tube that is closed at its top end and fitted with two inlet ports to feed a spray material and a plasma forming gas. Releasing gas into the tube and energizing the copper helix by a high frequency current that sets up an intense magnetic field inside the tube causing ionization of the gas. Continuous feeding of the gas causes it to escape through the open bottom of the tube. Powder fed into the plasma filled tube is melted and relying on either gravity or the plasma flow is conveyed to the work surface.

Coatings produced using RF plasma has shown to be generally homogeneous and not porous. This method, using neutral atmospheres, can deposit reactive and toxic metals including calcium, uranium, niobium and titanium.

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INTERNATIONAL THERMAL SPRAY ASSOCIATION

*Bringing Technology and Technique Together*

The ***International Thermal Spray Association*** is closely interwoven with the history of thermal spray development in this hemisphere. Founded in 1948, and once known as Metallizing Service Contractors, the association has been closely tied to most major advances in thermal spray technology, equipment and materials, industry events, education, standards and market development.

A company-member trade association, ITSA invites all interested companies to talk with our officers, committee members, and company representatives to better understand member benefits. A complete list of ITSA member companies and their representatives can be found at www.thermalspray.org

**Officers**

Chairman: John Read, National Coating Technologies
Vice-Chairman: Ed Simonds, Cincinnati Thermal Spray
Treasurer: Bill Mosier, Polymet Corporation
Corporate Secretary: Kathy Dusa

**Executive Committee** (above officers plus)

Past Chairman: Scott Goodspeed, Plasma Technology, Inc.
6-Year Term: John Hayden, Hayden Corporation
4-Year Term: Joe Stricker, St. Louis Metallizing
2-Year Term: Jimmy Walker, F.W. Gartner Thermal Spraying

**Audit Committee**

Chair: Warren Mickle - Plasma Technology, Inc.

**Environment & Safety Committee**

Chair: John Wilson - Flame Spray, Inc.

**Expositions Committee**

Chair: Jimmy Walker - F.W. Gartner Thermal Spraying

**Marketing Committee**

Chair: Mae Wang, Saint-Gobain Ceramic Materials

**Membership Committee**

Chair: Jim Ryan - H. C. Starck

**Meetings Planning Committee**

Chair: Ed Simonds - Cincinnati Thermal Spray

**Scholarship & Awards Committee**

Chair: Alan Burgess - Northwest Mettech Corporation

**Statistics Committee**

Chair: Marc Froning - Engelhard Surface Technologies

**Website Committee**

Chair: Chip Arata - Carpenter Powder Products

## ITSA Scholarship Opportunities

The International Thermal Spray Association offers annual Graduate and Undergraduate Scholarships. Since 1992, the ITSA scholarship program has contributed to the growth of the thermal spray community, especially in the development of new technologists and engineers. ITSA is very proud of this education partnership and encourages all eligible participants to apply. Please visit www.thermalspray.org for criteria information and printable application form.

## ITSA Materials Camp Student Sponsor

Commencing in 2001, the International Thermal Spray Association provides an annual $1,500 student scholarship to the ASM International Foundation Materials Camp.

## ITSA Thermal Spray Historical Collection

In April 2000, the International Thermal Spray Association announced the establishment of a Thermal Spray Historical Collection which is now on display at their headquarters office in Fairport Harbor, Ohio USA.

Growing in size and value, there are now over 30 different spray guns and miscellaneous equipment, a variety of spray gun manuals, hundreds of photographs, and several thermal spray publications and reference books.

Future plans include a virtual tour of the collection on the ITSA website for the entire global community to visit.

This is a worldwide industry collection and we welcome donations from the entire thermal spray community.

## ITSA Headquarters

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tel: 440.357.5400 fax: 440.357.5430
itsa@thermalspray.org
www.thermalspray.org

## ITSA Opens Technical Program to Public

At their Spring Meeting, the International Thermal Spray Association member companies agreed to allow non-member attendees at the technical program portion of future membership meetings. ITSA semi-annual membership meetings are typically a three-day event with a thermal spray technical program on Friday from 8:00am through 5:00 pm.

In revising their long-standing "member only" attendance policy for the Technical Program, ITSA is responding to continuous interest from non-member individuals wanting to take advantage of these valuable thermal spray educational programs.

**Future ITSA Technical Programs** will be held October 8, 2004 in Greenville, South Carolina, April 22, 2005 in Cincinnati, Ohio and October 21, 2005 in Montreal, Canada. The cost for non-members to attend the all day ITSA Technical Program will be $200, which includes breakfast and lunch.

**For more information**, contact
Kathy Dusa, ITSA Corporate Secretary
kathydusa@thermalspray.org

## Thermal Spray Processes Used By Various Industrial Segments

| INDUSTRY | Oxy-fuel | Spray/fuse | HVOF | D-gun | Air plasma | Vac-plasma | Shroud plasma |
|---|---|---|---|---|---|---|---|
| Aero gas turbine | ✔ | | ✔ | ✔ | ✔ | ✔ | ✔ |
| Stationary gas turbine | ✔ | | ✔ | ✔ | ✔ | ✔ | |
| Hydro-steam turbine | ✔ | | ✔ | ✔ | ✔ | ✔ | ✔ |
| Automotive engines | ✔ | | ✔ | | ✔ | | |
| Diesel engines | ✔ | | ✔ | | ✔ | | |
| Transportation non-engine | ✔ | | | ✔ | ✔ | | |
| Agriculture implementations | ✔ | ✔ | | | ✔ | | |
| Railroad | ✔ | | ✔ | | ✔ | | |
| Iron and steel manufacture | ✔ | ✔ | | | ✔ | | |
| Steel rolling mills | ✔ | ✔ | ✔ | | ✔ | | |
| Iron and steel casting | | | ✔ | | ✔ | | |
| Forging | ✔ | | ✔ | | | | |
| Copper and brass mills | ✔ | | | | | | |
| Ship and boat manufacture and repair | ✔ | | | | | | |
| Oil and gas exploration | ✔ | ✔ | ✔ | ✔ | ✔ | | |
| Mining, construction and dredging | ✔ | ✔ | ✔ | | ✔ | | |
| Rock products | ✔ | ✔ | ✔ | | ✔ | | |
| Screening | | | | | | | |
| Cement and structural clay | ✔ | ✔ | ✔ | | | | |
| Chemical processing | ✔ | ✔ | ✔ | ✔ | ✔ | | |
| Rubber and plastic manufacture | ✔ | ✔ | ✔ | | ✔ | | |
| Textile | ✔ | | ✔ | ✔ | ✔ | | |
| Food processing | ✔ | ✔ | ✔ | ✔ | ✔ | | |
| Electrical utilities | | | ✔ | | ✔ | | |
| Pulp and paper | ✔ | | ✔ | | ✔ | | |
| Printing equipment | | | ✔ | ✔ | ✔ | | |
| Defense and aerospace | ✔ | | ✔ | ✔ | ✔ | ✔ | |
| Nuclear | | | ✔ | ✔ | ✔ | | |
| Medical | | | ✔ | ✔ | ✔ | ✔ | ✔ |
| Business equipment | | | ✔ | ✔ | ✔ | | |
| Electrical and electronic | | | ✔ | ✔ | ✔ | ✔ | |
| Architectural | ✔ | ✔ | | | ✔ | | |
| Glass manufacture | | ✔ | | ✔ | ✔ | | |

## Thermal Spray Coating Applications According To Industry Served

| INDUSTRY | WEAR | | | | | | TBC | Clearance Control | | Restoration | Corross/Oxidat | Electrical | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Abrasive | Adhesive | Fretting | Erosion | Cavitation | Impact | | Abradable | Abrasive | | | Resistance | Conduct |
| Aero gas turbine | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Stationary gas turbine | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Hydro-steam turbine | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | ✓ | | |
| Automotive engines | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Diesel engines | ✓ | ✓ | | ✓ | | ✓ | ✓ | | | ✓ | ✓ | | |
| Transportation non-engine | ✓ | ✓ | | | | | ✓ | | | ✓ | ✓ | ✓ | |
| Agriculture implementations | ✓ | | | ✓ | | ✓ | | | | ✓ | | | |
| Railroad | ✓ | ✓ | | | | ✓ | | | | ✓ | ✓ | | ✓ |
| Iron and steel manufacture | ✓ | | | ✓ | | ✓ | | | | ✓ | ✓ | | |
| Steel rolling mills | ✓ | ✓ | | | | ✓ | | | | ✓ | ✓ | | |
| Iron and steel casting | ✓ | | | ✓ | | ✓ | | | | ✓ | ✓ | | |
| Forging | ✓ | ✓ | | | | ✓ | | | | ✓ | ✓ | | |
| Copper and brass mills | ✓ | | | | | | | | | ✓ | ✓ | | |
| Ship and boat manufacture/repair | ✓ | | | ✓ | | | | | | ✓ | ✓ | | |
| Oil and gas exploration | ✓ | ✓ | | ✓ | | ✓ | | | | ✓ | ✓ | | |
| Mining, construction and dredging | ✓ | | | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | |
| Rock products | ✓ | | | | | ✓ | | | | ✓ | ✓ | | |
| Screening | ✓ | | | | | ✓ | | | | ✓ | ✓ | | |
| Cement and structural clay | ✓ | | | | | ✓ | | | | ✓ | ✓ | | |
| Chemical processing | ✓ | | | ✓ | | | | | | ✓ | ✓ | | |
| Rubber and plastic manufacture | ✓ | | | ✓ | | ✓ | | | | ✓ | ✓ | | |
| Textile | ✓ | | | | | | | | | ✓ | | | |
| Food processing | ✓ | | | | | | | | | ✓ | | | |
| Electrical utilities | ✓ | ✓ | | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | |
| Pulp and paper | ✓ | | | | ✓ | ✓ | | | | ✓ | ✓ | | |
| Printing equipment | ✓ | ✓ | | | | | | | | ✓ | | | |
| Defense and aerospace | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | |
| Nuclear | | | | | | | | | | | ✓ | | |
| Medical | ✓ | | ✓ | | | | | | | | ✓ | | |
| Business equipment | ✓ | ✓ | ✓ | | | | | | | | | | |
| Electrical and electronic | | | | | | | | | | ✓ | ✓ | | |
| Architectural | ✓ | | | | | ✓ | | | | | | | |
| Glass Manufacture | ✓ | ✓ | | | | | | | | ✓ | ✓ | | |

## Industrial Use of Gas Metallic Materials

| INDUSTRY | Chrome carbide | Self-fluxing | Iron & steel | Nickel Alloys | Superalloys | MCrAlY | Cobalt Alloys | Non-Ferrous |
|---|---|---|---|---|---|---|---|---|
| Aero gas turbine | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Stationary gas turbine | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Hydro-steam turbine | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Automotive engines | ✓ | | | ✓ | ✓ | ✓ | ✓ | |
| Diesel engines | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Transportation non-engine | | | ✓ | ✓ | | | | ✓ |
| Agriculture implementations | | ✓ | ✓ | ✓ | | | | ✓ |
| Railroad | | ✓ | ✓ | ✓ | | | | ✓ |
| Iron and steel manufacture | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Steel rolling mills | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Iron and steel casting | | ✓ | ✓ | | | | | ✓ |
| Forging | | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| Copper and brass mills | | | | | | | ✓ | |
| Ship and boat manufacture/repair | | | ✓ | ✓ | | | | ✓ |
| Oil and gas exploration | | ✓ | ✓ | ✓ | | | ✓ | ✓ |
| Mining, construction and dredging | | ✓ | ✓ | | | | | ✓ |
| Rock products | | ✓ | ✓ | | | | | ✓ |
| Screening | | | ✓ | | | | | |
| Cement and structural clay | | ✓ | ✓ | | | | | ✓ |
| Chemical processing | | | ✓ | ✓ | ✓ | | ✓ | |
| Rubber and plastic manufacture | | ✓ | ✓ | ✓ | | | ✓ | |
| Textile | | | ✓ | | | | | |
| Food processing | | ✓ | ✓ | | | | | |
| Electrical utilities | | ✓ | ✓ | ✓ | | | ✓ | ✓ |
| Pulp and paper | | ✓ | ✓ | ✓ | | | | ✓ |
| Printing equipment | | | | | | | | ✓ |
| Defense and aerospace | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Nuclear | | | | | | | | |
| Medical | | | | | | | | ✓ |
| Business equipment | | | | | | | | ✓ |
| Electrical and electronic | | | | | | | | ✓ |
| Architectural | ✓ | | | | | | | ✓ |
| Glass Manufacture | ✓ | ✓ | ✓ | | | | | |