DOI: 10.32703/2415-7422-2025-15-1-120-151

UDC 331.105.44:338.23:629.331:93:94

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Automotive engine innovation in Francoist Spain through the *Sociedad de Técnicos de Automoción* (STA), 1949–1974

Abstract. *In Spain, there is a lack of historical-sociological approaches to the professional association of engineers of all kinds in general, and automotive engineers in particular, due to the absence of any academic trend or school interested in the study of professions. For this reason, the purpose of this article is to examine the technological changes and development of automobile engines manufactured in Spain during the Francoist regime, based on the innovations of professionals working in the Spanish automotive industry explained by themselves. Our research is grounded in a theoretical framework stated by Cultural History and its reflections on collective imaginations, understood as a mental or conscious frame that can be studied by researchers, to the extent that they are shared by members of any kind of human group as an identity issue: in our case, the Spanish automotive engineers. In addition, the chosen methodology is the study of historical scientific press, where the review of 32 articles written by engineers for the journal Revista de la STA and published by the Sociedad de Técnicos de Automoción between 1949 and 1974, provides a glimpse of these people's collective imagination as they describe their inventions and the entire procedure to achieve them, bringing to light successful discoveries, problems, ill-fated attempts and concerns of all kinds. During the years of Francoist autarky, automotive engineers grappled with the great challenge of overcoming financial adversity and scarce resources to physically produce their innovations in engines, whereas during the developmentalist period, which enjoyed better socio-economic conditions following the Economic Stabilisation Plan of 1959, they undertook new experiments to produce increasingly sophisticated innovations. In its own way, automotive engineers' work was therefore essential in promoting economic growth in Francoist Spain, leaving behind the poverty of the 1940s and 1950s for the consumer society of the 1960s and 1970s. Ultimately, the article concludes how the Revista de la STA, employed as an historical primary source throughout the research, demonstrated its complete preference for innovations promoted by engineers related to automotive state-owned companies, leaving aside those ones from private companies.*

Keywords: *automobile; engineering; technology; innovations; Francoism; Spanish engineers*

Introduction.

The autarkic experiment initiated by the Francoist dictatorship in Spain from 1939 on plunged the economy into an unsustainable situation characterised by poverty, famine, shortages of raw materials, international isolation and more (Richards, 1999; Del Arco Blanco, 2006). While autarky and state interventionism would continue to be presented as indispensable principles to sustain a mirage of national wellbeing and alleged economic independence in the 1950s, several changes in economic policy gradually led to economic —but by no means political— liberalisation that was firmly established by the 1960s (Mayayo, Lo Cascio, & Rúa, 2011, p. 73).

Those years witnessed a new movement called developmentalism, which triggered an industrial, technological and social transformation that the historians and political scientists Guy Hermet (1977), Fernando Heredia (1997), Antonio Cañellas (2006), Sebastian Balfour (2012) and Anna Catharina Hofmann (2023) have described as the authoritarian modernisation of Francoism. Specifically, the turning point came in 1959 with the implementation of the Economic Stabilisation Plan, which launched a few years of accelerated economic expansion that would change the structure of society and modernise Spain (Payne & Palacios, 2014, p. 391; Risques, 2015, pp. 182–183).

While the trade deficit, the rate of inflation and the budget deficit had increased excessively since 1950 (Maluquer de Motes, 2014, p. 258), the opposite started to happen in 1960: the trade balance recorded a surplus, inflation stopped and the budget deficit vanished, enabling the country's incipient incorporation into the dynamics of the Western consumer society and overcoming the fallout of the autarkic disaster (Risques, 2015, pp. 182–183), to such an extent that historians describe the period from 1960 to 1973 as an economic miracle (Maluquer de Motes, 2014, p. 293),[1] promoted by the indicative planning of the three Development Plans: 1964–1967, 1968–1971 and 1972–1975 (Zaratiegui, 2019, p. 489).

Eager for legitimacy, the dictatorship gave credit to Francisco Franco's genius and skill, which was refutable since he personally was solely interested in autarky and demonstrated little common sense and even naïve credulity in applying it (Preston, 2017, p. 741). Indeed, the true developmentalist impulse only came from the technocratic government formed in 1957 with ministers attached to Opus Dei like Laureà López Rodó, Mariano Navarro Rubio and Alberto Ullastres Calvo, who, charged with designing a new economic policy, chose to liberalise Francoist Spain and integrate it into the international capitalist system (Preston, 2017, p. 742; Payne & Palacios, 2014, pp. 437–438).

[1] Other authors delimit the period of the economic miracle between 1962 and 1973, the eleven years of the highest growth in Spanish history with a 7% annual GDP (Mayayo, Lo Cascio, & Rúa, 2011, pp. 120–125).

Spanish economic growth during Francoism occurred in a context of exceptional prosperity in the Western world, the golden age of capitalism that Eric J. Hobsbawm (1995, p. 261) places between 1945 and 1973, from the end of World War II to the first oil crisis. The development therefore established new guidelines for behaviour and consumption that changed all areas of personal, family and collective life in Spanish society (Risques, 2015, pp. 172–173), the most significant being the increase in mobility and independence provided by the automobile, a symbol of social modernisation, as a means of private transport (Maluquer de Motes, 2014, p. 307).

Several academic studies analyse the impact and transformation brought by automobiles to societies all over the world. The first one ever published, by John C. Burnham (1961), speaks of the concept of automobility. Works with a worldwide approach include Steven Parissien's *The Life of the Automobile* (2014), covering the history of the automobile from 1885 and the first motorcar to the present, and two studies by Gijs Mom (2015; 2020) focused on the Atlantic dimension of automobiles first and on their completely global expansion later, giving way to a modern automotive culture throughout the 20th century that remains active today. Furthermore, there are quite a few national perspectives, such as, for example among many others, those by John B. Rae (1965), James J. Flink (1976), Michael L. Berger (2001), Tom McCarthy (2007) and John A. Heitmann (2009) for the United States; Harold J. Perkin (2016) for the United Kingdom; David Inglis (2004) and Éamon Ó Cofaigh (2022) for France; Rolf Spilker (2012) and Bernhard Rieger (2013) for Germany; Jonathan R. Zatlin (1997), Lewis H. Siegelbaum (2011) and Luminita Gatejel (2017) for former USSR republics and other Soviet satellite countries; and Ricard Rosich for Spain itself (2022a; 2022b; 2023).

In Francoist Spain, the automobile certainly brought about industrial, technological and social transformations characteristic of the new developmentalist economic dynamic. In this context, there was an expansion of automobiles at relatively affordable prices for a considerable mass of people, though still not the majority, considering that the number of automobiles manufactured soared from 637 in 1950 to 1,140,776 in 1978 (Ortiz-Villajos, 2010, p. 138, 151), with socio-cultural data showing a rise from 4% of households with an automobile in 1960, one vehicle for every fifty-five inhabitants, to 35% in 1971 and 46% in 1974, one vehicle for every nine inhabitants (Cazorla, 2016, pp. 260–261; De Riquer, 2010, p. 657).

From the triple industrial, technological and social transformation that led to the expansion of the automobile in Francoist Spain, this article aims to investigate its involvement in technological change, highlighting the development of automotive engineering from the years of autarky to those of developmentalism and approaching the collective imagination of professionals in the automotive industry. In fact, this people achieved their expansionist objectives and turned into a new social elite alongside, whilst providing society with innovations in favour of more and better automobiles to be driven, contributing through their modernisation to the political survival of the Francoist regime. This supports Lino Camprubí's thesis (2014) attributing a social and political role to all kinds of Spanish engineers in the configuration of the country during both the periods of autarky and developmentalism under Francoism by using technology as the key for modernisation towards Spaniards' progress and thereby propping up the dictatorship itself.

Research Methods.

This article concerns about the lack of historical-sociological approaches to the professional association of engineers in Spain, which Darina Martykánová (2021, p. 310) has attributed to the absence of any academic trend or school interested in studying the professions in Spain. In order to place a contribution in this area, we propose the Spanish automotive engineers' case of study during Francoism, taking attention on a chronology when several innovations were made and Spanish society started its motorization process. Our interest is focused on all those technological experiments and reflections explained personally by the key figures in this history, that is, the Spanish automotive engineers themselves. This approach considers academic theories from Cultural History field of study, which explores how reality takes part in the construction of collective representations in human experience (Chartier, 1992, p. IV). Thus, the research engages with the concept of collective imagination: mental or conscious frameworks shared by groups, communities or societies that possess an identity issue in common (Burke, 2006, pp. 83–85).

Our qualitative methodology seeks to document the technological innovations embedded in the collective imagination of Spanish automotive engineers during the Francoist era. In order to uncover their contributions to the modernisation of the country, this article adopts a case study approach centred exclusively on innovations made in automobile engines. We use as a historical source the review of 32 articles written by automotive engineers for a periodical publication called *Revista de la STA*, which was issued by the *Sociedad de Técnicos de Automoción* (STA), a private institution in charge of overseeing progress in automobile technology by bringing together under its philosophy the professionals ready to make it possible. The article spans the period from 1949 (autarky), when both the STA and the *Revista de la STA* were founded, to 1974 (developmentalism), when the journal published its last issues before stopping temporarily for one year. The body of the article is structured in four main sections: 1) the importance and contributions of the STA to Spanish automotive engineering; 2) the significance of experiments with diesel engines to motorise a country in great need of improvement in the transport of goods and passengers by road (trucks, taxis and buses); and mechanical innovations applied to both diesel and petrol engines, highlighting 3) the internal combustion process on the one hand and 4) the lubrication process on the other.

Results.

1. The STA: inception, essence and domestic and international projection.

The STA (see Figure 1), which still exists today, was created on 24 February 1949 during the assembly of an organising committee made up of automotive engineers from

Spain at the time, residing in Barcelona, who worked together to create an associative organisation that looked after collective benefits with the technological advancement of an industry that was being (re)built after the destructive Spanish Civil War and its following backwardness.[2] The new association was established in the premises lent by the *Asociación Técnica Española de Estudios Metalúrgicos* (ATEEM), which had existed since 1943 (ATEEM, 1946, p. 55), and its registered office was also in Barcelona. It could only see the light of day after the chair of the organising committee, Ramón Durán, obtained authorisation from the sub-secretariat of the Ministry of the Interior, and during the founding act the minutes state that it was created for the ultimate purpose of "putting automotive technology in our country where it belongs".[3] The STA was managed by two boards: the supervisory board, formed by Wifredo P. Ricart as chair and by board members Andrés Barcala, Julio Rentería, Manuel Junoy, Mariano Fernández de Córdoba and Sebastián Nadal; and the managing board, composed of Wifredo P. Ricart as chair, with Miguel Guinea as first deputy chair, Miguel Elizalde as second deputy chair, Carlos Coll as secretary, Manuel Serdá Torelló as vice-secretary, Manuel Torrado as treasurer, Ramón Durán as accountant and voting members Carlos María Carreras Rius, Fernando Medialdea, Juan Miralles de Imperial and Andrés Montaner.[4]

SOCIEDAD DE TÉCNICOS DE AUTOMOCIÓN

Figure 1. Logotype of the *Sociedad de Técnicos de Automoción* (STA, wo/d).

The Article 4, letter d) of the founding statutes explained the initiative "to promote congresses and periodic meetings to publicise and discuss the information received or other topics of interest for the purposes of the Association and to attend international congresses and meetings with the same ends".[5] This goal was particularly important due to the web of alliances and transnational connections weaved between the Spanish automotive engineers associated with the STA and their foreign European, Anglo-Saxon and even Japanese counterparts, flowing with exchanges of ideas that were mutually enriching and especially valuable for the professionals of the STA, who not

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[2] STA Editorial Team (1949). Actividades sociales. Constitución de la S.T.A. en la asamblea de 24 febrero, 1949. *Revista de la STA*, I (1), 75 [in Spanish].
[3] Ibid.
[4] Ibid.
[5] Archive of the Sociedad de Técnicos de Automoción (ASTA). *Sociedad de Técnicos de Automoción (S.T.A.). Estatutos*, wo/d, wo/b [in Spanish].

only were pleasantly interested in finding out what was being invented on the other side of the Pyrenees, the Atlantic and the Pacific, but they also wanted to share their own studies with the rest of the world.

We cannot understand this eagerness and determination without knowing Spain's historical importance before the Civil War as a world-class benchmark in automobile manufacturing during the first third of the 20th century, with Barcelona as the cradle of the engine and the launch of various small and medium-sized initiatives such as Elizalde, but also brands with greater global impact like Hispano-Suiza and Ford. Due to their historical awareness of their predecessors, the founding members of the STA unsurprisingly decided to appoint several honorary members. These included international automotive engineering authorities like France's Maurice Norroy and the United Kingdom's Harry R. Ricardo, clearly for their critical contributions, but also figures of the Spanish automotive industry such as Switzerland's Marc Birkigt, who had co-founded the now-defunct company Hispano-Suiza with Spain's Damià Mateu and Francesc Seix in 1904, and Carmen Badía, the widow of Arturo Elizalde, who had continued to run the company Elizalde (founded in 1908) since her husband's death in 1925, even though it focused on aviation engines and no longer on automobiles at that time.[6]

Despite autarkic Spain's international isolation, the STA expressed its desire to connect associated technicians with their European counterparts in the first steps it took as an institution. During the first meeting of the supervisory and management boards on 3 March 1949, the chair of both boards, Wifredo P. Ricart, proposed to incorporate the STA into the *Féderation Internationale des Sociétés d'Ingenieurs des Techniques de l'Automobile* (FISITA), based in Paris, with an alternating presidency that would begin with Maurice Norroy and later pass on to other figures, including Ricart himself between 1957 and 1959. Created in 1948, the FISITA still exists today (see Figure 2). Ricart's motion was approved unanimously. As explained during the session in question, the FISITA served as an umbrella for different automotive engineering associations equivalent to the STA that had been created in different countries and with which it was interested in maintaining close intellectual contact.

These associations included the French *Societé d'Ingenieurs de l'Automobile* (SIA), the Italian *Associazione Tecnica dell'Automobile* (ATA), the Franco-Polish *Societé d'Ingenieurs Téchniques Polonais – Française* (SITF) and the *Swiss Schweizerischen Auto Techniker-Verband* (SATV).[7] With the addition of the STA, we can see that the FISITA had five members from its early days in the late 1940s, though the number of federated automotive engineering associations would grow in the years to come and reach a total of fourteen members by its 25th anniversary in 1972, with the anticipation of achieving twenty members shortly thereafter, following the

[6] ASTA. *Primera Sesión de las Juntas Superior y Directiva de la S.T.A., del 3 marzo 1949*, wo/d, wo/b [in Spanish]; ASTA. *Sesión de las juntas superior y directiva del 4 marzo 1949*, wo/d, wo/b [in Spanish].

[7] STA Editorial Team (1950). La reunión de F.I.S.I.T.A. del día 10 de octubre de 1949. *Revista de la STA*, II (3), 90–91 [in Spanish].

momentous incorporations of the *British Institution of Mechanical Engineers – Automobile Division* (IMechE-AD), the *German Verband Der Automobilindustrie* (VDA), the *Belgian Societé Belge d'Ingenieurs de l'Automobile* (SBIA), the *American Society of Automotive Engineers* (SAE), the *Japan Society of Automotive Engineers* (JSAE) and the *Society of Automotive Engineers – Australasia* (SAE-A); in 1972, it was also estimated that around 25,000 engineers were part of FISITA.[8]

Figure 2. Logotype of the *Féderation Internationale des Sociétés d'Ingenieurs des Techniques de l'Automobile* (FISITA, wo/d).

The main outcome of the interrelationships and transnational links maintained between these federated automotive engineering associations was the *FISITA World Automotive Congress*, held once every two years until the present day in different places around the world.[9] Simultaneously, each of the FISITA member associations, spread over different countries around the world, would also participate separately and outside the federal body in different editions of an international congress that dealt specifically with internal combustion engines, the *Congrès International des Moteurs/Machines à Combustion Interne* (CIMAC), which also is still held today biennially or triennially in different places around the world (Fleishhack & Russak, 2001).

Alongside all the congresses in which the STA would participate, there was another showcase for its scientific and technical dynamism, the aforementioned periodical publication *Revista de la STA*. This technical journal would serve as an essential megaphone for Spanish automotive innovation that disregarded national borders and spread throughout the world via a web of federated relations woven by the FISITA. It was a primary objective of the STA from the start; indeed, its creation was planned in the founding statutes' section on means of action, specifically in Article 5,

[8] STA Editorial Team (1972). FISITA = 25 Años. *Revista de la STA*, XXIV (94), 78–79 [in Spanish].

[9] An almost complete chronology with geographical locations of the editions of the congress in question can be found at: Japan Society of Automotive Engineers (JSAE). *Venues*. FISITA World Automotive Congress [online]. Date of check: 28 February, 2023. Available at: https://www.jsae.or.jp/en/int_rel/fisita.php

letter a): "Publication of a technical automotive journal, whenever possible, which will be sent to each of the associates".[10]

Once that was established, the first issue of the journal was published in June 1949.[11] Future issues would be published quarterly until 1974, when the one hundredth issue was released.[12] However, the STA published no issues in 1975 due to a budgetary deficit.[13] It resumed publishing in 1976 with a smaller format and irregular periodicity, while trying to cope with the high printing costs that a journal of such magnitudes entailed. This continued until 2013, when the last issue was published. Certainly, the journal aroused the interest of foreign automotive engineers who wished to publish their studies there to share them and exchange innovative knowledge with their Spanish counterparts, but above all a considerable majority of its scientific and technical articles were written by Spanish automotive engineers working for the benefit of collective technological progress in Spain.

2. A demiurge for the developmentalist automotive industry: the diesel engine.

After the tragic use of producer gas to run automobiles in the years immediately after the Spanish Civil War (Preston, 2019, p. 369), there was great concern about abandoning its precarious use to turn to fossil fuels like the other Western countries. Faced with a shortage of raw materials determined by the Francoist dictatorship's authoritarian nature and consequent international isolation, with an oil embargo in force (Maluquer de Motes, 2014, p. 199; Caruana, 2009, p. 25, 32), the most attractive option for business was to invest in diesel engines, as they were more fuel-efficient than those of the petrol system and would better optimise the dosed amount of oil that arrived in Spain during the toughest period of autarky in the 1940s. This innovation came to stay.

It is true that the timid economic liberalisation of the 1950s would allow attention to shift back to petrol engines as a result of a better supply of larger amounts of essential resources.[14] Moreover, the automobiles that proliferated intensely in the streets of developmentalist Spain in the 1960s and 1970s were powered by both petrol and diesel engines in roughly balanced measure. Nevertheless, it is worthwhile to study the impact of diesel engines specifically as the first great innovation that would mark the beginning of domestic automotive development in the wake of the interruptions caused by the Spanish Civil War, focusing especially on serving industrial vehicles (like trucks) and passenger cars (like cabs or buses) that were used day in and day out for work by transporters, while also impacting the rest of the automobile users to build something that could be called diesel culture, which would surely continue during the

[10] ASTA. *Sociedad de Técnicos de Automoción (S.T.A.). Estatutos*, wo/d, wo/b [in Spanish].
[11] *Revista de la STA*, I (1), 1949 [in Spanish].
[12] *Revista de la STA*, XXVI (100), 1974 [in Spanish].
[13] STA Editorial Team (1976). Editorial. *Revista de la STA*, XXVIII (101), 9 [in Spanish].
[14] A clear example of this is the emblematic SEAT 600 (1957–1973), which always had an inline 4-cylinder engine fuelled with petrol. See: Martín, 2022, pp. 42–61.

intense motorisation of the late Francoism, the following decades and even into the 21st century.

That is, whilst Spanish-made trucks and buses were primarily factory-equipped with diesel engines, many taxi drivers, but even private users in general, gradually became interested in transforming their original petrol-powered utilitarian vehicles into diesel-powered ones thanks to mechanic workshops that could install English-made Perkins diesel engines or cheaper and equally efficient Spanish-made Barreiros diesel engines (García Ruiz & Santos Redondo, 2003, p. 73, 75, 77–78, & 83). This successful implementation of a diesel culture in Spain reflects some similarities with the situation of other European countries, like Germany, where Volkswagen and Mercedes-Benz's diesel engines became more popular between the 1960s and 1980s by achieving low fuel consumption together with good performance and good driveability; yet it differs totally from what happened in the United States in the same period of time, as General Motors' diesel engines offered low reliability, and as a result, American customers had very negative perceptions of all diesel engines, regardless of the manufacturer (Neumaier, 2010, pp. 123–126 & 136–137).

As Spanish technician Adrián Fonollosa Rodríguez explained in the opening lesson of the 1971–1972 Advanced Automotive Course organised by the STA, the diesel engine works in such a way that an injector obtains the diesel fuel via a pump and sends it into the combustion chamber of the cylinders, where it is ignited by some heated parts. When the pistons slide up, the air is compressed and heated at a much higher ratio than petrol engines operating with spark plugs. This results in less fuel use each time the fuel ignition process is repeated while the engine is running.[15]

Pegaso trucks and buses were subjects of the pioneering research in diesel engines carried out in Spain since the creation of the *Empresa Nacional de Autocamiones, S. A.* (ENASA) in 1946, in the midst of the autarkic economy. Aimed at producing its own technology and achieving independence from external supplies, ENASA was driven by the talent of professionals who were part of the *Centro de Estudios Técnicos de Automoción* (CETA), created that same year. Their mutual cooperation involved CETA acting as an automotive laboratory for planning and research-based experiments whose results it shared with ENASA at the time or later. Apart from the designers and engineers on ENASA's team, who were usually affiliated with CETA at the same time, it was also formed by a workforce trained for industrial manufacturing and production (González et al., 2013, p. 439; Nadal, 2019, p. 290).

Both companies, whose mission was to promote automotive industrialisation, were created by Juan Antonio Suanzes as president of the Spanish government's *Instituto Nacional de Industria* (INI), a public institution in the image and likeness of the fascist Italian *Instituto per la Ricostruzione Industriale.* It was founded in 1941 to ensure state supervision and intervention in several industrial projects with substantial

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[15] Fonollosa García, A. (1972). Inyección en el motor diésel. *Revista de la STA*, XXIV (93), 38–44 [in Spanish].

financial investment (San Román, 1995, p. 142; De Corso, 2015).[16] This is where Wifredo P. Ricart entered the scene (see Figure 3). An industrial engineer who had acquired extensive knowledge at the Italian firm Alfa Romeo, Ricart was working with a group of people that included specialists from the Barcelona-based manufacturers Eucort and Elizalde (Catalan, 2017, p. 91; Catalan, 2000, p. 124; Nadal, 2019, pp. 288–289). As such, the INI chose him between 1945 and 1946 as the ideal person to be entrusted with managing the leading both ENASA and CETA (Lage, 1992, p. 119).

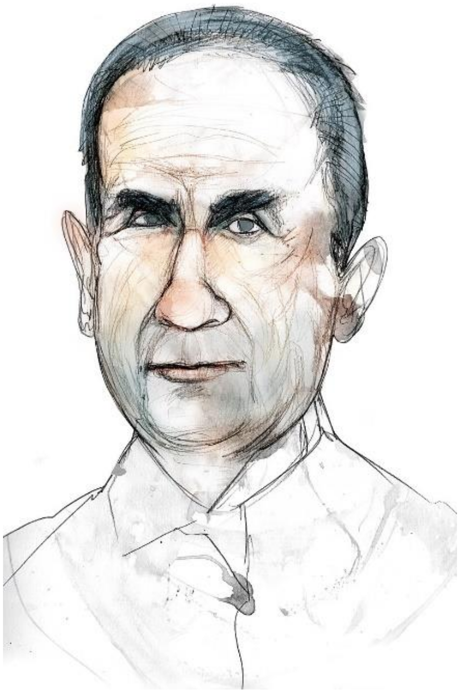

Figure 3. Portrait of Wifredo P. Ricart (Merle, 2011).

To be precise, ENASA was built over the ruins of the legendary company Hispano-Suiza, which had been in decline since the Second Republic and was unable to sell its luxury cars after the Spanish Civil War: as soon as it was forced to cease operations, the INI, which had never done anything to help it to survive, took advantage of its fall to buy the La Sagrera factory (see Figure 4), thereby capturing its technical and infrastructural capital for ENASA (Nadal, 2019, pp. 295–296; Catalan, 2017, p. 92; Catalan, 2000, p. 124). ENASA inherited from Hispano-Suiza a diesel engine prototype devised in 1946 by engineers Marc Birkigt and Louis Birkigt called 66D (Lage, 1992, pp. 111 & 142–145), which it presented as the ideal basis for building the heavy vehicles that it was charged to produce (Nadal, 2019, pp. 287–288). These heavy

[16] Ley de 25 de septiembre de 1941 por la que se crea el Instituto Nacional de Industria. *Boletín Oficial del Estado (BOE)*, 273, 30 September 1941, 7516–7519 [in Spanish].

vehicles were considered necessary for boosting the sluggish economic activity in Spain under the terms laid out in the National Motorisation Plan of 1940.[17]

Figure 4. Old Hispano-Suiza's factory in La Sagrera, Barcelona (Hispano-Suiza, wo/d).

Considered a towering figure in the business world and one of the fathers of the Spanish automotive industry during the Francoist era, Wifredo P. Ricart is also remembered for having been the president and a founding member of the STA itself. In early 1950, he was already well aware of the ever-increasing supremacy of diesel technology, particularly in the field of utility trucks for transporting goods and people, saying:

> *"The development of industrial transport by road in all countries [...] is creating major problems from a technical and constructive point of view. The competition demands a continuous drop in the cost per useful tonne-kilometre. [...] For vehicles with over eight tonnes of total cargo weight, on the ground, we find that the diesel engine is used almost exclusively for new types of construction in Europe".*[18]

In fact, this is how he justified the significance of his research in later years, which consisted of manufacturing a diesel engine model that offered higher performance to improve driving, gears —while making them more refined— and the relationship between useful weight and tare. To top if off, even if it seems contradictory, he also sought to further reduce fuel consumption specifically. This is how he adapted a torque converter and a turbine to a simple kind of diesel engine: the invention could suck the gases from the exhaust pipe and recirculate them through the mechanical system,

[17] Decreto de 10 de febrero de 1940 dando normas para implantar la fabricación del automóvil. *BOE*, 56, 25 February 1940, 1378-1380 [in Spanish].
[18] Ricart, W. P. (1950). Motores para Vehículos Industriales. *Revista de la STA*, II (3), 13 [in Spanish].

generating energy that sent more air to the engine (supercharging). This improved performance without needing to use more fuel, thereby reducing the global consumption index.[19]

The emergence of this mechanical engineering, designed and manufactured entirely in Spain as a result of the insurmountable cooperation between CETA (Madrid) and ENASA (Barcelona), was inspected at great length in 1950 by the industrial engineer Manuel Serdá Torelló, CETA's head of experiments and chief mechanical engineer, who analysed each component piece by piece, including the cylinder block, crankshaft, pistons, connecting rods, cylinder heads, valve distribution and cams, greasing circuits, cooling equipment, injectors, injection pump, turbines and other accessories that gave it such decisive characteristics. In particular, he was impressed by the "overall lightness of the unit together with great rigidity and robustness of all vital components, direct injection and a special combustion chamber with which a low fuel consumption is obtained, absence of vibration and easy starting".[20]

In the late 1950s, the continuation of the mechanical studies carried out by Wifredo P. Ricart and his team of professionals would result in the appearance of a new engine model intended for maritime use. This may seem surprising because they specialised in trucks, but in the end it is understandable since ENASA had been founded in 1946 to support the Francoist regime's action and intervention in the old Hispano-Suiza company and was called upon to work in general for the "indispensable industrial development of our Nation".[21] That would not be all: demonstrating that there were no limits to the engineering capabilities of CETA and the highly qualified workforce of ENASA, by 1951 a mobile engine would see the light of day, as Manuel Serdá Torelló said, built on a cast iron bench that turned it into a mechanical system expressly designed to run generator sets —like those required by travelling commercial and/or professional activities— or to operate any type of factory machinery.[22] In 1967, Serdá Torelló summarised the many different versions, developments and modifications carried out on the original Pegaso diesel engine from the creation of ENASA in the midst of the autarkic period until the years of developmentalism.[23] By this time, he had been promoted to deputy director of the company's projects and experiments due to this brilliant career within the company, working side by side with Wifredo P. Ricart.

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[19] Ibid., 13-24.

[20] Serdá Torelló, M. (1950). El Motor Pegaso Diésel. *Revista de la STA*, II (3), 25 [in Spanish].

[21] Decreto de 1º de mayo de 1946 sobre creación por el Instituto Nacional de Industria, de una Empresa mixta para la construcción de autocamiones pesados y medios y de motores Diésel. *BOE*, 122, 2 May 1946, 3189–3190 [in Spanish].

[22] Serdá Torelló, M. (1950). El Motor Pegaso Diésel Marino. *Revista de la STA*, II (6), 22–23 [in Spanish]; Serdá Torelló, M. (1951). El Motor Industrial Pegaso Diésel – Instalación Móvil. *Revista de la STA*, III (8), 67–73 [in Spanish].

[23] Serdá Torelló, M. (1965). Evolución de los motores Diésel de 4 tiempos con bloque de aleación ligera para camiones pesados. *Revista de la STA*, XVII (67), 44–49 [in Spanish].

In the automotive professionals' imagination, the oil shortage was still important, as Spain continued to suffer from it just as in the early 1950s, however much their creation of their own diesel engines had been a good step forward in energy savings. Faced with the great obstacle of the lack of elementary raw materials, it seems that the only possible solution was to continue innovating without falling into despair, as revealed in the testimony of Juan Miralles de Imperial, chief engineer of the engine department at *Maquinista Terrestre y Marítima, S. A.* (MTM), when he shared his work in the development of diesel engines that could run on gas with the spectre of the possible depletion of liquid fuel in Spain, focusing on the dual diesel and diesel gas patents that had been released in the USA and in the rest of Europe, respectively.[24]

Another possible way to deal with diesel fuel, which arrived in Spain in very limited amounts and at a very expensive price, was proposed by Juan José de Quixano, an industrial engineer working in MTM's engine department. His alternative featured the waste obtained in diesel refineries after its substance was distilled, given that this waste produced a fuel much more economical than diesel that was called fuel oil.[25]

Throughout the Francoist period, the improvement and perfection of the combustion process of diesel engines remained a subject of great concern for automotive engineers. An early example of this came in 1950 when Manuel Serdá Torelló vindicated the unquestionable importance of properly tuning manufactured diesel engines to guarantee that the combustion process provided the desired results once the customer had taken possession of the vehicle. In his judgment, several conclusive evidences were the key, such as ensuring that the diesel and air be mixed in equal amounts, that the combustion chamber must be shaped to allow an intermediate compression system to perform well at both low and high temperatures and that the injectors and injection pump must be synchronised to act according to whether the engine revs more or less and tows a heavier or lighter load if the use of fuel is to be optimised at all times and not wasted. [26]

A more recent example came in 1972 when Carlos María Carreras Rius, an industrial engineer and technical secretary of ENASA's factory in Barcelona, pointed out the clear differences between petrol and diesel engines, stressing the greater complexity of the latter since it required a constant intake of air, the air and fuel had to mix inside the cylinder and not outside and the mixture had to ignite via thermal compression. Since the diesel engine does not use a carburettor or spark plugs, which petrol engines require to regulate the combustion process, Carreras Rius proposed a method of turbulence in the diesel engine's cylinders that caused the air inside to react

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[24] Miralles de Imperial, J. (1950). La marcha Diésel-Gas. Motores alimentados con combustible líquido o gaseoso indistintamente. *Revista de la STA*, II (5), 75 [in Spanish].

[25] De Quixano, J. J. (1951). Empleo de fuel-oil en los motores Diésel. *Revista de la STA*, III (10), 52–62 [in Spanish].

[26] Serdá Torelló, M. (1950). Puesta a punto de la combustión en los motores Diésel rápidos. *Revista de la STA*, II (4), 61–69 [in Spanish].

uniformly with the incoming fuel, satisfactorily ensuring that "each molecule of fuel finds its corresponding oxygen molecule to guarantee good combustion".[27]

Closely linked to the issue of fuel, automotive professionals also thought about the nature of the power that a diesel engine could generate and the factors that influenced it for better or for worse. Thus, in 1965, José G. Pérez Castillo, an engineer and head of quality control at ENASA in Madrid, theorised that the driving force of a diesel engine was conditioned by an atmospheric factor —depending on whether more or less air entered the cylinders—, due to the state of the fuel —namely, the hotter it got, the more calories were activated in the combustion chamber, boosting performance— and ultimately owing to the engine itself —since the injection pumps had a fuel transfer limit that could not be exceeded, so the power was limited to their maximum performance—.[28] Pérez Castillo revisited the subject again in 1969, setting out to investigate the extent to which atmospheric variations caused by meteorological or geographical changes, as well as variations in the composition of diesel fuel coming from different refineries, could alter engine power and/or the amounts of fuel consumption.[29]

We must also mention a series of small experiments that would willingly help to diesel technology to advance during the Francoist era. In 1951, Ramón Pintó Oliveras, an industrial engineer and professor specialised in thermal engines at the *Escola Especial d'Enginyers Industrials de Barcelona*, pointed out the twofold problem of vehicles that transported people, as bus passengers wanted more comfort based on reducing the noise of fast diesel engines, while their drivers wished for improvements to the accelerator to achieve the smoother experience provided by petrol engines. Pintó Oliveras was frustrated with his experiments using mechanical regulators until he found satisfactory results with the invention of a hydraulic regulator that allowed him to lower the idle speed, and thereby to reduce mechanical noise, with no danger of stalling the engine, while simultaneously providing better power output measurement when stepping on the accelerator. Both goals were achieved because such a hydraulic mechanism always kept the moving parts of the engine in light and lubricated operation.[30] Like many other innovations, this one in particular clearly shows how important it was (and of course still is) for an automotive engineer to relate to drivers and automobile users by establishing a dialectic relationship that, above all, allowed Pintó Oliveras to discover non-technical factors from common people who, as explained, would help him to innovate with satisfactory results for the consumer's

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[27] Carreras Rius, C. M. (1972). Combustión en los motores Diésel rápidos. *Revista de la STA*, XXIV (93), 31–37 [in Spanish].
[28] Pérez Castillo, J. G. (1965). Corrección de potencia en los motores «Diésel». *Revista de la STA*, XVII (67), 34–43 [in Spanish].
[29] Pérez Castillo, J. G. (1969). Variación de la potencia de los motores Diésel con las condiciones atmosféricas y de combustible. *Revista de la STA*, XXI (82), 131–145 [in Spanish].
[30] Pintó Oliveras, R. (1951). Regulación hidráulica en motores Diésel rápidos. *Revista de la STA*, III (9), 55–58 [in Spanish].

experience. In fact, researchers like Andreas Knie and Mikael Hård (2000; 2001; 2010) have put into value this kind of technological labour procedure, under the need for engineers not to stop just in the constructive work of their innovations and get in contact with, in terms of historian John M. Staudenmaier (1985), a broad cultural ambience around them to achieve the expected success, by knowing the broader industrial context, regulatory frameworks, user views and interpretations, as well as the cultural integration of a specific technology.

In 1952, José Ramón Ricart (the son of the great Wifredo P. Ricart), an industrial engineer and head of MTM's technical office of diesel engines, set out to solve the classic problems presented by adapting a turbocharger to a diesel engine, thinking that doing so still had merit because if it turned out well, it would possibly provide a way to boost power without having to manipulate the engine's rotation system. With this aim in mind, he explained how to adjust the air flow for the turbocharger, its boost pressure, the exhaust gases, the valve overlap, the injection rates and the amount of water needed.[31]

In 1962, A. Monclús Torá, a chemist working for ENASA in Barcelona, came up with an equally important way to extend the life of diesel engines: unaware of how diesel engine oil, which is fundamental for lubrication, evolved, and since it was impossible for drivers to run tests in laboratories, his technique was to take a sample of used oil and a sample of new oil and to pour drops periodically onto a paper filter so he could compare both pieces of evidence. As the kilometrage progressed, the spot of used oil gradually lost the four colour zones characteristic of new oil and became concentrated in a uniform colour, showing how the various ingredients had lost their properties.[32]

3. Improving the internal combustion process in diesel and petrol engines.

The existence of every combustion engine is justified in a process that takes place in a matter of seconds. This process is called internal combustion, as is commonly the type of engine itself, due to a metonymic urge to take the part for the whole. Various mechanical agents are involved in internal combustion, such as the crankshaft, cylinders, combustion chambers, pistons, connecting rods, cylinder head, intake valves, exhaust valves, injectors and carburettor, all of which participate in burning the fuel that generates driving power for the automobile.

In 1959, Gerardo Soeliger, an engineer working for the *Sociedad Española de Automóviles de Turismo* (SEAT, S. A.) —the state manufacturer of utility automobiles promoted since 1950 by the INI, six Spanish banking institutions and the *Fabbrica Italiana Automobili Torino* (FIAT) (Catalan, 2012, p. 48)—, explained that every

[31] Ricart, J. R. (1952). Adaptación de la turbosoplante a motores Diésel. *Revista de la STA*, IV (11), 18–29 [in Spanish].
[32] Monclús Torá, A. (1962). El control del aceite de motor en vehículos Diésel. *Revista de la STA*, XIV (55), 46–49 [in Spanish].

internal combustion engine had a four-stage combustion cycle of air and fuel, just like today: the intake, the compression, the expansion caused by spark plugs (petrol engines) or by block heaters (diesel engines), and the expulsion of resulting gases. He also pointed out that all four stages of the process could be fulfilled in a two-stroke or four-stroke system, depending on whether the engine was designed so that the combustion took place in two half-turns of the piston or in four.[33]

While it can be assumed that any mechanical component of a combustion engine is indispensable to the point that any failure in particular impairs the dynamics of the whole, one core piece for its proper operation is the combustion chamber included in each cylinder of an automobile. The masses of air and volumes of fuel that it receives form a potentially reactive mixture that ignited by a spark or by heat when a piston causes compression each time it moves back and forth due to the motion of a connecting rod connected to the crankshaft axis. Due to the complexity of working as the space where ignition takes place after concentrating all the components that are part of it, it is hardly surprising that when the automotive industry resumed after the Spanish Civil War, the combustion chamber was the first part of the combustion engine to attract interest and even concern among automotive technicians.

A clear example of this is the research conducted in 1950 by Juan Miralles de Imperial, the chief engineer of MTM's engine department. Focusing on the diesel engine, as it was presented as crucial for promoting motorisation in Spain, he discovered that the combustion chambers in some models were designed in such a way that they were unable to achieve the most successful performance possible. After running a series of tests, he was able to formulate more efficient proposals. Considering slow and large engines, he noted that the shape of their combustion chambers prevented air from circulating easily. To remedy this, he decided to remove a central mount from the structure and place a peripheral ring there instead, thereby allowing air to circulate faster from the edges toward the centre. Turning his attention to small and fast engines, he identified the smaller space of the combustion chambers as the cause of deposits of particles that had accumulated harmfully after not having had the time or place to burn up and discovered that by designing an orthogonal wall inside it, he could get the accepted fuel to bounce off it and, consequently, allowing those particles' burn up. In both cases studied, Miralles de Imperial took the additional step of causing turbulence in the air to make it circulate even faster, either by installing a valve with a deflector or screen, as designed by Hesselman, or by means of the swirl compression method innovated by the Swiss manufacturing company Saurer.[34] Fourteen years later, in 1964, he would run more tests, generating turbulence to boost the efficiency of high-performance engines, with equally successful results.[35]

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[33] Soeliger, G. (1959). ¿Motores de dos o de cuatro tiempos?. *Revista de la STA*, XI (42), 45–48 [in Spanish].
[34] Miralles de Imperial, J. (1950). Cámaras de combustión. Consideraciones y experiencias. *Revista de la STA*, II (3), 55–59 [in Spanish].
[35] Miralles de Imperial, J. (1964). Turbulencia. *Revista de la STA*, XVI (63), 57–59 [in Spanish].

In an attempt to boost internal combustion engines' power, Carlos María Carreras Rius, an industrial engineer and technical secretary of ENASA's factory in Barcelona, pursued a procedure in 1952 that he described as clean to the extent that it had no negative impact on fuel consumption. While it could be applicable to the trucks manufactured by the company for which he worked, it actually focused on the fast engines of vehicles that might even be prepared to enter in competitions.[36] Though not explicitly acknowledged in his research, this must be considered in context, as at around the same time Wifredo P. Ricart was leading ENASA's creation of the Pegaso Z-102 (1951–1958) (see Figure 5), a sports car with a limited production run of only 84 units that would give rise to some offshoot versions suitable for racing, well beyond the coupé and cabriolet bodies designed for use in the street (Lage, 1992, pp. 161–167). The net increase in power that Carreras Rius advocated was specified in a basic aspect that was nonetheless not always easy to achieve, such as ensuring that any voids in the combustion chamber inside each cylinder were optimally filled by multiple carburettors, at best one for each cylinder, as a way to boost the pressure of air and fuel during their injection into the cylinders and keep both substances there firmly when their mixture was ignited.[37]

Figure 5. Advertisement of the Pegaso Z-102 (Álvarez, 2014).

[36] Carreras Rius, C. M. (1952). Orientaciones para el proyecto de motores rápidos a alimentación atmosférica. *Revista de la STA*, IV (12), 38–46 [in Spanish].
[37] Ibid., 44–45.

As one can see, the issue of carburation, operating exclusively for petrol engines —old diesel engines operated with a set of pre-chamber injectors—, was hardly inconsequential for internal combustion. José Mañas, an industrial engineer and head of experiments at CETA, linked to ENASA, used three different types of carburettors in Spain in 1954. The first was a carburettor with a tube-shaped section for the constant passage of air, which worked by delivering a diameter of fuel passage for each diameter of air passage based on a plate popularly known as a butterfly that acted as a horizontal throttle valve connected to the accelerator pedal cable to control the amount of air entering to combine with the fuel coming from an open container and closed with a valve. The second was a carburettor with a variable airflow section, which had a noticeably different layout: the butterfly was replaced by an intake runner valve that opened and closed on a large airflow rising and falling vertically as calibrated by the accelerator pedal cable, while the fuel, which entered in a smaller amount through the lower part of the component, had to be sucked by a conical needle each time the intake runner valve was lifted, at the same time that the suction stopped when it was closed. The third was a constant depression carburettor, which maintained the air and fuel at low pressure. Rather unusual and only marketed by the English manufacturer S. U. at the time, it had an internal structure very similar to that of the variable air passage carburettor, although it worked in reverse: the accelerator pedal cable was not connected to the main jet opening and closing to regulate the entry of air and fuel, but moved a butterfly located at the end of the carburettor right before the engine. This created a backward depression —a vacuum effect— that opened the main jet and sucked the desired mixture towards the engine, without the need to exert the pressure necessary in the other two types of carburettors.[38]

A few months later, as Mañas continued exploring carburation, he came up with the concept of inertia as a key variable for those who studied carburettors for basically preventative reasons: whereas engines with a single carburettor supplying more than one cylinder did not waste fuel because it was mixed with an equal amount of air, when better engine performance was desired and a carburettor was mounted to supply each cylinder, the air-to-fuel ratio was three quarters of fuel for every quarter of air. This meant that the air was consumed faster than the fuel. As a result, when the main jet of the carburettor was closed, this produced an inertial effect on the excess fuel that caused its rejection towards the outside. Mañas proposed recovering this wasted fuel by designing a container attached to the carburettor that would collect all the fuel to be supplied from the start and repeatedly send it into the carburation cycle in proper amounts to mix with the doses of air.[39]

Examining innovations in combustion chambers in 1956, aeronautical engineers Segismundo Sanz Aranguez, head of the CETA laboratory department linked to

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[38] Mañas, J. (1954). Carburación. *Revista de la STA*, VI (21), 44–57 [in Spanish].
[39] Mañas, J. (1954). Diferencias características entre los carburadores según se destinen a la alimentación de un solo cilindro o de varios. *Revista de la STA*, VI (22), 35–41 [in Spanish].

ENASA, and Gregorio Millán, head of the aerodynamic studies division of the *Instituto Nacional de Técnica Aeroespacial* (INTA), led the publication of some essays that were not aimed at modifying the structure of combustion chambers as had been done in the early 1950s, but rather at adjusting minor activity involved in the ignition process. They started with the spraying action, when injected fuel became atomised into droplets: both engineers argued that the size of these droplets had to be as regular as possible to mix properly with air, which is more uniform and complete. The evaporation of these droplets would follow. Once mixed with doses of air, these droplets would then be subjected to powerful heat that Sanz and Millán recommended to be around 3,000º K by means of the compression ratio between the piston and cavities in the combustion chamber housed by the cylinder, fundamentally considering it the ideal temperature for ignition. However, if the laminar flame coming out of the spark plugs by default was insufficient, a turbulent flame could be produced that would significantly speed up its propagation through the air-fuel mixture.[40] This approach was clearly inspired by the study of air current turbulence originally reported by Jaime Miralles de Imperial.

In 1957, the editorial team of *Revista de la STA* drew up a state of the question on a very recent technological advancement that was still in the practical testing phase, despite the years of research behind it, and prompted Spanish engineers to look in the mirror, even though it had not even been implemented in Spain. This was Electronic Fuel Injection (EFI). Presented as an alternative to the carburettor fitted to petrol engines —and which would replace the diesel engine's pre-chamber injector at the end of the 20th century—,[41] it was detailed a long list of advantages such as more power at high revs, more low-end torque, more efficient fuel consumption and lower amounts of polluting gases emitted, alongside disadvantages like very high production costs, noisy operations, burdensome installation and fears that mechanical automobile repair workshops lacked the experience to introduce electronic fuel injection into serial production. There was a certain number of EFI devices made by some multinational specialised firms: American Bosch Arma Corporation, Robert Bosch, Joseph Lucas, Ramjet by Chevrolet, Bendix Electrojector, Fullcharger Corporation and Simmonds Aeroccessories.[42], but all were involved in a technology to which autarkic Spain did not have access; still, Spanish automotive technicians wanted to get to understand EFI, as it was a potential alternative for the carburettors with which they were widely familiar.

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[40] Sanz Aranguez, S., & Millán, G. (1956). La combustión de combustibles líquidos. *Revista de la STA*, VIII (28), 37–48 [in Spanish].

[41] EFI is connected to multiple sensors and to the Engine Control Unit (ECU), which intelligently determines the most efficient doses of air and fuel to be sent to the combustion chambers and can adapt to every circumstance of the engine's operations and avoid wasting resources as a result (Parissien, 2014, pp. 205–208, & 326).

[42] STA Editorial Team (1957). La inyección de gasolina en los motores de automóvil. *Revista de la STA*, IX (35), 29–39 [in Spanish].

After seventeen years with no new contributions to the study of combustion in internal combustion engines, in 1974 industrial engineer Domingo Cabarrocas Pruneda released a study aimed at identifying the substances inherent in fuel that wore out the pre-chamber injectors that supplied diesel engines. Discussing the important role played by impregnated paper filters for injector equipment, it was detected that the oil left both inorganic and organic elements on its surface, the latter more dangerous than the former. He therefore recommended frequently replacing such filtering components to prevent the combustion chambers from receiving fuel at an insufficient flow rate and pressure for supply due to the eventual obstruction of the injectors caused by waxes and asphaltenes.[43]

4. Discovering the best lubrication for diesel and petrol engines.

Whether an internal combustion engine is run on diesel or petrol, its mostly metallic components can only function properly with oils intended for lubrication, responsible for ensuring gentle contact between them and eliminating the damaging possibility of wear and tear.

In early 1951, an industrial engineer and laboratory chemical specialist named Emilio Lluch provided an overview of the precariousness of raw materials in autarkic Spain, when as historians say, it was established a system of ration cards for all goods available in low quantities: food limitations are widely known, but the automotive sector also suffered from industrial restrictions of steel, metallurgical materials, rubber, fuels, etc. (Preston, 2019, p. 366; Maluquer de Motes, 2014, p. 213). This is how we can understand Lluch's testimony deploring the alleged lack of supply of lubricants for the various automobiles: he wrote that in Spain, with an "insufficiently stocked market, the types and brands recommended are not found and the user's choice of the oil to use presents serious problems".[44]

It seems that the shortcomings he outlined were offset in the worst cases by the use of any lubricants that did not conform to the characteristics reported by the respective car manufacturers. However, even if no damage to the engines was clear in the short term, from his scientific experience he knew that it would appear in the medium and long term, entailing more frequent visits to the mechanic's workshop, a greater consumption of oil and fuel, difficulty starting in cold temperatures, damage to the spark plugs and so on. While lubricant suppliers performed a juggling act in the best of cases, trying to get oils to meet the requirements of each car as much as possible, Lluch actually advised both users and suppliers to focus on the required viscosity of the oily liquid and its degree of unctuousness, also discussing the possibility of adding additives to lubricants available in Spain to achieve the properties of others that were

[43] Cabarrocas Pruneda, D. (1974). El circuito de combustible y su influencia en el desgaste del equipo de inyección. *Revista de la STA*, XXVI (97), 49–56 [in Spanish].
[44] Lluch, E. (1951). Características y especificaciones de lubricantes para motores. La lubricación bajo el punto de vista del cliente. *Revista de la STA*, III (9), 85–90 [in Spanish].

not available. Whatever the case may be, he impetuously recommended as suitable those lubricants whose viscosity varied slightly before changes in temperature and could constantly maintain the metals' protective molecular films.[45]

Two years later, in 1953 Manuel Serdá Torelló, the head of experiments and chief mechanical engineer at CETA, linked to ENASA, produced an extensive dissertation on lubricants that not only kept each and every mechanical engine component lubricated, but also had to prove unalterable when exposed to harsh working conditions inside the combustion chamber, such as high temperatures or the constant expulsion of gases.[46] Such effects were even more pronounced in diesel than in petrol systems where the oil blackened much more rapidly, becoming a soiled gummy or muddy substance —responsible of fatally seized engines— due to carbon particles in suspension coming both from the road and from successive combustions that not even the impregnated paper filters through which the fuel and oil passed were able to retain, as would be carefully studied twenty-one years later by Domingo Cabarrocas Pruneda.[47]

Based on the degree of unctuousness that Emilio Lluch had described as essential to guarantee the existence of a lubricant-based protective molecular film, which had to protect the contact between metal parts during mutual friction, Manuel Serdá Torelló went further and divided it into two subtypes: the degree of unctuousness of an oil that allowed fluid lubrication, in the sense that two or more components rubbed against each other but never quite touched thanks to the slippery liquid that lubricated them as planned, and the degree of unctuousness of an oil that worked with boundary lubrication, when the conditions in which it operated (temperature, pollution, etc.) refined the protective layer between the components to the maximum and intermittently suffered from dry friction, a risk scenario that could destroy the machinery if aggravated. With a critical tone levelled at the scarcity of resources in autarkic Spain, Serdá Torelló rised in a kind of representative collective voice attributed to the Spanish automotive engineers and concluded that the sad reality was that there were many lubricants in the market but few of guaranteed quality, and regular supply of the latter —essential for the national economy— was no longer reliable. For petrol engines, the problem of oil supply was generally not serious, but he said that the overall quality required by diesel engines caused several problems for users of good will who wanted to use the required oil so the engine of their truck did not have to be reviewed prematurely.[48]

In 1966, three petroleum chemical engineers, Francisco López de Miguel, of *Refinería de Petróleo de Escombreras, S. A.*; José Luis Martínez Cordón, of *Empresa Nacional Calvo Sotelo, S. A.*; and Aurelio Mompeán, of *Compañía Española de Petróleos, S. A.*, analysed different types of lubricants, quantitatively and qualitatively

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[45] Ibid., 85-90.
[46] Serdá Torelló, M. (1953). Engrase y lubricantes. *Revista de la STA*, V (16), 66–76 [in Spanish].
[47] Cabarrocas Pruneda, D. (1974). El circuito de combustible y su influencia en el desgaste del equipo de inyección. *Revista de la STA*, XXVI (97), 49–56 [in Spanish].
[48] Serdá Torelló, M. (1953). Engrase y lubricantes. *Revista de la STA*, V (16), 71–72 & 76 [in Spanish].

comparing and evaluating characteristics such as viscosity, viscosity index, freezing point, inflammation, foaminess, colour, density, carbon residue, sulphate residue ash and acidity index. These efforts prompted them to make a series of conclusions to recommend the best oils for specific engine work situations to automotive professionals on all levels and to automobile users in general.[49]

They made three distinctions for petrol engines. If subjected to mild conditions, a Regular-type, minerally pure and well refined oil without the need for additives was perfectly valid. For moderate demands that caused heating of the crankcase, making the oil so hot that it oxidised metal components, a Premium-type oil composed of corrosion-inhibiting particles and detergent substances had to be used. Finally, if the work required by the engine was severe, whether due to wear and tear from compulsively stopping and starting it (the case for transporters, taxi drivers, etc.), or due to overheating, they did agree that an oil with corrosion and wear inhibitors, as well as detergents and dispersants to avoid the concentration of harmful agents, was the most beneficial option.[50]

The same distinctions were made for diesel engines, following the load index they had to bear as a guideline. If it was low, there was no oxidation of heavy component wear, so normal Heavy-Duty oil could be used. If it was moderate, the same diesel fuel, with high sulphur content, could cause operational problems through deposits of gummy or muddy particles in such a way that the lubricant should reverse it, making the Heavy Duty oil Series 2 or Supplement the solution. Finally, if it was high, the accumulation of unwanted gum and sludge could obviously reach worrying rates that could only possibly be eradicated with Long Life oils with high detergency and could even allow travel for many kilometres without having to be changed.[51] These three engineers' final observations on diesel engine lubricant demonstrate a greater and better supply of quality oils for this kind of machinery in 1966, a scenario completely different from the lubricant supply shortage that Manuel Serdá Torelló had complained about in 1953.

The last innovation in automotive lubricants made during the Francoist Spain is highly specific: multigrade oils. Even though the team of petroleum chemical engineers made up of López de Miguel, Martínez Cordón and Mompeán had mentioned their recent emergence in 1966's research, it was not until well into the 1970s that their use spread as a sure thing. Given these circumstances, in 1974, one of the members of the aforementioned group, López de Miguel, argued that multigrade oils had nothing to do with the conventional oils known until the 1960s thanks to containing dispersants, detergents, oxidation inhibitors, anti-rust agents, anti-wear additives, viscosity index enhancers, freezing point depressants and antifoaming agents that made them the safest

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[49] López de Miguel, F., Martínez Cordón, J. L., & Mompeán, A. (1966). Características de los lubricantes y tipos de servicios en automoción. *Revista de la STA*, XVIII (72), 54–66 [in Spanish].
[50] Ibid., 56–57 & 61.
[51] Ibid., 58–61.

option for all types of engines prone to problems, although such a wide composition increased both production costs and sales price. Yet their main feature, in accordance with their name, was the resilience to the work required in all kinds of situations without suffering much effect or variations in temperature, making them an attractive alternative for users who needed an engine that performed to the maximum in suboptimal working conditions, such as adverse weather, high transport load, unrefined fuel, successive stops and starts and so on. After conducting different chemical studies, López de Miguel concluded that this innovative lubricant product conferred the following advantages: first, it started up cold engines more easily, which avoided a high penalty for starting the engine and saved fuel; second, its constant fluidity greased the ducts and components immediately in all kinds of temperatures as soon as the engine was started; third, its optimal and continuous lubricating conditions prevented premature wear of the mechanics, so the engine remained cleaner and emitted less polluting gases while extending its useful life; and fourth, its virtually unalterable viscosity in any adverse scenario was the great secret to protect all engine parts and give automobile users peace of mind.[52]

Discussion.

This exhaustive analysis of the 32 selected articles on innovations in automobile engines published by the *Revista de la STA* between 1949 and 1974 documents automotive engineers' collective imagination during technological change in Francoist Spain and has uncovered satisfactory discoveries, problems, ill-fated attempts and concerns of all kinds that turned out to be the only way to make technological progress, based on the experimental method of trial and error. It reveals an impressive amount of inventions along with the processes carried out to achieve them, but a separate issue that deserves special assessment, given that the engineers almost never mentioned it explicitly, is the hardship imposed by the historical, political, social and economic contexts that professionals working in the automobile industry, and in any other field of technology, had to overcome to achieve their goals.

Indeed, the period studied between 1949 and 1974 coincides with the Francoist dictatorship, which never managed to make Spain one of the main world economies, and was not well-regarded by most neighbouring powers for its anti-democratic outlook, whether in its autarkic or developmentalist stage. Thus, and compared to most of the Western world, Spain suffered a delay in achieving real technological modernisation until developmentalism took hold in the 1960s. Franco's regime never was against innovation, but it had ushered in the previous autarky in 1939 as part of its politico-economic approach. Responsible for the harsh scarcity of primary resources available, the autarky stood in stark contrast to technical development in the country and even made it harder.

[52] López de Miguel, F. (1974). Los aceites multigrados y su utilización. *Revista de la STA*, XXVI (98), 30–56 [in Spanish].

It must be taken into account that the Francoist dictatorship chose and committed to a strategy of autarky between 1939 and 1959 both to: 1) isolate authoritarian Spain from democratic countries all around, except for export business with other European countries, some unavoidable imports and rapprochement with the United States in the 1950s due to Cold War geostrategic interests; and 2) as a repressive technique especially aimed at harming all non-fascist dissidents that had sided with the republicans during the Spanish Civil War (1936–1939), though in practice, fatal autarkic consequences were suffered by everybody, supporters and non-supporters (Richards, 1999, pp. 22–23; Del Arco Blanco, 2006, pp. 241–243). As such, the Spanish government's authoritarian nature was not ideal for encouraging steady technological development. In practice, however, the engineers' constant tenacity in creating innovations prevailed, and only this perseverance, verified by the evidence provided in this article, made it possible to meet Francoist Spain's automotive needs from autarky to developmentalism.

As widely demonstrated, the Francoist dictatorship depended on the innovations of so many Spanish engineers to put Spain on the path of modernisation, where it trailed the rest of the Western world, which had got a head start after the end of World War II. Spain was running behind schedule, because despite the impetus for research since 1949, documented by the *Revista de la STA*, its structural conditions would not improve until economic liberalisation after 1959. In any case, it is indisputable that automotive professionals gathered under bodies like the STA played a crucial role by doing everything they could get their hands on in good times and bad, seeking technological survival during the depths of autarky and subsequently rolling out new inventions and improving them to fill the roads with ever-more sophisticated automobiles within the range of industrial possibility, thereby promoting the developmentalism trumpeted by the dictatorship's propaganda and discourse in their own way and making it abundantly clear that the Francoist regime's technocratic shift starting in 1957 would not have been of much use without well-prepared automotive professionals fully able to transform Spanish society through the vehicles they created and manufactured.

These technical professionals repeatedly had to overcome scarcities of resources and technological shortcomings, more pronounced during the period of autarky than during that of developmentalism, and it was even possible to grasp their efforts in search of alternatives that could ingeniously solve the problems by themselves. With the passage of time and benefitting from a gradually improving socio-economic context, to which they had directly contributed with inventions that developed the technological modernisation of Spain, these people would acquire even more professional expertise and continue to make fresh progress for automotive companies, with access to more and better-quality raw materials and industrial machinery.

All in all, it has been realised that the great bulk of the innovations collected in *Revista de la STA* for the period between 1949 and 1974 came from a state-owned company such as ENASA, the manufacturer of Pegaso vehicles, and its experimental laboratory, CETA. There are two possible reasons for this. First, these companies were funded by the Francoist government through the INI, giving them an advantage in disseminating their innovations compared to private companies. Second, Wifredo P. Ricart, a founder and president of the STA, was also a respected director of ENASA and CETA at the same time, so he naturally gave high visibility to his talented discoveries and those of the rest of his team members first and foremost. What is odd, however, is that the engines of private companies without links to the government did not receive any kind of exposure in *Revista de la STA* and their important technological contributions were deliberately not covered, such as —among many others— Eduardo Barreiros' pioneering transformations from petrol engines to diesel engines since the early 1950s and his subsequent serial productions as part of his company *Barreiros Diésel, S. A.* (Thomas, 2007, pp. 169, 344 & 366; García Ruiz & Santos Redondo, 2003, pp. 73, 75, 78, & 83). In all probability, exponents like this were silenced because of the competition they posed towards the state-owned companies ENASA and CETA, as we must never forget that they both, as well as the INI and Franco's Ministry of Industry, tried to hinder the development of private initiative led by Eduardo Barreiros (see Figure 6) and *Barreiros Diésel, S. A.* as much as possible.

Figure 6. Eduardo Barreiros at his office (FEB, wo/d).

Conclusions.

This careful study of the scientific projects initiated and explained by automotive engineers in their own words aims to address the gap in our knowledge revealed by Darina Martykánová (2021, p. 310), namely the lack of historical-sociological approaches to the professional association of engineers, due to the absence of any academic trend or school interested in studying the professions in Spain. This effort has identified numerous technological steps forward in the design, construction and improvement of all types of engines, while tracing the technological development of Spanish automobiles over the timeframe of the study (1949–1974), thanks to its long-term perspective and broad scope.

Thus, after briefly considering the importance and contributions of the STA to Spanish automotive engineering, the research first explores work on diesel engines and the establishment of a diesel culture, driven by the significant fuel savings they offered for frequently used vehicles, particularly taxis, trucks and buses. It then examines improvements to all the mechanical components involved in the internal combustion process of diesel and petrol engines. Finally, it focuses on the lubrication of diesel and petrol engines, through various experiments aimed at achieving optimal performance.

In this way, the article's main objective —analysing the automobile's role in technological change during Francoist Spain— has been fulfilled by considering the collective imagination of professionals in the automotive industry. This mental framework, as stated throughout the research, did not remain static, but rather went through two distinct phases during the dictatorship.

On the one side, in the 1950s automotive engineers combined their efforts on innovations with a critical and occasionally dissenting stance against the rules of economic autarky. However, this bold commitment was limited —presumably due to the fear of expressing oneself freely under an authoritarian regime—, meaning that they continued to face challenges in accessing the necessary resources and technologies throughout the decade.

On the other side, the resilient minds of those automotive engineers shifted from resignation to optimism in the 1960s and 1970s, as they saw their ideas, capabilities, knowledge and expertise gain greater significance. It was largely due to improvements in primary means and industrial machinery driven by the new developmentalist economy, to which they had undoubtedly contributed through their unwavering dedication to their professional mission: to achieve the best possible technological progress for Spanish automobiles, regardless of economic conditions.

None of this would have been possible without the historical source *Revista de la STA*, the journal published by the *Sociedad de Técnicos de Automoción* (STA) in which automotive engineers used to disseminate their own technical research, representing the companies they worked for. Moreover, the article highlights that *Revista de la STA* had a clear preference for showcasing engineering advances made by state-owned companies —particularly those carried out under ENASA and CETA—, while leaving no space for engineers from private automotive firms.

Acronyms and Abbreviations.

ASTA: Archive of the Sociedad de Técnicos de Automoción.
BOE: *Boletín Oficial del Estado*.
No.: number.
Vol. / vols.: volume / volumes.

Wo/b: without box.
Wo/d: without date.

Funding and Acknowledgements.

This article received financial support from the *Centre d'Estudis Històrics Internacionals* (CEHI), a consolidated research group affiliated with the University of Barcelona (UB) and recognized by the *Agència de Gestió d'Ajuts Universitaris i de Recerca* (AGAUR) of the *Generalitat de Catalunya* (SGR-Cat 2021, Government of Catalonia) [Ref.: 2021 SGR 01079]. It also benefited from a publication grant awarded in 2023 by the Research Commission of the Faculty of Geography and History of the University of Barcelona (UB).

I would like to express my sincere thanks to Dustin Lee Langan for his time and effort in providing excellent technical English language editing of my text. I am also grateful to Andreu Mayayo and Paola Lo Cascio for their candid feedback and their encouragement, both of which proved invaluable during the preparation of this work. Finally, special thanks to Lola Harana, for her consistent assistance with the administrative procedures related to securing the financial support that promoted this research.

Conflicts of interest.

The author declares no conflict of interest.

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Інновації автомобільних двигунів в Іспанії часів режиму Франко через *Sociedad de Técnicos de Automoción (STA)*, 1949–1974

Анотація. *В Іспанії спостерігається нестача історико-соціологічних підходів до аналізу професійних об'єднань інженерів загалом, а особливо автомобільних інженерів. Це пов'язано з відсутністю академічних шкіл або напрямів, зацікавлених у вивченні професій. Саме тому метою цієї статті є дослідження технологічних змін і розвитку автомобільних двигунів, що вироблялися в Іспанії за часів режиму Франко, на основі інновацій, створених фахівцями іспанської автомобільної промисловості, описаних ними самими. Наше дослідження спирається на теоретичну основу культурної історії та її підходів до колективної уяви, що розуміється як ментальна або свідома структура, яку можна досліджувати настільки, наскільки вона поділяється членами певної людської спільноти й стосується їхньої ідентичності – у нашому випадку, іспанських автомобільних інженерів. Обрана методологія полягає в аналізі історичної наукової преси: розгляд 32 статей, написаних інженерами для журналу Revista de la STA і опублікованих Sociedad de Técnicos de Automoción у 1949–1974 роках, дозволяє зазирнути у колективну уяву цих фахівців. У своїх публікаціях вони описують власні винаходи та процеси, що до них призвели, висвітлюючи як успішні відкриття, так і проблеми, невдалі спроби та різні занепокоєння. У роки франкістської автаркії автомобільні інженери стикалися з великими труднощами – фінансовими обмеженнями та браком ресурсів – у процесі реалізації своїх інновацій. Натомість у період розвитку, що настав після економічного стабілізаційного плану 1959 року та відзначався кращими соціально-економічними умовами, вони змогли перейти до експериментів з більш складними технологіями. У такий спосіб діяльність автомобільних інженерів зробила суттєвий внесок в економічне зростання Іспанії за часів Франко, допомагаючи подолати злидні 1940–1950-х років і забезпечити перехід до споживацького суспільства 1960–1970-х. Зрештою, стаття робить висновок, що журнал Revista de la STA, використаний у дослідженні як історичне джерело, демонструє явну прихильність до інновацій, створених інженерами, пов'язаними з державними автомобільними компаніями, нехтуючи при цьому розробками з приватного сектора.*

Ключові слова: *автомобіль; інженерія; технології; інновації; франкізм; іспанські інженери*

Received 28.03.2025
Received in revised form 06.06.2025
Accepted 22.06.2025