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STARTING OF THE NAVAL DIESEL-ELECTRIC PROPULSION. THE VANDAL

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ABSTRACT

Until the advent of diesel engines, electric propulsion craft needed the energy stored in batteries (primary or secondary) fitted on board. That was the beginning of electric propulsion of ships. Their limitations were, like earlier today, the power and battery capacity restricting its usefulness as an energy source for propulsion of merchant ships. In the early twentieth century are starting to get on board diesel engines a technological revolution, but these first units were not reversible machines. Thus arises as a solution to this critical operational limitation, the first vessel with diesel-electric propulsion, the "Vandal", followed by another twin hull ship, the "Sarmart", also with diesel-electric propulsion, but with a different propulsion plant design.

This paper reviews the pioneering, yet little known, carried out in a river tanker early twentieth century history of the kind of widespread naval propulsion for large cruise ships of the early twenty-first century.

Keywords: Electric propulsion ship, reversibility, power sources, innovation.

INTRODUCTION

Until the nineteenth century, for ocean sailing, vessels are propelled by the wind pressure on the windward face of the sails, making it impossible to move against the wind. The course and speed depended on the direction and intensity of wind. The

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giant leap in large sailing guessed the appearance of steam. Its first experimental application was in 1707, where the French inventor Dennis Papin installed a small steam engine 1,5 hp on a paddle wheel boat. The first transatlantic voyage sailing only with steam was performed in 1837 by the ship "*Sirius*". Since the early years of the twentieth century gradually imposed Diesel propulsion. In 1914 there were just over 300 diesel-powered ships, 10 years later there were over 2000 ships and about 8000 in 1940. In that year, about 60% of ships coming out of the shipyards were diesel powered and virtually the rest with steam turbine or reciprocating engine.

The first practical diesel engines appeared from 1897, resulting from the work of its inventor Rudolf Diesel. These engines were very bulky and heavy, they developed an output of 17,8 hp (13,1 Kw) to 154 rpm and its consumption was 238g/hp·h (efficiency 26,2%) was a single cylinder engine, four stroke, with a bore and stroke of 250 mm and 400 mm respectively. The following were already two-cylinder, 70hp at 160 rpm, weighed 15,5 tons, giving a ratio of 221 kg/hp. In 1905 consumption had fallen to 185g/hp.h with fuel calorific value of 10.000 Kcal/kg.

The main drawback of these engines to be applied for naval propulsion was its non-reversibility. In 1904 the first diesel engine for propulsion was fitted at the vessel " Petit Pierre " , a small river vessel 38 m in length. It was the first ship diesel mechanics (conventionally powered) and also had a reversible-pitch propeller. Many sources say that the first ocean-going vessels with diesel propulsion were the "*Selandia*" (launched in 1912), a passenger/cargo ship, with 2 Burmeister & Wain of four stroke, 8 cylinders, 1250 hp, 140 rpm reversible, each moving its propeller and the "*Monte Penedo*" also in 1912, with two Sulzers of 625 Kw each, 160 rpm (it was the first ship powered by a two stroke Diesel).

As mentioned earlier, the first diesel engines were not reversible, and therefore could not be used as propellers in vessels as they lacked the necessary manoeuvrability. Another solution to this problem was proposed by Italian electrical engineer Cesidio del Proposto with his patent of 1903 .(Proposto, 1906)

The innovative proposals in naval propulsion are continuous, also from Spain (Llana, 2009)

YEAR 1900. STATE OF THE ART

The transition from steam power to diesel propulsion was justified by the lower fuel consumption (assumed to spend about 700-180 g/hp.h) that is to say, less fuel was needed to travel a great distance. It is also apparent that for a weight of fuel stored given, autonomy would be much higher. The boiler consumed coal, in front of, the liquid fuel of the diesel engine. Liquid fuel, unlike coal, could be stored in double bottom tanks or structural difficult for other uses, remaining free spaces for holds, cabins, cargo tanks,…but against was the cost per kg of fuel, much cheaper the coal than gasoline. An economic study done at the time for two identical vessels was a fuel cost for a vessel powered by diesel engine of the third part of the steam-powered machine.

In the late 20's of XX century, fuel consumptions, depending on the locomotive engine, was as show in the tables below (Ludwig, 1933)

Table 1: Fuel consumptions with steam machine.

Machine class	Power in HPI	Saturated steam g/HPI·h	Superheated steam g/HPI·h
Compund Machine small	50 - 200	1800 - 1400	
	With condensation	1300 - 1000	
Triple expansion Machine	400 - 1000	870 - 700	700 - 600
Triple expansion Machine	1500 - 3000	690 - 640	580 - 530
Quadruple expansion Machine	5000 - 10000	680 - 630	570 - 520
Installation of two steam engines and exhaust turbine in the central shaft	10000 - 50000	550 - 500	510 - 450
Triple expansion engine with exhaust turbine on the same central shaft	1000 - 5000	520 - 480	440 - 400

This data includes auxiliary machinery, and burning coal of 7800 cal/kg. Using liquid fuel of 9600 cal/kg, the consumption lowered by 25%.

Table 2: Fuel consumptions with steam turbine

Machine class	Power in HPI	Saturated steam g/HPI·h	Superheated steam g/HPI·h
Turbine working independent in each tree	3000 - 5000/shaft	750 - 700	
Turbine in serie working on several shafts	10000 - 75000	700 - 600	
Turbine with reduction gear	5000 - 20000/shaft	600 - 550	550 - 450

Equally including the auxiliary engines, and burning coal of 7800 cal/kg. Using liquid fuel of 9600 cal/kg, the consumption lowered by 25%.

Table 3: Fuel consumptions with engine diesel

Diesel engine Class	g/HPE·h
Four Stroke - Single effect	180- 185
Four Stroke - Double effect	182 - 188
Two stroke - Single effect	188 – 194
Two Stroke - Double effect	190 - 195

These dates considered that the injection compressors, water circulating pumps, oil pumps, and turbocharger are clouped to the engine.

In all cases the date refers to average values for marine equipment. The highest rates are for low power and lower to the higher powers. Today, early twenty-first century, the large marine diesel engines of two stroke have a consumption smaller than 170g/Kw·h (127g/hp·h). (Weisser, 2004)

Other disadvantages of steam propulsion, turbine or reciprocating machine, starting from initial state, is the enormous time for starting, whose remedy is also for port days, keeping the boiler continuously running, with the need permanent personnel for watching and operation and consuming fuel. Moreover, the embarrassment is great for this type of installations.

In front of the undeniable advantage of higher thermal efficiency, characteristics against diesel propulsion were:

1. Non-availability of large power per unit.
2. Non-directly reversible.
3. Difficult regulation
4. Special difficulty in working at low revolutions. Little torque available.

Let see each of the items listed.

1. In 1906 three years after of the launched of " Vandal ", the maximum power per cylinder was 250 HP, which accounted for a four cylinder, four stroke and single effect, normally in this time the diesel engine was 1000 HP. The bore and stroke of these engines were respectively 700 and 770 mm, and 150 rpm speed.

One solution to increase the total power was fitting three propulsion engines, each one moving its tail shaft and propeller. A total of 3000 HP, power certainly not depreciated and sufficient for most merchant vessels. Although from the standpoint of power is a satisfactory solution, it has several disadvantages. The first, it is an expensive solution, three tail shafts with its propellers, and the two axial shafts with its propeller shaft stay, three stern bush,… Moreover, three sets of machines occupy much space in the engine room.

2. Non-reversible. The non-reversibility implies that it cannot be used as naval propulsion, and they are deprived of the necessary handling, essential not only in the mooring and unmooring.

Since 1899 patent arise to make it reversible. A first patent was based on a double camshaft. Its practical application was not satisfactory as some subsequently.

Solutions provided in these in these early years were the use of reversible-pitch propellers or mechanical clutches, but that served only to small powers (fishing, tugs, yachts)

3. Difficult regulation. When working out the condition of constant load torque, as is the case for example of navigation in bad weather, it is difficult to adjust the amount of fuel to be injected. Bosch injection does not appear until 1927.

4. Reduced torque at low revolutions.

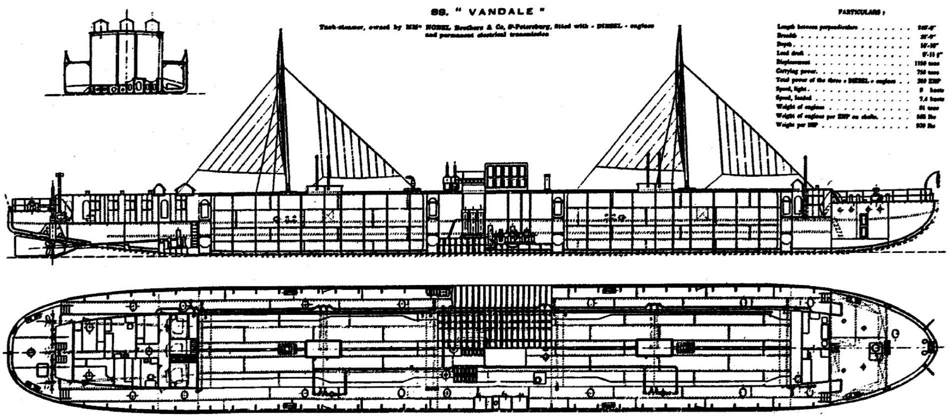

Figure 1. Vandal. General arrangement.

Diesel engines have a torque-speed characteristic with a very low torque at low revolutions, which prevents them for working at very low speed. Say another way, the torque available at very low speed is less than the resistive torque exerted by the propeller and therefore the engine would stop. Unable to work at very low revolutions, if necessary a low speed, we need to work cycles of start-stop-start either starting ahead-stop-astern.

Another drawback, although minor, it is that the engine room is very noisy.

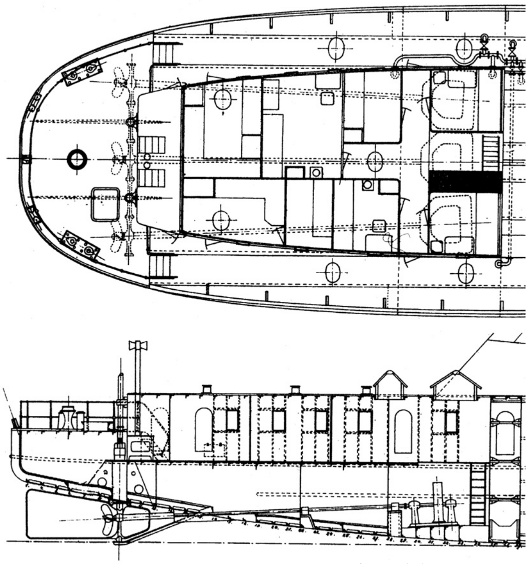

Figure 2. Stern of Vandal.

CHARACTERISTICS OF THE "*VANDAL*"

Length between perpendiculars: ...	75 m.	Deck cargo:	750 Tm.
Breadth:	9,70 m.	Power:	360 EHP
Depth:	3,33 m.	Speed:	8 Knots
Draught:	1,83	Load speed:	7,4 Knots
Displacement:	1150 Tm.	Machine weight:	81 Tm.

The "*Vandal*" ,tanquer vessel of 1150 tonnes of displacement, shallow draught, was built in the yards " Nobel Brothers Company " of San Petsburgo under the direction of Immanuel Nobel (son of Ludwing Nobel) and engineer Hagelin KW. (Koehler, 1998).

Designed to carry oil through for the Volga River and Caspian Sea was launched in 1903 and operated by the " Nobel Brothers Petroleum Company ". Its first voyage was in the spring of that year, to get rid of winter ice. The Nobel brothers (Robert and Ludwing) drove the business and the oil industry in Azerbaijan. In 1903 the Baku region provided 50% of word oil production.

Figure 3 shows a bad photo, a model and a little faithful picture of the Vandal.

This vessel had three generators (diesel engine-dynamo) each diesel engine, three cylinders with bore/stroke 290/430 mm, 120 hp runnig to 240 rpm(another reference gives the date of 255 rpm), simple effect, moving a generator of 87 Kw and 500 V (figure 1). Each dynamo fed to its propulsor electric-motor, reversible, of 75 Kw directly coupled to the propeller shaft. Speed control of each propeller is made with a "controller" from the bridge which acts on the excitation current of the dynamo, current from a small exciter located within the same axis line of the main dynamo.

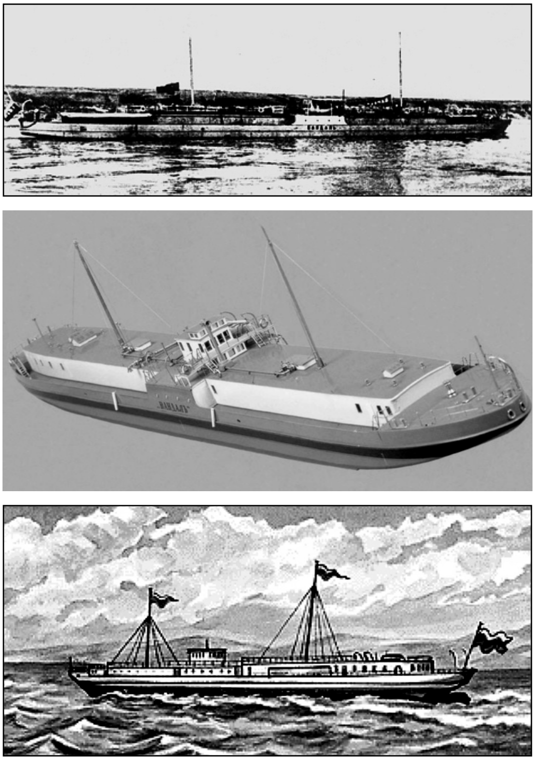

Figure 3. Photo, model and picture of Vandal.

This is achieved by controlling a large current (the induced main generator and propulsor motor) to adjust a small current (the excitation main generator), with a small rheostat. In this ship could move from ahead machine to astern machine all in under 10 seconds (between 8 and 12 according to another reference). The speed of the propellers could be adjusted between 30 and 300 rpm.

On the bridge is available for three controls (drum manoeuvre or "controller") on which it acted by a handle outside, and therefore could independently regulate the speed of each propeller. Inside the "controller" has a cylindrical drum and turning some contacts opening and closing other, with several connections, suitable for any situation desired. The switching elements were supplied by ASEA (Sweden).

The figure 4 shows a combiner, but after these years. The signalling lamp H indicates that is now available to operate the propeller and the voltmeter V indicates the

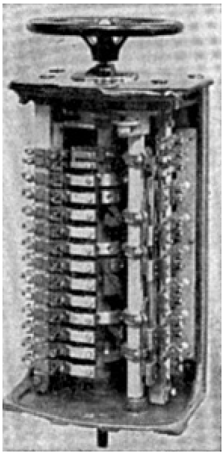

Figure 4. "Controller".

speed of the propeller as propulsion engines since it is independent of excitation voltage is (approximately) directly proportional to the rotation speed. The reversal of the progress achieved by reversing the current in the winding excitation of the main generator, which, by staying the same direction of rotation imposed by the diesel, it reverses the polarity of the voltage produced by the main generator for that in the propulsor motor, to keep the polarity of the field inductor , the rotation is reversing, by reversing the feed current of the inductor.

That is, both the combinators as the lamps H and the voltmeters V were located on the bridge, which is just where you could manoeuvre.

The electrical connection between the main generator and electric motor propulsor was direct and permanent, that is, without any interference of some element of manoeuvre or protection in this line. This design has certain advantages (simpler, cheaper, less faults, not interference..) but also some drawbacks (unable to feed from a generator to another engine than the yours, not being able a fault).

The machinery was distributed between the engine room, located half a length (Figure 1), where diesel engine were installed, aligned in the direction forward-aft, with output power by the forward end to the continuation of the flywheel that follows the coupling and the dynamo and exciter. That is: diesel engine – flywheel - bearing support – dynamo – bearing support exciter. And the whole multiplied by three, distributed in parallel: one in the center and the other at the line to both sides. Electric motor room was located in the aft. As in the main engine room, electric motors are fitted one in the center, and the other two to both bands. Each engine moving through the tailshaft , about 10 m in length, its propeller (fixed pitch) respectively. Tailshafts could not be shorter, seeing that, the electric motors, for its diameter, could no be located more aft. Therefore, the motor-side assemblies, tailshaft, propeller were slightly divergent alignment, as open in angle, of about 3º each. Between each two propellers were fitted two semicompensed rudders. As can be seen in cross section (figure 2), the tailshafts had a slight fall towards the aft (about 5 degrees). At the plan does not appearence drawn the three thrust bearings.

Table 4. Characteristics.

Diesel-Engine	Dynamo	Exciter	Electric-motor	Total Weight	Speed (knots)
Nº cylinders 3	Power(Kw) 87,5	Power (Kw) 20	Power (Kw) 75	81(Tm)	Unload (8)
HPE 120	Tension (V) 500	Weight (Tm) 1,7	Weight (Tm) 4,2	—	Load (7,4)
Rpm 240 (255)	Weight (Tm) 4,5	—	—	—	—
Weight (Tm) 16	—	—	—	—	—

The simplified scheme of the propulsor system is as follows:

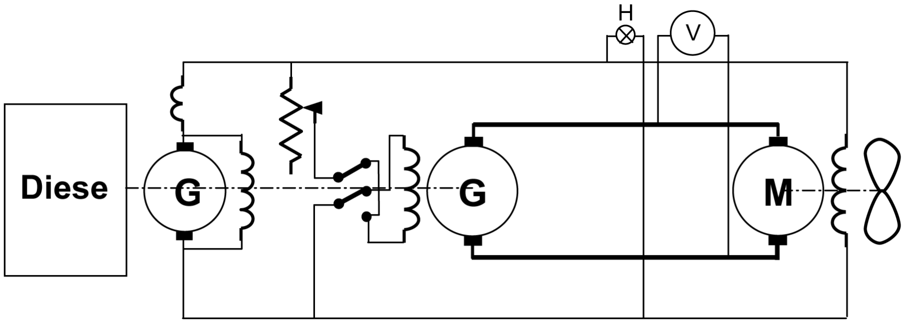

Figure 5. *"Vandal"* Electric scheme.

Diesel engines manufactured by the "Swedish manufacturer A.B. Diesel Engines" (later Atlas Diesel Company), had been delivered in the Autumn of 1902. Electrical machines were built by General Electric Company of Sweden (later A.S.E.A.).

Table 4 above are some characteristics relating to this ship.

The arrangement is as a Ward-Leonard system, where it replaces the alternating current motor fed from a three-phase network by diesel engine. It can be seen both in the cut of Figure 3 as in the photo of the centre in the annex, for the same power the size of the electrical machine is much smaller than the diesel engine.

Another possible scheme of the electrical propulsion of this vessel can be seen in Figure 6, very similar to previously represented in figure 5; the inversion will be progressively achieved by acting on the double switch by means of the controller. (Horne, 1939)

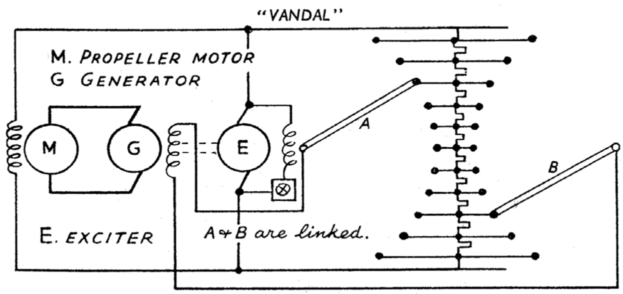

Figure 6. " *Vandal*" Alternative electrical scheme.

As an example could be the following:

Initial position represented: " HALF AHEAD " (potential of "A" greater than "B").

Acting on the drive to the left, the cursor of the left side turns in the clockwise, and the right cursor in counter clockwise together. The electric potential difference between the two cursors decreases, the excitation current of the dynamo G decreases, the magnetic flux and the voltage generated by G lows, and the voltage applied to the armature M lows, without changing its magnetic flux, its speed lower proportionately. (M: Propulsor engine directly coupled to the propeller).

If you continue turning the slide and a position is reached, that in the figure corresponds to both cursors aligned, connected to two terminals at the same potential, and therefore without excitation current from the generator E, and without feeding the propulsor engine. Position "STOP".

If the drive continues turning to the left, now the cursor of the left is connected to a potential more negative (less positive) than the right. Therefore the current is reverses in the inductor of the generator G and the polarity of the brushes is reversed. In the propulsor motor the flux was not changed, thus to reversing the current in the armature, the torque will be reduced and it will rotate counter clockwise. It corresponds to the position "LITTLE ASTERN"

A drawback of this system and it is the argument that always is invoked against the electric propulsion, they are some loss of power at each processing of power and also that the propulsion plant is more expensive. In this vessel the output of the diesel engines amounted to 360 HP, instead the power transmitted to the propeller was 290 HP. That is, the loss was almost 20%.

This vessel was operational until 1913, usually carrying lighting oil, although it could not operate during the long Russian winter, due to the ice.

The reason of such a short life period may be due to the fact that these first electrical machines, by the fact that they were working continuously, the maintenance was expensive and the fact that some of these operations of maintenance and repairing could not be carried out on board, with the consequent need for disassembly, transfer to the ground, unavailability... together with the resulting cost, it would have been to the ship-owners to choose another possibility.

In 1913 reversible diesel engines had already appeared , but the fact that the engine rooms were half a length, did not allow an easy transformation.

HANDLY AND SAFETY

The "*Vandal*", with its three lines of axes completely independent, it gave a great manoeuvrability, safety and reliability. Keep in mind that there is no delay from that, since each controller on the bridge, from the starting order in one direction until that the propeller is started, there is not conventional telegraph orders. Manoeuvres of go astern could be performed without difficulty.

The time to stop the vessel, as mentioned above, and the path overhauling would be very small, to be able to invert the rotation of the three propellers in a short time and also by the fact of the three propellers would be very effective.

The turning radius would be also reduced by the fact of having two rudders and, as has been said, of being able to work, for example, the starboard propeller " ALL AHEAD" and the port "ALL ASTERN".

As the rudders was not fitted on the aft of the propellers, it was a drawback from the standpoint of manoeuvrability, seeing that, with the vessel stopped or at very slow speed the rudder does not work. The advantage of the solution adopted was that the rudders were protected against impact, against the quay during the manoeuvres by the bulwarks of aft. Keep in mind that due to the small depth of the vessel, the surface of the rudder is based on the length, and as noted above the length of the tail was considerable.

Since the ship had two masts and four sails ready for sailing, they could be used if in that moment the wind blows "land" , by unmoored the vessel of the quay, or if the wind blows of the "sea" to bring it to the quay during the docking maneuver.

Regarding security, the fact of having three propulsor set independents, it is a safety because when a critical failure is produced in any of them (in the diesel, in the exciter, in the the dynamo or in the electromotor) the vessel could have continue working with the other two tailshafts. If the failure is on the central axis, the other two could continue working at full power. The consequence is that the speed will be now more reduced, but more than two thirds of which would be before the failure. If, however, that failure was one of the lateral axes (worst case), for example the starboard, we could navigate only with the central axe to full power, although the speed of the vessel will be smaller, or to increase the speed, with the center a full power, with the port a little less than full power, and to avoid falling to starboard, the rudders a little to port.

Keep in mind that the reliability of each propulsor set, being four machines, one thermic and three electrical, is less than each individually. In a chain of four links, if one fails, it fails the whole. And the repair of electrical engines, in many cases is not feasible on board with the consequences of the unavailability.

The use of the sails may be reserved only for cases with good weather navigation and wind very favourable. How curious, it is said that the stay and both masts instead to go to forward and aft, it goes in the direction of port bow- starboard.

CONCLUSIONS

In this paper was showed the first application of the Diesel electric propulsion in the naval field. But cannot say that it was the first step on the technology that was developed for ships propellant because it constitutes an experience that went unnoticed in the rest of the word, is enough to prove this check as the first monograph published in the UK and U.S., *The Electric Propulsion of Ships,* written by engineering H.M. Hobart in 1911, eight years after that the " *Vandal* " was launched, and discusses the possibilities and fields of applications of this technology, does not make mention of it. This engineer picks up, however, the first case of diesel electric propulsion in the United Kingdom, the " *Electric Arc* " a pleasure boat 50 feet, launched in Dumbarton in February 1911 (Times, 1911). The Diesel engine moved a three-phase alternator 800 rpm and the propeller was moved directly by a cage motor with two separate windings, one of four poles and the other six. (Hobart, 1911).

A paper published in 1918 by Civil Engineering A. Foillard appointment as first experiences in America to the vessels " *Frieda* " with propulsion turbo-electric, cargo of 5000 Tns, and the " *Tynemount* " (1913), electric diesel to navigate for the Great Lakes (in its first voyage in early 1914, carrying coal to Santander suffered a damage that the vessel was towed to port), the *"Jupiter"* a coal cargo, electrical-turbo of the Navy United States launched in April 1913. For Europe appointment as the first unit to *"Mjölner"* electrical-turbo, launched in December 1914.(Foillard,1918).

Finally, among others, a 1925 paper presented by A. Kennedy Frank Smith shows a propulsion type Ward-Leonard for two boats of Chicago fire, "*Joseph Medill*" and "*Graeme Stewart*", working in 1908.(Kennedy, 1925).

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INICIO DE LA PROPULSIÓN NAVAL DIESEL-ELÉCTRICA. EL VANDAL

RESUMEN

Hasta la aparición de los motores Diesel, la propulsión eléctrica en las embarcaciones precisaba de la energía almacenada en las baterías (primarias ó secundarias) montadas a bordo. Ese fue el principio de la propulsión eléctrica de buques. Sus limitaciones eran, antes igual que hoy en día, la potencia y la capacidad de las baterías que restringían grandemente su utilidad como fuente de energía para la propulsión de los buques mercantes. A principios del siglo XX se empiezan a montar a bordo los motores Diesel, una auténtica revolución tecnológica, pero estas primeras unidades eran máquinas no reversibles. Surge así, como solución a esta crucial limitación operativa, el primer buque con propulsión Diesel-eléctrica, el "Vandal", al que siguió otro buque con casco gemelo, el "Sarmat", también con propulsión Diesel-Eléctrica, pero con un distinto diseño de la planta propulsora.

Este artículo muestra la experiencia pionera, y sin embargo poco conocida, llevada a cabo en un petrolero fluvial a principios del siglo XX, antecedente del tipo de propulsión naval ampliamente extendido para los grandes cruceros de inicios del siglo XXI.

Palabras clave: Propulsión Eléctrica Naval. Reversibilidad. Fuentes de Energía. Innovación.

INTRODUCCIÓN

Hasta el siglo XIX, para las navegaciones oceánicas los buques se impulsaban gracias a la presión que el viento ejercía sobre la cara de barlovento del velamen, siendo imposible avanzar contra el viento. Rumbo y velocidad dependían entonces de la dirección e intensidad del viento. El paso de gigante en grandes navegaciones lo supuso la aparición del vapor. Su primera aplicación experimental data de 1707 donde el inventor francés Dennis Papin instaló una pequeña máquina de vapor de 1,5 hp en una embarcación de paletas. La primera travesía trasatlántica navegando sólo con vapor fue realizada en 1837 por el buque *Sirius*. Desde los primeros años del siglo XX se impuso progresivamente la propulsión Diesel. En el año 1914 había poco más de 300 buque propulsados por motores Diesel, 10 años más tarde había sobre 2.000 buques y en 1940 alrededor de 8.000. En ese año, alrededor del 60% de los buques que salían de los astilleros eran con propulsión Diesel y, prácticamente, el resto con vapor, turbinas ó máquina alternativa.

Los primeros motores Diesel con aplicación práctica aparecieron a partir del año 1897, fruto de los trabajos de su inventor Rudolf Diesel. Estos motores eran muy voluminosos y pesados, desarrollaban una potencia de 17,8 hp (13,1 kW) a 154 rpm y su consumo era de 238 g/hp·h. (rendimiento del 26,2%) Era un motor de un solo cilindro, cuatro tiempos, con un diámetro y carrera de 250 mm y 400 mm respectivamente. Los siguientes ya eran de dos cilindros y 70hp a 160 rpm, pesaba 15,5 Tm, lo que daba una relación de 221 kg/hp. En el año 1905 el consumo ya había bajado hasta 185 g/ hp.h con combustible de poder calorífico de 10.000 Kcal/kg.

El principal inconveniente de estos motores para poder ser aplicados para la propulsión naval era su no reversibilidad.

En el 1904 se monta el primer motor diesel para propulsión de un buque: el "*Petit Pierre*", un pequeño buque fluvial de 38 m de eslora. Fue el primer buque con propulsión diesel mecánica (propulsión convencional) y además disponía de una hélice de paso reversible. En muchas fuentes se dice que los primeros buques de navegación oceánica con propulsión Diesel fueron el *Selandia* (botado en 1912), un buque mixto de carga y pasaje, con 2 Burmeister & Wain de 4 tiempos, 8 cilindros, 1250 hp, 140 rpm, reversible; cada uno moviendo su hélice y el *Monte Penedo*, también de 1912, con dos Sulzer de 625 kW cada uno, 160 rpm (fue el primer buque propulsado por un Diesel de dos tiempos) . Otras fuentes, bien documentadas, dan como buques mercantes para navegación marítima, pioneros en la propulsión Diesel, al "Orion" (1907) -aunque con una propulsión híbrida-, una goleta de 26m ; al "Rapp" y al "Schnapp" (1908) cargueros de 350 DWT, ambos con motores de 120 BHP y 300 rpm.,el mecanismo de reversión con patente Hesselman. En los tres casos los Diesel eran A.B. Motorer.

El "Toiler", botado en 1911, un buque diseñado para navegar por los canales de los Grandes Lagos transportando mineral fue el primer buque con propulsión Diesel en atravesar el Atlántico. El "Petit Pierre" ,1903, fue el primer buque al que se le montó un diesel (un cilindro horizontal, dos pistones opuestos, 25 BHP, 360 rpm. Era un buque para navegar sólo en aguas interiores . Poseía una hélice de paso reversible. Del 1910 son los buques oceánicos "Romagna" y "Vulcanus"

Como se dijo antes, los primeros motores Diesel no eran reversibles y por tanto no podían ser utilizados como propulsores en los buques ya que carecían de la necesaria maniobrabilidad. Otra solución a este problema fue propuesta por el ingeniero eléctrico italiano Cesidio del Proposto con su patente de 1903 que se verá en un artículo posterior, y otra , de la que trata este artículo, la propulsión diesel-eléctrica.

Las propuestas innovadoras en propulsión naval son continuas, también desde España.(Llana, 2009).

CONCLUSIONES

En este artículo se mostró la primera aplicación de la propulsión Diesel eléctrica en el ámbito naval. No obstante no puede decirse que constituyó el primer peldaño sobre el que se desarrolló esta tecnología propulsiva para los buques porque constituyó una experiencia que pasó desapercibida en el resto del mundo, basta para demostrar lo anterior comprobar cómo el primer libro monográfico editado en Reino Unido y Estados Unidos, *The Electric Propulsion of Ships*, escrito por el ingeniero H. M. Hobart en 1911, ocho años después de haber sido botado el *Vandal*, y que trata sobre las posibilidades y campos de aplicación de esta tecnología, no hace ninguna mención del mismo. Si recoge, por el contrario, el primer caso de propulsión Diesel eléctrica en el Reino Unido, el *Electric Arc*, una embarcación de recreo de 50 pies botado en Dumbarton en Febrero de 1911. El motor diesel movía un alternador trifásico a 800 rpm y la hélice era movida directamente por un motor de jaula con dos devanados independientes, uno de cuatro polos y el otro de seis .

Un artículo publicado en 1918 por el Ingeniero Civil A. Foillard cita como primeras experiencias en América a los buques *Frieda* con propulsión turboeléctrica, carguero de 5000 Tm ; el *Tynmouth* (1913), Diesel eléctrico para navegar por los Grandes Lagos (en su viaje inaugural, principios de 1914, llevando carbón a Santander sufrió una avería que le obligó a ser remolcado a puerto) ; el *Jupiter,* un carbonero turboeléctrico de la marina de guerra de Estados Unidos botado en Abril de 1913 . Para Europa cita como primera unidad al *Mjölner*, turboeléctrico, botado en Diciembre de 1914.

Por último, entre otros, un artículo de 1925 presentado por A. Kennedy y Frank Smith señala propulsión Ward Leonard para dos embarcaciones de bomberos de Chicago, *Joseph Medill* y *Graeme Stewart*, puestas en servicio en 1908.