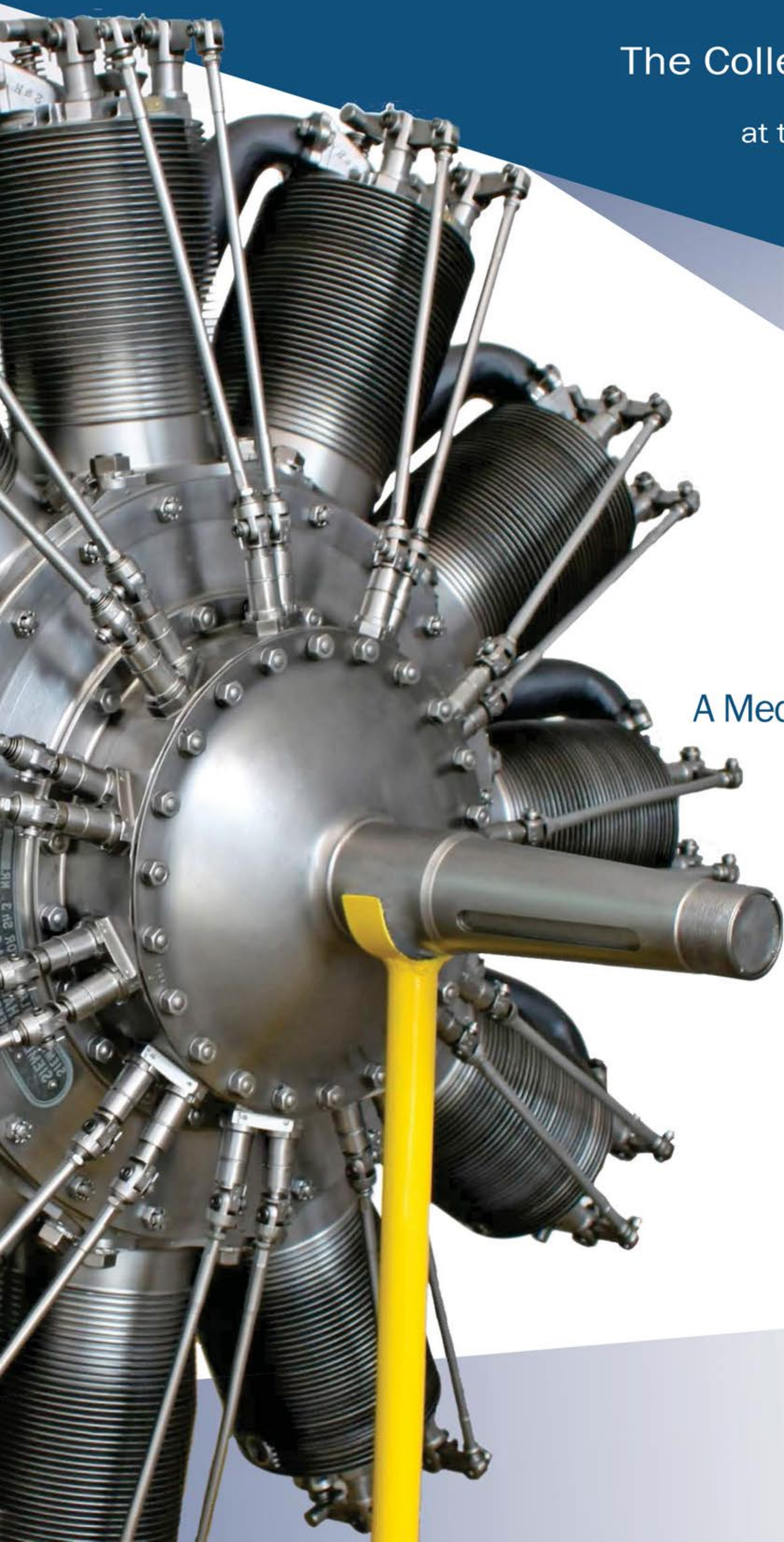
The Collection of Engines

at the Museum of Engines and Mechanisms University of Palermo



A Mechanical Engineering Heritage Collection

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MECHANICAL ENGINEERING HERITAGE COLLECTION

MUSEUM OF ENGINES AND MECHANISMS
UNIVERSITY OF PALERMO

With over 100 artifacts, the collection of engines illustrates the evolution of steam and internal combustion engines in a european context from the late nineteenth through twentieth centuries. It includes both stationary and transportation power units with an emphasis on automotive and aircraft engines.

Both reciprocating and turbine designs are represented, and many are now rare. Among the more significant examples are FIAT 8V and FIAT-Ferrari Dino automobile engines, Siemens-Halske Sh.IIIa counter-rotary aircraft engine, Neville steam engine and Ljungström counter-rotating steam turbine.

ASME THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS - 2017

The History and Heritage Program of ASME

Since the invention of the wheel, mechanical innovation has critically influenced the development of civilization and industry as well as public welfare, safety and comfort. Through its History and Heritage program, the American Society of Mechanical Engineers (ASME) encourages public understanding of mechanical engineering, fosters the preservation of this heritage and helps engineers become more involved in all aspects of history. In 1971 ASME formed a History and Heritage Committee composed of mechanical engineers and historians of technology. This Committee is charged with examining, recording and acknowledging mechanical engineering achievements of particular significance.
For further information, please visit www.asme.org

Nominator

Marco Ceccarelli received his PhD degree in 1987 at the University La Sapienza in Rome. He is Director of LARM (larmlaboratory.net), the Laboratory of Robotics and Mechatronics at the University of Cassino and South Latium. He is scientific editor of the Springer Book Series on the History of Mechanism and Machine Science and associate editor of several journals. He is author/co-author of several books and papers. For his activities he has received the Degree of Doctor Honoris Causa from a non-Italian University and ASME's Engineer-Historian Award. He is an ASME fellow. He was elected Secretary-General of the International Federation for the Promotion of Mechanism and Machine Science (IFToMM) in 2004-2007 and IFToMM President in 2008-2011 and 2016-2019.

Landmark Designations

There are many aspects of ASME's History and Heritage activities, one of which is the landmarks program. Since the History and Heritage Program began 263 artifacts have been designated throughout the world as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general.The Landmarks Program illuminates our technological heritage and encourages the preservation of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. It also provides reminders of where we have been and where we are going along the divergent paths of discovery. ASME helps the global engineering community develop solutions to real world challenges. ASME, founded in 1880, is a not-for-profit professional organization that enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education and professional development programs provide a foundation for advancing technical knowledge and a safer world.

Author

Giuseppe Genchi, Mechanical Engineer, received his Ph.D. in Energetics in 2004 at the University of Palermo (Italy) where he is member of the research group on Fluid Machinery and Applied Mechanics. His main research activities focus on internal combustion engines with homogeneous charge compression ignition (HCCI) and double fuel combustion. Co-author of several scientific papers and co-editor of the book Essays on the History of Mechanical Engineering (Springer International, 2016), he is the founder and the operations manager of the Museum of Engines and Mechanisms of the University of Palermo, where he planned and personally carried out the conservation/full restoration of the 300+ artifacts in the museum collection. He has helped organize and manage 40+ cultural events, temporary exhibits, and technical conferences at the museum. He is member of the Scientific Committee of the Museum System (University of Palermo) and he is also member of the national culture committee of the Automotoclub Storico Italiano (Italian Federation of Classic Vehicles Clubs, part of FIVA).

Energy and History, the Museum of Engines and Mechanisms.

▪ Energy can be neither created nor destroyed, it can only be transformed. A large variety of machines have been invented to transform energy, and these machines have led to significant changes in science, the economy, and society. Steam engines were among the first machines used to produce mechanical power for industry and transportation. They played a key role in the Industrial Revolution at the end of the 18th century. Since that period dependence on energy-transforming machines has spread everywhere, leading to irreversible effects on industrial production, transportation systems, and the general quality of life. For example, they influenced the shift from a socio-economic system mainly based on agricultural and commercial activities to the modern industrial system. By the early 20th century internal combustion engines, such as spark-ignition or Diesel engines, had found application in many fields of technology and industry and had begun to displace steam engines. Internal combustion engines prompted the development of new transportation systems dependent on the automobile and modern aircraft. In summary, devices for energy transformation are the basis of modern technological society. They can be considered part of our general cultural heritage, and, therefore, it is important to preserve, to make broadly available, collections of machinery as a visual representation of the evolution of technology. Italy is internationally known for its artistic and archeological heritage, but it also has a broad technological heritage preserved in many museums and private collections. The Museum of Engines and Mechanisms (figure 1 and 2) of the University of Palermo [1], inaugurated in 2011, has a vast and heterogeneous collection of engines and scientific equipment, one of the most important in Italy. Many of the collection's components were used in the University in various fields of research and teaching from the time when the Royal Application School for Engineers and Architects was founded in Palermo in 1866 onwards [2]. Today, outdated by new technologies, the machines in the collection are a remarkable heritage that nicely depicts the evolution of science and technology in the field of machines and mechanics over more than a century [3]. Awareness of the considerable historical value of these assets, as well as the need to preserve them, provided the impulse for their restoration (figure 3) and, as a direct consequence, for the establishment of the Museum in 2008. Meticulous historical research and the acquisition of technical data have allowed the museum to provide each item in its collection with an explicative poster that contains historical and technical information, as well as photographs and drawings. The simple, linear arrangement of the museum groups all related items chronologically to highlight the development of different systems, technical arrangements, and materials. Of particular interest for their rarity and value are several engines used in early high performance aircraft, a stationary steam engine from the late nineteenth century, several record-setting sports car engines, and the rare historic FIAT G.59 aircraft. As part of the University of Palermo, the Museum promotes many activities in the fields of education and cultural enrichment, including scientific conferences and restoration workshops to enhance its collections. Located in the Department of Industrial and Digital Innovation, the Museum is part of the Museum System of the University of Palermo (MUSEIUNIPA, musei.unipa.it), whose task is to promote the preservation and the public enjoyment of the region's historical and scientific heritage [2]. The Museum system is composed of six scientific museums, various artistic and scientific collections, historic buildings, and archaeological sites.

Figure 1 - Panoramic view of the Museum

Figure 3 - Restoration activities

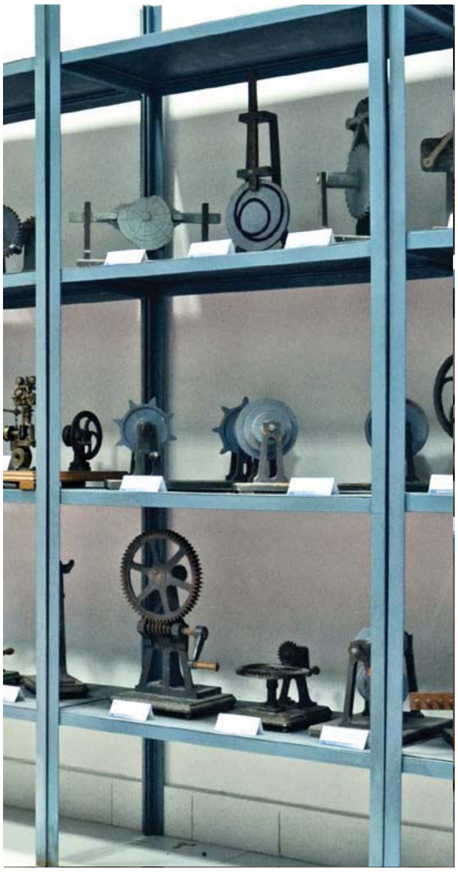

Figure 2 - A part of the instructional mechanisms collection

Figure 4 - Neville stationary steam engine, ca. 1880

Figure 5 - Marine steam engine, ca. 1890

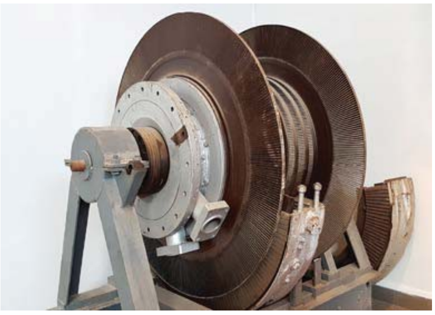

Figure 6 - Ljungström steam turbine, 1928

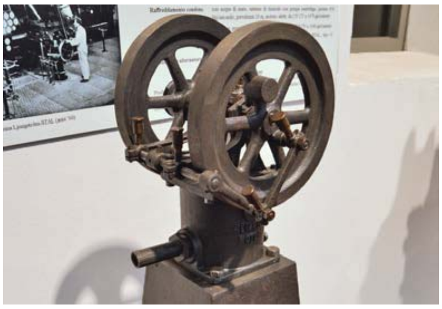

Figure 7 - Stationary Stirling engine, Louis Heinrich Maschinenfabrik, 1905

The collection of engines

Steam and stationary engines

▪ The collection of engines of the Museum is wide and heterogeneous, ranging from steam engines to turbojet engines. The oldest artifact in the collection is a typical stationary steam engine (figure 4), widely used for power production in industry during the nineteenth century. This type of engine can be considered an icon of the industrial revolution, and very few specimens of large dimensions have survived. The Museum's engine is a single-cylinder, double acting engine, which has a displacement of 26148 cm^3 (1596 cu in). Its large flywheel has a diameter of 2000 mm (6.56 ft). The engine has a power output of about 10 HP at 120 rpm, with a steam pressure of 8 bar (116 psi). The engine, manufactured in Venice by the E. G. Neville & Co, features a Meyer-type variable valve timing system controlled by a Buss-type automatic speed regulator (Schaeffer & Budenberg). The collection also includes a marine steam engine dating back to the end of the 19th century. It is a compound engine (i.e., double expansion type) with two in-line "double effect" cylinders (figure 5), with a power output of about 50 HP at 350 rpm with a steam pressure of circa 10 bar (145 psi). It is equipped with two sliding valves (for high and low pressure cylinders) driven by a Stephenson reverser system. The overall structure suggests its application in medium-sized vessels, such as yachts and fishing boats. Both this machine and the "Neville", entirely restored, are equipped with electric motors which allows viewing of the complex movements of their parts.

Late in the second half of the 19th century steam turbines began to challenge piston steam engines in large power plants and for marine propulsion. Today steam turbines are commonly used in most power stations. The collection of engines includes a Ljungström turbine (figure 6), which owes its name to the Swedish engineering brothers Birger and Fredrik Ljungström, who patented it in 1908. Its particular feature is that it is a multi-stage, counter-rotary, centrifugal steam turbine. It consists of two discs of appropriate configuration facing each other, connected with two independent counter-rotating shafts. Several rings of blades are connected to the disks. Steam is introduced into the central compartment through hollow shafts and flows through the vanes of the two discs in ordered succession towards the periphery. Counter-rotary turbines found extensive use in stationary power plants, with some applications also in locomotives, thanks to their favorable mass-to-power ratio.

The limited number of radial stages, the need to install two separate electric machines, and the growing demand for more powerful turbines led to the decline of counter-rotary turbines in favor of the traditional type (axial flow) beginning in the late 1950s.

The Ljungström machine is closely related to the history of the city of Palermo: it was produced by S.T.A.L. (Svenska Turbinfabriks Aktienbolaget Ljungström) in 1928, and it was used in the city's Alessandro Volta power station, providing electricity to a large part of the town until 1952.

It had a maximum power output of 9100 kW at 3000 rpm, using super-heated steam at 350 °C (662 °F) at a maximum pressure of 14 bar (203 psi); it drove two three-phase alternators coupled in parallel, both also manufactured by STAL.

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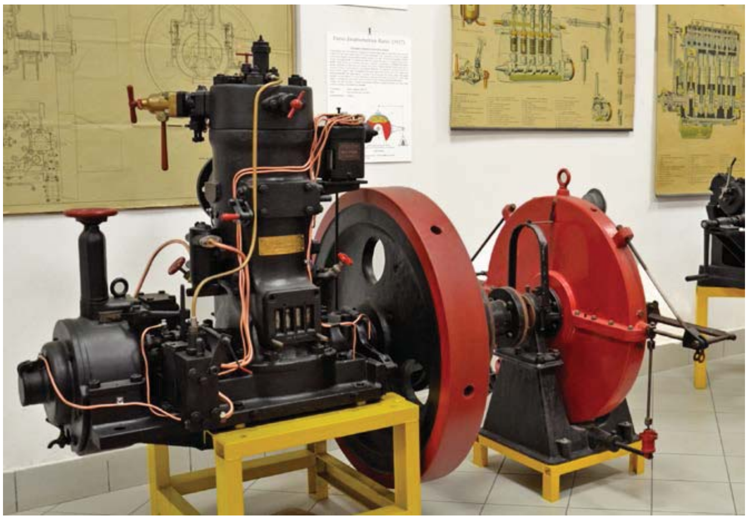

Figure 10 - DWK two-stroke Diesel engine with Ranzi hydraulic brake, 1927

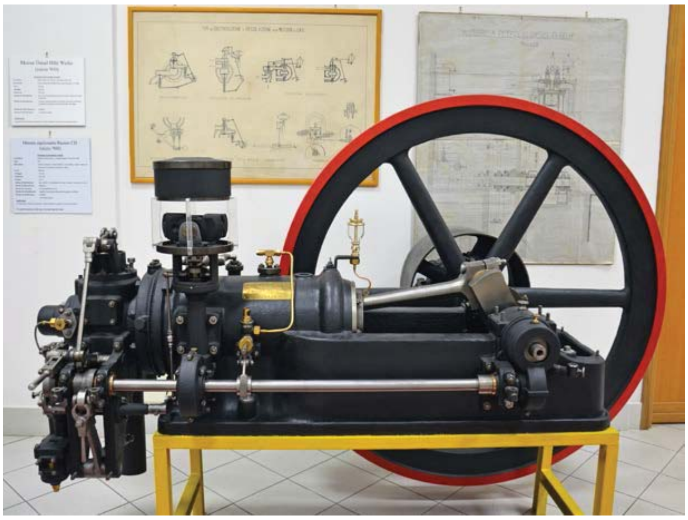

Figure 11 - Hille Werke Diesel engine, ca. 1910-1920

achieved a certain degree of commercial success. The Museum's collection includes two Stirling engines (the smaller shown in figure 7) manufactured by the Louis Heinrich Maschinenfabrik between 1895 and 1905. This company was one of the leading manufacturers of small and medium size stationary engines operating on the Stirling cycle. This type of reciprocating engine operates by cyclic compression and expansion of air at different temperatures, using an external combustion process like the steam engine. It has a very simple design, noiseless operation, and it can use various fuels, both liquid and gaseous. For these reasons Stirling engines were often employed to drive small industrial or laboratory machinery, as well as domestic equipment such as small hydraulic pumps or fans. Nowadays these engines are quite rare and pique the interest of many collectors.

At the beginning of the 20th century, internal combustion systems with spark ignition or compression ignition, with two- or four-stroke cycles, developed rapidly. Although the early internal combustion engines derived their overall design from the contemporary steam engine, the absence of a steam boiler, as well as related devices, on internal combustion engines resulted in a better mass-to-power ratio and easier working. Spark ignition engines were usually liquid- or gas-fueled. The oldest spark ignition engine of the collection is a Langen & Wolf stationary four-stroke, single-cylinder engine (figure 8), manufactured between 1895-1905. This is a very rare model that demonstrates some of the typical arrangements of early internal combustion engines. In particular, it has an archetypal valve train system with a sliding intake valve, directly derived from that commonly used on steam engines in the same period. The same sliding valve is also used to trigger the combustion process, which is started by means of a pilot flame. During the first decades of the 1900s, a series of technical advances led to important changes in the overall arrangement of internal combustion engines, as can be easily seen by comparing the Oreglia & Co. stationary engine (figure 9) with the one discussed above. Similar to contemporary automotive engines, it is an in-line, four-cylinder, four-stroke gasoline engine, which has a modern spark ignition system with a magneto generator and spark-plugs, flathead combustion chamber with a side valve drive train system, and an archetypal carburetor with a Venturi nozzle. This engine, manufactured in Italy by the Oreglia Company in 1920, is one of the very few surviving specimens of this manufacturer, probably the only one preserved in a public museum.

At the beginning of the twentieth century, the compression ignition engine, proposed by Rudolf Diesel in 1892, gradually came into use, at first, mainly in stationary and marine power plants. This engine type is well represented in the collection. The older ones date back to 1910-1920: the stationary single-cylinder, two-stroke DWK (Deutsche Werke Kiel) engine (figure 10); the four-stroke, single-cylinder Hille Werke engine (figure 11); and the single-cylinder, two-stroke HMG (Hanseatische Motoren Gesellschaft) engine (figure 12). The DWK engine was long used for research and instructional activities at the University of Palermo. For this reason, it is displayed together with its original Ranzi hydraulic brake, showing a typical experimental and instructional setup.

Figure 8 - Langen & Wolf petrol engine, ca. 1900

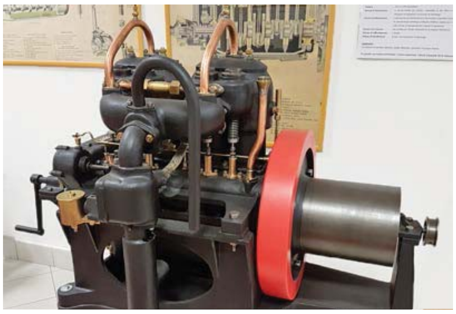

Figure 9 - Oreglia & Co., four-cylinder petrol engine, ca. 1910-1920

Figure 12 - HMG two-stroke Diesel engine, ca. 1910-1920

Figure 13 - Daimler Mercedes D.IV aircraft engine, 1916

Figure 14 - Basse & Selve BuS.IV aircraft engine, 1917-1918

Figure 15 - Siemens Halske Sh.IIIa counter-rotary aircraft engine, 1917-1918

Figure 16 - FIAT A.50 aircraft engine, 1928-1940

Aircraft engines

After the first flight of the Wright brothers in 1903, the aviation industry underwent rapid development. As a direct consequence, early aircraft piston engines, often directly derived from the automobile industry, evolved to match aeronautic needs as illustrated by many engines of the collection. The oldest are part of a batch of German-manufactured engines originally purchased for research purposes. Their arrival in Palermo was linked to Antonio Capetti, Professor of Aircraft Engines of the Polytechnic University of Turin (where he was Dean years later), who held the chair of Thermal and Hydraulic Machines at the Royal University of Palermo in 1925. The oldest aircraft engine is the Mercedes D.IV (figure 13), the first mass produced German engine to be equipped with a reduction gear mechanism to drive the propeller. This engine also represents the first attempt by Daimler to develop an eight-in-line engine. The engine passed its acceptance test in December of 1915, but Daimler manufactured only 429 copies because of its poor reliability, mainly due to problems in the crankshaft design. For this reason the Museum's D.IV engine is very rare, probably one of around ten surviving specimens. The engine's overall design, however, was very common in that period: aluminum alloy crankcase, cylinders and heads of steel with thin wall welded steel cooling jackets. The pistons were made of two steel parts (top and skirt), screwed and welded together. The engine has a displacement of 19770 cm^3 (1206 cu in), a compression ratio of 4.6:1 (due to the very poor knock resistance properties of gasoline at that period), and a maximum power output of 232 HP at 1440 rpm. This engine was fitted into several airframes, such as the AEG C.V and Albatros C.V. reconnaissance aircraft.

The collection also includes a very rare Basse und Selve BuS.IV engine (figure 14), which is probably one of only two surviving. The Basse und Selve AG in Altena (Westphalia, Germany) was a renowned factory, with a leading position in the production of aluminum pistons. At the end of 1915 Basse und Selve developed an aircraft engine using "Mercedes-type" cylinders with screwed heads, four valves per cylinder, and an overhead camshaft driven by gears. Only in October of 1917, after working through a series of problems that occurred with the first models, did Basse und Selve put the Bus.IV engine into production. It had a displacement of 22700 cm^3 (1385 cu in) and an outstanding maximum power output of 278 HP at 1400 rpm. Basse und Selve manufactured circa 330 BuS.IV engines, which were used to equip also the Siemens-Schuckert R.VIII, the largest aeroplane in the world at the time.

The Siemens & Halske Sh.IIIa engine (figure 15) is a masterpiece of the collection due to its particular arrangement and its rarity. At one point, it represented the highest development of the rotary engine, which was widely used for aircraft propulsion in the early period of aviation, from 1908 to 1918. The Sh. IIIa is radial counter-rotary engine with eleven cylinders and a maximum power output of 240 HP at 1000 rpm at sea level. Unlike a conventional radial engine, in the counter rotary engine the internal parts, such as the main connecting rods and crankshaft, rotated clockwise (seen from the front of engine) while the crankcase and the propeller (connected to the crankcase) rotated counter-clockwise. This particular arrangement allowed a reduction in the propeller's speed within its best efficiency range, increasing the power output by means of a higher combustion cycle frequency (which was the sum of the absolute speed of two counter-rotary parts). Furthermore, since the main rotating masses of the engine had to rotate with equal speed in opposite directions, the gyroscopic effect was partially reduced (compared to the standard rotary engines of that period). This increased aircraft maneuverability. Despite some drawbacks, the Sh.III was a technically advanced engine for its time, capable of remarkable performance in terms of maximum power output, specific fuel consumption, and mass-to-power ratio.

Figure 17 - Farina T.58 aircraft engine, 1930-1940

Figure 18 - Colombo S.53 aircraft engine, 1928-1940

Figure 19 - FIAT A.74 aircraft engine, 1935-1942

In September 1918, a Siemens-Schuckert D.IV equipped with the Sh.IIIa engine set a record by reaching an altitude of 8100 meters (26,575 ft) in 36 minutes.

Within the collection, Italian aircraft engines are represented mainly by those designed for light and training aircraft, such as the FIAT A.50, 100 HP, seven-cylinder radial engine (figure 16); the Farina T.58 (1930s), 135 HP, five-cylinder radial engine (figure 17); and the Colombo S.53 (1928-40), 94 HP, inline-four-cylinder engine (figure 18).

Before the 1930s FIAT mainly produced liquid-cooled aircraft engines. The FIAT A.74 (figure 19) and the FIAT A.80 (figure 20) were the first high power (900-1000 HP) air-cooled airplane engines produced by FIAT and date from the 1930s. Designed in 1935 by the well-known Italian engineers Tranquillo Zerbi and Antonio Fessia, these engines were based on a Pratt and Whitney license and were then developed by FIAT with several original improvements. The A.74 and the A.80 were designed with a large number of common parts (heads, pistons, valves, etc.) in order to simplify production. Both engines have a centrifugal compressor and an epicyclical Farman-type bevel gear transmission to drive the propeller.

The FIAT A.74 is a twin-row, fourteen-cylinder engine with a total displacement of 31250 cm^3 (1907 cu in) and a maximum power output of 840 HP at 2400 rpm at 3800 m (12,467 ft) above sea level. The Fiat A.74, although still in use when its performance was already outdated, was appreciated by pilots and mechanics for its excellent reliability and ease of maintenance, even when fed with fuels of poor quality and operated in difficult climates.

The FIAT A.80 is a twin-row, eighteen-cylinder engine with a remarkable displacement of 45720 cm^3 (2790 cu in). It was designed before the A.74, and mass production started in 1937, even though the engine's design was not yet fully settled. Under real operating conditions, due to the poor quality of the fuels available in Italy during the war, it suffered from poor reliability. This led to serious difficulties, and even when operated under better conditions its 1000 HP proved inadequate for its time. These engines were, nonetheless, produced in large numbers up to the first part of the 1940s and were widely used in many aircraft, but only a few specimens have survived.

Between 1920 and 1940, aircraft piston engines were continuously improved, reaching their maximum technical evolution during the 1950s. At the beginning of the 1940s the Daimler Mercedes DB 605 (figure 21) was one of the most advanced aircraft engines, along with the contemporary Rolls Royce engines (figure 22).

Daimler-Benz AG developed the DB 605 at the beginning of the 1940s as a replacement for the previous DB 601 model. The 605 is an inverted 60° V-12-cylinder engine, with a displacement of 35700 cm^3 (2179 cu in), and a maximum power output of 1475 HP at 2800 rpm. Its significance in the history of aircraft engine development is widely recognized in the technical and historic literature. Although a significant number of specimens still exist, they have very high value and are usually exhibited in the most important engine collections, as well as being used in historic airworthy airplanes. Technically the most interesting characteristic of the engine is its injection and super-charging system. The engine actually has a Bosch in-cylinder direct injection system that, though not a novelty for a German engine, was reliable and safe, avoiding dangerous backfiring and making the power output insensitive to the aircraft's maneuvering (especially during negative g-force flight conditions). The supercharging system is equipped with a single-stage centrifugal compressor driven by the engine via a hydraulic coupling. This system is governed by an automatic controller, which continuously varies the impeller speed (by acting on the transmission ratio of the hydraulic coupling) depending on altitude and manifold pressure. The compressor speed increases with the flight altitude and reaches its maximum value at 5700 meters (18,700 ft). The DB 605 equipped many high-performance airplanes such as the German Messerschmitt Bf 109 and the most advanced Italian airplanes of the 1940s, such as the FIAT G.55 and the Macchi MC.205.

Figure 20 - FIAT A.80 aircraft engine, 1935-1942

Figure 21 - Daimler Benz DB 605 aircraft engine, 1941- 1945

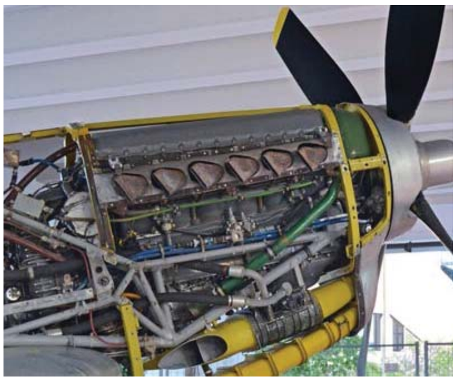

Figure 22 - Rolls Royce Merlin 500-20, 1950s

Figure 24 - General Electric J47 turbojet engine, 1948-1956

Figure 25 - Franklin 6V4, 1946-1970.

After the Second World War, turbojet engines gradually replaced aircraft piston engines in all but light aircraft. Early in the turbojet's development, manufacturers tried several different component arrangements. One of the main features which differed in early turbojet designs was the type of compressor: British manufacturers mainly used centrifugal compressors while others, such as Heinkel, BMW, and Junkers in Germany and General Electric in USA, preferred the multistage axial flow arrangement. After a few years, the latter became more widely accepted since it entailed a lower engine front section. The Museum's collection includes both centrifugal compressor engines, such as the de Havilland Ghost and General Electric's J47 axial flow turbojet (figure 24). The GE J47 emerged from the earlier GE J35 and was the first axial-flow turbojet approved for commercial use in the United States. Between 1948 and 1956, when its production ended, more than 30,000 units were built. Manufactured in various versions, with and without afterburner, it underwent continual development over the years, with considerable benefits in terms of power, reliability and maintenance. The J47 was used in many aircraft, including the North American F-86 Sabre. The F-86 Sabre was used in Italy beginning in 1956, notably by the "Acrobatic Team" of the Aeronautica Militare (the Italian Air Force).

The Museum collection is continuously improved through acquisitions. One of the most important would certainly be the FIAT G.59 aircraft (figure 23), a two-seater trainer aircraft of the 1950s, one of only five surviving today, and therefore one of the most valuable items in the museum's collection. The FIAT G.59 was one of the last high-performance aircraft equipped with a piston engine, and it is a symbol of the rebirth of the Italian aeronautical industry after the Second World War. Moreover, the FIAT G.59 is equipped with a Rolls Royce Merlin engine, one the most advanced aircraft piston engines in its period, as widely recognized in technical and historic literature. Although a significant number of copies still exist, these have very high value and are usually exhibited in important engine collections and are still used in historic airworthy airplanes. Thanks to the V-12-cylinder Rolls Royce Merlin (version 500-20), providing a maximum power of 1660 HP, the FIAT G.59 was mainly used as an advanced trainer and sometimes used as an acrobatic aircraft. It could reach a top speed of 609 km/h (378 mph) at an altitude of 6400 m (20,977 ft) above sea level, and had a ceiling of 12100 m (39,698 ft). The Museum's FIAT G.59 4B was purchased in 1964 by the former Institute of Aeronautics of the University of Palermo and is displayed after having undergone a thorough restoration in the Museum's workshop.

The collection includes piston engines designed for light aircrafts and helicopters produced after the Second World War: the most noteworthy are the unique prototype aero Guzzi V50, developed by Moto Guzzi in the 1970s for ultralight aircraft, and the Franklin 6A8 and the Franklin 6V4 (figure 25), both air-cooled boxer 6-cylinder engines developed at the end of the 40s, which well represent the typical arrangement widely used even nowadays for light aircraft piston engine. The Franklin 6A8 engine has been used over the years on seaplanes and light aircrafts, including the Piaggio P.136 and the Republic RC-3 Seabee. The Franklin 6V4, strictly derived from the 6A8 model, has a vertical cylinder block arrangement specifically designed for light helicopters such as the Bell 47.

Figure 23 - FIAT G.59 4B trainer aircraft equipped with a Rolls Royce Merlin 500-20 engine, 1950

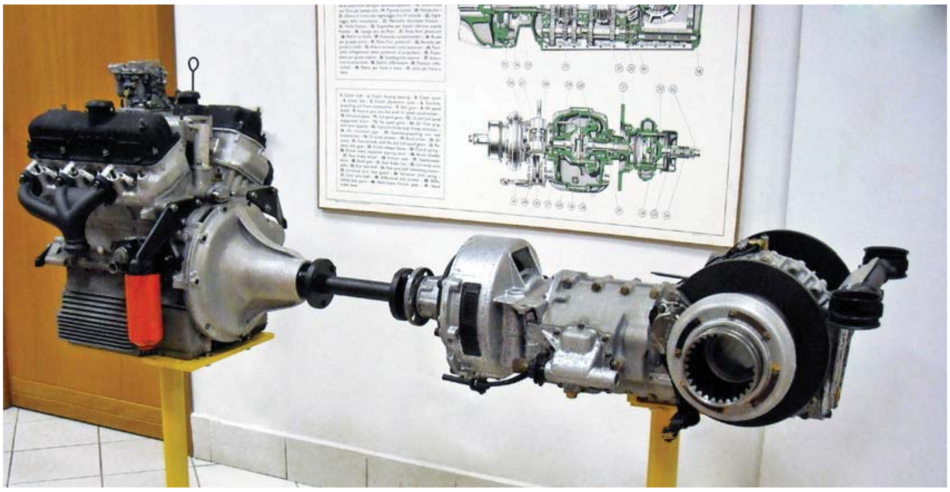

Figure 29 - Lancia Flaminia sedan transaxle power train, 1957-1970

Figure 26 - FIAT type 101 car engine, 1919-1926

Automotive engines

The Museum's collection of automobile engines extends chronologically from the early twentieth century to present. Most of them were originally used for instructional and research purposes in the laboratory of fluid machinery of the University of Palermo. The collection's oldest automotive engine is a Fiat type 101 (figure 26), produced from 1919 to 1926. This engine is typical of automotive engine design at the beginning of the last century. It is a four-cylinder engine with an aluminum crankcase and cast iron cylinder block and head, a displacement of 1460 cm^3 (89 cu in) and a classic magneto ignition system. It had a maximum power output of 23 HP at 2600 rpm. It was designed for the FIAT 501 and, then, the FIAT 503 car, models that were very wide spread in Italy in the 1920's and 1930s. Among the heavy truck engines the Lancia Junkers Type 89 engine (figure 27) stands out for its rarity and for its special technical features. This engine was produced by Lancia between 1932 and 1938, when it acquired a manufacturing license from Junkers. It is an in-line, two-cylinder, two-stroke Diesel engine, with a very nicely designed piston-crankshaft mechanism, derived from Junkers aircraft engines (such as the Jumo 205 et al.). The Type 89 engine has two counter-swinging pistons in each cylinder, with two different stroke lengths: 150 mm (5.9 in) for the upper pistons and 100 mm (2.94 in) for the lower ones, with a displacement is of 3181 cm^3 (194 cu in) and a maximum power output of 64 HP at 1500 rpm. The engine case is made of aluminum, while the cylinder barrels are made of steel. The engine is equipped with a direct injection system with two injectors fed by a reciprocating high pressure pump. The air intake system has automatic valves and an air wash pump with two pistons with a bore of 150 mm (5.9 in) fixed to the upper pistons of the engine.

Among the notable automotive engines in the collection is the FIAT type 104, commonly named 8V (figure 28). It stands out due to its rarity as well as for its historical and technical importance. The FIAT 8V was a very fine, high-performance engine designed in 1947 by one of post-World War II Italy's most important mechanical engineers, Prof. Dante Giacosa. Initially designed for a luxury sedan intended for the American market, it was modified to fit in a sports car (also named FIAT 8V), with a total production of only 114 chassis between 1952 and 1954. However, as usual in that period, a certain number of 8V chassis with powertrain system were also sold to well-known automotive coachbuilders who manufactured specialty cars, such as the FIAT 8V Ghia Supersonic and FIAT 8V Zagato. A good number of 8Vs , especially those fitted in the Zagato cars, were successfully used in automotive races, such as in the Targa Florio in 1955 (1st FIAT 8V Zagato, 2nd FIAT 8V) and at AVUS in the Grand Prix of Berlin in 1955 (1st FIAT 8V Zagato). The FIAT 8V Zagato won five consecutive Italian 2-litre GT championship (1954-1958). The FIAT 8V of the engine collection is fully original with only a few hours of running time and has undergone careful restoration. In many ways it represents an important development in automotive sports engine design in the 1950s.

During the 1940s the Lancia company began development work that led to the first V-60°, six-cylinder engine produced in significant numbers. The development of this new cylinder arrangement was the result of the work of engineer Francesco De Virgilio, who was then head of Special Studies and Patents office of Lancia. He designed it with the aim of creating a very compact engine that was free of the vibration problems that characterized the four-cylinder, narrow-V engines previously produced by Lancia. The V6 engine, originally fitted in the Lancia Aurelia in 1950, underwent continuous development. The 2458 cm^3 (150 cu in) displacement model was used in sports cars and in the Lancia Flaminia, which remained in production, in different versions, from 1957 to 1970. The Lancia V6 engine of the collection (figure 29) came from a Lancia Flaminia sedan. It had a maximum power output of 102 HP at 4600 rpm. The engine was designed to use a well conceived "transaxle" powertrain in which the clutch-gearbox-differential mechanisms were placed in the rear

Figure 27 - Lancia type 89 truck engine, 1932-1938

Figure 28 - FIAT type 104 *8V car* engine, 1952-1954

Figure 30 - Alfa Romeo type 00100 *Bialbero 1300* engine, 1960

Figure 31 - FIAT-Ferrari type 135B *Dino 2000* engine, 1966-1969

Figure 32 - FIAT-Ferrari type 135C *Dino 2400* engine, 1969-1976

Figure 33 - Diesel engine prototype, 1961-1962

part of the vehicle, thus ensuring the car was better balanced. The 60° V6 arrangement had considerable success and it was soon adopted by many other manufacturers. Today, it is one of the most widely used engine arrangements in the automotive field.

As Lancia was developing its innovative V6, Alfa Romeo put into production a new version of its famous in-line, four-cylinder engine, commonly named "Bialbero" because of its double overhead camshafts. The engine (figure 30) made extensive use of aluminum alloys for cylinder block, head, and oil pan. The engine originally had a displacement of 1290 cm^3 (79 cu in), with a maximum power of 62 HP at 6500 rpm. The "Bialbero" is a noteworthy representative of Italian mid-class automotive engines since it was manufactured, improved, and installed (in various versions) in many Alfa Romeos from the 1950s to the early 1990s.

Two other important artifacts in the collection are the Dino 2000 (figure 31) and Dino 2400 (figure 32) engines. They emerged from a technical collaboration between FIAT and Ferrari that was sparked by a new rule adopted by FIA (Fédération Internationale de l'Automobile) in 1964 for the 1967 racing season: to race in the 1967 Formula 2 championship, a car had to be equipped with an engine used in a car that had at least 500 exemplars built in 1966. At the time Ferrari was not equipped to produce a car in such a quantity. Thus, Enzo Ferrari negotiated an agreement with Giovanni Agnelli, chairman of FIAT in 1965. As a consequence FIAT undertook the design of a high-performance V6 engine in collaboration with Ferrari, while at the same time FIAT undertook the production of a new car chassis for that engine which would be produced in sufficient numbers to qualify the new engine under the new F2 rules. The Fiat-Ferrari engine design took advantage of the extensive experience already acquired in auto racing by Ferrari's well-respected designer Vittorio Jano, who had designed several V6 engines in the mid-1950s, with Alfredo Ferrari (called "Dino" and son of Enzo Ferrari). After Alfredo's untimely death in 1956, the Ferrari V6 engine series adopted the nickname "Dino." These high performance internal combustion engines, developed with various displacements from 1500 to 2000 cm^3 (91.5 to 122 cu in), were among the most advanced of their time. Dino engines were fitted in many of Ferrari's best race cars. The final product of the FIAT-Ferrari collaboration was the FIAT "Dino Spider 2000," a sports car equipped with an aluminum V6 Dino engine with a maximum power of 160 HP at 7200 rpm, properly modified by the FIAT designer Aurelio Lampredi for a mass produced vehicle. Produced and installed in over 500 units, the FIAT Dino engine was ready to compete in the 1967 racing season, and in 1968 Ferrari won the F2 world championship with the Dino 166 F2 (using a deeply tuned up V6 engine). After the Dino Spider, FIAT introduced the FIAT Dino Coupé. Ferrari, meanwhile, started producing a sports road car with the Dino brand, called 206 GT, using the same V6 2000 cm^3 engine (with a different transmission design).

In 1969 FIAT replaced the Dino 2000 engine with a new version displacing 2400 cm^3 (146.5 cu in). The new FIAT Dino engine was used in the FIAT Dino 2400 Spider/Coupe and the Ferrari Dino 246GT/GTS. Later the same engine was adopted by Lancia for its Lancia Stratos sports car. In this car the FIAT Dino engine won the Group 4 world rally Championship in 1974, 1975, and 1976. Both the FIAT-Ferrari Dino 2000 and Dino 2400 engines in the Museum's collection have only few hours of running time and have undergone careful restoration. The Museum collection has more recent engines with electronic control systems, as well as some motorcycle engines, including a very rare 250 Frera VL (1926-1932) and a Benelli 500 VL (late 1930s). It also has other less conventional pieces, such as a Sachs Wankel rotary engine and an experimental prototype of a rotary engine (figure 33) with toroidal combustion chambers developed at the Institute of Machines of the University of Palermo in the early 1960s.

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The Collection Of Engines

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- Marine compound steam engine, ca. 1890, 2 - cylinder steam engine
- S.T.A.L., Ljungström steam turbine, 1920s
- Peroni & C., *donkey* steam pump, 1930-1950
- Heinrici Maschinenfabrik, Stirling engine (cyl. bore 40 mm), 1895-1905
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- Stabilimenti Farina, T.58, 1930-1940
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- FIAT, Tipo 101, 1919-1926
- Lancia (lic. Junkers), Tipo 89, 1932-1938
- FIAT, Tipo 104.000 (*8V*), 1952-1954
- Lancia, Tipo 813.00 (*Flaminia 2500*), with Lancia transaxle transmission, 1957-1961
- Alfa Romeo, Tipo 00100 (*1300 bialbero*), 1960-1961
- Jaguar, XK 4.2 litre (E-Type engine), 1964-1968
- FIAT, Tipo 135B.000 (*Dino 2000*), with FIAT gearbox, 1967-1969
- FIAT, Tipo 135C.000 (*Dino 2400*), with ZF gearbox, 1969-1974

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The Museum of Engines and Mechanisms
University of Palermo

Energy can be neither created nor destroyed, it can only be transformed. To this purpose, a large variety of machines have been invented, whose development brought significant changes in the scientific, economic and social field. The Museum has important collections of engines, mechanisms, scientific and didactic equipment, as well as one of the five remaining aircraft Fiat G.59. The oldest pieces date from the second half of the nineteenth century. Several pieces have been employed for research and didactic purpose. Nowadays, outdated by the new technologies, they still represent an invaluable heritage describing the development of machines in various fields of use. The Museum is endowed of a fully equipped workshop for maintenance and restoration activities, in which all pieces have been patiently and carefully restored, following a conservative approach when possible. The activities of the Museum focus on preservation, enhancement as well as public enjoyment of its heritage. To this end, the Museum carries out researches, restoration, temporary exhibits and educational activities. The Museum, part of MUSEIUNIPA, frequently promotes cultural events, also in collaboration with other institutions and partners, as part of the development policy promoted by the University of Palermo.

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