The First Internal Combustion Engine

G Ricci, P Gasparini, P Lazzerini, R Lazzerini, F Viola
Barsanti and Matteucci Foundation

Synopsis
Two Italian scientists/engineers developed the first internal combustion engine using the free-piston principle. Patents were established in various countries and a working engine was manufactured and ran successfully for several years at a railway station in Florence and before the engines of Lenoir and of Otto and Langen. Other engines were developed but the chaotic political and social conditions during the reunification of Italy created problems in promoting their engine and defending their patents. The death of Barsanti, whilst supervising the production of the engine at Cockerill's plant at Seraing, Belgium, coupled with Matteucci's ill-health effectively ended the engine's promotion and development. Lenoir's engine introduced at this time was commercially successful but much less efficient than Barsanti and Matteucci's engine, and it was left to Otto and Langen, using a very similar free-piston design, to establish an efficient internal combustion engine.

KEYWORDS: Barsanti, Matteucci, Lenoir, Otto and Langen, First gas engine.

Abbot Eugenio Barsanti from Pietrasanta Lucca, a gifted mathematician and physicist, was drawn towards his invention of a gas engine after studying a new concept electric pistol, which was originally used by inventor Alessandro Volta to study the behaviour of Marsh Gas. Barsanti used metal instead of glass, completed the pistol with an upper cork plug, with a flexible bottom end, and used a device to create an internal spark (Figure 1). He completed various experiments from which he realized that he had identified an energy source ready to be used practically. It also became apparent that the pressure on the cap increased in direct proportion to the temperature, and in inverse proportion to the expansion of the membrane that limited its depth, the basis of the Laws of Thermodynamics.

It was the spring of 1843. There was a full industrial and scientific revolution that had signalled that the time had come to find an alternative to the steam engine; a large number of scientists had for some time been engrossed in this research. Barsanti however lacked the mechanical knowledge essential to exploit the results of his intuitions. Only in 1849, when he was transferred from Volterra to Ximeniano Institute in Florence, did he find the support he needed. Among the

many scholars who attended the Institute was an engineer by the name of Felice Matteucci from Lucca, who was already interested in the same subjects as Barsanti.

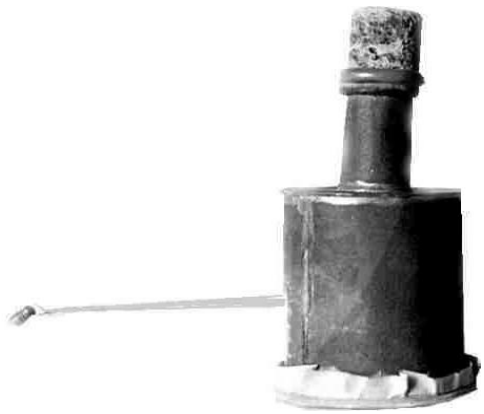

Figure 1. Photograph of the "Pistola di Volta" constructed by Barsanti and conserved at the Museum of Volterra.

From their meeting a spontaneous collaboration arose; their affinity was confirmed by the intensity and continuity of the work undertaken. It was the end of the year 1851. The following year the conditions were present for the formulation of different hypotheses about the engines, from which were taken the four described in the memoirs that the two scientists deposited in a sealed envelope at the "Academy of the Georgifili" of Florence on 5 June 1853.

Experimental Phase

The prototype of the first experimental model, shown in Figure 2, was constructed in the foundries of Pietro Benini of Florence: the awkward barrel of the pistol was replaced with a cast iron cylinder with a piston stopper and a solid piston with a long pole that ran into the cylinder from the bottom to the top and vice versa. Barsanti's idea materialized clearly: the force of the explosion and the thrust was great, but the majority of work came upon the return of the piston towards the base. Now all that remained was to harmonize this force to achieve a high and consistent performance.

The first difficulties began to appear at once and it could not have been otherwise because the principles of thermodynamics and the laws of chemical kinetics had not yet reached sufficient verification and diffusion.

The first prototype, in fact, had fully fulfilled its expectations, but had also revealed the first problem: at the end of the track, the piston showed an oscillating movement for a short time, caused by the compression of the residues of combustion gases. It was necessary to find a way to release these gases to blend

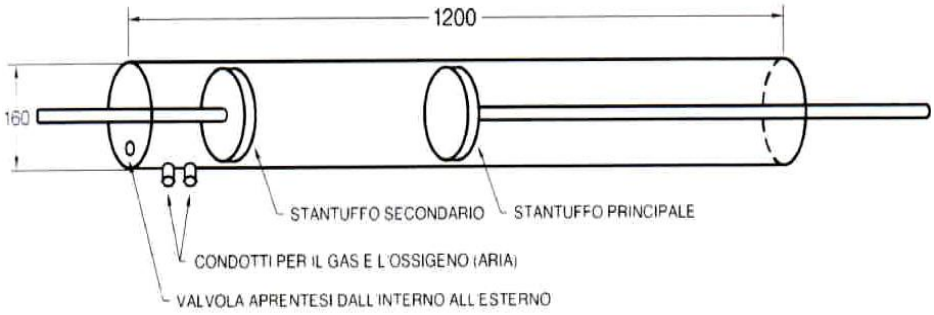

Figure. 2. Diagram of the first experimental model constructed by the two inventors.

with the explosive mixture: a cylinder of larger dimensions was thus constructed, with an internal diameter of 160 mm and a length of 1200 mm; two pistons ran internally opposite one another, one was called *the primary piston*, and was pushed by the explosion, and the other named *the secondary or contra-piston*, was used to expel the combustible gases and regulate the amount of fuel mixture in the chamber (Figure 2).

Initially the two pistons were in contact. The secondary piston was then moved to allow movement through two ducts, one for gas and the other for oxygen or air, detonating the mixture which was ignited by sparks produced by the method of De La Rive. After the primary piston had made the return stroke, the combustion gases were expelled from the secondary piston through an *internal-external* valve placed on the bottom and which simultaneously started a new intake and a new cycle.

This model proved to be appropriate to facilitate the type and proportions of the mixture to use.

The research on the most suitable blends and convenient track was treated with the utmost care: the mix of hydrogen and oxygen used for the first experiments was quickly ruled out because of the high costs of production and a hydrogen–air mixture, in the proportion of 1 to 7, was substituted. Eventually the hydrogen was replaced with coal gas from the city of Florence. Later, several experiments confirmed that the mixture that gave the best results was made from coal gas and air in a proportion of 1 to 12.

The Four Hypotheses

From the Memoirs lodged at the "Academy of the Georgofili"[1] and a document found at the Ximeniano Institute[2] we find that in the design of the internal combustion engine the two scientists followed the principles found therein. It is convenient at this point to report how much they wrote in the Memoirs of the

Georgofili of the various procedures of research. Four hypotheses were invented to reach their goal. The first and the second hypotheses were excluded after the early experiments, since they were not easily achievable with the means of the time; we pass therefore to analyze the other two. The third hypothesis:

> "Not to make the piston function in a hermetically sealed cylinder, but open at the top where it would suffice that the shaft found a guide, and then extend to the other piston in its ascent, a system of springs or other elastic bodies, that ceasing the impulsion, would react with the force received on the piston, thus rendering it capable of producing a useful effect on its return."

The fourth hypothesis:

> "To make the piston function in a cylinder open at the top as in the previous case, and to assign a cylinder of such length and capacity, that the expansive force did not arrive to come after the piston. In this case, during the initial stroke, a vacuum would form under the piston, and the useful force from this would be the atmospheric pressure on the base."

> "The third system, which required less perfection of the instruments and a very simple mechanism, would be tried as soon as possible, that is as soon as we were able to obtain the elastic bodies which we had committed to the project. The fourth system was not really developed after the unexpected difficulties that were found with the third. Needless to say, since the systems are single-acting, twin cylinders would be needed with an alternate motor."

In the spring of 1853, when depositing the envelope, the inventors were not convinced of the superiority of their fourth solution, but the doubt was brief because in the following spring this solution was first named in a British patent application.[3]

Another important aspect to be highlighted is the fact that the first three solutions included a reduction of the expansion; this may have led to more confidence in the fourth system. As we shall see later, the two inventors were directed towards the research of larger and prolonged expansion.

Although the principle underpinning the engines of Barsanti and Matteucci was always the same, several solutions were designed and, from a functional point of view, were equally valid; this makes it difficult, if not impossible, to identify a single machine as their invention. The authors will begin by describing the principle of operation and then move on to analyze the structure of the engine that gave the most satisfactory results, and finally, we will describe which engines were actually built.

The engines had gravity-atmospheric or atmospheric action that delayed the work output until the return stoke; those with direct action, while mechanically simpler, were excluded due to their reduced efficiency.

In these motors, the driving force was the constant and continuous action of the atmospheric pressure, to which was added, in the vertical cylinder machines,

the weight of the piston and rod. The violent and instantaneous action of the explosion was not used to produce external work but to accelerate and lift the piston and piston rod, which was eventually brought to rest by the action of gravity and a vacuum in the cylinder.

The piston, as a result of the explosion, expanded the gas beyond the point at which the internal pressure of the cylinder was equal to that outside, and a vacuum inside the cylinder was created. This brought the piston to rest. On its return course, called the *active stroke*, the piston's weight and atmospheric pressure transmitted its motion to the engine through a gauge line onto which an integral sprocket was grafted with the engine shaft; the sprocket was fitted with a spool that allowed the transmission of motion only on the return stroke, while on the initial stroke this remained neutral: the rectilinear motion was thus converted into rotary motion. The fact that the resistance was minimal during the primary stroke had allowed a high volumetric expansion ratio to be attained, which had always been pursued by the two inventors.

In the version with the auxiliary piston, Figure 3, at the sides of the engine shaft, there are two wheels that rotate through an integral gear with the shaft. These wheels, structured eccentrically onto them through two tie-rods, transmit a continuous oscillating motion to a crossbar placed under the cylinder and connected to the rod of the secondary piston, located under the main piston, and which moves along with the crossbar, through which a transversal rod transmits an alternate motion to the spool valve.

In the model without the auxiliary piston (Figure 4), a countershaft is connected to the engine shaft via a pair of sprockets; these rotate in conjunction with two protrusions so that when they encounter two teeth aptly placed on the shaft of the piston, they provide an alternate movement. The alternative and discontinuous movement of the spool valve is generated by the contact, at appropriate moments, of the teeth on the shaft and countershaft, that is, against the projections of a vertical shaft directly connected with the spool valve.

The experimental phase was ending, as can be witnessed by the content of a note of indebtedness from the Benini Company to Matteucci on 9 June 1853.

The First Models and Patents

In September of 1853, out of all this matured experience, Matteucci commissioned Peter Benini to construct a small experimental model in which the force of the return stroke was used to move a sprocket by means of a gauge line (rack) that transmitted the rotary motion to a flywheel. The company returned in a short time with the engine and an invoice on 2 November 1853 in which is cited a gear, a bracket with a gauge line (rack), various other pieces and, finally, the mounting of all of these. The results were encouraging and began to attract the attention of many Florentine interests, the first of which was the Grand Duke.

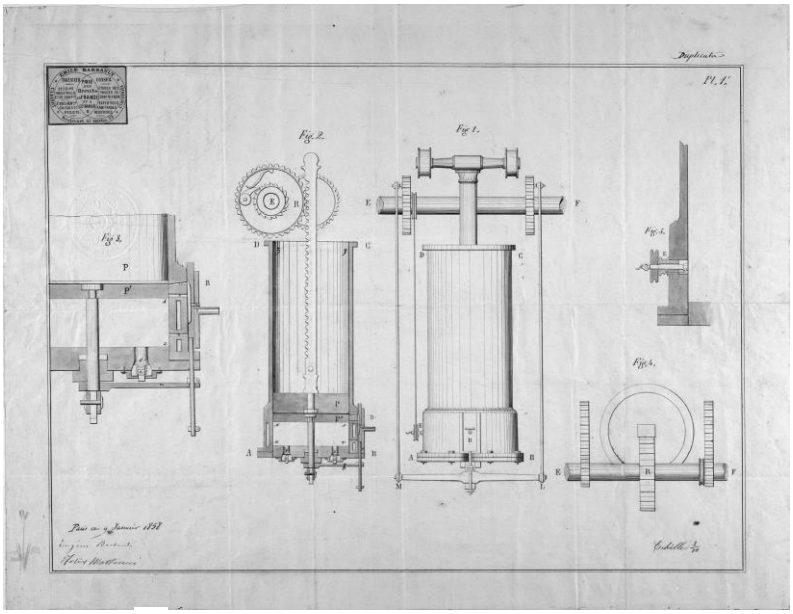

Figure 3. Original drawings of the model with auxiliary piston

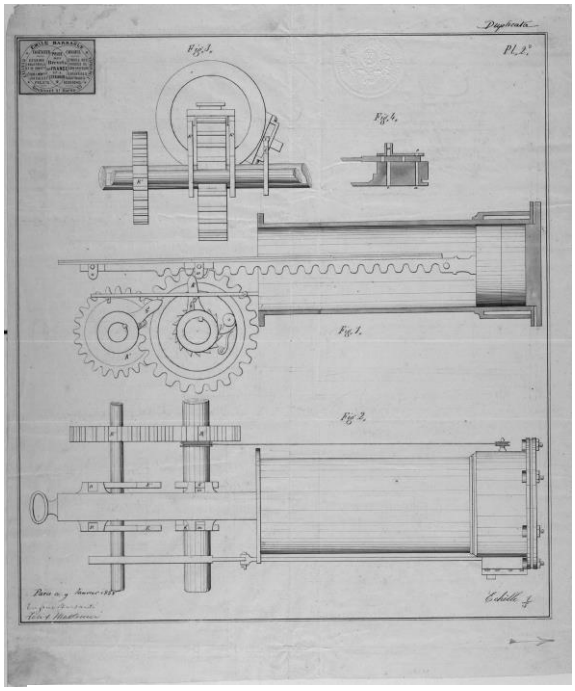

Figure 4. Original drawings from the model without auxiliary piston

But it was necessary to turn to countries with a more developed industrial capacity where it would be possible to develop the invention for a greater financial return. Barsanti and Matteucci opted for England and France. They decided to employ a skilled and active German businessman, the owner of a commercial agency located in Livorno and who was Honorary Consul of Saxony and Wurtemberger, William Haehner, an expert in international practices. A letter from Haehner of 10 November 1853 to Matteucci was very encouraging. The decision was immediate, and, overcoming the last doubts, the Benini workshop was given the project of a new interdependent two-cylinder engine and a prime example of the application of the control of the machine tools. Haehner made arrangements for patent protection in both England and France.

Our scientists, not having received any news by the early days of April of 1854, asked for an explanation; Haehner answered that from the investigations made at the London Patent Office, their invention did not appear original, even suggesting that they change the title to improve their chances. The response of 28 April 1854, signed by Barsanti is clear and decided:

> ... our machine applies the driving force so completely differently from the others, that is to say it has produced a new way to apply this force, thus we are able apply for a patent ..... We therefore persist in our resolve not to change its title ....[4]

On 26 June Haehner at last reported that the Provisional Specification had been given the number 1072 and published in the *Morning Journal* on 13 May 1854**.** It would become operational only after filing the complete specification and after paying the required fees, but these matters were not performed; the indecision of Haehner led to the breakdown in the relationship and to consequent litigation. Unfortunately, with the breakdown in the relationship, the prosecution of the French application was also stopped. But the work and the intentions of the two inventors did not stop.

Work preceded so successfully that in the early days of May 1856, in the Offices of the Maria Antonia Railway Station in Florence, an engine was exhibited that aroused both interest and wonder. It can be said with certainty that this was the very engine that the two scientists wanted to patent in England and France and that had so worried Mr. Haehner.

There are documents that confirm the experimentation from the end of 1853 to the beginning of 1854 (Figure 5). Today, after so much time, what is still amazing is the trust and confidence with which the two tirelessly undertook the project despite the fact that the time was not the best. The entire Italian peninsula had been shaken by widespread instability as a result of the 1848 uprising, when all of the major Italian cities rebelled for the sacrosanct claims born out of the ideas of Mazzini. France also came down upon Italy in defence of the Church, thus further

complicating the situation even after the Wars of Independence and the proclamation of the unification of Italy on 17 March 1861.

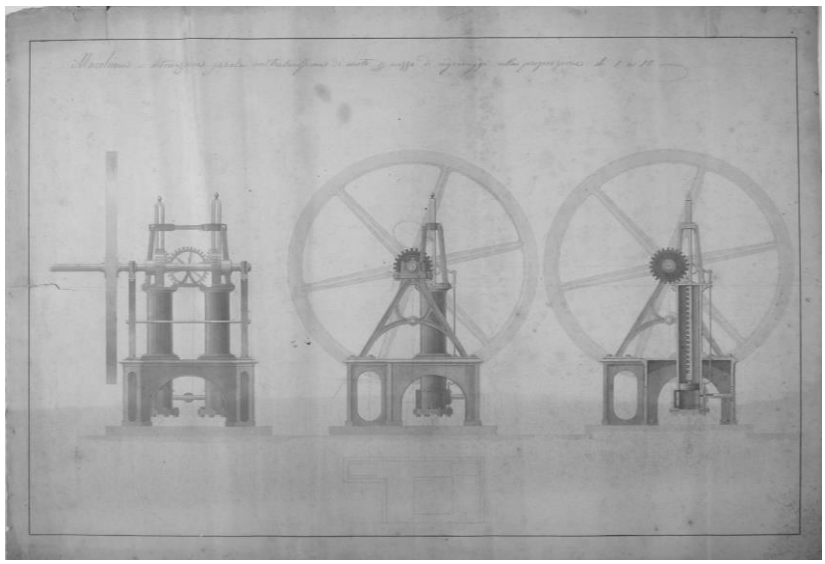

Figure 5. Original drawings of the working engine at the Maria Antonia Station

In the early months of 1857, the two scientists entrusted to the Benini Workshops the designs of a new engine. The mechanics had undergone few variations, but the power was increased to ensure a working mechanism when asked for a greater impulse. The echo of their success reached the ears of Haehner, their earlier agent; evidently the relationship was not totally spoiled. Through him, Barsanti and Matteucci requested a new patent in England. The patent is dated 12 June 1857, No. 1655 and is cited in *The Engineer*.[5] The engine is a vertical, single-cylinder unit, both in the version with the secondary piston and the one without. On 30 December 1857, the State of Piemonte granted the directive (Patent) No. 579 and in close succession came the French patent dated 9 January 1858, No. 35009, and the Belgian patent dated 10 February 1858, No. 5533.

An avid mechanic had joined the two scientists in the meantime and had suggested a solution which had already flashed into the mind of Barsanti, but which was not much shared by Matteucci: to place a single horizontal cylinder and two pistons opposing each other. The newcomer was Giovan Battista Babacci from Forlì; Babacci in fact, as is highlighted by a memoir of the fathers Antonelli and Cecchi of the Ximeniano Institute, had suggested details that had already been the subject of technical discussions between Barsanti and Matteucci. The suggestion was to allow communication between the two spaces with an opening to give rise to the two opposing forces and have an effect equal to zero. The ultimate goal was

to eliminate the kickback. Just at this time, a request from the "Larian" Navigation Society of Como had come for an engine to be mounted on a "Veloce" boat.

Matteucci, in agreement with Barsanti, immediately decided to make some modifications to the prototype built by the Benini Workshops and to commission a similar engine but of the capacity of 20 horses from the foundry of Vincent Callegari of Livorno. This correspondence ends with the signing by the owner of the company without the usual obsequious forms. Evidently, to work for two demanding people such as Barsanti and Matteucci would not have been easy. From existing documents, it cannot be understood if this project was interrupted by technological difficulties or economical problems. There is reason to believe that in this particular case, it was the prevailing sense of dissatisfaction of the two inventors; it seems that the technical problems encountered up until this point were due to their inability to find workshops to ensure the precision that their designs imposed. This engine obtained the Piemonte directive on 26 July 1858, No. 700, (Figure 6) and the French patent on 4 February 1859, No. 39730.

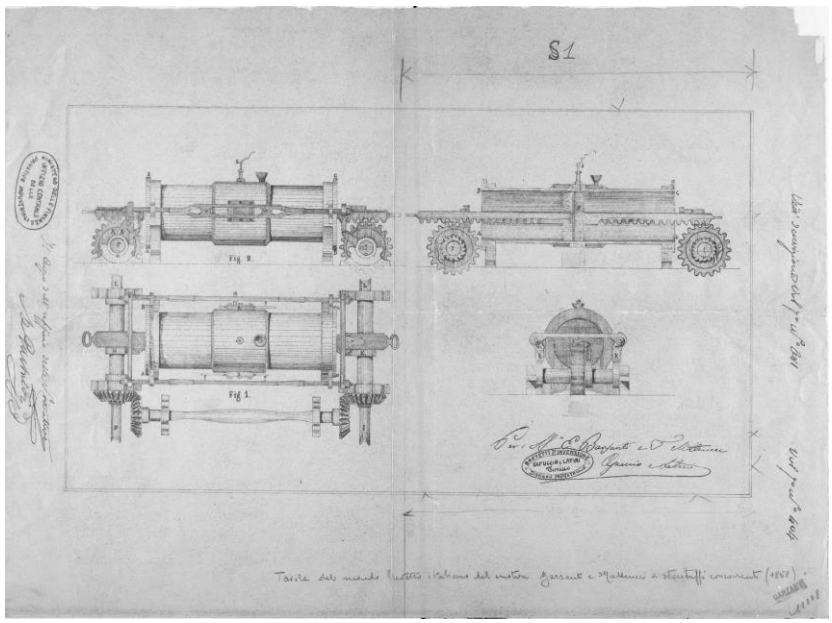

Figure 6. Original drawings attached to the Piedmont Directive N ° 700

The inventive frenzy did not end here; from an invoice of P. Benini from December 17, 1858 emerges a list of various parts that may suggest a new engine: [6] the number of cylinders is not shown, but four gauge lines (racks) are mentioned, these should have been two, one for each piston. Four movable wheels are mentioned which are the idlers that engage on the gauge line and convey the motion of the return stroke, while the four bevel gears transmit the motion referred

to the frame of distribution. One particular invoice of interest was sent to Barsanti, Matteucci and Co.; this was not only due to the arrival of Babacci and Bastianelli, the mechanic who had made his garage available, but also to a host of friends and fans who, having seen the satisfactory results, decided to form a society. Thus was born the *Society of the New Engine of Barsanti and Matteucci*, which was made up of the capital of new shares of 84 lira, equivalent to 100 Tuscan lira; the President was Count Zucchini of Bologna and the Vice-President was Marquis Lottaringo Della Stufa of Florence, the Chief Technical Directors were Father Professor Eugenio Barsanti and Engineer Felice Matteucci. The shares were sold in a short time in Italy and abroad, especially in France, where the notable popularizer of science, Louis Figuier, was the promoter.

The Company's bylaws were approved on 19 Oct. 1860 from S. A. R., the Lieutenant of the Prince of Carignano of S. M. Vittorio Emanuele II in the Tuscan Provinces.

Lenoir's Engine

In the meantime, news had arrived from Paris that a Belgian mechanic, Stefano Lenoir, had invented a new gas-driven engine that attracted much publicity and created great expectations. This excitement must have struck Figuier, a strong supporter of our inventors, so much so that by 1860 he began to defend Lenoir. Another Frenchman, however, more peaceful and more profound, the learned Abbot Migne, defended the beautiful Italian heritage in the *Le Monde* newspaper. In Italy, Barsanti and Matteucci would never have been supported unconditionally, as had occurred with Lenoir, even after the establishment of the Italian State. Nevertheless, the two scientists did not cease work and they overcame their bitterness when they saw that the solutions adopted by Lenoir were exactly those of their own initial experiments and which were soon discontinued because they were less economical. They received word from Paris that confirmed their assumptions:

> " ..... in the second of these experiments, the cost per horse/hour of the Lenoir engine resulted in Paris in 0.825 francs, compared to spending, also per horse/hour in steam engines, also in Paris, 0.20 francs, reducible to 0.12 francs in the machines most recently constructed. "[7]

Lenoir had built the engine without taking into account the economic aspect (it had a low thermal efficiency); and if it had been meant to supersede the steam engine, this quickly appeared inappropriate and thus the sensation aroused seemed rather exaggerated.

Barsanti and Matteucci did not despair, indeed it was all the more reason to accelerate the study and construction of the motors which could satisfy the many requests. They immediately worked to cover the latest projects with the necessary guarantees: they obtained the Piedmont Directive, undersigned for the first time

also by Babacci, on 9 October 1861, No. 1397; then that of the English on 31 December 1861, No. 3270 (Figure 7); that of the French, signed only by Matteucci, on 31 March 1862, No. 53609; and that of the Belgians on 16 July 1862, No. 12922.

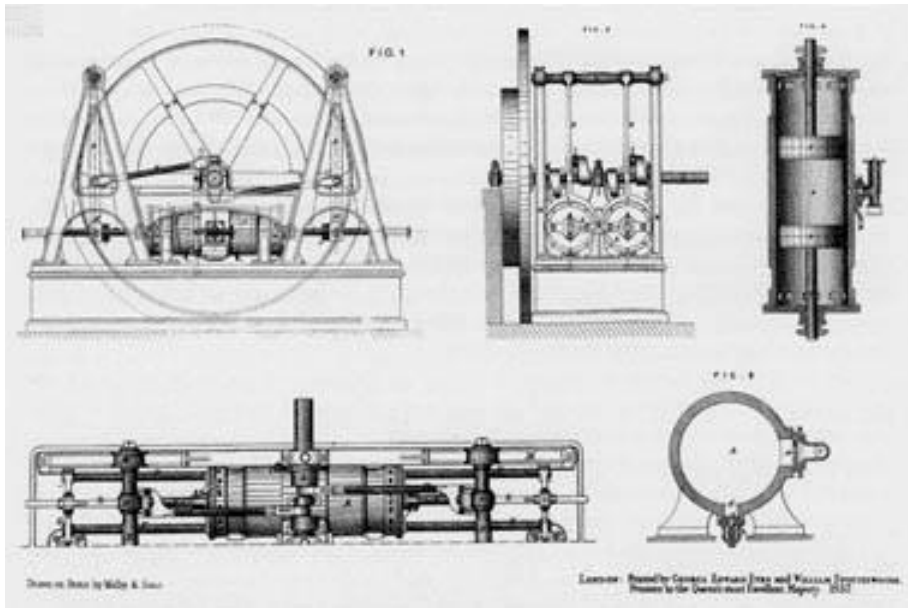

Figure 7. Original drawings attached to the British Patent No. 3270

At the end of 1860, Barsanti went to Zurich to the firm Escher Wyss and Co. with a project for the construction of a new 12 horsepower engine with two horizontal cylinders that he defines as: "according to my new system", and a note of debt from the firm Escher Wyss & Co. addressed to the Society.[8] One could be induced to think it was a direct reaction, as is reported in the works of B. Besso.[9] This engine was presented at the First Italian Exhibition of Arts and Crafts, held in Florence in 1861, which from reviews from various magazines of the era must have had success and resonance.

This engine is exactly that which was patented in England on 31 December 1861, No. 3270, and that, although having changed in appearance, was always based on the principle of the gravity-atmospheric engine with deferred action. Initiatives and the decisions followed each other in a feverish manner. Matteucci, then in Paris, received continuous communications from Barsanti that forced him to revise many of their agreed ideas; in a letter of 19 March 1862, there are obvious signs of conclusive decisions: "It is good that the design must be redone because thus you can better indicate the changes undergone by the machine--"[10]

Matteucci's Ill-health and a New Engine

The work of Matteucci in Paris was neither easy nor trivial; he had to work to revise completely the projects brought with him and to prepare new descriptions according to the new ideas, and even more, to bear the humiliation of seeing the claims rejected at the departments of the Governor, that, not only served to protect the Lenoir engine, but helped with the wide dissemination of resources. He also seems to have tried and failed to meet Lenoir. In the autumn of 1862, the robust health of Matteucci took a serious turn: a nervous breakdown forced him to forego any form of activity; on 18 December 1862, his letter of resignation arrived at the Presidency of the Society.

The loss of his friend Matteucci could not have been helpful to Barsanti, who found himself alone in having to deal with a job that required more and more time and energy. Having received from the Council of the Society the permission to negotiate with the Workshops of Bauer & Co, named Elvetica of Milan, the future Breda Workshops, the engine was built at once and worked so regularly and with such overall satisfaction as to persuade Barsanti and the Society to present it at the "Competition with prizes of encouragement" organized annually by the Royal Lombard Institute of Sciences, Literature and Arts of Milan (Figure 8).

On 5 and 6 June 1863, the Selection Committee, composed of Professors G. Codazza, C. Haiech and L. Magrini, subjected the engine to tests from which was taken that:

> the consumption per horse/hour was one-fifth of the consumption per horse/hour of the Lenoir engine. Thus while the cost per horse/hour of the Barsanti and Matteucci engine was nearly equal to the cost per horse/hour of the steam engine, the Lenoir engine resulted in a cost five times more.[11]

This comparison was possible because the tests of effective consumption made on the Lenoir engine by the engineer Tresca, director of the "Conservatoire d 'Arts et Metiers" in Paris, were known and contained in the "Annals de Conservatoire d 'Arts et Metiers" and specifically in the issue of 4 April 1861. After a detailed description of the engine, the Selection Committee read their report of the competition stating the undeniable priority of the Barsanti and Matteucci invention, compared to that of Lenoir, which came to light seven years later, and it sanctioned the absolute superiority.

It could not have been otherwise because the Commission had made findings on the technical aspect of the Lenoir engine, and even the report of the Engineer Tresca, had drawn the conviction of the immaturity of such a machine that contrasted naturally with that of Barsanti and Matteucci and that was described in the following way:

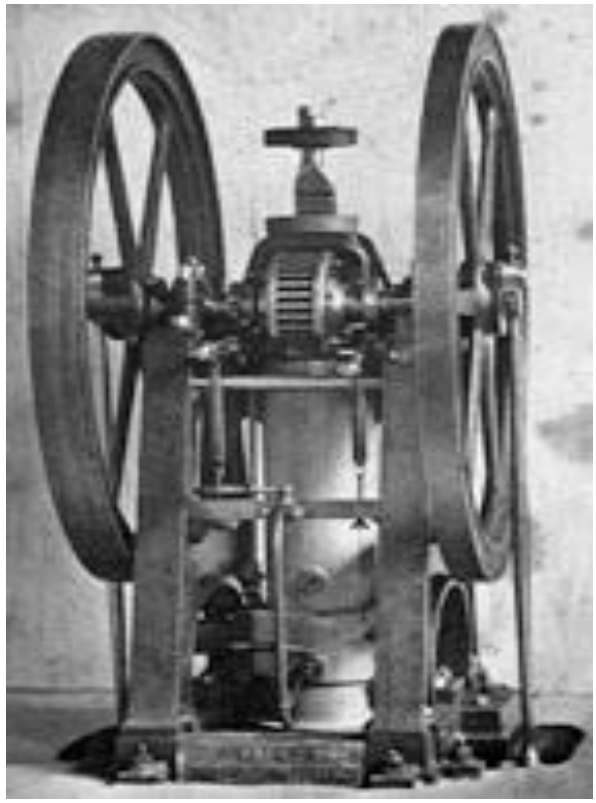

Figure 8. Photo of the time of the motor constructed by Bauer & Co.

> for the ease and comfort of its application, it can be demanded from small industries who lie in those circumstances where the use of steam is not desirable; that it can be powered by a generator at any distance, introduced in the mines, in factories and in any kind of laboratory without the fear of explosions and fires; without the inconvenience of the excessive heat and smoke, with the advantage of being able to ignite and suspend the action without preparations and without any other maneuver other than to open or close a tap.

It was concluded: "the silver medal was awarded, with judgement suspended for the greater prize until after the outcome of further experience".[12]

These further experiences most likely referred more to the construction processes than to the concept because on page 405 of those Acts can be read: "however, there remains a desire for more finiteness of the smiths, to avoid even small impacts of the joint", that is, that precision of work which Barsanti and Matteucci had always sought and expected.

Production

All of this was sufficient to make Barsanti decide that it was time to start mass production, which was also seen in the increased demand. He resumed contact with the firm Escher Wyss & Co. of Zurich, and also spoke to the Pietrarsa Workshop of Naples, but both declared themselves unavailable. However, before venturing into a large enterprise, Barsanti felt the need to clarify definitely the priority of his work, and not now having his close friend Matteucci, this gave him some discomfort. The man was greatly missed at exactly the moment of success when he felt most alone. He remembered how fervently he had defended him when a newspaper of the time by error had attributed the invention of the new engine only to Barsanti: he immediately ran to clarify to the Tuscan Monitor Authority its duty to rectify the mistake

> the invention of that which really consists of the work of the detonation of a gaseous mixture to produce a driving force to replace the steam belongs to both in common, but in its origins and its progressive development, it belongs to the undersigned and to his friend Felice Matteucci, valiant lover of physical-mathematical sciences. Such declarations are made as a debt of justice.

He decided accordingly to visit him in that small village of Monti Pisani where Matteucci was trying to recover his strength and where Barsanti hoped to regain the energy of the initial enthusiasm. The meeting must have invigorated both, as they decided it was time to open that envelope that had been given to the 'Accademia dei Georgofili' ten years earlier to protect their experience, on the condition that it should not be opened except upon their request. Having thus had the consent of his friend, Barsanti formally asked the Secretary of the Academy to remove the seals from the Memoir deposited on 5 June 1853, having found themselves in the circumstance of having to contest the date of the invention described within; on 20 September 1863, after the recognition of the seals, the envelope was opened. From this, the clarity of their ideas can be deduced exactly, which they faithfully pursued without ever departing from them; such was their assurance.

Also under the signatures of Barsanti and Matteucci were included the signatures of many of the eminent scientists of Florence. The publication of the document would have put an end to all doubt and any controversy. The majority of the public was not shaken, not by the signatures of prominent figures, nor by a citation that came out in a Florentine newspaper *La Nazione*[13] in which was recorded that the engine had been operating since 1856 at Maria Antonia Station of Florence: which meant that without a shadow of doubt, it was still in operation. In addition, this engine failed to account for the one presented at the First Italian

Exhibition of Arts and Crafts in Florence and that which was honoured at the Royal Lombard Institute of Science, Literature and Arts.

The new government, formed just two years earlier in Turin for the emerging Italy, was not yet wholly unified geographically, and was in no condition to interest itself in other problems. The high hopes of prosperity foreseen with the destruction of the customs barriers were at once unfulfilled; however, so great were the difficulties that they began to diminish only at the beginning of 1876 when a balanced state budget was laboriously reached.

Fortunately Barsanti was not a man who held much for applause. He wanted to give a safe, economical and suitable instrument to the workers in order to alleviate their hardships.

Production at Cockerill, Seraing

Coming from the knowledge that in Belgium, at Seraing, near Liege, the workshops of the Cockerill Society operated for the construction of steam engines, Barsanti sent a letter on December 16, 1863 to the Directorate of Society in which he illustrated the engine built by Bauer of Milan, described its characteristics and showed its efficiency. Cockerill's response was swift, asking the Society to send the engine to their workshops to see how it worked, and as an even greater guarantee, that they also wanted a technician to follow the assembly.[14]

This answer was brought to the attention of the Council of the Society of the New Engine of Barsanti and Matteucci; the decision was immediate: Barsanti had to go personally to Seraing. These decisions, while on one side encouraged Barsanti, on the other hand worried him because he was no longer the young man from the first experiments, and also his health, already poor, began to suffer the consequences of nights lost at work on the engine, and what was hardest to bear was the decay of his sight, he was inexorably going blind. The famous Ximeniano Manuscript, fundamental for the reconstruction of the work of the two inventors, which has no date, does not even have Barsanti's handwriting, but contains arguments that only he could have known.[15] It can only be that he dictated it because of the myopia that had long prevented him any amount of prolonged work. His superiors also noted this; however he did not oppose the will of Society: the inventor had to follow his creation. Barsanti, out of respect for the Society and the affection that bound him to Matteucci, saw that he could not be replaced at such a delicate juncture, and agreed to leave.

Thus far we have always spoken of Barsanti as a scientist and inventor and never of Barsanti the Priest; he practiced his ministry with a care greater than that put forth for his studies. There should be no surprise therefore that Barsanti, before leaving for such a difficult trip, addressed His Holiness to ask for the 'Apostolic Blessing'. We must not forget that Pope Pius IX was schooled by the Scolopi in precisely the same Volterra school where, many years later, Barsanti had his first teaching assignment.

The request for the Blessing was an exemplary page of complete dedication:

> Thanks to the Divine assistance I can say that my persevering and laborious studies are now reaching a point to give grounds for hopes of favourable success: such that, on behalf of some industries and with the approval of my Superiors, as in Italy there are not enough workshops for small jobs, I prepare to leave for Liege, and there to build engines according to the system invented by me.
>
> Since, however, in the middle of serious difficulties and obstacles of every kind ..... I have always been inspired and supported by the idea that my work, although aimed for itself at a useful material and land, may, however, and should be directed to a more noble and high purpose, in the moral and religious interests of the people, and perhaps, in these miserable times, be able to be advantageous to the Church, to which I in my circumstances, I believe exclusively sacred: ..... I humbly implore the 'Apostolic Blessing' on me and on this part of my intelligence, and on my labours, so that all the profits and effects which may ensue, in the end redound to the benefit and glory of our Holy Catholic Religion at least because it may be seen, even after their enemies, but not to be opposed to fostering and cultivating the discoveries of science and industry.[16]

Barsanti left in the last days of February 1864 and stopped for some days in Paris trying in vain to meet Lenoir; it is likely that, as had happened to Matteucci, the unavailability was not just random. Having reached Seraing on 25 March 1864, Barsanti wrote the following to the President of the Society for the New Engine of Barsanti and Matteucci:

> I was immediately put into action and the outcome fully corresponded to all my hopes, that which had attracted a sudden wonder in the midst of all those workers who were not waiting for a point a resolution of this sort. Before long, the news had spread through the establishment, not only to employees, but to the workers and the engineers, virtually all were brought to see it .....
>
> As a true story and to give just satisfaction in these latter gentlemen, members of the board, and to all of our stakeholders, I should add that the impression was so great that during the suspension of the work of the workers, with pleasure, I had to put the machine back into action again and satisfy their vivid curiosity. I cannot quote all of the details and anecdotes of this interesting exhibition, just to say only that the head of the workshops, in inviting me to show the machine to his friend, asked me to keep it in low action, because otherwise it was the distraction to all of his workers. [17]

The engine which arrived at Seraing from Milan was that which had been built by Bauer the year before, but Barsanti did not have the intention to reproduce it exactly, but rather to implement some changes and to apply a more streamlined

system which had already been designed Matteucci in 1857. Following the success, Barsanti agreed with Mr. Dawans from the Directorate of Cockerill Workshops that 1 April 1864 would be the beginning of the mass production.

Barsanti's Death

On the morning of 30 March, Mr. Dawans, who was to define the final minor details with Barsanti, waited in vain; a delegate went at once to the house of Don Giuseppe, the chaplain of Italian miners, who had accommodated Barsanti, and found him seriously ill with a very high fever. The diagnosis was not encouraging: it was suspected to be a fever of typhoid origins. After the diagnosis was confirmed, a swing of hopes and disappointments began that ended on 19 April with the death of Barsanti. The body returned to Italy at the end of May and was buried in San Giovannino in Florence.

Upon Barsanti's death, it seemed logical that Matteucci would become the Technical Director of the Society, but the President was in disagreement and appointed as Technical Directors of the Society, P.P. Scolopi Antonelli and Cecchi. To exclude Matteucci was a serious mistake, because, even during his poor physical condition, he had never felt outside of the issues, and now restored, was ready to reclaim his principles.

With his knowledge of the difficulties that had blocked the project of the Society, he tried to save the situation by offering the President his full availability; in his letter of 15 January 1866, he proposed to introduce, at his own expense, a larger machine than that which had been built in Zurich, with transformations which he believed would improve profits.[18] The response was late and interlocutory: the Society for the New Engine of Barsanti and Matteucci was closed before the end of that year.

Barsanti and Matteucci were the true soul of the Society, which, without them, fell victim at once to the differences of opinion created internally by the Board of Directors.

Matteucci applied for a patent titled "Double effect igneous-pneumatic engine" which was issued by the kingdom of Italy to Mr. Felice Matteucci and the Companions of Florence, No. 3096 for two years from 30 June 1866. The machine described was the result of the changes proposed by Matteucci in the larger machines built in Zurich. Matteucci attempted the implementation, at his own expense, of such a machine, according to a committee for the fusion of several pieces of the Livornese Workshops of the railways, but these do not record the conclusion of this initiative. At the same time he also carried out, together with Babacci, the study of a "New system of gas engine".

Otto and Langen's Engine

The Engineer Felice Matteucci was particularly impressed when the news arrived in Paris that at the Hall of the Mechanics at the International Exhibition, the

Prussians Otto and Langen had exhibited an engine that had won the gold medal and that had made everyone forget even the Lenoir engine. The great outcry was also fuelled by controversy that disputed without reserve that there was a strange resemblance to the engine patented by two Italians Barsanti and Matteucci on 9 January 1858. Ironically, the French were the ones who were most committed to defending the rights of the Italians. The first and foremost was M. Durand, director of the newspaper *Le Gaz* of Paris, who on 22 August 1867 wrote the following to Matteucci:

> Illustrious and Honoured Master. Permit me to ask some information and excuse me for the intrusion in the midst of your learned work. I will quickly ask my question. On 9 January 1858, a patent of invention for a gas engine was taken in France by Father Barsanti.
>
> At the exhibition of 1867, a machine was copied onto your design by two Prussian engineers. This engine was honoured with the gold medal. I have criticized this reward in my newspaper *Le Gaz* and send you the issue that contains my article marked in pencil to save the trouble of searching for it.
>
> This article has been appreciated by many but it is the object of a complaint by those who presented the Prussian machine.
>
> Not being able to choose a better judge on this occasion than you, I take the liberty to ask you to read my article and tell me your opinion on the judgement that I gave and the explanations that I have given regarding the reasons that caused the abandonment of your patent ... ".

Reported here is the following significant part of the article:

> We are not able to applaud as much for the distinction in which Essa (exhibition) has honoured the gas engine of Mr. N. A. Otto and Co. of Cologne; we believe that in this circumstance, a mistake has been made and that the gold medal that has been given to them was an error. At first glance, this model appeared to us to be none other than a poor imitation of the invention of Mr. Barsanti and Mr. Matteucci, patented in France on January 9, 1858, if this was not the same model, it was at least its brother and the way it works shows this relationship as evidence.
>
> In its integrity, it is more or less the Barsanti and Matteucci engine.[19]

This was another disappointment that went towards adding to the many already suffered. Nevertheless Matteucci decided once again to defend his rights and those of his close friend. He went to Paris and tried to make his voice heard through the collaboration of faithful friends, but the only thing he got was an answer, the most contradictory that the French could give: "You shouldn't protect the inventor, but the invention".

They had wanted to forget that the output of the Lenoir engine had followed exactly the opposite concept. The thing that made Matteucci the saddest was the uncooperative behaviour of the Italian Delegation of the International Exhibition. The only major voice that rose in defence of the Italian cause was Professor Engineer Giuseppe Colombo, who certainly had seen the Italian engine function when it was in competition in Milan for the Royal Lombard Institute of Sciences, Literature and Arts. In the comments on the progress of the machine at the Paris Exposition, he expanded thus:

> "For Italians, this machine (the Otto and Langen engine) should awaken the most painful impression; it should arouse a universal feeling of shame, if the general public really knew how much you would rather not and do not care about the attempts that they do, indeed, are sceptical in their regard. We do not intend to speak about the fact and we want to believe that it will be announced shortly and universally in the same city where the Langen machine was a real triumph; the fact that the Prussian machine is purely and simply the Barsanti and Matteucci machine, that has been for many years published and known in Italy ..... . Except that, as always happens in Italy, they appointed a Committee to judge; they had favourable reports; but they was never known to form a serious Society who pushed forth the application and made the merits known abroad: and Barsanti, the inventor of the machine, died without having had the satisfaction of knowing appreciation.[20]

Columbus was the last Italian of the nineteenth century, who officially and publicly took up the defence of the two inventors. Inventors who became, over time, of a progressive neglect nationally; indeed one can say that from this moment, almost all foreigners mention Barsanti and Matteucci as protagonists in the research of the machine which replaced the steam engine.

Already in 1868, the authoritative French scientist Achille Cazin published in *Le Monde* an article *Sur les machines a gaz* in which is cited the French patent from 9 January 1858 of the Italians Barsanti and Matteucci and explains the operation of the related engine.[21] The same article features an interview by Professor Kuhlman regarding the priority of the invention of a gas machine and among other things says:

> "We should recognize that Barsanti and Matteucci on one hand, and Otto and Langen on the other, have invented this machine without the first having had knowledge of the design of the second."

Obviously if this was true for Barsanti and Matteucci, it was not true for Otto and Langen who built their machine eleven years after that which worked in Florence at the Maria Antonia train station.

Subsequent History

Everything seemed to force the Barsanti and Matteucci engine into oblivion, although someone in Italy continued to believe and to work. Babacci, in fact, made the request to the Kingdom of Italy and a directive was granted on 15 April 1868 for certain "Improvements made to the original engine of Barsanti and Matteucci".[22]

He had had little time to spend because the fate of many states was disturbed: in June of 1870, the French army was crushed by the Prussian one, the great protector of the Papal States fell, thus enabling the young Kingdom of Italy to complete their unification. On 20 September, Rome was occupied and the temporal power of the church was cancelled, the Pontiff was removed to within the Leonine walls and the black velvet robe of excommunication was laid upon Italy and its government. This shocked the consciences of all Italians in such a way as to interrupt all relations between ecclesiastical institutions and civil society; the dreaded "miserable time" had been reached.

Strangely, from this moment no one, except in a few cases in Italy, expended more words in defence of the inventors of the internal combustion engine, no one felt entitled to do so and Barsanti and Matteucci became as such the first victims of this situation. This appears to be the most likely hypothesis, especially after it was discovered that the Ximeniano opened its archives after the Agreement stipulated in 1929. In the period between 1870 and 1929, only studies and quotes from foreigners existed; an episode worthy of mention is the grand prize Montyon awarded in 1878 to Lenoir by the Academy of Sciences in Paris proclaiming him the creator of the first internal combustion engine.

Times changed, the competitors left the scene, the Prussians were forgotten, and it was decided that it was no longer appropriate to take care of the invention but to look out for the inventor. The only Italian voice of the period was that of the Advocate Tito Martini in an article: "A Brief History of the Barsanti and Matteucci Engine"**.** And he praised this work such that in 1931, after the Italian State and the Governor were returned to the Blessing of the Holy Father, the director of the Ximeniano Observatory, Father Guido Alfani, published the first official study which claimed priority in a decisive manner, producing documents, original and indisputable eyewitness accounts, such that they cannot coincide with what is stated by the German historian Schotten, who commenting on the enthusiasm generated by Otto and Langen, said:

> the rest of this machine was not without precursors: the Italians Barsanti and Matteucci had already some years previously thought something similar to that ..... If the arrangement of Barsanti and Matteucci was more generally known, the new invention would hardly have made so much wonder, in so much as the Italians show an identical way of constituting the essence.[23]

The German engineer Hugo Guldner on page 3 of his famous treatise[24] started with the Barsanti and Matteucci engine declaring: "with this started the true practical evolution of our machines'.[25] Furthermore, the Director of the Museum of Munich using a statement from Dr. Engineer Friedrigh Sass on pages 8 and 9 of his treatise reaffirmed this.[26]

After Alfani's study, many illustrious Italians, such as the engineers Armando Levi-Cases, Giuseppe Orsi, Maurizio Cavallini, and others, made available data and unpublished documents; they had produced detailed works that were the motivation behind the posthumous interest that would lead to the solemn national recognition of the two inventors and which concluded on 24 October 1954 with the transfer the mortal remains of Barsanti from San Giovannino to the Church of Santa Croce in Florence, house of the Italian genius, while Matteucci upon his death was placed in the Villa in Campi Bisenzio.

To please the audience, it is fair to conclude that a Scotsman, Sir Dugald Clerk, spoke up in this sense in his 1893 work, "The Gas Engine". Clerk, commenting on the Otto and Langen engine, wrote that: "it was absolutely identical in principle with the previous invention of Barsanti and Matteucci."

Notes and References

Archives of the Barsanti and Matteucci Foundation of Lucca (Lu), Via S. Micheletto 3.

[2] National Library of Lucca.

[3] British Patent 1072, 12 June 1854 (Patent Express, The British Library, London) .

[4] See note 1

[5] *The Engineer*, 22 January 1858, pp. 73/4.

[6] See note 1

[7] M. Bramanti, *Il motore Barsanti e Matteucci*, ETS Edition, Ch. 6, p. 91 ff.

[8] Ximeniano Archives of Florence.

[9] B. Besso, *Le grandi invenzioni antiche e moderne*, Milan, 1869 ed. Trevas, vol. III, p. 127 ff.

[10] See note 1

[11] Report: "The new gas engine designed by Mr. Barsanti and Matteucci", *Proceedings of the Royal Lombard Institute of Science, Arts and Literature*, Volume III, Issue XVII-XVIII, Milano Bernardoni Printing, 1863.

[12] See note 11.

[13] *La Nazione*, 238, fifth year, Wednesday 26 August 1863.

[14]National Library of Lucca

[15]See note 1

[16] M. Bramanti, *Il motore Barsanti e Matteucci***,** ETS Edition, Letter n. 5, p. 159.

[17] Ibid., Letter n. 16, p.167.

[18] See note 1

[19] *Le Gaz*, n. 6 from 31 July 1867 (National Library of Paris, Rue Richelien, côte 4069/10).

[20] Annurario Scientifico Italiano (Milan, Treves, 1867),

[21] *Le Monde*, 6th year, 16th cycle, pp. 496-500, Paris 1868.

[22] *Proceedings of the Royal Venetian Institute of Literature, Sciences and Arts*, 1906/07, Cycle LXVI Part II.

[23] See note 22.

[24] Hugo Guldner, in *Das entwerfen und der berechnem verbrennungsmotoren* (Internal combustion engine design and Calculations), p. 3.

[25] On 28/10/2004 at the ceremony of the first full-size model of the Barsanti and Matteucci engine donated by the Foundation.

[26] Dr. Ing. Friedrich Sass in *Geschichte des deutschen verbrennungsmotorenbaues* (History of the German Internal Combustion Engine), pp. 8, 9.

A Note on the Fondazione Barsanti e Matteucci

The purpose of the Foundation is to spread and promote reasons for the first claim of the invention of the free-piston internal combustion engine, and to explain the historical reasons for which Barsanti and Matteucci were temporarily forgotten.

The Foundation was established on June 4, 2003, through the involvement of the Rotary of Lucca, the Foundation of the Cassa di Risparmio of Lucca, the Foundation of the Banca del Monte di Lucca, the Chamber of Commerce of Lucca, the Industrial Association and the ICA.

The Foundation is non-profit making and considered it opportune to also take a legal personality, and promote and restoration of historical truth that has led to the search of the documentation traceable in the Italian and international patents obtained by the two scientists of Lucca, and to demonstrate to the world the true paternity of the invention. From this point, historical tests in hand, it has begun work on the continuous and effective promotion, both nationally and globally, to restore the historical truth and to make it recognizable by everyone that the real inventors of the internal combustion engine were Barsanti and Matteucci.

Via San Micheletto 3, 55100 Lucca, Italy
info@barsantiematteucci.it
www.barsantiematteucci.it