People's Democratic Republic of Algeria
Ministry of Higher Education and scientific research
University of Kasdi Merbah Ouargla
Institute of Technology
Department of Applied Engineering

Thesis of

Professional license

Specialty: Measurement, Metrology and Quality

Theme:

Study of On-Board Diagnostics applied on an Engine-Generator "Case study ENTP"

Made by:
Mahi Abd El Madjid
Tamri Abdelwahab

Jury Members

Dr. Meshri Mohammed Laid	University of Ouargla	President
Dr. Rouabah Boubakeur	University of Ouargla	Examiner
Dr. Settou Belkhir	University of Ouargla	Overseer

University year: 2022/2023

Acknowledgements

First of all, we thank Allah for giving us the patience and courage and guiding us throughout our lives to be able to reach the point we are at and be able to make this modest work.

We are very grateful, and would like to give our warmest thanks to Mr. Settou Belkhir for making this work possible and for assisting us during our work period, none of this would've been possible without his help.

We also thank ENTP TP212 site manager for allowing us do our internship and providing a great work environment, we also thank all of the TP212 workers especially Mr. Ouled Elbekai, Mr. Ahcen bobker, Mr. Ayoub and Mr. Akram Belkhalouat for guiding us in our internship and providing us with all the information we needed.

Furthermore, we would like to thank the jury president Dr Meshri Mohammed Laid and the examiner Dr. Rouabeh Boubakeur for accepting to be a part of the jury and examining this work.

Our most sincere thanks to all those who have facilitated the task of obtaining the documents necessary to carry out this work and everyone else who motivated us.

Dedication 01

I want to dedicate all of this work to my dear parents, my father Mohamed and my mother C.M because they made me who I am today, and without them I would have never reached where I am now. I want to sincerely thank all of my family especially my brothers and sisters whom I have nothing but love for. I appreciate all the advices from my classmates, especially my partner Abd El Madjid.

In the end, I want thank my friends who encouraged me to continue and do my best in university and everyone who helped me even if with a single word.

Tamri Abd Elwahab

Dedication 02

I would like to dedicate this work to my beloved parents, my father Cheikh and my mother B.R, for supporting me throughout my life and encouraging me to get to where I am today. I would have been nothing without them.

To my brother and my sisters, who have been a source of inspiration and motivation for the entirety of my life and who are always there whenever I need them.

I want to thank my partner, Abd Elwahab, and all of my friends who have made these past three years some of the best years I have ever lived.

And in the end, this is dedicated to everyone who helped, whether directly or indirectly, mentioned or not. You were all part of this, and I am very grateful for every single one of you.

Abd El Madjid

Table of Contents

List of figures

List of tables

List of abbreviations

Abbreviation	Meaning
AC	Alternating Current
ADR	Australian Design Rules
ALDL	Assembly Line Diagnostic Connection
CAN	Controller Area Network
CAT	Caterpillar
CEL	Check Engine Light
DC	Direct current
DLC	Diagnostic Link Connector
DMP	Direction du mécanique pétrolier
DSP	Direction de Service au Puit
DTC	Diagnostic trouble codes
DTP	Direction Des Travaux Pétroliers
ECM	Engine Control Module
ECU	Engine control unit
EMCP	Electronic Modular Control Panel
ENTP	Enterprise Nationale de Travaux aux Puits
EOBD	European On-Board Diagnostics
ET	Electronic Technician
GE	General Electric
GND	Ground
HD-OBD	On-board Diagnostics for Heavy-Duty Diesel Engines
HP	Horse power

Hz	Hertz
IADC	International Association of Drilling Contractors
ID	Identification
ISO	International Standardisation Organisation
J-OBD	Japanese On-Board Diagnostics
L	Liter
LB-FT	pound foot
MIL	malfunction indicator light
Mm	millimeter
OBD-I	On-Board Diagnostics 01
OBD-II	On-Board Diagnostics 02
Rpm	Revolutions per minute
SAE	Society of Automotive Engineers
SGP	Société de Gestion des Participations
SONATRACH	Société Nationale pour la Recherche, le Transport, la Transformation et la Commercialisation des Hydrocarbures
SPP Spa	Services Para Petrol (Société par actions)
TRAVEN	Travaux Energetiques
USB	Universal Serial Bus
VIN	Vehicle Identification Number

General Introduction

The industrial field requires electricity to operate, which is why most factories and worksites are connected to power grids. But there are still many places that are located in remote areas far from any power source, making engine-generators a necessity in order to get power. These remote areas are not the only ones that need generators because even the ones that are connected to grids must have them on standby as a security measure to provide a stable power source in case of emergencies.

Diesel generators are the most commonly used type of generator because they are known to be durable with the fact that diesel is widely available, and these generators are very fuel efficient. Modern generators are widely different from their early counterparts as they have evolved with the invention of new technology through the years.

Generators work by creating a magnetic field and moving an inductor through it, generating electrical current. Most of these generators keep working for prolonged periods of time without stopping, which in the long term can lead to multiple malfunctions that can be very serious and may cause the generator to break if not fixed.

Generator malfunctions can be detected by the on-board diagnostics method, which allows for on-site diagnosis by workers in order to fix the malfunctions quickly without stopping the engine for too long, which is important for a lot of industries that cannot afford to stop the operation for too long. For generators that have an electronic system like the Caterpillar 3512B, they can be connected to a special program to be diagnosed in case the on-site workers were unable to detect the fault.

In this thesis, our objective will be to perform a study on the application of the on-board diagnostic method on a CAT 3512B diesel generator by ENTP, utilizing both of the engine-generator’s control panel diagnostic fault codes and a special computer program to precisely determine the sources and causes of malfunctions in order to avoid a complete generator breakdown.

This thesis is divided into three chapters as follows:

Chapter 01: An overview about On-Board Diagnostics

Chapter 02: General Information about generators and CAT 3512B

Chapter 03: The application of the OBD method using ET on a CAT 3512B

Chapter I: On-Board Diagnostics

1-1 Introduction

Diagnostics are an integral part of sustaining an engine's functionality, as they allow for the detection of defaults and can help evade major problems. There are a lot of types of diagnostics, each with their own tools and each focusing on specific problems. One of the most common diagnostic types is the on-board diagnostic, which can be found on practically all new engines and generators as it is considered essential to avoid malfunctions and facilitate repair.

1-2 Diagnostics

Diagnostics are operations used to monitor an engine's performance and determine whether it is working as intended. Diagnostics are very effective in the case of a malfunction because they are used to gather important data to find out the type, location, and cause of the fault so that it can later be repaired. They are also used in things like emission testing to confirm that an engine adheres to the emission standards[1].

1-2-1 Types of diagnostics

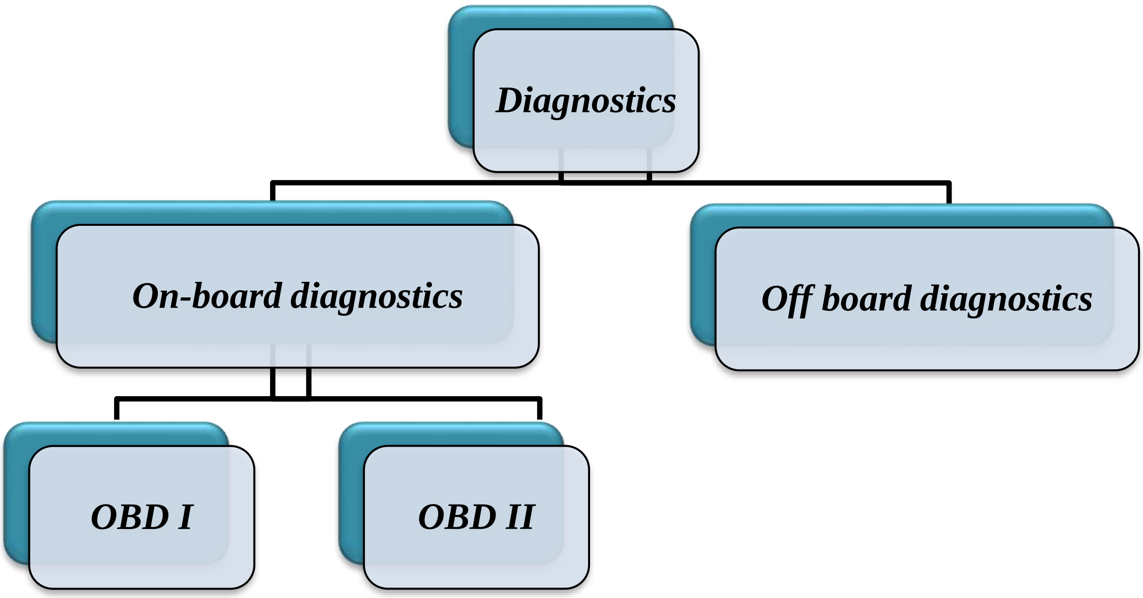


Figure 1-1: Diagnostic types

1-3 Off-board diagnostics

Off-board diagnostics are mostly used when the engine is turned off; this type is mostly done by experts who communicate with the Engine Control Unit using special hardware and codes that are stored in the memory of the ECU; these codes can only be read by an expert who can later fix, delete, or reset them. This method also allows the operator to format and rewrite the codes entirely in the form of diagnostic trouble codes.

1-4 On-Board Diagnostics

On-board diagnostics (OBD) is a computer-based system that was first intended to minimize emissions by monitoring the functioning of various engine components and providing technicians with access to subsystem data for performance monitoring and assessment. Since its inception[2], the quantity of diagnostic information provided via OBD has changed greatly. If a problem was found, early versions of OBD would merely activate a malfunction indicator light (MIL) or "idiot light," but not offer any information about the nature of the problem. Current OBD implementations employ a standardized digital communications interface to deliver real-time data as well as a defined set of diagnostic problem codes, or DTCs, which allow a human to quickly diagnose and correct issues[3].

1-5 History of diagnostics

- **1969**: Volkswagen type 3 modules were the first vehicles to ever be fitted with a primitive version of what would later become OBD.
- **1980**: General Motors uses a proprietary interface and protocol on the car manufacturing line to test the Engine Control Module (ECM). The so-called 'assembly line diagnostic connection' (ALDL).
- **1988**: The Society of Automotive Engineers (SAE) suggests a standardized diagnostic connector and set of diagnostic test signals.
- **1991:** Basic on-board diagnostics are now required in every vehicle by the state of California and they are called OBD-I.
- **1994:** The system is now officially called OBD-II and is mandatory in the state of California starting in 1996.
- **From 2008 onwards** all vehicles were required to implement OBD-I as specified by the ISO 15765-4 standard [3].

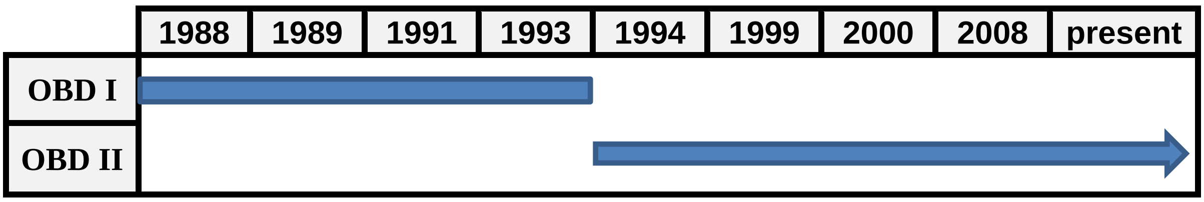


Figure 1-2: Naming history of OBD[3]

1-6 OBD-I

The initial version of the now-common On-Board Diagnostics system was the OBD-I, which lacked a defined diagnostic link connection, DTC definitions, and any consistent technique for reading trouble codes. which meant that every manufacturer had its own versions of these OBD1 systems, and it was almost impossible for any person without prior knowledge of the manufacturer specific DTCs to read them or diagnose the problem[3].

1-7 OBD-II

As the successor to OBD-I, the OBD-II was improved in every aspect and became capable of providing DTCs that had been generated by the computer system when the malfunction occurred, as well as the real-time status of the systems based on the output of the attached sensors. The OBD-II standard also specifies the type of diagnostic connector and its pinout, the electrical signaling protocols available, and the messaging format. It also includes a proposed list of parameters to monitor, as well as instructions on how to encode data for each; it also includes a pin in the connector that powers the scan tool from the vehicle battery, removing the need for an external power source; and in addition to that, it provides an extensible list of DTCs, which made most manufacturers make the OBD-II Data Link Connector the only one in the vehicle through which all systems are diagnosed and programmed[4].

1-7-1 OBD2 Standards

OBD evolved through the years which mandated changes in standards with time as shown in Table 1-1 [4].

Table 1-1: OBD standards in different areas

	Year	Area
OBD I	1981-1995	California
OBD II	1996-present	USA
EOBD	2001-present	EU
EOBD II	A Marketing term that refers to an OBD system than has manufacturer-specific features	
J-OBD	1996-Present	USA + Japan
HD-OBD	1996-present	USA
ADR 79/01	2005	Australia and New Zealand
ADR 79/02	2008	Australia and New Zealand
OBD III	In the future	USA

1-8 Importance of OBD

OBD is an essential part telematics, especially when it comes to vehicles' engines. Thanks to the system, we can:

- monitor wear patterns to determine which car parts are wearing out faster than others.
- detect vehicle issues before they arise, encouraging proactive management
- measure driving behavior, speed, idling time and so much more
- Enhance Safety by evaluating risks and working on eliminating them.
- Diagnose failing engine parts early which can help avoid bigger problems and save time and money.
- Reduce pollution by taking engine emissions [2].

1-9 What differentiate OBD-I from OBD-II?

Because of the fact that OBD-II is an improved and upgraded version of OBD-I, there are a lot of things that were made different for the sake of improving functionality and convenience. These changes are shown in the table 1-2 below.

Table 1- 2: Differences between OBD-I and OBD-II[3]

OBD-I	OBD-II
Nonstandard diagnostic connector (every vehicle has a different type)	Standardized protocol and socket
Nonstandard error codes (different for each producer)	Standardized error codes (DTC)
Nonstandard engine and emission control system	Standardized emission control system
Nonstandard MIL	Standardized MIL and MIL functions
Different technical approaches for the same error (different for each producer)	Saves environment data when the system fails (Freeze Frame)

1-10 OBD port and OBD connector

Before OBD, every manufacturer had their own port, making the diagnosis process difficult for most people. The OBD standard made all ports identical regardless of the manufacturer making it way easier to diagnose problems while also improving the overall functionality of the port[5].

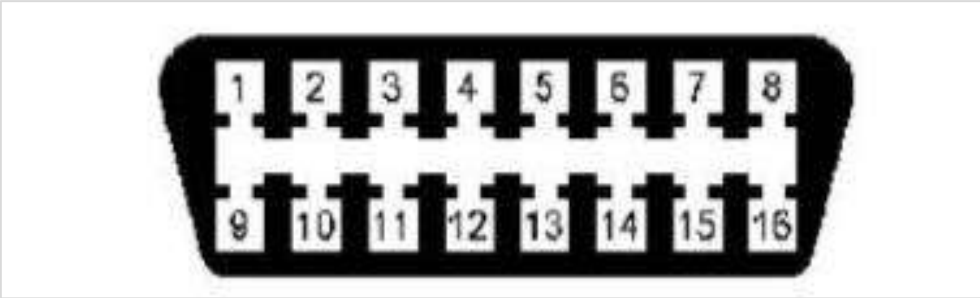


Figure 1- :3 OBD port pinout

Table 1- 3: OBD Port Pinout Discription[5]

PIN	Description	PIN	Description
1	Manufacturer Specific	9	Manufacturer Specific
2	J1850 Bus+	10	J1850 Bus
3	Manufacturer Specific	11	Manufacturer Specific
4	Chassis GND	12	Manufacturer Specific
5	Signal GND	13	Manufacturer Specific
6	CAN High	14	CAN Low
7	ISO-91441-2 K-LINE	15	ISO-91441-2 K-LINE
8	Manufacturer Specific	16	+12V(Battery Power)

1-11 Engine control unit

The engine control unit allows for the exact, centralized control of all engine-related processes. Electronics handle things like fuel injection and ignition, as well as start/stop systems and turbocharger control. The majority of processing capability in today's engine control units is used for diagnostic and monitoring activities. When the signals vary from normal, the ECU stores standard fault codes for both major and minor defects. A warning bulb will also light to inform the operator in the event of a significant issue. It also implies that technical employees may, among other things, read out the fault memory of the vehicle's systems installed in the vehicle. If the fault memory contains error code entries, the expert mechanic must interpret them correctly. If the fault memory includes error code information, the expert mechanic must properly interpret it. For this reason, the workshops contain advanced diagnostic devices that allow for vehicle-specific, guided troubleshooting. After the repair process is finished, the diagnosis system can remove the fault from memory[6].

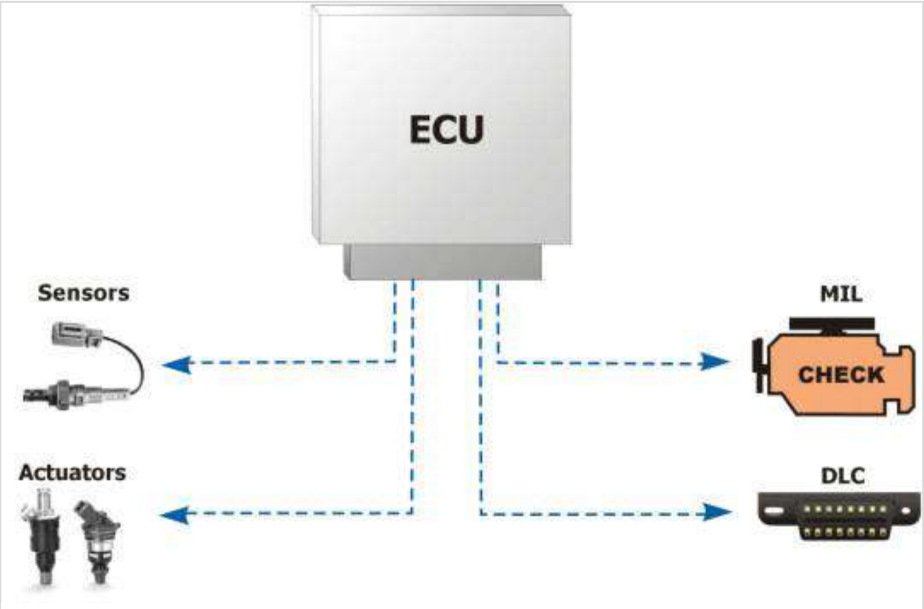


Figure1- :4 ECU connection

1-12 OBD2 accessible data

- Emission readiness status information
- Oxygen sensor test data
- ignition cycles data
- The vehicle’s mileage since the Check Engine Light (CEL)
- Vehicle Identification Number (VIN)
- Diagnostic trouble codes (DTCs)
- the state of the Check Engine Light
- freeze frame data
- Real-time information

1-13 On-board diagnostics trouble codes

When a fault occurs in an engine and it is detected, the On-Board Diagnostics system generates a set of codes relating to that fault known as the Diagnostic Trouble Codes (DTCs) or simply Fault Codes. These codes consist of five characters in the form of a letter followed by four numbers; the letter indicates the system that the malfunction relates to (body, chassis, powertrain, or network), followed by the number that indicates the type of the code, and the rest are used to identify the location and the exact fault code[7].

DTCs can indicate a lot of problems, ranging from major mechanical and electrical problems to minor ones. They were first invented to make the diagnosis process easier, and they can be accessed using an OBD scan tool[8].

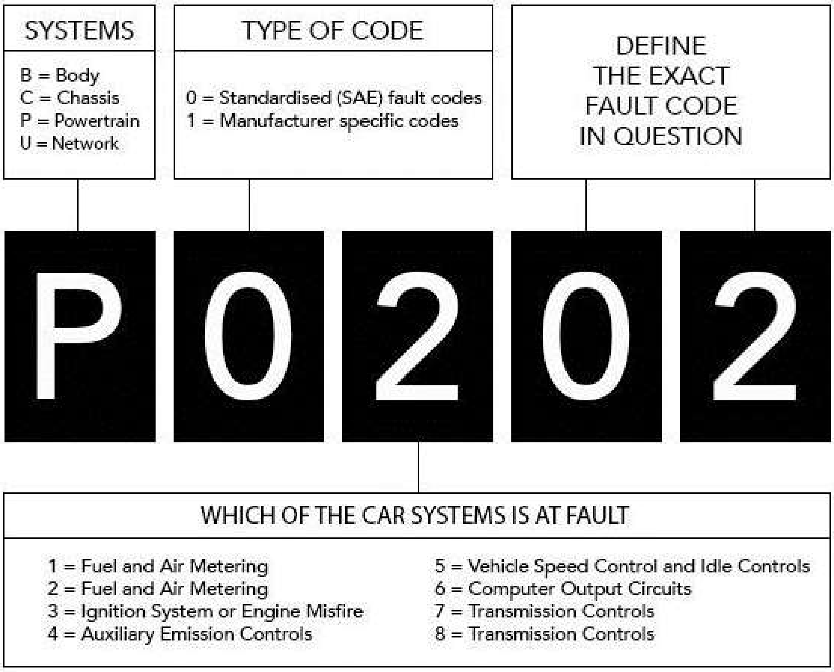


Figure 1-:5 Example of diagnostic trouble codes [9]

1-14 OBD applications

OBD scan instruments come in both wireless as well as wired variants. The generic versions of these variants are just essentially code readers that can only perform basic operations like reading or clearing diagnostic codes, while the enhanced versions can give detailed code definitions, and some can read freeze frame data and permanent codes. There are also specialized versions that are used mostly by manufacturers when making engines, and they are split into three types.

1-14-1 Wired scan tools

The most popular variant of the scan tools are the wired ones, which are connected directly into the OBD diagnostic link. Wired scan tools require a power source, usually a battery or straight through the port, that allows them to use the vehicle’s power. There is a big difference between the OBD-I and OBD-II scanners, as shown in the Table 1-4 below [10].

Table 1- 4: Differences between OBD-I and OBD-II scanners:

	OBD-I Scanners	OBD-II Scanners
engine Support	Only supported vehicles made before 1996.	Support vehicles made after 1996.
Interface	An OBD1s scan tool often works for only one manufacturer	One OBD2 can support different manufacturers.
Code Standardization	Codes aren't standardized; different manufacturers give different results with the same engine issue.	Trouble codes have been standardized

1-14-2 Wireless scan tools

Wireless scan tools work almost identically to their wired counterparts, with the only major difference being that they connect to the vehicle either via Bluetooth or Wi-Fi, which makes them way more convenient because they are more flexible and can work from a distance[11].

1-14-3 PC-based scan tools

Computers can be used as scan tools and they are way more convenient and more advanced than the other variants because of the various programs that exist which provide all kinds of information and all that is needed is an OBD-II connection kit in addition to the previously mentioned software[12].

1-14-4 Scan tool variants’ features

Each one of the previously mentioned scan tool variants has its own set of features that make it different from the rest, and different types can be more convenient for different situations depending on the conditions at hand.

Table 1- 5: Features of each scan tool variant[10-12]

Types	Features
Wired	Consumer-level scanning tool. Real-time monitoring. Facilitates diagnosis
Wireless/Mobile	Uses Phones to display data Can manipulate OBD-II data via Wifi or Bluetooth
Pc-Based	Uses standard Pcs and Mac Large storage capacity for data logging Flexible thanks to the ability of using multiple programs

1-15 Parameter Identification Numbers

A standard J1979 by SAE defines On-board "Parameter Identification Numbers", commonly known as OBD-II PIDs, which are codes used to get fault data from the engine control unit using a diagnostic tool; the primary commands are as shown in table 1–6 below[8].

Table 1- 6: PID command names [8]

Mode	Description
$01	Show Current Data
$02	Show Freeze Frame Data
$03	Show Stored DTCs
$04	Clear DTCs
$05	Test Results (Oxygen sensors)
$06	Test Results (others)
$07	Show Pending DTCs
$08	Control Operation of On-Board Components.
$09	Request Vehicle Information
$0A	Permanent DTCs (Cleared DTCs)

1-16 Conclusion

In this chapter, we discussed the definition and importance of On-Board Diagnostics in sustaining an engine’s functionality for as long as possible. It is essential for the early detection of faults, which helps avoid major problems. As well as the various applications of OBD.

Chapter II: Engine Generator (Cat 3512B)

2-1 Introduction

Engine-generator sets are widely used around the world to provide power in case of emergencies or on a regular basis in remote areas because they are reliable and highly effective without consuming too much fuel, which makes them the first choice for both individuals and companies in all fields. One of the most commonly used generator sets in Algeria is the CAT 3500 series, which is predominantly used in the oil industry and in some factories. They have garnered a great reputation for being very rugged and easy to fix, and thanks to their on-board diagnostics system, most malfunctions can be easily avoided.

2-2 Engine generator

An engine-generator is a type of machinery that combines an electrical generator and an engine (the primary mover) into a single unit. This combination is also known as a gen-set (engine-generator set), but it is mostly referred to simply as a generator because the engine is usually assumed.

An engine-generator might be a permanent installation, a vehicle component, or small enough to be portable. A generator can be used for a number of things. When utility power is absent, an engine generator is usually used to provide electrical power. They are also frequently utilized to provide a short-term alternative when electricity is only temporarily required. Another popular application for an engine generator is to power electrical equipment on building sites, amplifier systems on worksites, and even drilling equipment for an extended period of time [13].

2-3 History of engine generator

- The first electromagnetic power dynamo was built by Michael Faraday in 1831 which produced a small DC voltage. “Faraday Disk”
- In 1882, a British electrician, J. E. H Gordon built a large two-phase alternating current generator
- In the 1860s, AC and DC generators were invented. By the 1870s, the AC and DC generators were produced to run an outdoor lighting system
- Diesel engine was developed by Rudolf Diesel in the ’1890s
- In the early 1900s, generators became a common thing and were mass produced by multiple companies such as GE, Siemens, and Westinghouse. The modern form called an engine-generator, incorporates the engine into the generator, forming a single unit [14].

2-4 The functioning principal of engine generators

An engine generator is a machine that converts mechanical energy from an outside source into electrical energy.

It must be understood that a generator does not 'create' electrical energy. Instead, it pushes the passage of electric charges present in the wires of its coils through an external electric circuit using the mechanical energy provided to it. The generator's output electric current is represented by the passage of electric charges. By contrasting the generator with a water pump, which creates the flow of water but does not "generate" the water that flows through it, this mechanism can be better understood.

The modern generator is based on Michael Faraday's discovery of electromagnetic induction in 1831-32. Faraday noted that the aforementioned flow of electric charges might occur when an electrical conductor—such as a wire carrying electric charges—is moved in a magnetic field. Through the flow of electric charges and the resulting creation of electric current, this movement creates a voltage differential between the two ends of the wire or electrical conductor[15].

2-5 Types of engine generator

Generators are split into two types: AC and DC

2-5-1 AC Generators

These are also known as alternators, and they operate according to the electromagnetic induction principle. There are two different kinds of AC generators: synchronous and induction generators. The induction generator doesn't need a separate DC excitation system, regulator controls, frequency control, or governor. This concept occurs when conductor coils move in a magnetic field, causing a current and a voltage to be generated. In order to transmit a stable AC voltage, the generators must run at a constant pace. Large generators, or synchronous generators, are typically employed in applications including wind power plants, mining equipment, oil and gas extraction, and ships. These generators are packaged with an engine or turbine to be used as an engine-generator set [15].

2-5-2 DC Generators

DC generators are commonly encountered in off-grid situations. These generators provide a continuous power supply to DC power systems and electric storage devices without using any new equipment. DC-to-AC converters are used to transport the stored energy. As batteries charge, the DC generators can be reduced to a standstill to recover significantly more fuel [15].

2-5-3 What are the differences between AC and DC Generator?

AC and Dc generators have a lot of different properties that distinguish them from one another as shown in Table 2-1*Table 2- 1: The differences between AC and DC generators [15]*

No.	Property	AC Generator	DC Generator
1	**Definition**	AC generator is a mechanical device which converts mechanical energy into AC electrical power.	DC generator is a mechanical device which converts mechanical energy into DC electrical power.
2	**Direction of Current**	In an AC generator, the electrical current reverses direction periodically.	In a DC generator, the electrical current flows only in one direction.
3	**Basic Design**	In an AC generator, the coil through which the current flows are fixed while the magnet moves. The construction is simple and costs are less.	In a DC generator, the coil through which the current flows rotate in a fixed field. The overall design is very simple but construction is complex due to commutators and slip rings.
4	**Commutators (an electrical switch changing the direction of field current).**	AC generator does not have commutators.	DC generators have commutators to make the current flow in one direction only.
5	**Rings (electrical connections used to transfer to and from the generator)**	AC generators have slip rings.	DC generators have split-ring commutators.
6	**Efficiency of Brushes (conducts current between stationary wires and moving parts in the generator)**	Since slip-rings have a smooth and uninterrupted surface, they do not wear quickly and are highly efficient.	Both brushes and commutators of a DC generator wear out quickly and thus are less efficient.
7	**Short Circuit Possibility**	As the brushes have high efficiency, a short circuit is very unlikely.	Since the brushes and commutators wear out quickly, sparking and short circuit possibility is high.

2-6 Caterpillar 3512B

The Caterpillar 3512B diesel generator sets are 12-cylinder, 1650-hp generators. These have a maximum output of 600 volts and 5296 lb.ft. of torque while being durable, dependable, and fuel-efficient, which is the primary reason they are employed in a lot of countries around the world in bore/drill rigs, chippers, construction, cranes, forestry, and more [16].

2-6-1 The components of Cat 3512B

The components shown in the figures 2-1[17] and 2-2 [17] are of the actual main generator which is usually also connected to other parts later as shown in figure 2-3 to form the final functioning unit.

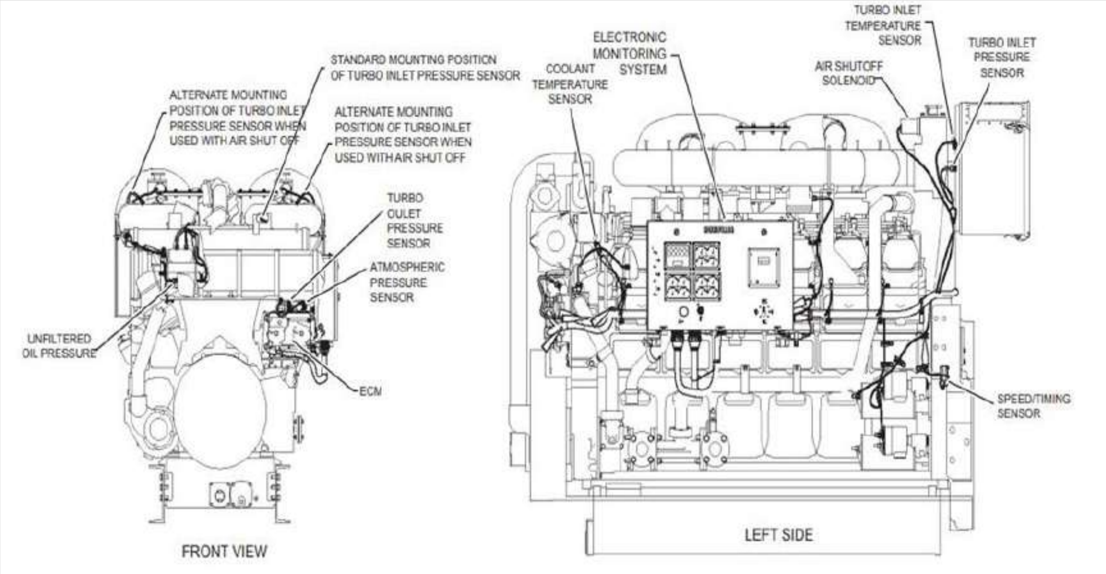


Figure 2- 1: Cat 3512B components as seen from the front and the left side

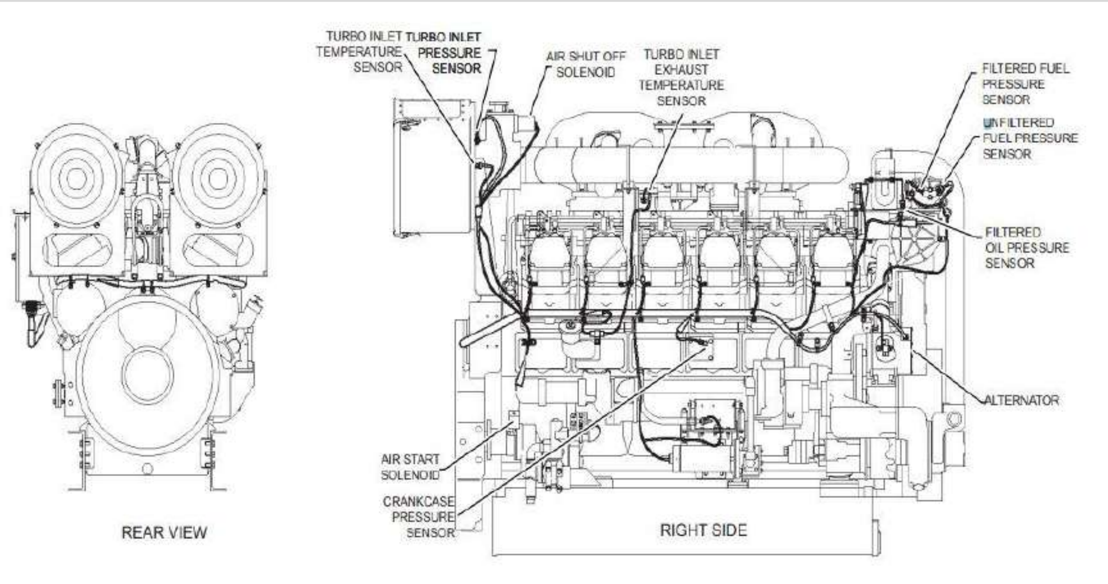


Figure 2- 2: Cat 3512B components as seen from the rear and the right side

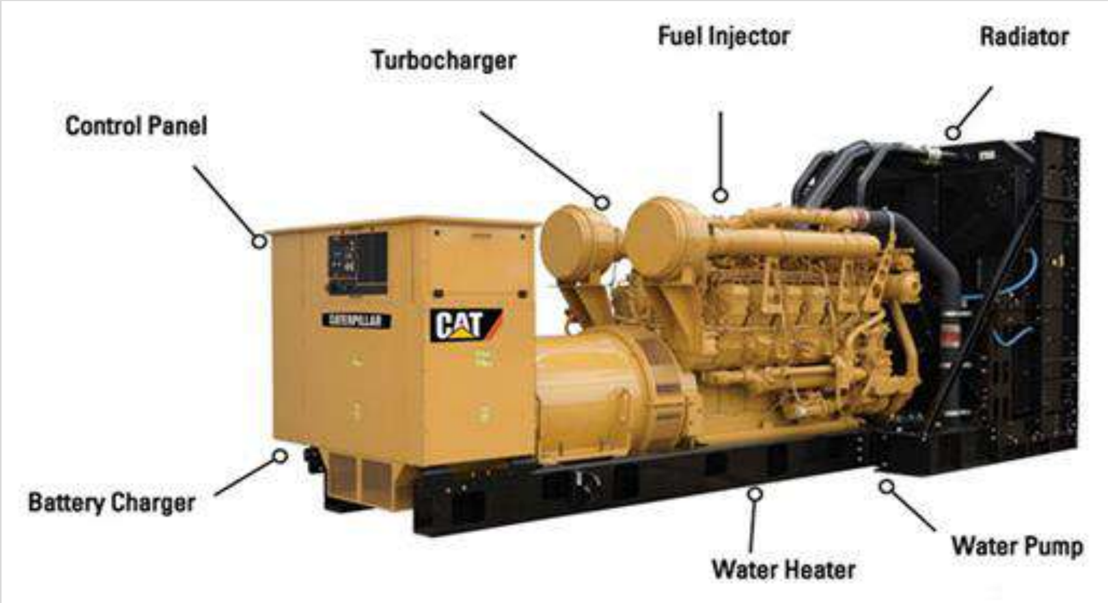
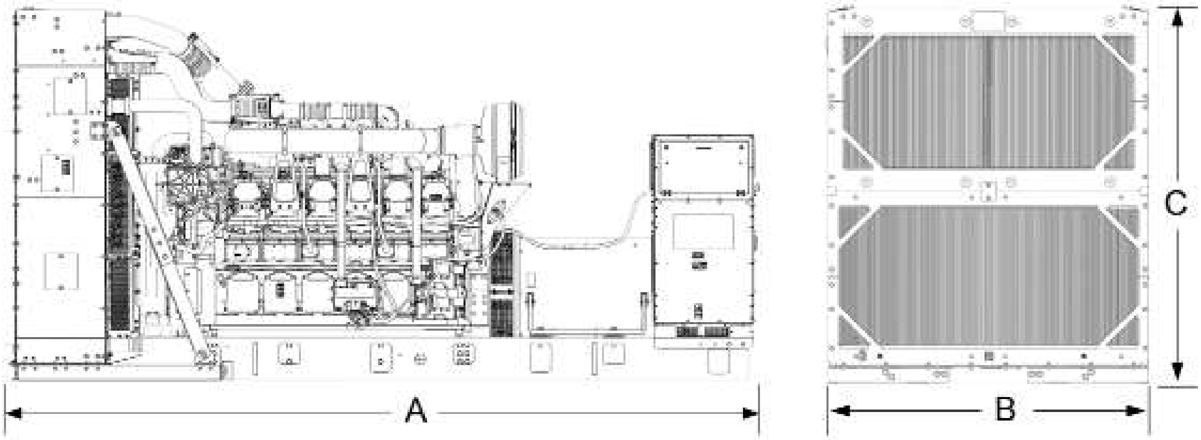


Figure2- 3: CAT 3512B gen set complete unit

2-6-2 Cat 3512b weights and dimensions:

Weights and Dimensions



Dim "A" mm (in)	Dim "B" mm (in)	Dim "C" mm (in)	Dry Weight kg (lb)
5399 (212.5)	2279 (89.7)	2652 (104.4)	13 141 (28,971)

Figure 2-4 : Cat 3512B weights and Dimensions [17]

2-6-3 Cat 3512b specifications

Table 2- 2: Generator Set Specifications [18]

Rating (kVA)	1500
Voltage	415 Volts
Frequency	50 Hz
Speed	1500 rpm

Table 2- 3: Engine Specifications [18]

Engine Model	3512B, V12, 4-stroke Water-cooled Diesel
Bore	170 mm
Displacement	51.8 L
Stroke	190 mm
Compression Ratio	14.0:1
Aspiration	Turbocharged Aftercooled
Governor Type	ADEM™ A3
Fuel System	Electronic Unit Injection

2-6-4 The features of Cat 3512b

Diesel Engine:

• Reliable, rugged, durable design.
• Field-proven in thousands of applications worldwide.
• Four-stroke-cycle diesel engine combines consistent performance and excellent fuel economy with minimum weight.

Generator:

• Matched to the performance and output characteristics of Cat engines.
• Industry-leading mechanical and electrical design.
• High efficiency [18].

2-7 Failures and detection

Just like every mechanical piece of equipment, the CAT generator is prone to failures for a multitude of reasons, ranging from small and easy to fix to critical failures that may cause the entire system to stop working. Those failures can be diagnosed in different ways depending on the failure itself; there are two types of onsite failure detection methods.

2-7-1 through observation

There are a lot of failures that can be diagnosed without any special gadget or program; these are most of the time critical failures, and if not fixed fast, they can cause a big problem. These failures include:

- **Leaks:** oil, water and diesel leakage can be spotted on the ground or next to the generator.
- **Overheating:** usually produce smoke or a smell of burning.
- **Misalignment:** can be diagnosed either via the sound of moving parts or seeing an unusual amount of vibration.

2-7-2 through control panel

Some failures are way harder to spot and can cause massive problems if not diagnosed, which is why the CAT3512b is fitted with an EMCP 4 control panel that can be used to monitor the performance of the generator while also providing fault causes as soon as a fault occurs, which are used to get a detailed description of the fault type and location, making the process of fixing it way easier.

2-8 Control panel

The EMCP control panel (EMCP 4) is a scalable control platform that offers comprehensive data on power output and engine operation in order to assure dependable generator set operation. Through programming and expansion modules, EMCP 4 systems can be further customized depending on the user's needs[19].

2-8-1 Control panel components

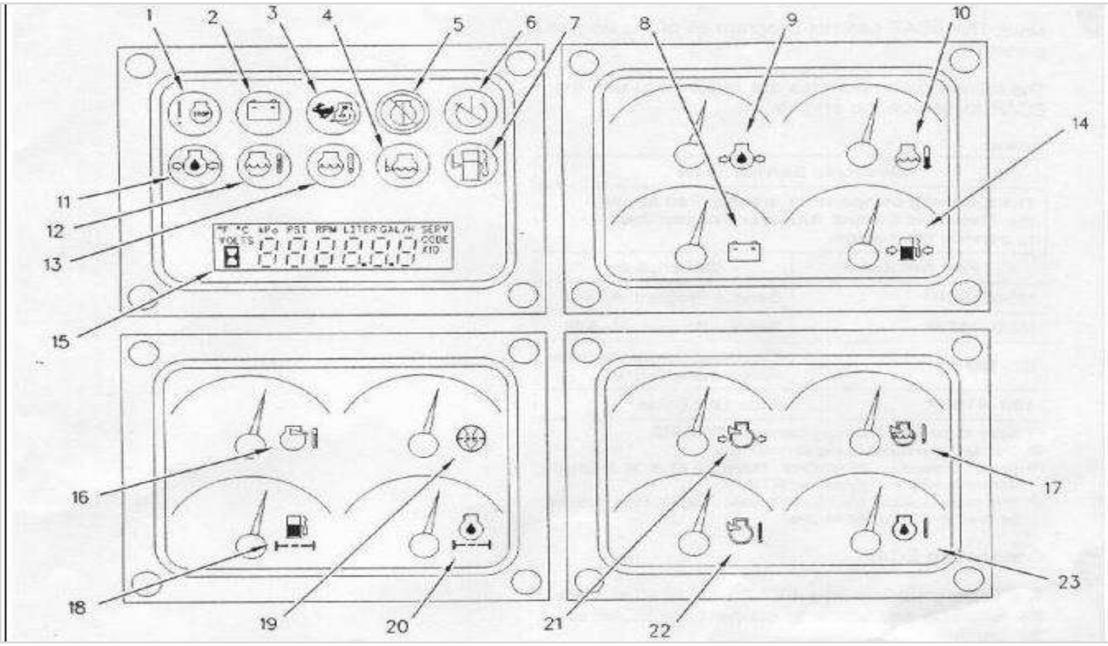


Figure 2-5 : Control panel components [17]

1- stop

2-system supply voltage

3-over-rev

4-low coolant level

5-non-start

6-not automatic

7-low fuel level

8-batrrey voltage

9-oil pressure

10-cooling temperature

21-air intake pressure

11-low oil pressure

12-high coolant temperature

13-low coolant temperature

14-oil pressure

15-digital screen

16-exhaust temperature

17-post-cooling temperature

18-fuel filters restriction

19-air intake filters restriction

20-oil filters restriction

22-air intake temperature

23-oil temperature

2-9 Conclusion

In this chapter, we presented an overview of the engine generators, explained how they function while mentioning their types, and later also presented the CAT3512B generator set and how failures are usually detected in them.

Chapter III: Application of On-Board Diagnostics on CAT 3512B by ENTP

3-1 Introduction

In this chapter, we have applied the On-Board Diagnosis process to examine malfunctioning CAT 3512B generators in the ENTP's workshop and determine the causes of the defects using a special program.

3-2 Company presentation (ENTP)

With a history spanning more than 50 years, Entreprise Nationale de Travaux aux Puits (ENTP) is now internationally renowned. It has been able to impose its know-how and its position as an essential contactor for oil drilling in Algeria. ENTP is SONATRACH's drilling subsidiary. It derives its roots from the Direction des Travaux Pétroliers (DTP), created in 1968, which became, in 1981, after the restructuring of SONATRACH, the National Company for Well Works.

ENTP has always had the capacity and the dynamism necessary to equip itself with the assets that allow it such ease and mastery in the field of oil drilling because it has always been able to put itself in tune with the upgrades. New developments and technological advances are required by the constantly changing reality of oil drilling around the world.

The ENTP explores the Algerian subsoil with 72 drilling rigs for drilling and workover that allow it to master the various layers of the subsoil.

ENTP is an essential expert in:

- Oil drilling and Work-Over since 1968.
- Horizontal drilling since 1996.
- Short-range drilling since 2002.
- Drilling underbalanced since 2003.

Since its inception to date, ENTP has achieved:

- More than 2,900 oil drilling and more than 4,800 Work-Over operations.
- Internationally, ENTP has drilled 30 wells: 3 in Tanzania, 16 in the Sultanate of Oman and 11 in Libya [20].

3-2-1 History of ENTP

- **1968:** Algerian drilling has been a product of SONATRACH since 1968. Keskassa 1 was the first well drilled. The operational structure was called the Direction de Service au Puits (DSP) and had a fleet of four drilling rigs.
- **July 1972:** DSP is renamed the Direction de Travaux au Puit (DTP).
- **01 August 1981:** From the restructuring of SONATRACH to the beginning of the 1980s, the ENTP has emerged as the heir to the DTP for the activities of drilling and work-over. Created by Decree No. 81-171, ENTP became operational on January 1, 1983.
- **June 1993:** ENTP became a member of the International Association of Drilling Contractors (IADC).
- **January 1, 2005:** Transfer of shares held by the equity management company TRAVEN to the management company holdings referred to as "INDJAB".
- **28 December 2005:** Free transfer of shares held by the SGP INDJAB (49%) in favor of the SONATRACH Holding "SPP Spa". ENTP becomes 100% SONATRACH.
- **25 March 2006:** Holding SONATRACH Services Para Petrol "SPP Spa" becomes the sole shareholder of the ENTP [20].

3-3 ENTP Drilling worksite and Rig composition

The TP212 worksite is one of ENTP’s 72 worksites, which at the time that we were there was located in Hassi Massoud, and it was performing a workover operation, which is any operation done on, within, or through the wellbore after the initial completion. Although proper drilling, cementing, and completion practices minimize the need, virtually every well will need several workovers during its lifetime to satisfactorily fulfil its purpose. in addition to deviations performed by another company at the same worksite. The worksite consists of many parts, from the main drilling rig to the generators that power the whole thing, as shown in Fig. 3-1.

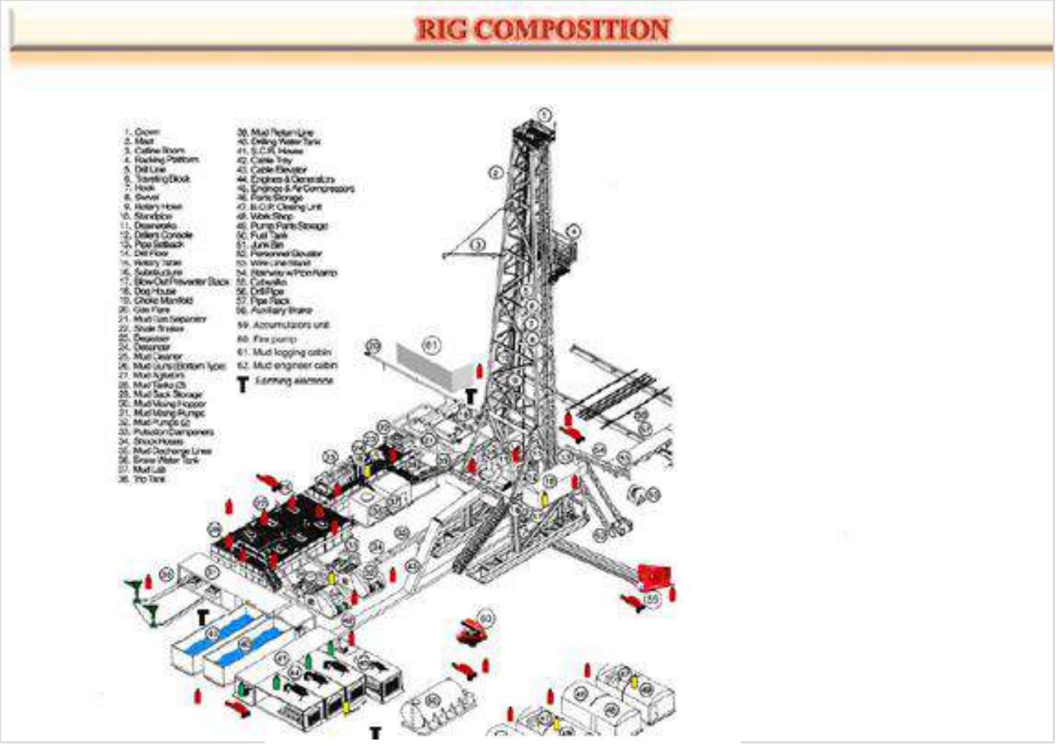


Figure 3- 1 : Drilling rig composition [17]

3-4 Generator diagnostics at worksites

On the drilling worksite, most diagnostics are done either through observation or through the control panel, as mentioned in Chapter 02 and as shown in Fig. 3-2, but in a lot of cases, these types of diagnostics are not enough and cannot effectively locate the cause of the malfunction, which is when the generator must be taken to the base for further examination using special OBD software.

Figure 3-2 : Cat 3512B control panel showing multiple warnings

3-5 DMP examination

When a generator is sent to the ENTP base for examination, it goes straight to the Petroleum Mechanics Department, where it goes through multiple tests by a team of expert mechanics and electricians who use special OBD diagnostic software provided by the Caterpillar company called ET2020B Electronic Technician to determine the cause of the malfunctions, which are fixed on site either through the program for software problems or by fully disassembling the generator and changing the malfunctioning part.

3-6 Caterpillar Electronic technician

Caterpillar Electronic Technician (Cat ET) is a diagnostic tool necessary for communicating with, identifying, and maintaining Cat engines and machines that are controlled electronically. A technician can configure and calibrate the product, diagnose current and potential issues, and acquire data for analysis when connected to an Electronic Control Module (ECM).

When connected to the Electronic Control Module (ECM), the software can access data. Cat ET also does other tasks, such as:

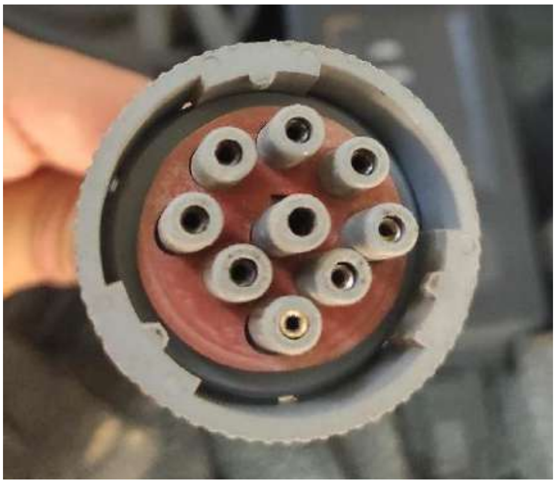
- Status Parameters Display.
- Active Diagnostic Codes Viewing Capabilities.
- Disassembly and Assembly Instructions.
- Logged Diagnostic Codes Viewing and Clearing Capabilities.
- Electronic Control Module (ECM) Configuration Manipulation.
- Diagnostic Tests and Calibration.
- Machine Totals Retrieval.
- Machine Information Recording [17].

Cat ET comes in a suitcase with a CD containing the software's special connection cables as shown in Fig 3-3

Figure 3- 3 : CAT ET Tools

3-6-1 Cat ET connection

Cat ET must be installed on a PC and then connected to the generator via a special cable through a designated port. Each one of the port's pins is used to transfer different types of data, and the cable is connected to the USB port on the PC as shown in Fig 3-4.



A

B

C

Figure 3- 4: CAT ET connection cable (A/B) and port (C)

3-6-2 CAT ET 2020B software interface

After the generator is connected to a PC, a pop-up is displayed to confirm the connection, and then a table appears that has some information about the generator that it is connected to, like the generator's ID, serial number, and name, as well as the ECM ID and serial number. The program also has some tools that are displayed atop that can be used to see active diagnostic and event codes and also logged data about the genset and its ECM; it can even be used to flash the ECM in case of a problem within it.

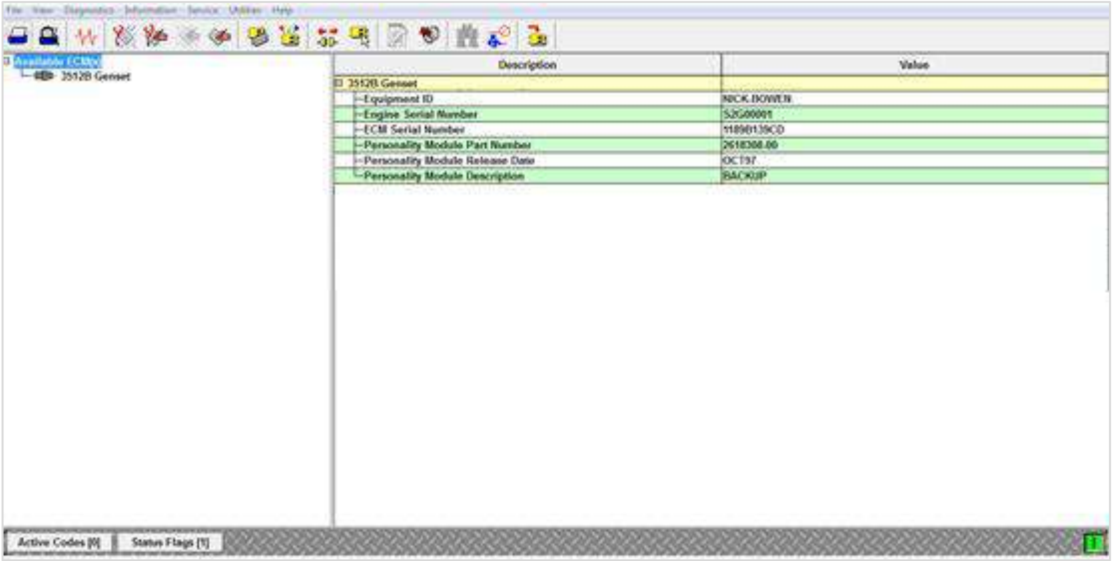


Figure 3- 5 : CAT ET 2020B interface

3-6-3 How to access fault codes through ET

Cat ET allows the user to access active diagnostic codes by clicking on the active codes button in the lower left that has a number indicating the quantity of faults actively present. This button only appears when there is a default in the engine; after clicking, it gives the user fault codes and a description of what the code means and why it probably happened, which facilitates the diagnosis process.

Figure 3-6 : the ET active codes screen

3-6-4 How to perform tests using ET

Cat ET offers a wide range of diagnostic tests that vary depending on the type of generator or machine that it is connected to. In order to perform a diagnostic test using ET, you simply have to click Diagnostics and then choose Diagnostic Tests, which will give you a list of available tests, some of which require the generator to be turned on, like the cylinder cutout test, and others that only require the generator to be connected to a power supply, like the injector solenoid test.

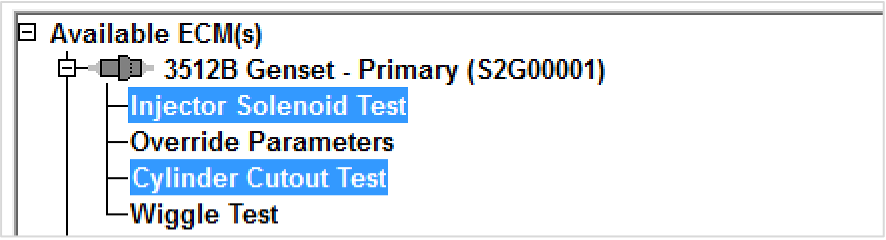


Figure 3- 7: CAT ET Diagnostic Tests

3-6-5 Getting a status report from Et

ET allows for access to various data through the status tool, which provides a list of groups, each of which provides a different set of parameters that the technician can add or remove from groups depending on what he needs. These parameters include engine speed, pressure, temperature, fuel level, etc. You get live values of the selected parameters in addition to the normal range that they should be in, which helps the technician spot any malfunction or abnormality in the generator's performance.

The program also allows the user to get a file called a product status report, which includes every identifying information about the generator, like its name and ID and the ECM ID, and also the values of all the parameters, in addition to active diagnostic codes if present, logged codes that were previously fixed, and also the results of tests that were performed, providing a very informative and very helpful report that can be used later.

CAT ET2020B has a feature called trainer mode, which allows any user, even without licensing the program, to use it to learn how it works using some virtual values for variables and even allows for the creation of a status report, as shown in fig 3-8.

Configuration - 3512B Genset

Description	Value	Unit
Equipment ID	NICK-BOWEN	
Engine Serial Number	S2G00001	
ECM Serial Number	1189B139CD	
Personality Module Part Number	2618308-00	
Personality Module Description	BACKUP	
Personality Module Release Date	OCT97	
FLS	5	
FTS	7	
Low Idle Speed	0	rpm
Air Shutoff	Disabled	
Total Tattletale	0	

Active Diagnostic Codes - 3512B Genset - Primary (S2G00001)

Code	Description
No Active Diagnostic Codes	

Current Totals - 3512B Genset - Primary (S2G00001)

Description	Value	Unit
Total Time	15	hours
Total Fuel	456	L

Figure 3- 8 : Status report as shown in trainer mode

3-7 Example of application

1- First of all, in the PMD section of the ENTP base, a group of experts examine every malfunctioning generator to detect the causes of faults, and that’s done through the Caterpillar Electronic Technician 2020B because most of the generators that they use are compatible with it, and the vast majority are 3512B generators that are used in most worksites.

Figure 3- 9 : A malfunctioned 3512B generator at the DMP for diagnosis

2- The generator must then be connected to both a power source and the pc through the cable as shown in Fig3-10

Figure 3- 10 : Generator connected to the PC via ET port

3- Afterwards, a pop-up screen appears confirming that the generator is connected, and you get a status table detailing most information about the generator and the active codes as shown in Fig 3-11, which was captured when connecting the engine shown in Fig 3-11, which was malfunctioning, and the codes proved that the fault was in the left turbocharger inlet pressure sensor, which has an above-normal voltage.

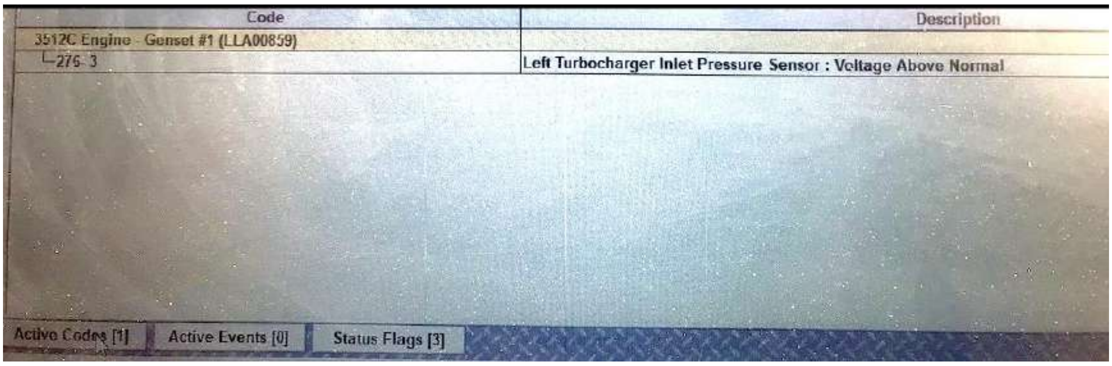


Figure 3- 11 : Active codes of a malfunctioning 3512B generator

4- Because the generator was off and couldn’t be turned on, the only test that was actually possible to realize was the injector solenoid test, which doesn’t require the engine to be on. The injector test is very simple and can be done by the press of a button to test that all the 12-cylinder injectors’ solenoids and electrical connections are functioning properly, and you get OK as the test result if everything goes as intended.

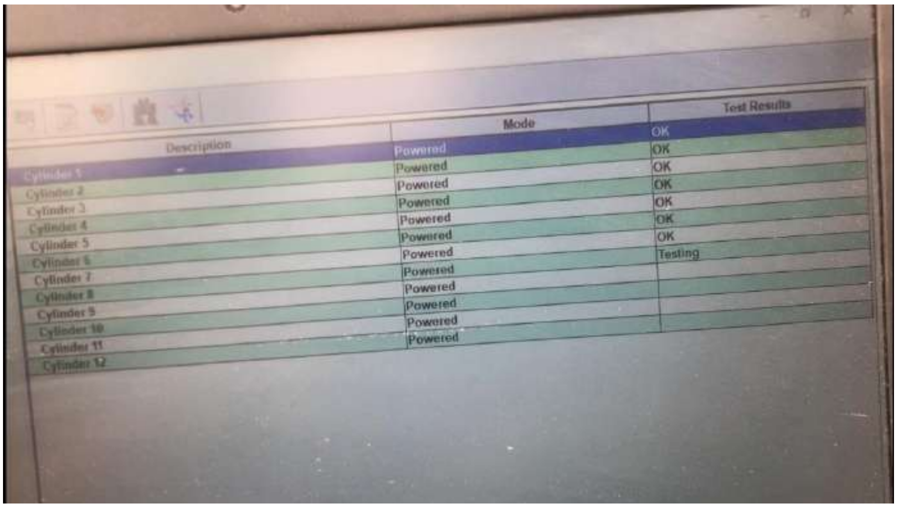
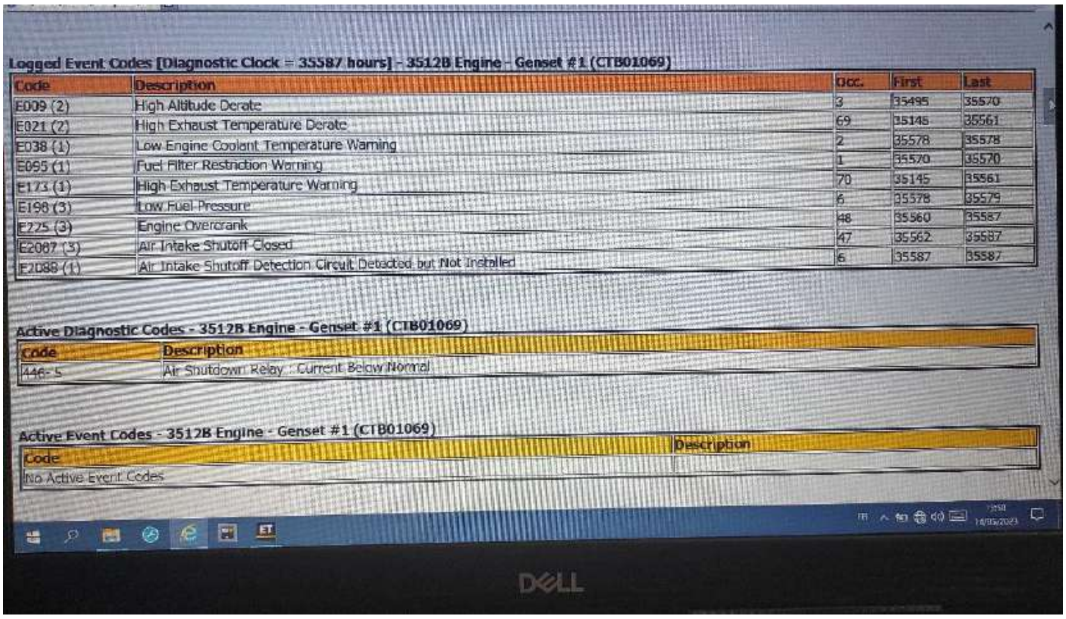


Figure 3- 12 : CAT ET injector solenoid test results

5- The final step of every diagnosis process is to create a product status report that has all the information about the generator, the faults, and the results of every test that was performed. This report is usually kept to be used as a reference for any future diagnosis.



Logged Event Codes [Diagnostic Clock = 35587 hours] - 3512B Engine - Genset #1 (CTB01069)

Code	Description	Occ.	First	Last
E009 (2)	High Altitude Derate	3	35495	35570
E021 (2)	High Exhaust Temperature Derate	69	35145	35561
E038 (1)	Low Engine Coolant Temperature Warning	2	35578	35578
E095 (1)	Fuel Filter Restriction Warning	1	35570	35570
E173 (1)	High Exhaust Temperature Warning	70	35145	35561
E198 (3)	Low Fuel Pressure	6	35578	35579
E225 (3)	Engine Overcrank	48	35560	35587
E2087 (3)	Air Intake Shutoff Closed	47	35562	35587
E2088 (1)	Air Intake Shutoff Detection Circuit Detected but Not Installed	6	35587	35587

Active Diagnostic Codes - 3512B Engine - Genset #1 (CTB01069)

Code	Description
446-5	Air Shutdown Relay : Current Below Normal

Active Event Codes - 3512B Engine - Genset #1 (CTB01069)

Code	Description
No Active Event Codes	

Figure 3-13 : CAT 3512B Product status report

3-8 Conclusion

In this chapter, we showed the results of our application in our ENTP internship of the On-Board Diagnostic program ET2020B by CAT to identify the exact part that caused the a CAT3512B engine-generator to malfunction and test the injector solenoid and cylinder cutout in order to verify that they were functioning properly.

General Conclusion

In this thesis, we studied the On-Board Diagnostics method and the functioning principle of the engine generator in order to apply the OBD method on these engines, specifically the CAT3512B, to facilitate the process of fault detection thanks to the control panel fault codes that locate the exact part that resulted in the malfunction of the engine.

We also observed in our internship at ENTP how the generator sends information to its parts using the engine control unit, which also allows the engine to be connected to the CAT Electronic Technician (ET), which is a computer software that can only be used with CAT products because of the special port it requires. It allows for an easy diagnosis process that can precisely determine the cause of the defect while also having testing capabilities to ensure that other parts of the engine function properly, making it one of the best methods for early fault diagnosis.

We had the opportunity to observe the OBD technique in practice during the internship on a work site and in the DMP, which is the only location where the ENTP utilizes the ET software. We were only able to test two defective engines at the DMP, so we would have liked to be given more time. We also would have liked to use the more recent versions of ET, which weren't available, and apply this method to the 3512C generator, which is a more sophisticated model than the 3512B.

References

1. Ballé, R.I.a.P., *TRENDS IN THE APPLICATION OF MODEL-BASED FAULT DETECTION AND DIAGNOSIS OF TECHNICAL PROCESSES.* ControlEng.Practice, 1997. **5**(5).
2. Barreto, V. *What is OBDII? History of on-board diagnostics*. 2020 [cited 2023 03/2023]; Available from: https://www.geotab.com/blog/obd-ii/.
3. József, M., *ON BOARD DIAGNOSTIC (OBD) SYSTEMS.* 2013.
4. *OBD-I to OBD-II: A History of On-Board Diagnostics*. 2022 [cited 2023 03/2023]; Available from: https://www.moreycorp.com/obd-i-obd-ii-a-history-of-on-board-diagnostics/.
5. Embitel, *A handbook of OBD Modes and Services : Your go to guide for the OBd Software.* 2019.
6. *Engine control uniit.* my car dictionary.
7. Alexander Hentschel, E.N., *Design of an information system for vehicle diagnostic trouble codes*, 2013, CHALMERS UNIVERSITY OF TECHNOLOGY, Göteborg, Sweden.
8. Pirasteh, P., *Interactive feature extraction for diagnostic trouble codes in predictive maintenance.* 2019.
9. KINCROME, *Diagnostic scan tool OBD2 Manual*, 2016.
10. BOSCH, *Enchaced OBD I and OBD II Scan tool user guide* 2016.
11. Baek, S.-h., *Implementation of integrated OBD-II connector with external network.* 2014.
12. Pattengale, B., *Scan tool assessment.* MOTOR, 2005.
13. *DIESEL GENERATOR INSTRUCTION & MAINTENANCE MANUAL.* ETT Generator, 2016.
14. Shrinivasa, D.U., *The Evolution of Diesel Engines.* Resonance, 2012.
15. Sharma, M.M., *Generators: Working, types and advantages (Lecture).*
16. CATERPILLAR, *Cat® 3512B Industrial Diesel Engine Industrial.* 2007.
17. ENTP, *ENTP Document.*
18. CATERPILLAR, *3512B Generator set.* Caterpillar India, 2020.
19. *Application and installation guide EMCP4* Caterpillar, 2010.
20. ENTP. [cited 2023 04/2023]; Available from: www.entp.dz.

Study of On-Board Diagnostics applied on an Engine-Generator "Case study ENTP"

Abstract:

The objective of this study is to understand how diagnostics are used on a faulty CAT 3512B engine-generator to determine the source of the defect.

For this, we apply the On-Board Diagnostics method, which utilizes fault codes that are displayed on the generator's control panel as a first step, and then get more information by using the CAT ET software, which gives detailed descriptions of the state of the generator and the exact spot that caused the defect. We then perform further tests on the generator. This allowed us to get a complete diagnosis, which then allows for an easier repair.

Key words: Diagnostics; Generator; ET; Fault; On-board; ENTP.

دراسة تطبيق نظام التشخيص الذاتي على مولد "دراسة حالة ENTP"

ملخص :

الهدف من هذه الدراسة هو فهم كيف تستعمل عملية التشخيص في مولد CAT 3512B ذو عطب لتحديد مصدر العطب.

لذلك قمنا بتطبيق طريقة التشخيص OBD التي تستعمل كخطوة اولى رموز الاخطاء التي تظهر على لوحة تحكم المولد و يمكننا ان نتحصل على معلومات اكثر عن طريق استعمال برنامج CAT ET الذي يعطي وصفا مفصلا عن حالة المولد والمكان الدقيق الذي يسبب العطب ثم اجرينا المزيد من الاختبارات على المولد.ما سمح لنا بالحصول على تشخيص كامل، والذي يؤدي الى تسهيل عملية الاصلاح..

الكلمات المفتاحية : تشخيص؛ مولد؛ET؛ عطب؛ ENTP.