BACHELOR THESIS & COLLOQUIUM – ME141502

THE DEVELOPMENT OF TROUBLESHOOTING ANALYSIS TOOL FOR TURBOCHARGER FAILURE USING MICROSOFT ACCESS AND VISUAL BASIC APPLICATION

ROBBY RACHMAT SUSILO
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DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
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APPROVAL FORM

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Representative of Hochschule Wismar in Indonesia

Dr.-Ing. Wolfgang Busse

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This bachelor thesis has written and developed independently without any plagiarism act, and confirm consciously that all data, concepts, design, references, and material in this report own by Marine Operation and Maintenance (MOM) in Department of Marine Engineering ITS which are the product of research study and reserve the right to use for further research study and its development.

Name	: Robby Rachmat Susilo
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Bachelor Thesis Title	: The Development of Troubleshooting Analysis Tool for Turbocharger Failure Using Microsoft Access and Visual Basic Application
Department	: Marine Engineering

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Surabaya, July 2018

Robby Rachmat Susilo

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ABSTRACT

Turbocharged diesel engine has been adopted into marine industry for a long time. Hence, turbocharger becomes the important equipment due to its task in supplying compressed air into the combustion chamber. The absence of turbocharger will result in lower power produced by the diesel engine. As turbocharger is running, the problems may occur on the turbocharger. The turbocharger's manufacturer offered troubleshooting for turbocharger in the form of matrix charts. The user will only be given a few possible causes regarding to the problem occurred. Then the user started to think which cause fits best for giving rise to the problem. Therefore, turbocharger troubleshooting software is recommended to overcome this problem. It is able to give a shortcut to the user in eliminating the causes by giving only two possible causes that might lead to the problem. There will be an explanation regarding to the reason in selecting the cause. Any shown cause will be followed up with its troubleshooting. It is meant to give information to the user whether the troubleshooting could be done on board or not. The software can be updated with latest data in order to keep the troubleshooting more accurate. The user will be able to operate the software easily and shorten the time taken to find out the cause of turbocharger problem and its troubleshooting.

Keywords: Troubles, Turbocharger, Troubleshooting, Database

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PENGEMBANGAN ALAT ANALISA PEMECAHAN MASALAH UNTUK KEGAGALAN *TURBOCHARGER* MENGGUNAKAN APLIKASI *MICROSOFT ACCESS* DAN *VISUAL BASIC*

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Jurusan : Marine Engineering
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Dosen Pembimbing II : Dr. Eng. M. Badrus Zaman., ST., MT.

ABSTRAK

Mesin diesel yang dilengkapi *turbocharger* telah diadopsi ke dalam industri kemaritiman untuk waktu yang lama. Oleh karena itu, *turbocharger* menjadi peralatan penting karena tugasnya dalam memasok udara terkompresi ke dalam ruang bakar. Ketidak-hadiran *turbocharger* akan menghasilkan daya yang lebih rendah pada mesin diesel. Saat *turbocharger* sedang berjalan, masalah dapat terjadi pada *turbocharger*. Pabrikan *turbocharger* menawarkan pemecahan masalah untuk *turbocharger* dalam bentuk bagan matriks. Pengguna hanya akan diberikan beberapa kemungkinan penyebab masalah yang terjadi. Kemudian pengguna akan berpikir penyebab mana yang paling cocok untuk menimbulkan masalah. Oleh karena itu, perangkat lunak pemecahan masalah *turbocharger* direkomendasikan untuk mengatasi masalah ini. Hal ini mampu memberikan jalan pintas kepada pengguna dalam menghilangkan penyebabnya dengan memberikan hanya dua kemungkinan penyebab yang mungkin mengarah ke masalah. Akan ada penjelasan mengenai alasan dalam memilih penyebabnya. Setiap penyebab yang ditampilkan akan ditindaklanjuti dengan pemecahan masalah. Ini dimaksudkan untuk memberikan informasi kepada pengguna apakah pemecahan masalah bisa dilakukan di kapal atau tidak. Perangkat lunak ini dapat diperbarui dengan data terbaru untuk menjaga pemecahan masalah lebih akurat. Pengguna akan dapat mengoperasikan perangkat lunak dengan mudah dan mempersingkat waktu yang dibutuhkan untuk mengetahui penyebab masalah *turbocharger* beserta pemecahan masalahnya.

Keywords: Masalah, *Turbocharger*, *Troubleshooting*, *Database*

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PREFACE

In the name of Allah the most gracious and the most merciful. All praise the authors say into the presence of God Almighty, who has provided his grace so that the author can complete this thesis. This thesis is supposed to fulfill the Bachelor Thesis course at authors study and also be hoped that authors gain more information regarding this thesis in the future.

The authors would like to say thanks for those who helped the author in the making of the thesis.

1. Author's beloved parents, who always give prayer and support to the author.
2. Dr.Eng, M. Badrus Zaman, S.T., M.T., as Chairman of the Department of Marine Engineering Department, Faculty of Marine Technology ITS.
3. Ir. Hari Prastowo as the supervisor in the process of making this thesis.
4. Mr. Marten as Technical Superintendent from PT. Samudera Indonesia Ship Management who give many guidance to the author in doing this thesis.
5. Mr. Awan from PT. Turbotech Indonesia (Surabaya) who give quite of advices in doing this thesis.
6. Alvis Mu'afa Riestra as the author's best friend since high school who always support whether in good or bad condition.
7. Revina Putri Awalu as the author's friend who helped in conducting every author's idea into the software.
8. Dhea Amalia who always supports the author by reducing any stresses.
9. All of MOM Lab members who always there in bitter and sweet conditions.
10. Fellow friends of Double Degree in Marine Engineering batch 2014 who were struggling together for four years.

The author concerns in the imperfections of this thesis. Therefore, any criticisms and suggestions that are built from the reader will be expected. The author hopes this thesis provides benefits primarily for readers and additional for the author in the process of teaching and learning.

Surabaya, July 2018

Author

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CHAPTER I
INTRODUCTION

This chapter provides the explanation of background, problem formulation, objectives of research, and research boundaries of this thesis.

1.1. Background

MV. *"XXX"* is one of the container vessel that PT. Samudera Indonesia Ship Management is responsible for. The condition of the ship is the very important for this company. For that, this company have applied a schedule for maintenance and inspection. This is a part of the ship management process. This maintenance schedule is designed so that the ship will be fully operational at its best condition all the time. Although some accidents or failures might not be predicted and prevented.

On February 2017, this vessel had to deal a worse situation. The turbocharger which gives power and efficiency to the main engine is broken. The rotor shaft is bent and resulting to the rubbing of both the turbine and compressor blades. This problem leads to further damage to the blades. On the turbine side, the blades are chipped on the edges. It will result to small parts of the blade to enter the exhaust manifold which may lead to further damage to the exhaust manifold.

Figure 1. 1 Damaged compressor side of turbocharger
(Source: Samudera Indonesia Ship Management)

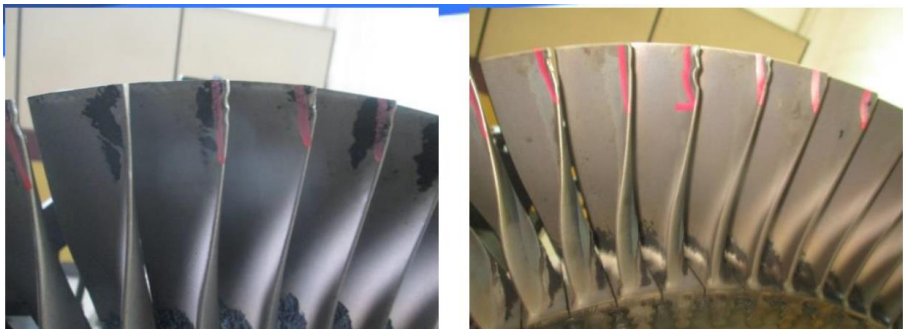

Figure 1. 2 Damaged turbine side of turbocharger
(Source: Samudera Indonesia Ship Management)

Nevertheless, the ship shall be able to voyage as soon as possible. The replacement of turbocharger system is done and the ship is able to continue the voyage. The repairing report is kept to undergo the failure analysis for the further likely event. Ship management needs to find out what the cause of any failure especially for the turbocharger in order to prevent the same failure occurred in the future. This prevention will result a reduction in unexpected cost for repairing. More than that, the ship will smoothly do the voyage for the contracted time and the customer will not have a delay shipment. Of course, the name of the shipping company will be better.

Unfortunately, the problem is arisen when the ship management tend to have not enough time to take deep research about the cause of failure. The important task of ship management is to ensure the ship in a good condition and the ship is always ready to sail. When the accident like that is happened, they will be focused on restoring the performance of the ship to be able to do the voyage due to every time taken by the ship for not doing the voyage is claimed by the company so as soon as possible they must restore the ship to the healthy condition. In addition, the improvement needed for the ship management to support them in determining the cause of the turbocharger failure due to the effect given by the turbocharger failures was big enough to affect the ship voyage. This thesis acted as the supporting tool to reduce the time taken for determining the cause of turbocharger failure.

1.2. Statement of Problem

Based on the description above the statement of problem of this thesis are;

1. What caused the turbocharger failure?
2. How did the causes lead to failure?
3. How to prevent such an event in the future?
4. What is the recommended database for the turbocharger failures?

1.3. Research Limitations

The limitations of this thesis are;

1. Human Error in this case are neglected.
2. Planned Maintenance System has been well implemented including on M/E maintenance.
3. The failure came from the electronic control system on M/E is neglected.
4. The errors came from Planned Maintenance System is neglected.

1.4. Research Objectives

The objectives of this thesis are;

1. Collecting all of the possible failure causes.
2. Determine the root cause of turbocharger failure.
3. To develop software application of troubleshooting on turbocharger.
4. Supporting PMS application for turbocharger.

1.5. Research Benefits

The benefits of this thesis are as follows;

1. Acknowledging the turbocharger failures.
2. Develop a troubleshooting software of turbocharger failures.

1.6. Deliverable

The benefits of this thesis are as follows;

1. Database of the turbocharger failures.
2. Troubleshooting software for turbocharger

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CHAPTER II
LITERATURE REVIEW

This chapter provides the literature study as the basic information for the thesis.

2.1. Problem Overview

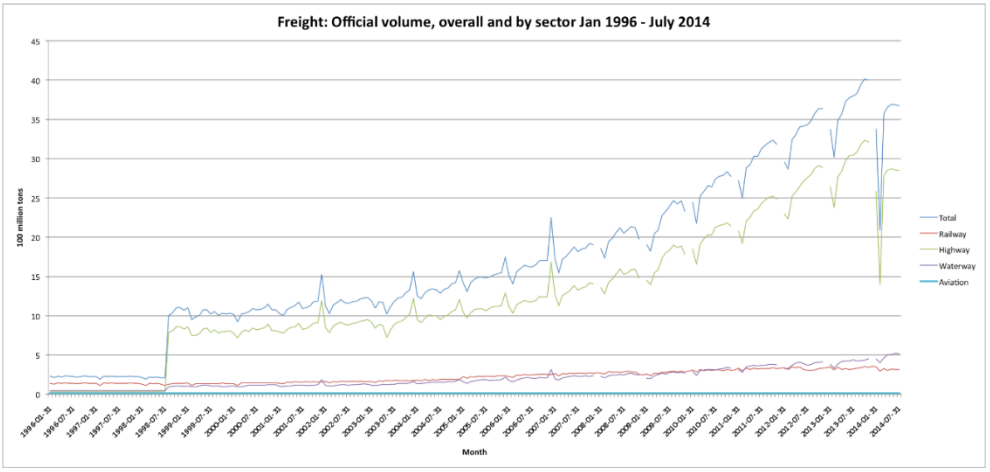

Figure 2. 1 Freight volume by sector (Source: China Economic Review)

Shipping is a vast growing business especially the waterway sector due to the large area of Earth which covered with water. These were resulted by the people which started to communicate across the border of every country. They started to exchange their personal goods with their own needs and all of them were involved by everyone on the globe. It was the important thing that triggered the growth of shipping business.

As the shipping business growing each year, the company needed a fleet to support the business. The idea of having more fleets was come from the demand itself. The shipping company wanted to find any customer who were able to deal a contract with them. Along with this action, the shipbuilding company is also triggered to produce more suitable merchant ship. The shipbuilding company provided their ship with the latest technology to improve their value for selling the ship.

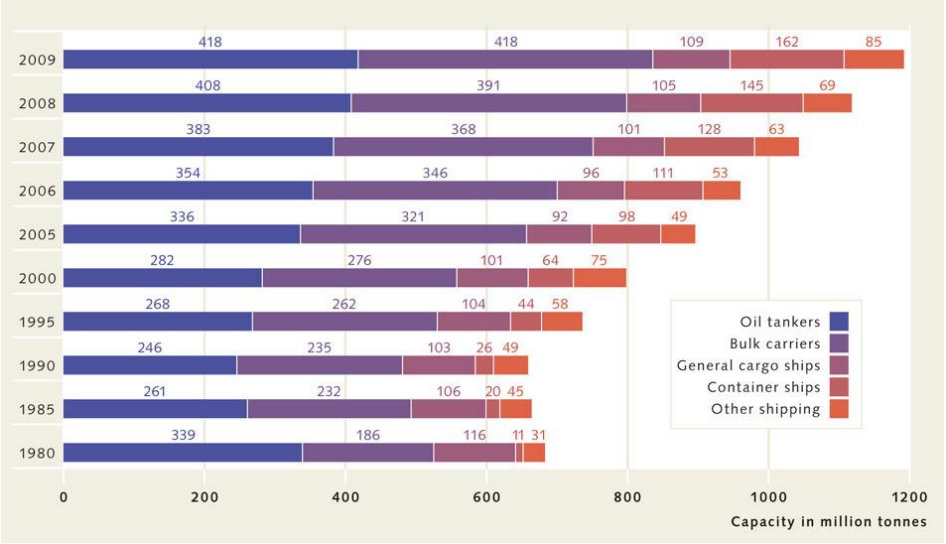

Figure 2. 2 The capacity of merchant ship (Source: World Ocean Review)

Many engineers were involved in inventing the technology which would later be installed on the ship. The inventions are including the construction, machinery and electricity equipment on board. Then the ship becoming more capable of doing shipping business. One of the sector on ship which provides the energy into ship was the machineries. Due to the ship used diesel engine as its main source for propulsion, there are invention which cause the greatest improvement to the diesel engine and it was called as turbocharger.

Turbocharger was a turbine-driven device that increases an internal combustion engine's power output by forcing extra air into the combustion chamber. This improvement is done by the compressor that is able to force more air and proportionately more fuel into the combustion chamber than atmospheric pressure. The objective of a turbocharger is to improve an engine's volumetric efficiency by increasing density of the intake air allowing more power per engine cycle.

By undergoing that action, turbocharger was believed to reduce the dimension of main engine. There will be an increase in free space of engine room to be filled with other equipment. On the other hand, the volume of engine room will be much lower than the engine room with the large dimension of main engine. The lower the engine room resulted an increase in the cargo space which indicate the increase of shipment on every voyage. These also increase the profit for the shipping company.

As the turbocharger has to provide the forced induction air to the main engine, it was meant that the turbocharger became an important equipment onboard. The pressure, temperature and others related to turbocharger shall be maintain in order to keep the performance of main engine. If the turbocharger is damaged, the main engine will slightly loss the power and reduce in speed couldn't be neglected. In the worse scenario, the turbocharger will stop rotating and there is no air entered the main engine. The result is the main engine will be stopped. This is bad because the ship shall do the voyage for the contracted time with the company. This accident will eventually reduce the profit owned by the company and also increase the money spent by the company to repair and maintenance the ship.

One of the bad scenario was happened to MV. *"XXX"*, one of Samudera Indonesia's ship. On February 2017, this vessel had to deal with a rough situation. The turbocharger which gives power and efficiency to the main engine is broken. The rotor shaft is bent and resulting to the rubbing of both the turbine and compressor blades. This problem leads to further damage to the blades. On the turbine side, the blades are chipped on the edges. It will result to small parts of the blade to enter the exhaust manifold which may lead to further damage to the exhaust manifold.

The turbocharger was jammed and the main engine was stopped. The ship was berth to wait for the repair that handled by the company. The shipping company has the ship management division to overcome this kind of situation. Due to the main engine was built by MAN B&W, it has time taken to order the spare part of the turbocharger and these resulted the increase in time to berth.

The repair data and the latest inspection data were collected to find out what the cause of the failure. Then it was found two possibilities which categorized as the root cause. The first cause is coming from the intercooler. It was failed to reduce the temperature of charged intake air and then caused the incomplete combustion. The result was black carbon residue which attached to the turbine side of turbocharger. The black carbon residue increased the rotating moment of turbine and increase the speed of turbine that connected to the compressor side. The compressor then rotated in over speed condition and increase the pressure of intake air. The high pressure in the compressor will give such a great back pressure to the compressor. After that the surging was happened and cause the shaft to bend. When the shaft was bent, it will lower the clearance of either the turbine side or the compressor side. For this

case, the shaft was bent to the compressor side which led to jammed compressor.

Besides that, the information was gathered by the MAN B&W costumers that the turbocharger was not able to perform better if the RPM of turbocharger is greater than 9700 RPM. According to the inspection data, the turbocharger was performed at 10075 RPM which is greater than the value stated by them. This cause will be the information for the further operational of turbocharger as the precaution of turbocharger failure.

Ship management needs to find out what the cause of any failure especially for the turbocharger in order to prevent the same failure occurred in the future. This prevention will result a reduction in unexpected cost for repairing. More than that, the ship will smoothly do the voyage for the contracted time and the customer will not have a delay shipment. Of course, the name of the shipping company will be better.

Unfortunately, the problem is arisen when the ship management tend to have not enough time to take deep research about the cause of failure. The important task of ship management is to ensure the ship in a good condition and the ship is always ready to sail. When the accident like that is happened, they will be focused on restoring the performance of the ship to be able to do the voyage due to every time taken by the ship for not doing the voyage is claimed by the company so as soon as possible they must restore the ship to the healthy condition. In addition, the improvement needed for the ship management to support them in determining the cause of the turbocharger failure due to the effect given by the turbocharger failures was big enough to affect the ship voyage.

2.2. Turbocharger

A turbocharger is an exhaust-powered supercharger[1], means that it is a turbine-driven device that increases the engine's power output by forcing extra air into the combustion chamber. The compressor will force more air into the combustion chamber. The delivered air has more pressure than atmospheric pressure. Thus, turbocharger is able to improve the engine's volumetric efficiency by increasing the density of air into the engine.

[1] Dempsey, P. (2008). *Diesel Engine Troubleshooting and Repairing.*

The turbocharger has three main components:

1. The turbine
2. The compressor
3. The center housing

2.2.1. Turbine

Figure 2. 3 Turbine wheel (Source: Uniturbine.com)

Turbine will rotate by the energy stored in exhaust gas. The exhaust gas has heat energy that is able to be converted to rotate the energy. The size of turbine wheel depends on the performance of the turbocharger. It means higher turbocharger performance will result a bigger turbine wheel.

2.2.2. Compressor

Figure 2. 4 Compressor Wheel (Source: Marineturbo.co.uk)

The compressor delivers more mass of intake air into the combustion chamber by compressing it until more than the atmospheric pressure. The compressor increases the mass of intake air entering the

combustion chamber. The compressor mainly consists of an impeller and a diffuser.

The compressor used in the turbocharger is centrifugal compressor. The engine attached by turbocharger achieves an increase in air intake pressure by adding kinetic energy to a continuous flow of fluid through the impeller. This kinetic energy will be converted to an increase in pressure by slowing the flow into a diffuser on the compressor wheel.

2.2.3. Center Housing

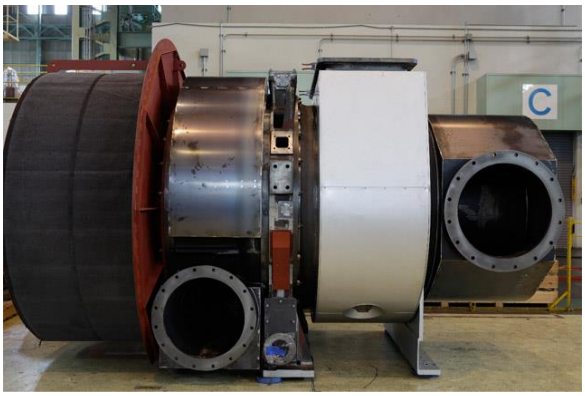

Figure 2. 5 Center Housing (Source: Mitsubishi Heavy Industries)

The center housing maintains the shaft or rotor that connected the compressor impeller with turbine. A bearing needs to be placed to suspend the shaft or rotor in order to allow the shaft or rotor for rotating in very high speed with low friction. The housing may be attached by individual water-cooled for cooling down the lubricating oil. This will prevent lubricating oil to undergo oil coking from the extreme heat from the turbine. Ball bearing is used to support the turbine shaft dealing with high speeds and temperatures. It also helps the turbocharger to accelerate more quickly and reduces an event called turbocharger lag.

2.2.4. Intercooler

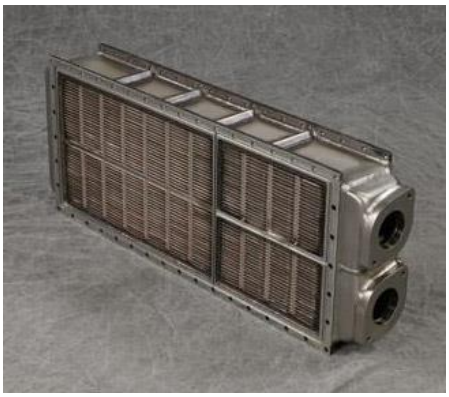

Figure 2. 6 Intercooler (Source: AAVID NIAGARA)

As the intake air gained more pressure, the temperature of intake air will also increase. Furthermore, the heat from exhaust gases on the turbine side will also heat the intake air. When the temperature intake air increase, it becomes less dense and lower oxygen molecule that will be delivered to the combustion. To overcome this situation, turbocharger often uses an intercooler or charged air cooler, to cool down the intake air and make the compressed intake air denser. On ship, the coolant used is either fresh water or sea water.

2.3. Turbocharger Failures

A turbocharger is able to fail because of many factors. It may come from the turbocharger itself, or it may come from other parts that are connected to the turbocharger. Turbocharger failures diagnosis are generally divided into 4 which are impact damage, insufficient oil supply, dirt in oil, carbon build-up.

1. Impact Damage

   It is caused by poor filtration of air that could bring foreign materials inside. This will then damage the impellers. If not attended immediately, a total loss of impellers may happen. Most extreme situation is the total loss of the turbocharger because of a broken rotor shaft due to vibrations.

2. Insufficient Oil Supply and Dirt in Oil

   A lack of lubrication may cause to overheat of rotor shaft, this will cause carbonization of the oil inside. Then it will condense and build up carbon layers whether at turbine side or compressor side. The lubrication quality is important because if there are foreign objects, then it is able to cause scratches or even rubbing among parts in rotor shaft. Another factor is the exhaust gas quality and air filtration system. If the exhaust gas is not clean, then it may cause carbon layer to form in the turbine.

3. Carbon Build-up

Figure 2. 7 Carbon Deposits on Nozzle Ring
(Source: Samudera Indonesia Ship Management)

It may cause severe damage to the shaft seal ring, bearings and shaft bearings. This will lead to loss of bearings function, which will cause the shaft to vibrate and eventually bend. This then will also cause the impellers to spin in different angles, which is able to cause scratching or rubbing between impellers and housing. This is a very dangerous situation because it could chip the edges of the impellers and those will rise another problem. So, it is wise to immediately repair bearings and sealing rings so that it does not escalate to a more extreme failure.

Another factor that might have played a big role in turbocharger failure is that the combustion did not occur properly. This may happen because the air mass that is going to the combustion chamber is not balanced with the fuel mass. It might be that the air mass is more than the fuel mass or vice versa. This event will occur either because a faulty fuel injector or a faulty intake air system.

1. Fuel Injector Fails

   This may happen because of:

   a. The fuel is in bad condition
   b. Fuel system blocked or clogged because of bad fuel quality
   c. Wear and tear in the fuel nozzle
   d. Blocked fuel nozzle
   e. Bad fuel pump condition

2. Air Intake System fails

   This may happen because a lot of factor, such as:

   a. Bad quality of air
   b. High temperature of air intake
   c. Failure of intercooler
   d. Failure of compressor at TC
   e. Bad air filter

Fuel quality will also contribute in the failure of a turbocharger, because if the fuel quality is bad, then the combustion quality will also be bad. This will lead to bad exhaust gas quality, it will contain more carbon than it should have. Which will make carbon deposits or carbon build-up inside the turbine.

2.4. Microsoft Access

Microsoft Access is a database management system from Microsoft with a graphical user interface and software-development tools. A database is a collection of information that is related to a particular subject or purpose.[2]

2.5. Microsoft Visual Basic

Visual Basic is a programming language and integrated development environment created by Microsoft for programming model. Microsoft Visual Basic application usually uses in the purpose of interface for database to make the database easier and more proper to be displayed.

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[2] Microsoft. (n.d.). Learn the structure of an Access database.

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CHAPTER III
METHODOLOGY

This chapter provides the adopted methodology for doing the thesis.

3.1. Methodology Flowchart

The adopted methodology will be shown in the flow chart below.

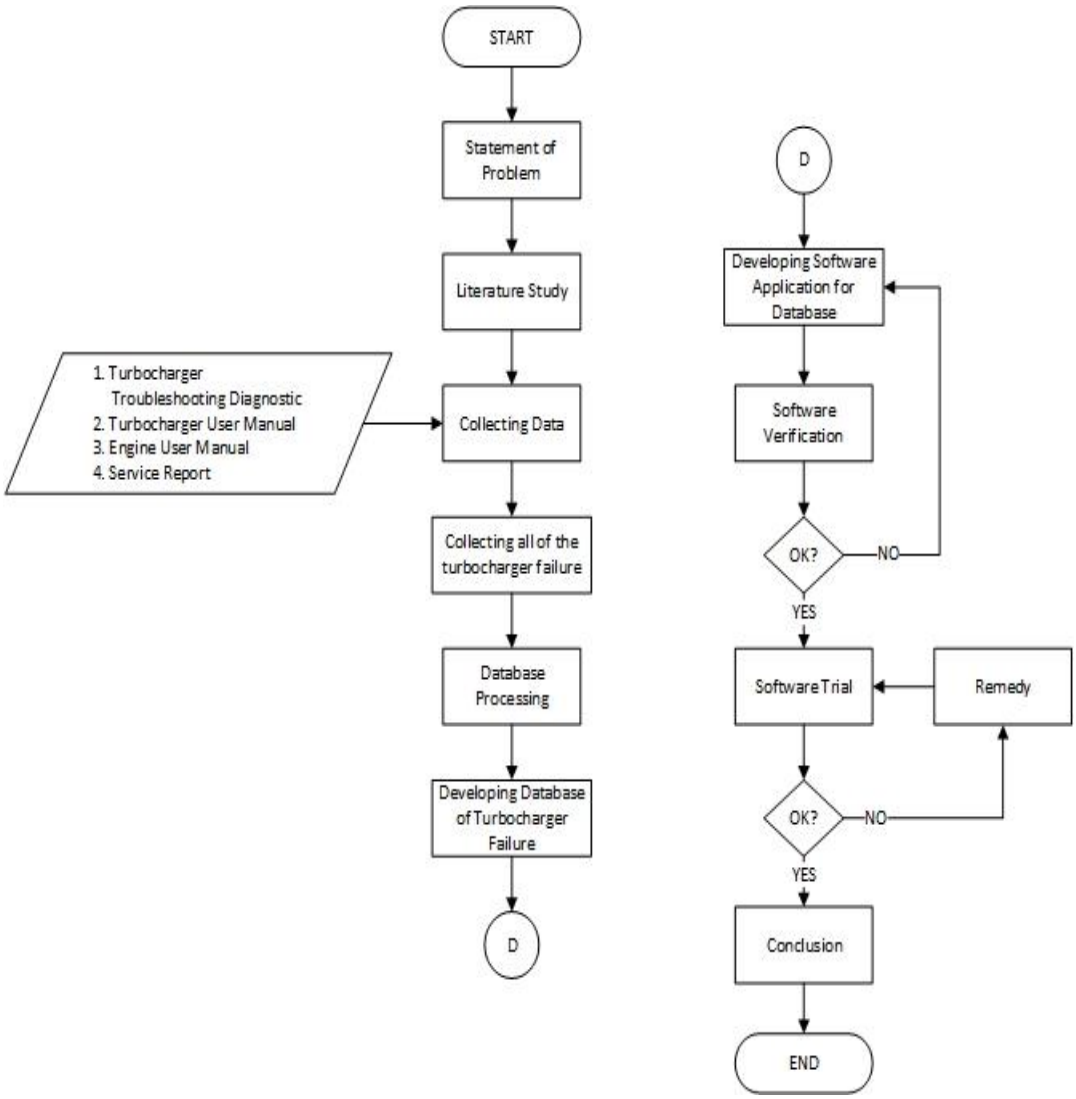

Figure 3. 1 Methodology Flowchart

3.2. **Definition of Methodology Flowchart**

The explanation of each process are as follows,

1. Statement of Problems

   In this stage, the early processes which include the selection of problem, objective and predicted solution shall be arranged. Thus, the objective and benefit of the thesis could be achieved.

2. Literature Study

   After having a certain in problem, the literature study must be taken. This will be the reason in solving the problem. The literature study was done by reading some sources of information. There are books, journals and other thesis which came from the trusted sources.

3. Collecting Data

   In this stage, the data collected will be matched with the literature study that has been done. The data collections are gathered to find the possible cause of the failure. Those are including the turbocharger troubleshooting diagnostic and turbocharger user manual. Some of the failure may come from the engine so the engine user manual might be needed. Other than the turbocharger data, some of the record must be taken as the data collection for the thesis. The records are regarding to the service report of the damaged turbocharger.

4. Collecting all of the turbocharger failures

   This stage is divided into three parts: collecting from literatures, from the vendor of turbocharger and from the shipping company. Collecting from literatures started with reading the books or literatures and clustering the failure by the source of failures.

   Collecting from the vendor of turbocharger was meant to fulfill the information about the troubleshooting of turbocharger. The information collected is about the troubleshooting analysis that implemented there.

   Collecting from shipping company is purposed to collect the real cases happened from the shipping company. The cases will be used to test the software that will be created

5. Database processing

   When all of the failures data are collected, the failures must be clustered according to the source of the symptoms. In this case the source of them are located in between the turbocharger parts. This will act as abridging the evidence to match with the database.

6. Developing database of turbocharger failures

   The troubleshooting data that has been collected and grouped will be processed in the form of a database table to be combined and easily read by the program (software) used. Program (software) that will be used is Microsoft Visual Basic, so the data is made in the form of tables in Microsoft Access. Microsoft Visual Basic program is used for the results that will be obtained in the form of application software, so that the user later is able to use and understand it easily.

7. Developing application software for database

   The database troubleshooting has been compiled in Microsoft Access will be input into Microsoft Visual Basic. Database of turbocharger troubleshooting is inserted in window interface that will be accessed by the user. The interface is supposed to facilitate the user accessing the database.

8. Software Verification

   In this section, rechecks the database data troubleshooting that has been prepared in Microsoft Access with project guide, literature books and website. This is done to minimize errors occurring in the grouping of troubleshooting types with the types of troubles that occur, other than that it aims to validate the troubleshooting database to be more relevant, well targeted, and help speed up the work of the planned database software because it does not experience any data changes again.

9. Software Trial

   In this stage, the final software will be tested with new input from either the shipping company or the vendor for turbocharger. The input may come from random case of turbocharger failure. If the software could detect the problem and fit with the troubleshooting recommendation, the software may be categorized as “Ok”. Otherwise, if the input couldn’t be detected by the software, the software is not suitable yet for being used in the future and the act of revision must be taken.

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CHAPTER IV
DATA ANALYSIS

This chapter provides the data analysis as the progress of developing software application for this thesis.

4.1 Collecting turbocharger failures

In developing software for turbocharger troubleshooting tool, the first step is collecting turbocharger failures. This is done by break-downing the turbocharger diagnostic matrix from MAN and from ABB. There are some additions from other manufacturer to give additional data of turbocharger failures. All of them could be seen on the attachments.

The failures will be categorized by its own location that is occurred. This supposed to ease in determining the failures as some of manufacturer have the same meaning in stating the turbocharger failures but differ in words used. For example: high lube oil consumption and lubricating oil loses. Both of them have the same meaning.

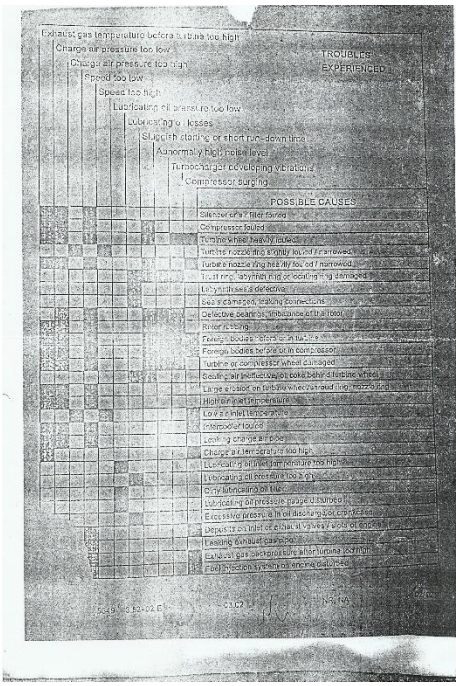

Figure 4. 1 MAN turbocharger diagnostic matrix (Source: Turbotech Indonesia)

4.2 Determining the cause of turbocharger failure

Every failure is happened by some of causes. Those must be categorized as root causes. Root cause is a factor that initiate the failures from beginning. It is good to overcome the problem in the future and prevent the same problem arises.

The cause of turbocharger failure was available in the turbocharger diagnostic matrix used in the first step. Then the problem and cause are placed on the table and analyze to be clustered. As the causes coming from multiple sources, the causes with the same meaning will be grouped as shown in the table 4.1.

Table 4. 1 Problem and causes

Problem	Cause before analysis	Cause after analysis
Compressor surging	turbine wheel heavily fouled	Air filter fouled and damaged
	turbine nozzle ring heavily fouled/narrowed	Intercooler failure
	foreign bodies before or in turbine	Leak in intake line
	foreign bodies before or in compressor	Faults in injection system
	low air inlet temperature	Insufficient ventilation
	intercooler fouled	Burnt valves and/or piston
	charge air temperature too high	Wastegate mechanism set incorrectly
	deposits on inlet or exhaust valve / slots of engine	
	exhaust gas back pressure too high	
	fuel injection pump or fuel injectors incorrectly set or disturbed	
	grid dirty	
	air filter fouling	
	turbine blade wear damage	
	problem with engine room ventilation	

In order to eliminate multiple causes, the *yes/no* question must be determined. Each question asked user regarding to the symptoms of the cause. Then the answers will result in summary so user will have less work in checking the causes occurred in the turbocharger.

Table 4. 2 yes/no questions

QUESTION_ID	QUESTION
1	Does your air filter seem dirty?
2	Black smoke produced?
4	Abnormal turbocharger speed?
5	Is the scavenge air pressure lower than 1.0 bar?
6	Is there any scratch on either turbine or compressor wheel?
7	Does the air inlet temperature exceed 50 C?
9	Does your engine suffer a poor idle and starting issues?
10	Does your exhaust gas temperature exceed 350 C?

4.3 Determining the troubleshooting for every causes

In overcoming the causes, troubleshooting is needed to fix the condition. The troubleshooting is divided into two components. General troubleshooting and detailed troubleshooting.

4.3.1. General Troubleshooting

General troubleshooting is a main feature of troubleshooting that stated in the turbocharger diagnostic matrix. The example of general troubleshooting is shown in table 4.3

Table 4. 3 Causes and general troubleshooting

CAUSE_TITLE	TROUBLESHOOTING
Air filter fouled and damaged	Clean the air filter
Intercooler failure	Inspect for the fouling on intercooler and check the coolant used in intercooler
Leak in intake line	Inspect for the leakage and repair. Replace if needed
Faults in injection system	Overhaul the injection system and adjust faulty components. Replace if needed
Insufficient ventilation	Improve ventilation

4.3.2. Detailed Troubleshooting

Detailed troubleshooting is a further explanation of general troubleshooting. In case the person who access the troubleshooting software has lack of knowledge about turbocharger, the detailed troubleshoot will briefly explain how to do it. The precautions, procedures and visualization by image will be shown in detailed troubleshooting.

REMOVE SILENCER AND CONFIRM THE ROTOR DEFLECTION. WHEN THE VALUE IS OVER THE LIMIT, REMOVE THE SILENCER AND CHECK THE SURFACE OF IMPELLER CLUTCH

According to BBC EXHAUST GAS TURBOCHARGER VTR 354P by ABB Turbo Systems, the cross section of turbocharger including the clearance are shown in figure below. Thus, the rotor deflection can be determined.

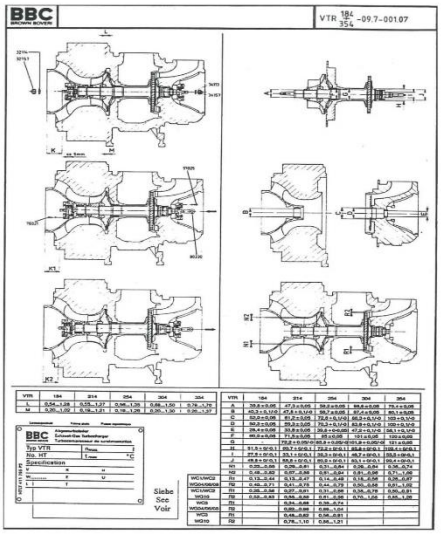

Figure 4. 2 Detailed troubleshooting (Source: Private Document)

4.4 Developing database

All of the data will be put into Microsoft Access in order to create database that is able to be read by the software. The figure below shows the data that been inserted into Microsoft Access.

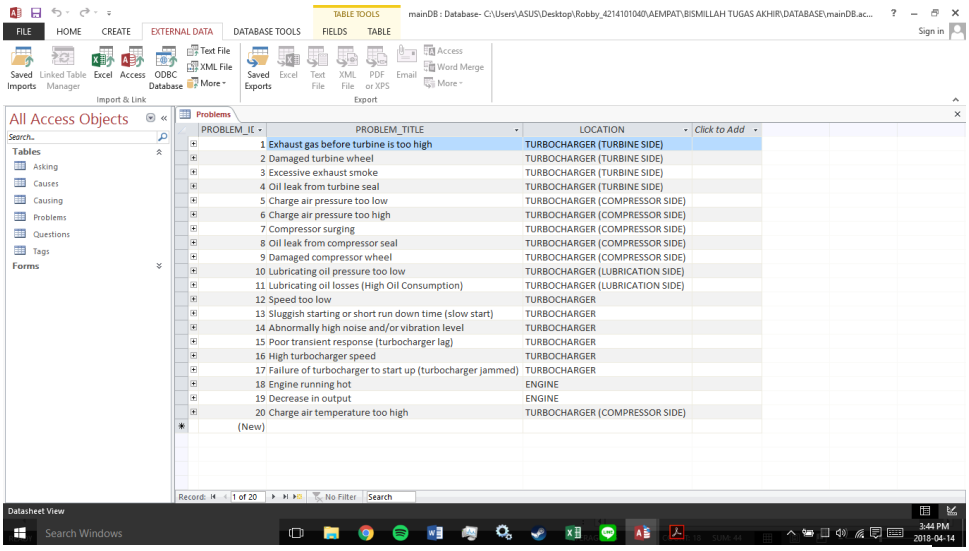

Figure 4. 3 Database in Microsoft Access (Source: Private Document)

Then the database will be verified by rechecking with the data from literature study and turbocharger diagnostic matrix. It is important to check the relationship of every table in Microsoft Access due to the software will be depended on the database.

4.5 Developing software application

After the database is established, software application will be developed in Microsoft Visual Studio. The flowchart of creating the software is shown in figure below.

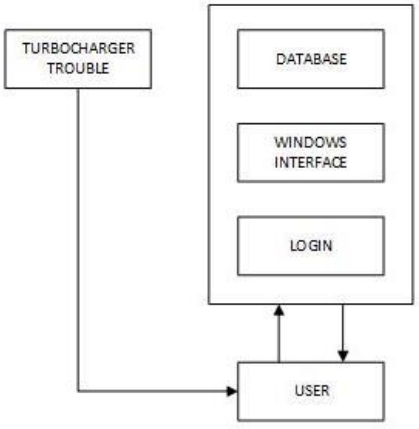

Figure 4. 4 Flowchart of creating the software

4.5.1. User

User is a person who want to access the software. Every user must be assigned in the software and then authorized by username and password for every user.

4.5.2. Login

To access the software, user needs to use the data of both username and password. This is supposed to track the person in charge of troubleshooting action that will be printed on the report.

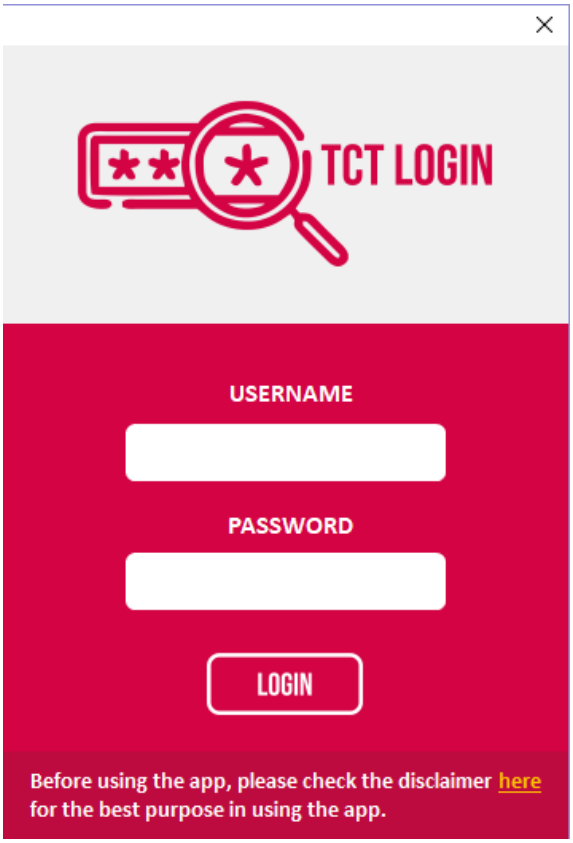

Figure 4. 5 User Login

4.5.3. Window Interface (Home)

After user has logged in, the window interface will be first shown to user is as figure below.

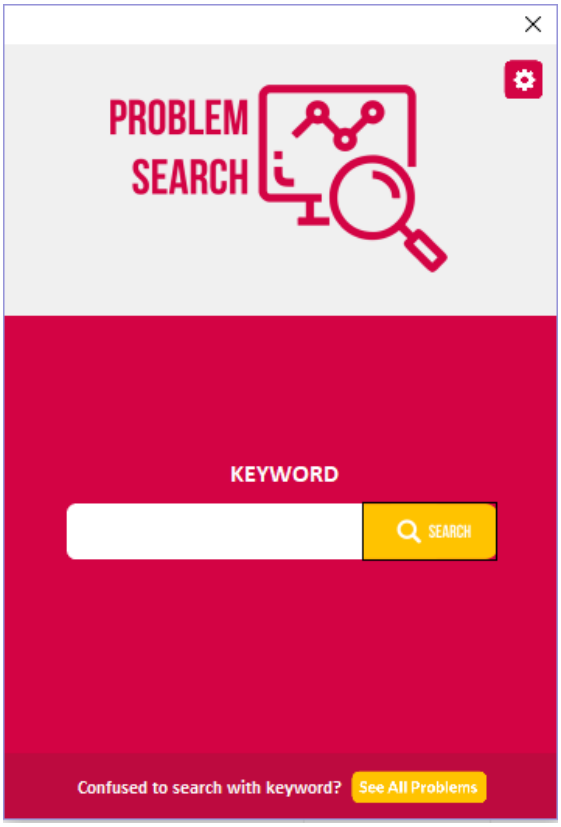

Figure 4. 6 Window Interface (Home)

The process of finding the troubleshooting started from the window interface so it was called home. There are search engine to find the problem. Another way to find problem is by manually searching the available problems. After finding the troubleshooting, user will be directed back to home.

4.6 Working principles of turbocharger troubleshooting software

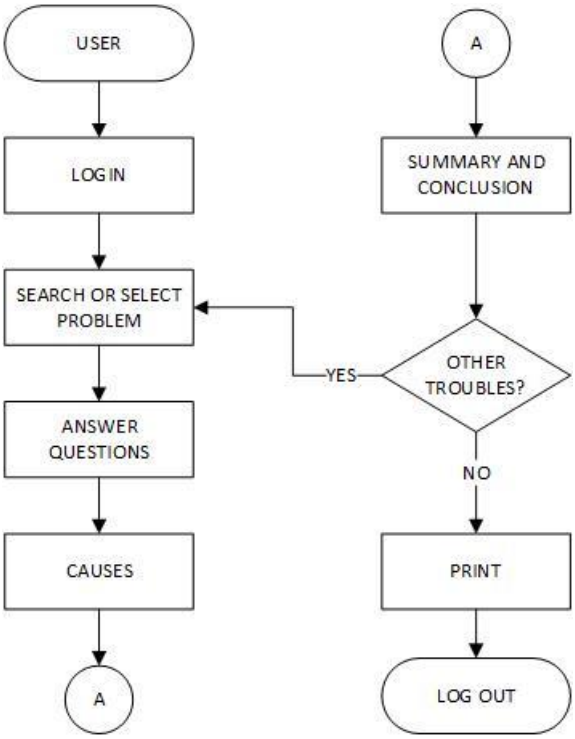

Figure 4. 7 Working principles of turbocharger troubleshooting software

The picture above shows the working principles of turbocharger troubleshooting software.

4.7 Software Trial

The software will be tested by some of problem from either shipping company or the vendor of turbocharger. The result of trials are as follows:

1. Software was tested with MV. XXX case and SOLVED.

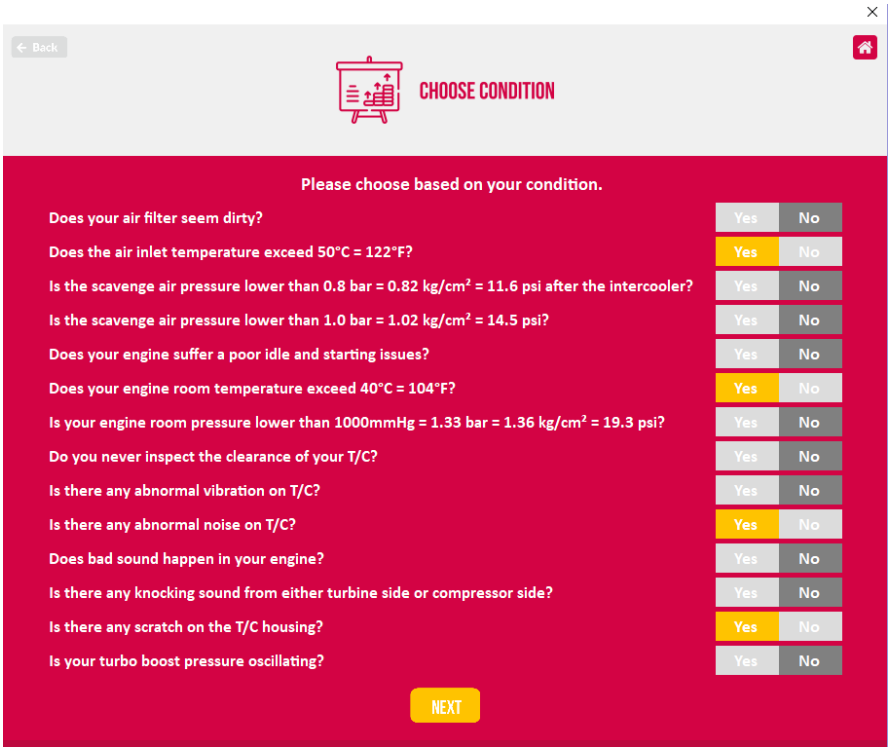

Figure 4. 8 Input from MV. "XXX"

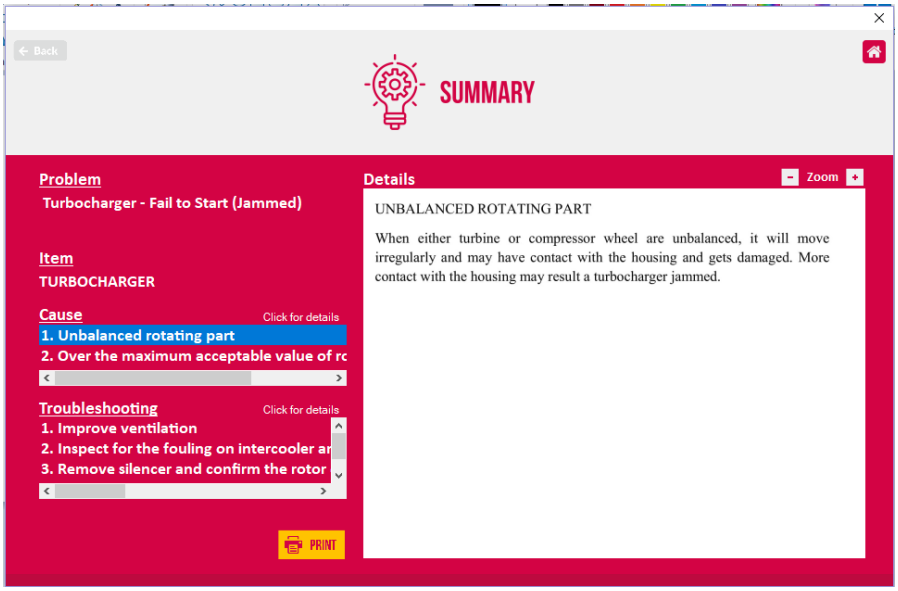

Figure 4. 9 Output for MV. "XXX" = SOLVED

2. Software was tested with “YYY” case and UNSOLVED.

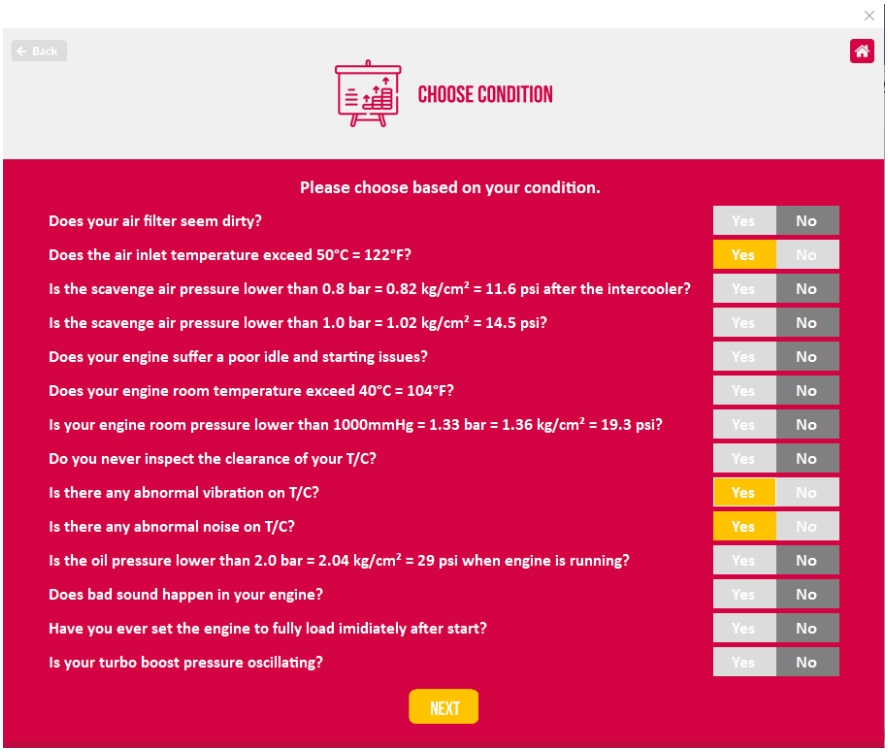

Figure 4. 10 Input from “YYY”

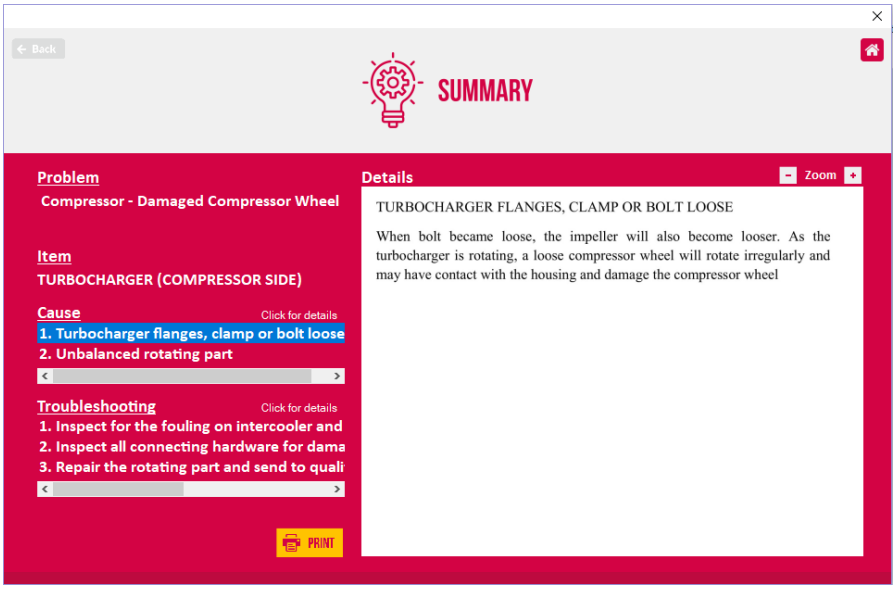

Figure 4. 11 Output for “YYY” = UNSOLVED

Remedy is taken and found out that the software is not able to detect the problem because the ship was sailing in 35°C of engine room temperature that categorized as acceptable as stated in the disclaimer.

3. Software was tested with 5 random samples of problem by PT. Turbotech Indonesia (Surabaya). The result is 4 of them SOLVED.

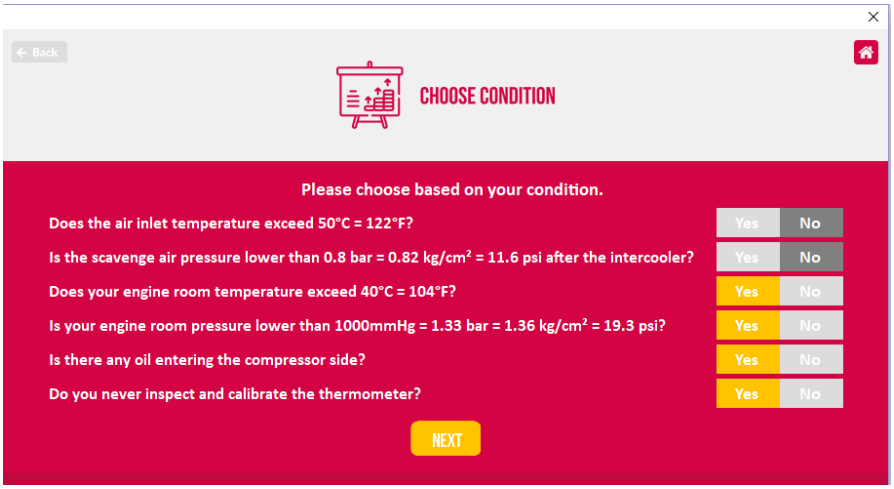

Figure 4. 12 Input from sample 1

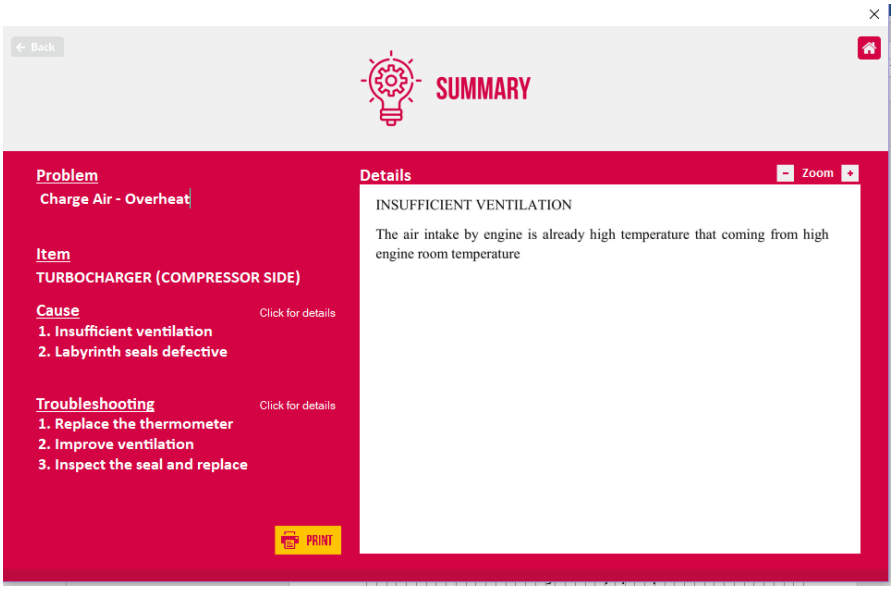

Figure 4. 13 Output for sample 1 = SOLVED

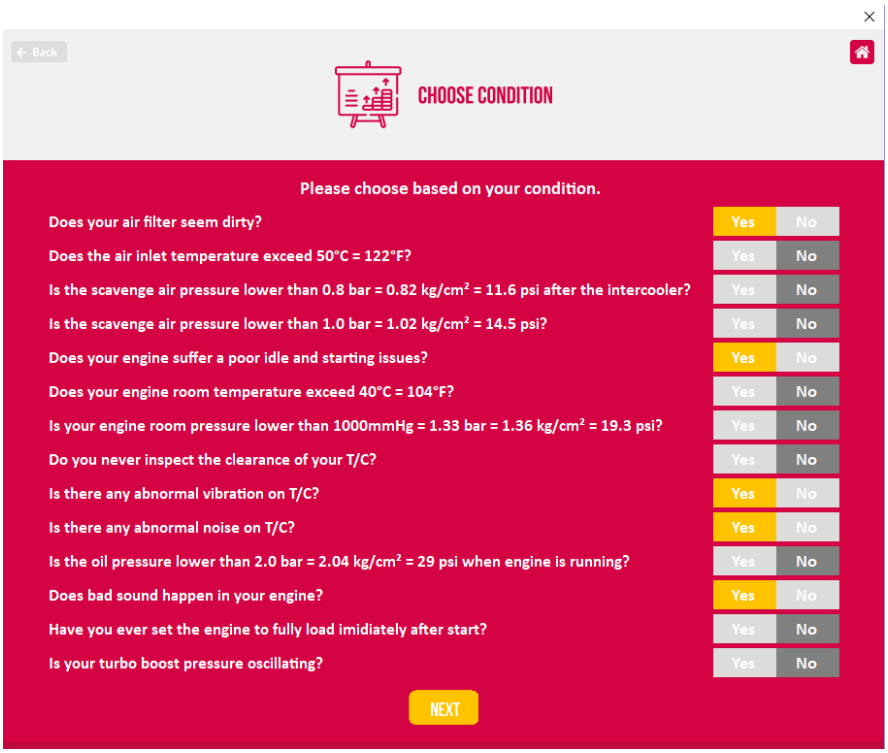

Figure 4. 14 Input from sample 2

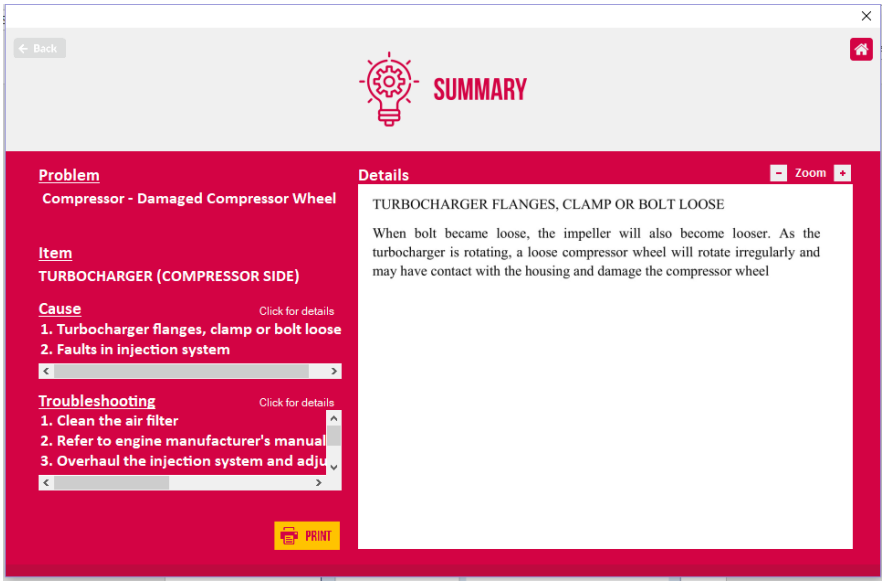

Figure 4. 15 Output for sample 2 = SOLVED

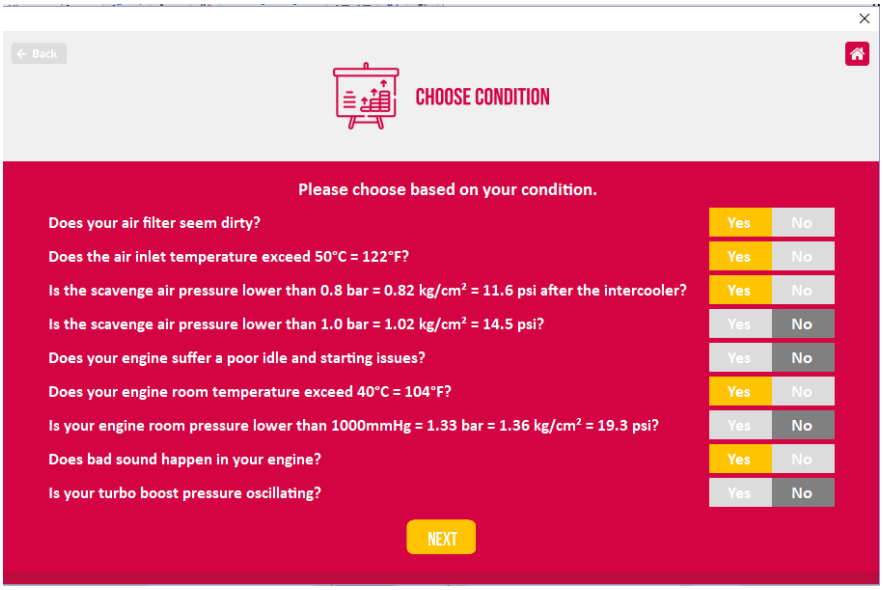

Figure 4. 16 Input from sample 3

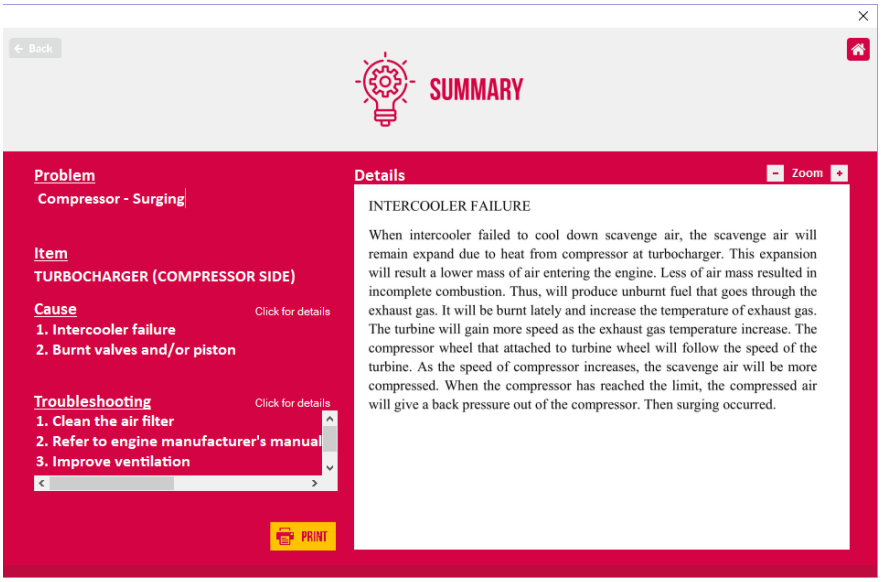

Figure 4. 17 Output for sample 3 = SOLVED

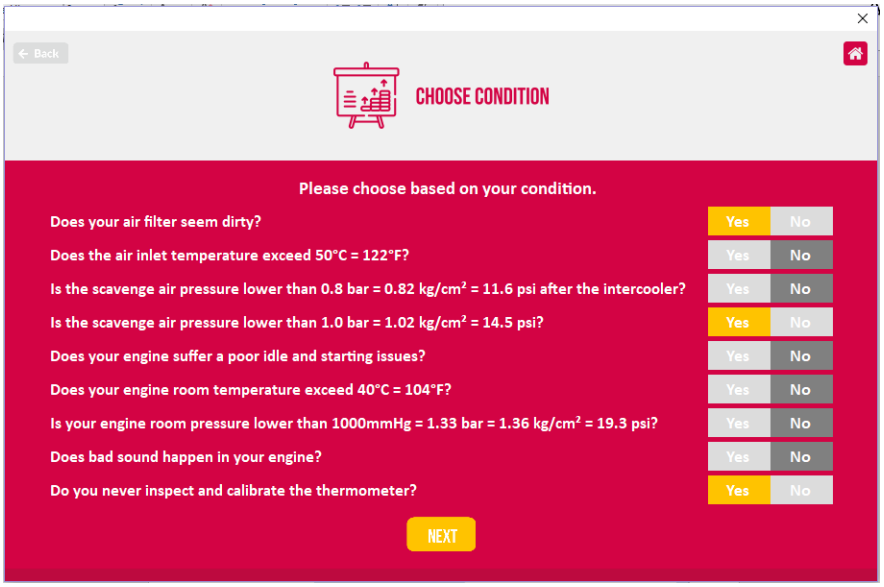

Figure 4. 18 Input from sample 4

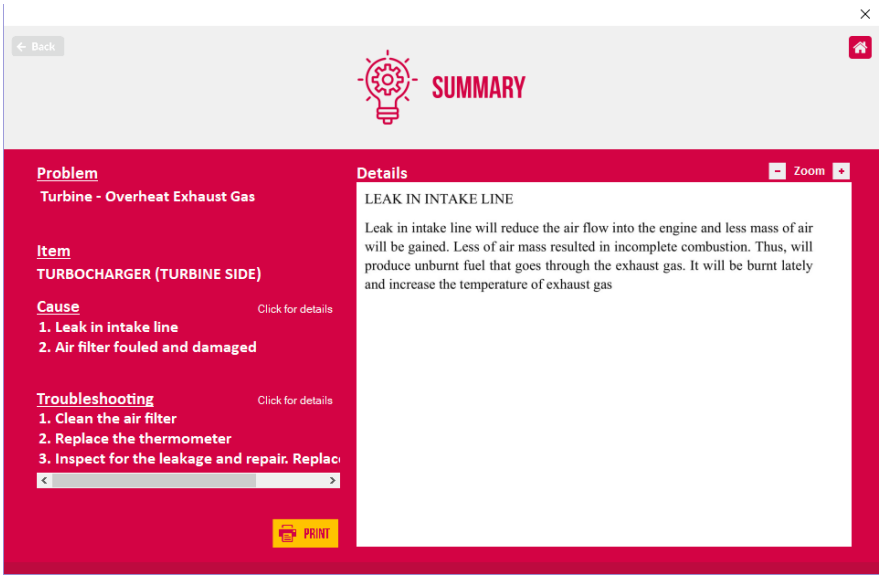

Figure 4. 19 Output for sample 4 = SOLVED

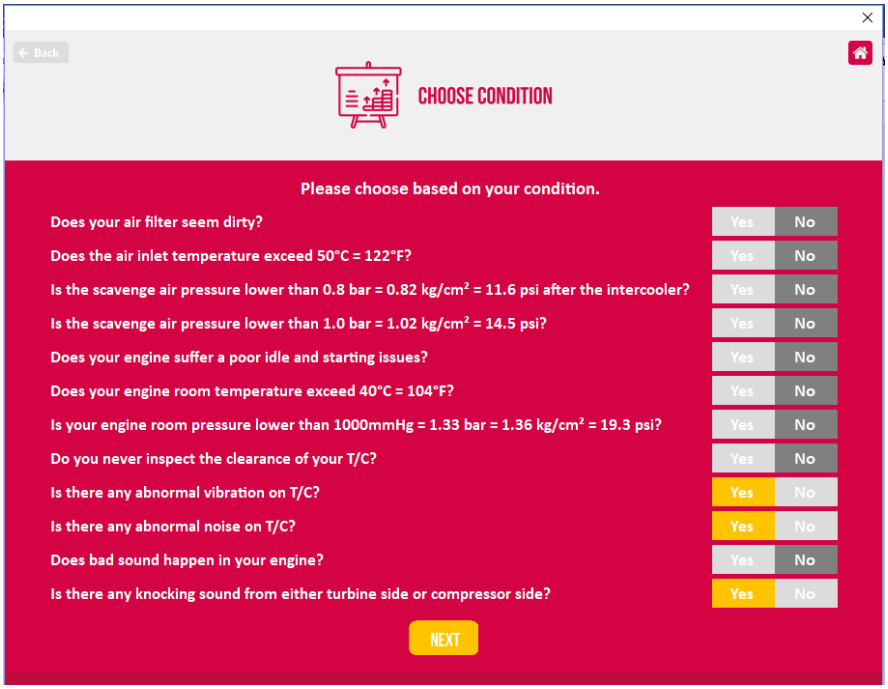

Figure 4. 20 Input from sample 5

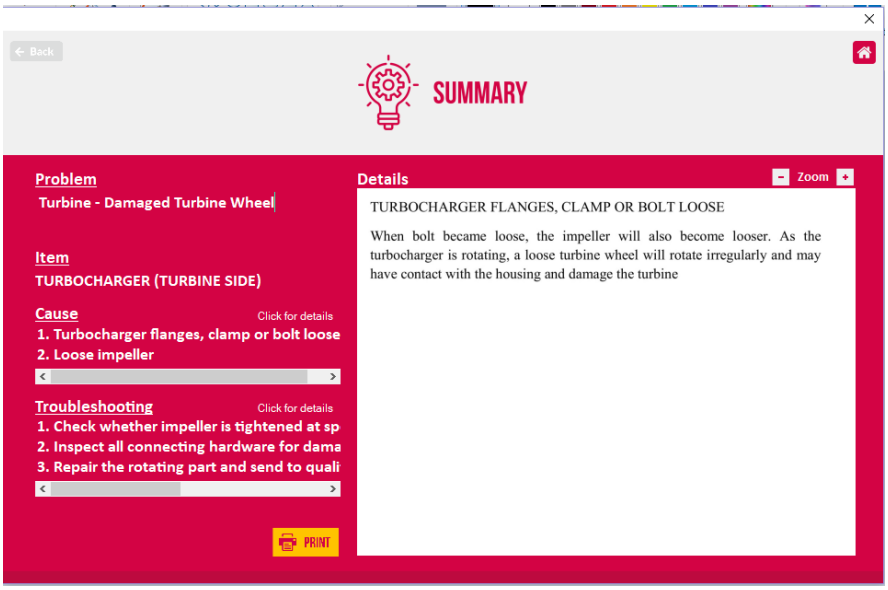

Figure 4. 21 Output for sample 5 = UNSOLVED

Remedy is taken and found out that the software could not detect problem if it caused by misleading referring to the disclaimer items.

4. Software was tested with MV. "ZZZ" case and SOLVED.

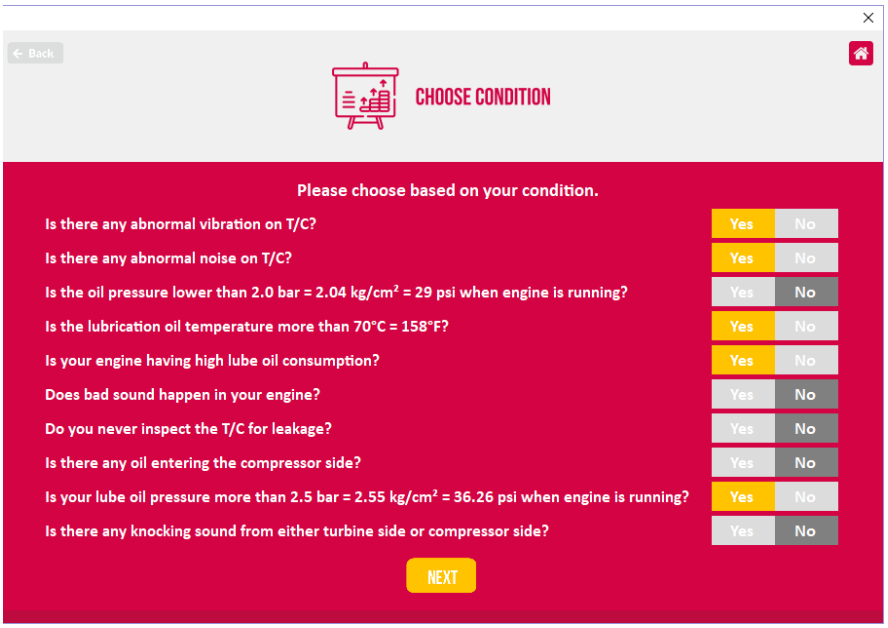

Figure 4. 22 Input from MV. "ZZZ"

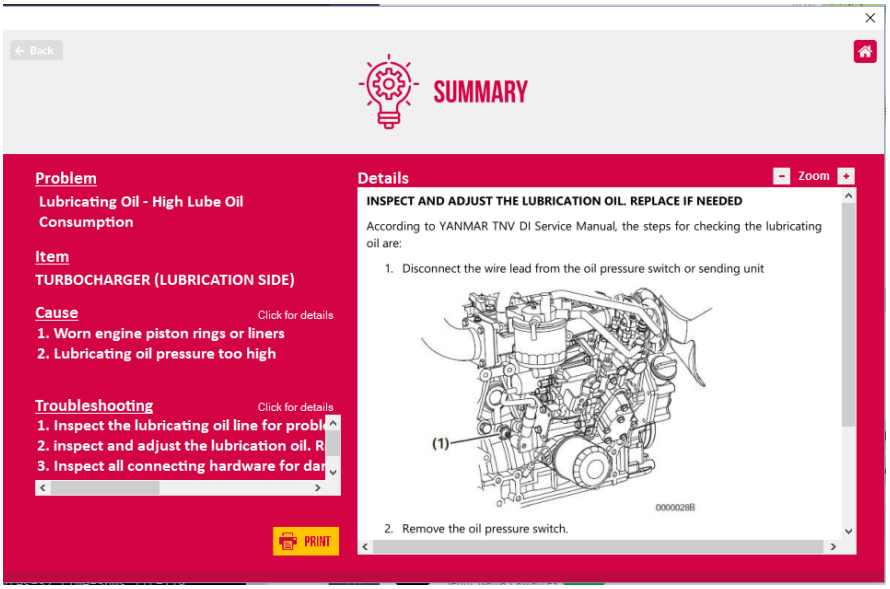

Figure 4. 23 Output for MV. "ZZZ" = SOLVED

CHAPTER V
CONCLUSION AND SUGGESTION

This chapter will provide information about the conclusion and suggestion regarding to the thesis.

5.1 Conclusion

The conclusions of this thesis are;

1. Turbocharger is mainly failed due to the effect coming from the main engine. For example: fault in injection system, damaged piston, intercooler failure and others.
2. Other than the causes coming from the main engine, turbocharger will also be damaged by any cause locating inside the turbocharger. For example: turbocharger flange or bolt loose, unbalanced the rotating part, worn bearing and some other in the form of flaw item that coming from the manufacturer defectiveness.
3. For causes coming from the main engine, the causes will affect the turbocharger through the turbine side of turbocharger. The damaged main engine will give either low or high energy to the turbine side affecting its rotational movement. If low energy transferred to the turbocharger, the result is low in compressed air intake. Nevertheless, a greater energy transferred to the turbocharger will cause the compressor side to overspeed. As the main engine has a limit in volume to absorb the air, the excess pressurized air will force back outward the compressor side and surging may occurred. This can lead to many causes for the turbocharger.
4. Turbocharger troubleshooting software could be run well and operated easily to suit all data input on the database that has been stored.
5. Turbocharger troubleshooting software could provide information as a source of information regarding the troubleshooting on turbocharger.

5.2 Suggestion

The suggestions for this thesis are;

1. Before running the turbocharger troubleshooting software, the user needs to install the required software in order to operate the turbocharger troubleshooting software in their computer.
2. Any user login information must be kept to secure the data so that the username logged on to access the data is recorded.

3. To keep the accuracy of the troubleshooting software, it is recommended to update regularly the database with any latest turbocharger problem. In addition, the data could be updated only by the person in charge to minimize the errors.

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Annex A
Source Codes

Form

1. LoginForm

```
Imports System.Runtime.InteropServices

Public Class LoginForm

    Private Sub LoginForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        'TODO: This line of code loads data into the 'UserDatabaseDataSet.User'
table. You can move, or remove it, as needed.
        Me.UserTableAdapter.Fill(Me.UserDatabaseDataSet.User)
    End Sub

    Private Sub LoginButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles LoginButton.Click
        Dim username As String = UsernameTextBox.Text
        Dim password As String = PasswordTextBox.Text

        If Me.UserTableAdapter.LoginQuery(username, password) Then
            Dim role As String
            If Me.UserTableAdapter.RoleQuery(username, password) Then
                role = "admin"
            Else
                role = "notAdmin"
            End If
            DataForm.user = username
            DataForm.role = role
            SearchForm.Show()
            Me.Close()
        Else
            PasswordTextBox.ResetText()
            MessageBox.Show("The username or password you entered is
incorrect", "Login Error", MessageBoxButtons.OK, MessageBoxIcon.Stop)
        End If
    End Sub
End Class
```

2. ChangeUsernameForm

```
Public Class ChangeUsernameForm

    Private Sub BackButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BackButton.Click
        SearchForm.Show()
        Me.Close()
```

```
    End Sub

    Private Sub goToLogin()
        LoginForm.Show()
        SearchForm.Close()
        Me.Close()
    End Sub

    Private Sub ChangeButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ChangeButton.Click
        Dim username As String = DataForm.user
        Dim currentUsername As String = Me.CurrentUsernameTextBox.Text
        Dim newUsername As String = Me.NewUsernameTextBox.Text
        Dim password As String = Me.PasswordTextBox.Text

        If currentUsername = username Then
            If Me.UserTableAdapter.LoginQuery(currentUsername, password) Then
                Dim          result          As          Integer          =
Me.UserTableAdapter.Update(newUsername, password, currentUsername, password)
                If result = 1 Then
                    MessageBox.Show("Change   username   successful.",   "",
MessageBoxButtons.OK, MessageBoxIcon.Information)
                Else
                    MessageBox.Show("Change   username   unsuccessful.",   "",
MessageBoxButtons.OK, MessageBoxIcon.Stop)
                End If
                goToLogin()
            Else
                MessageBox.Show("Please   enter   your   current   password
correctly.",     "Invalid     Current     Password",     MessageBoxButtons.OK,
MessageBoxIcon.Stop)
            End If
        Else
            MessageBox.Show("Please enter your current username correctly.",
"Invalid Current Username", MessageBoxButtons.OK, MessageBoxIcon.Stop)
        End If
    End Sub
End Class
```

3. ChangePasswordForm

```
Public Class ChangePasswordForm

    Private Sub PasswordForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        'TODO: This line of code loads data into the 'UserDatabaseDataSet.User'
table. You can move, or remove it, as needed.
        Me.UserTableAdapter.Fill(Me.UserDatabaseDataSet.User)
    End Sub

    Private Sub BackButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BackButton.Click
```

```
        SearchForm.Show()
        Me.Close()
    End Sub

    Private Sub goToLogin()
        LoginForm.Show()
        SearchForm.Close()
        Me.Close()
    End Sub

    Private Sub ChangeButton_Click_1(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ChangeButton.Click
        Dim username As String = DataForm.user
        Dim currentPassword As String = Me.CurrentPasswordTextBox.Text
        Dim newPassword As String = Me.NewPasswordTextBox.Text
        Dim reNewPassword As String = Me.ReNewPasswordTextBox.Text

        If Me.UserTableAdapter.LoginQuery(username, currentPassword) Then
            If newPassword = reNewPassword Then
                Dim result As Integer = Me.UserTableAdapter.Update(username,
newPassword, username, currentPassword)
                If result = 1 Then
                    MessageBox.Show("Change password successful.", "",
MessageBoxButtons.OK, MessageBoxIcon.Information)
                Else
                    MessageBox.Show("Change password unsuccessful.", "",
MessageBoxButtons.OK, MessageBoxIcon.Stop)
                End If
                goToLogin()
            Else
                MessageBox.Show("Please enter new password and confirmation
password identically.", "New Password Error", MessageBoxButtons.OK,
MessageBoxIcon.Stop)
            End If
        Else
            MessageBox.Show("Please enter your current password correctly.",
"Invalid Current Password", MessageBoxButtons.OK, MessageBoxIcon.Stop)
        End If
    End Sub
End Class
```

4. AddUserForm

```
Imports System.IO

Public Class AddUserForm

    Private Sub UserForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        'TODO: This line of code loads data into the 'UserDatabaseDataSet.User'
table. You can move, or remove it, as needed.
        Me.UserTableAdapter.Fill(Me.UserDatabaseDataSet.User)
```

```
    End Sub

    Private Sub BackButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BackButton.Click
        SearchForm.Show()
        Me.Close()
    End Sub

    Private Sub goToLogin()
        LoginForm.Show()
        SearchForm.Close()
        Me.Close()
    End Sub

    Private Sub AddButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles AddButton.Click
        Dim username As String = Me.UsernameTextBox.Text
        Dim password As String = Me.PasswordTextBox.Text
        Dim rePassword As String = Me.RePasswordTextBox.Text

        If password = rePassword Then
            Dim result As Integer = Me.UserTableAdapter.Insert(username,
password)
            If result = 1 Then
                MessageBox.Show("Add new user successful.", "",
MessageBoxButtons.OK, MessageBoxIcon.Information)
            Else
                MessageBox.Show("Add new user unsuccessful.", "",
MessageBoxButtons.OK, MessageBoxIcon.Stop)
            End If
            goToLogin()
        Else
            MessageBox.Show("Please enter password and confirmation password
identically.", "Password Error", MessageBoxButtons.OK, MessageBoxIcon.Stop)
        End If
    End Sub
End Class
```

5. RemoveUserForm

```
Public Class RemoveUserForm

    Private Sub goToLogin()
        LoginForm.Show()
        SearchForm.Close()
        Me.Close()
    End Sub

    Private Sub RemoveButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles RemoveButton.Click
        Dim username As String = Me.UsernameTextBox.Text
        Dim password As String = Me.PasswordTextBox.Text
```

```
        Dim rePassword As String = Me.RePasswordTextBox.Text

        If password = rePassword Then
            Dim result As Integer = Me.UserTableAdapter.Delete(username,
password)
            If result = 1 Then
                MessageBox.Show("Remove user successful.", "",
MessageBoxButtons.OK, MessageBoxIcon.Information)
            Else
                MessageBox.Show("Remove user unsuccessful.", "",
MessageBoxButtons.OK, MessageBoxIcon.Stop)
            End If
            goToLogin()
        Else
            MessageBox.Show("Please enter password and confirmation password
identically.", "Password Error", MessageBoxButtons.OK, MessageBoxIcon.Stop)
        End If
    End Sub

    Private Sub BackButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BackButton.Click
        SearchForm.Show()
        Me.Close()
    End Sub
End Class
```

6. SearchForm

```
Imports System.IO

Public Class SearchForm
    Dim role As String = DataForm.role
    Dim Access As SQLControl
    Private contextMS As ContextMenuStrip

    Private Sub SearchForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        SearchTextBox.Select()
        If role = "admin" Then
            contextMS = ContextMenuStrip1
        Else
            contextMS = ContextMenuStrip2
        End If
    End Sub

    Private Sub SearchButton_Click_1(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles SearchButton.Click
        Dim inputtext As String = Me.SearchTextBox.Text
        If String.IsNullOrEmpty(inputtext) Then
            MessageBox.Show("Please enter the keyword.", "No Keyword",
MessageBoxButtons.OK, MessageBoxIcon.Warning)
            Exit Sub
```

```
        End If
        Search(inputtext)
    End Sub

    Private Sub Search(ByVal input As String)
        Dim SQL As String
        Access = New SQLControl

        SQL = buildQuery(input)
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show(Access.Exception)
            Exit Sub
        End If
        If Access.RecordCount < 1 Then
            MessageBox.Show("Please enter other keyword.", "Keyword Not
Found", MessageBoxButtons.OK, MessageBoxIcon.Warning)
            Exit Sub
        End If
        goToProblem()
    End Sub

    Private Function buildQuery(ByVal input As String) As String
        Dim SQL As String
        Dim keywords() As String
        Dim keywordsUB As Integer
        Dim counter As Integer

        SQL = "SELECT DISTINCT Problems.PROBLEM_TITLE " _
                & "FROM Problems, Tags " _
                & "WHERE Problems.PROBLEM_ID = Tags.PROBLEM_ID AND ("
        If Not String.IsNullOrEmpty(input) Then
            keywords = Split(input, " ")
            keywordsUB = UBound(keywords)
            For counter = 0 To keywordsUB
                If Not counter = 0 Then
                    SQL = SQL & "OR "
                End If
                Access.AddParam("@keyword", "%" & keywords(counter) & "%")
                SQL = SQL & "Problems.PROBLEM_TITLE LIKE @keyword " _
                        & "OR Tags.TAG LIKE @keyword"
                If Not counter = keywordsUB Then
                    SQL = SQL & " "
                End If
            Next counter
        Else
            Access.AddParam("@text", "%" & input & "%")
            SQL = SQL & "Problems.PROBLEM_TITLE LIKE @text " _
                    & "OR Tags.TAG LIKE @text"
        End If
        SQL = SQL & ") ORDER BY Problems.PROBLEM_TITLE "
        Return SQL
```

```
    End Function

    Private Sub goToProblem()
        DataForm.ProblemList = Access.SQLDS.Tables(0)
        ProblemForm.Show()
        SearchTextBox.ResetText()
        Me.Close()
    End Sub

    Private Sub AllProblemsButton_Click(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles AllProblemsButton.Click
        Search("")
    End Sub

    Private Sub SettingsButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles SettingsButton.Click
        contextMS.Show(SettingsButton,          -(contextMS.Width          -
SettingsButton.Width), SettingsButton.Height)
    End Sub

    Private   Sub   ChangeUsernameToolStripMenuItem_Click(ByVal   sender   As
System.Object,      ByVal      e      As      System.EventArgs)      Handles
ChangeUsernameToolStripMenuItem.Click, ChangeUsernameToolStripMenuItem1.Click
        ChangeUsernameForm.Show()
        Me.Close()
    End Sub

    Private   Sub   ChangePasswordToolStripMenuItem_Click(ByVal   sender   As
System.Object,      ByVal      e      As      System.EventArgs)      Handles
ChangePasswordToolStripMenuItem.Click, ChangePasswordToolStripMenuItem1.Click
        ChangePasswordForm.Show()
        Me.Close()
    End Sub

    Private    Sub    AddNewUserToolStripMenuItem_Click(ByVal    sender    As
System.Object,      ByVal      e      As      System.EventArgs)      Handles
AddNewUserToolStripMenuItem.Click
        AddUserForm.Show()
        Me.Close()
    End Sub

    Private    Sub    RemoveUserToolStripMenuItem_Click(ByVal    sender    As
System.Object,      ByVal      e      As      System.EventArgs)      Handles
RemoveUserToolStripMenuItem.Click
        RemoveUserForm.Show()
        Me.Close()
    End Sub

    Private Sub LogOutToolStripMenuItem_Click(ByVal sender As System.Object,
ByVal   e   As   System.EventArgs)   Handles   LogOutToolStripMenuItem.Click,
LogOutToolStripMenuItem1.Click
        LoginForm.Show()
```

```
        Me.Close()
    End Sub
End Class
```

7. ProblemForm

```
Public Class ProblemForm
    Dim Access As SQLControl
    Dim problem As String

    Private Sub ProblemForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        'TODO:    This    line    of    code    loads    data    into    the
'KnowledgeDatabaseDataSet.Problems' table. You can move, or remove it, as
needed.
        Me.ProblemsTableAdapter.Fill(Me.KnowledgeDatabaseDataSet.Problems)
        'TODO: This line of code loads data into the 'DiagnoseDataSet.diagnose'
table. You can move, or remove it, as needed.
        Me.DiagnoseTableAdapter.Fill(Me.DiagnoseDataSet.diagnose)
        ' Load Problems List
        Me.ResultListBox.DataSource = DataForm.ProblemList
    End Sub

    Private Sub ResultListBox_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ResultListBox.Click
        Diagnose()
    End Sub

    Private Sub ResultListBox_KeyDown(ByVal sender As System.Object, ByVal e
As System.Windows.Forms.KeyEventArgs) Handles ResultListBox.KeyDown
        If e.KeyCode = Keys.Enter Then
            Diagnose()
        End If
    End Sub

    Private Sub MainButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MainButton.Click
        Diagnose()
    End Sub

    Private Sub Diagnose()
        Dim SQL As String

        problem = ResultListBox.GetItemText(ResultListBox.SelectedItem)
        DataForm.problem = problem
        Access = New SQLControl
        SQL = buildQuery()
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show(Access.Exception)
            Exit Sub
        End If
```

```
        If Access.RecordCount < 1 Then Exit Sub
        goToDiagnose()
    End Sub

    Private Function buildQuery()
        Dim SQL As String

        Access.AddParam("@problem", problem)
        SQL = "SELECT Causes.CAUSE_ID, Questions.QUESTION " _
              & "FROM Problems, Causing, Causes, Asking, Questions " _
              & "WHERE Problems.PROBLEM_TITLE = @problem " _
              &   "AND   Problems.PROBLEM_ID   =   Causing.PROBLEM_ID   AND
Causing.CAUSE_ID = Causes.CAUSE_ID " _
              & "AND Causes.CAUSE_ID = Asking.CAUSE_ID AND Asking.QUESTION_ID
= Questions.QUESTION_ID "
        Return SQL
    End Function

    Private Sub goToDiagnose()
        Dim rows() As DataRow = Access.SQLDS.Tables(0).Select()
        DataForm.rows = rows
        DataForm.problemForm = True
        Dim result As Boolean = GenerateDiagnose()
        If result = False Then
            Return
        End If
        Me.Close()
    End Sub

    Private Sub BackButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BackButton.Click
        BackToSearch()
        Me.Close()
    End Sub
End Class
```

8. SpeedTypeForm

```
Public Class SpeedTypeForm
    Public question As String
    Private Const CP_NOCLOSE_BUTTON As Integer = &H200

    Protected Overloads Overrides ReadOnly Property CreateParams() As
CreateParams
        Get
            Dim myCp As CreateParams = MyBase.CreateParams
            myCp.ClassStyle = myCp.ClassStyle Or CP_NOCLOSE_BUTTON
            Return myCp
        End Get
    End Property
```

```
    Private Sub SpeedTypeForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        QuestionLabel.Text = question
        DataForm.slow = False
        DataForm.med = False
        DataForm.high = False
    End Sub

    Private Sub SlowButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles SlowButton.Click
        DataForm.slow = True
        Me.DialogResult = Windows.Forms.DialogResult.OK
        Me.Close()
    End Sub

    Private Sub MediumButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MediumButton.Click
        DataForm.med = True
        Me.DialogResult = Windows.Forms.DialogResult.OK
        Me.Close()
    End Sub

    Private Sub HighButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles HighButton.Click
        DataForm.high = True
        Me.DialogResult = Windows.Forms.DialogResult.OK
        Me.Close()
    End Sub
End Class
```

9. DiagnoseForm

```
Public Class DiagnoseForm
    Dim Access As SQLControl
    Dim problem As String = DataForm.problem
    Dim causeslist As ArrayList = New ArrayList()
    Dim dominanCause As ArrayList = New ArrayList()
    Dim troubleshootlist As ArrayList = New ArrayList()
    Dim dominanCauseNum As ArrayList = New ArrayList()
    Dim troubleshootlistNum As ArrayList = New ArrayList()
    Dim yesNumber As Integer
    Dim contact As Boolean
    Public notyet As ArrayList = New ArrayList()
    Public question As ArrayList = New ArrayList()
    Public counter As Integer
    Dim cause10highest As Boolean
    Dim cause19highest As Boolean

    Private Sub DiagnoseForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        Me.DiagnoseTableAdapter.Fill(Me.DiagnoseDataSet.diagnose)
        yesNumber = 0
```

```
    End Sub

    Public Sub YesBtn_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs)
        If TypeOf sender Is Button Then
            Dim cb As Button = DirectCast(sender, Button)
            If TypeOf cb.Tag Is Integer Then
                Dim index As Integer = DirectCast(cb.Tag, Integer)
                Dim nobtn As Button = CType(Me.Controls("NoBtn" & index),
Button)
                Dim textbox As TextBox = CType(Me.Controls("TextBox" & index),
TextBox)
                If Me.DiagnoseTableAdapter.ValueQuery(index) = False Then
                    yesNumber = yesNumber + 1
                    Me.DiagnoseTableAdapter.Update(True, index)
                    cb.BackColor = Color.Green
                    cb.ForeColor = Color.White
                    nobtn.BackColor = Color.Gainsboro
                    For i As Integer = 0 To notyet.Count - 1
                        If TypeOf notyet.Item(i) Is Integer Then
                            Dim notyetindex As Integer =
DirectCast(notyet.Item(i), Integer)
                            If question.Item(i) = textbox.Text Then
                                Me.DiagnoseTableAdapter.Update(True,
notyetindex)
                            End If
                        End If
                    Next
                    If textbox.Text = "Is the scavenge air pressure lower than
0.8 bar after the intercooler?" Then
                        cause10highest = True
                    ElseIf textbox.Text = "Is your engine room pressure lower
than 1000mmHg (1.33 bar)?" Then
                        cause19highest = True
                    End If
                End If
            End If
        End If
    End Sub

    Public Sub NoBtn_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs)
        If TypeOf sender Is Button Then
            Dim cb As Button = DirectCast(sender, Button)
            If TypeOf cb.Tag Is Integer Then
                Dim index As Integer = DirectCast(cb.Tag, Integer)
                Dim textbox As TextBox = CType(Me.Controls("TextBox" & index),
TextBox)
                If Me.DiagnoseTableAdapter.ValueQuery(index) = True Then
                    Me.DiagnoseTableAdapter.Update(False, index)
                    cb.BackColor = Color.Red
                    cb.ForeColor = Color.White
```

```
                    Dim btn As Button = CType(Me.Controls("YesBtn" & index),
Button)
                    btn.BackColor = Color.Gainsboro
                    If textbox.Text = "Is the scavenge air pressure lower than
0.8 bar after the intercooler?" Then
                        cause10highest = False
                    ElseIf textbox.Text = "Is your engine room pressure lower
than 1000mmHg (1.33 bar)?" Then
                        cause19highest = False
                    End If
                End If
            End If
        End If
    End Sub

    Private Sub NextButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles NextButton.Click
        determineCause()
        analyzeCause()
        Dim result As Boolean = troubleshoot()
        If result = False Then Exit Sub
        Me.DiagnoseTableAdapter.Delete()
        If yesNumber = DataForm.questionsNumber Then
            MessageBox.Show("YOU MIGHT ENTER WRONG ANSWER(s), PLEASE RE-CHECK
YOUR    ANSWERS."    &    Environment.NewLine    &    Environment.NewLine    &
Environment.NewLine  &  "IF  YOU  ARE  SURE  ABOUT  YOUR  ANSWER(s),  YOUR
ENGINE/TURBOCHARGER COULD BE IN BAD CONDITION OR HAVING A MAJOR DAMAGE(s).
PLEASE  SEND  IT  TO  REPAIR  FACILITY  OR  CONTACT  AN  AUTHORIZED  WORKSHOP!",
"WARNING", MessageBoxButtons.OK, MessageBoxIcon.Warning)
        End If
        Summarize()
    End Sub

    Private Sub determineCause()
        Dim SQL As String

        Access = New SQLControl
        SQL = buildQuery()
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show("No  causes  found.  Please  check  your  answers.",
"Causes Not Found", MessageBoxButtons.OK, MessageBoxIcon.Warning)
            Exit Sub
        End If
        If Access.RecordCount < 1 Then Exit Sub
    End Sub

    Private Function buildQuery()
        Dim causesDT As DataTable = Me.DiagnoseTableAdapter.GetCauses(True)
        Dim          notCausesDT          As          DataTable          =
Me.DiagnoseTableAdapter.GetCauses(False)
        Dim causes() As DataRow = causesDT.Select()
```

```
        Dim notCauses() As DataRow = notCausesDT.Select()
        Dim cause As DataRow
        Dim notCause As DataRow
        Dim count As Integer
        Dim SQL As String

        Access.AddParam("@problem", problem)
        SQL    =    "SELECT    DISTINCT    Causes.CAUSE_TITLE,    Causing.SCORE,
Causing.DESCRIPTION " _
                & "FROM Causes, Causing, Problems " _
                & "WHERE Problems.PROBLEM_TITLE = @problem " _
                & "AND Causing.PROBLEM_ID = Problems.PROBLEM_ID " _
                & "AND ("

        count = 0
        For Each cause In causes
            Dim cancel As Boolean = False
            Dim cause_id As Integer = cause.Item(1)

            For Each notCause In notCauses
                Dim notCause_id As Integer = notCause.Item(1)
                If cause_id = notCause_id And cause_id <> 10 And cause_id <>
19 Then
                    cancel = True
                End If
            Next
            If Not cancel Then
                If Not count = 0 Then
                    SQL = SQL & "OR "
                End If
                Access.AddParam("@id" & count, cause_id)
                SQL = SQL & "Causes.CAUSE_ID = @id" & count & " "
                count = count + 1
            End If
        Next
        SQL  =  SQL  &  ")  AND  Causing.CAUSE_ID  =  Causes.CAUSE_ID  ORDER  BY
Causes.CAUSE_TITLE "
        Return SQL
    End Function

    Private Sub analyzeCause()
        Dim causesDT As DataTable
        Try
            causesDT = Access.SQLDS.Tables(0)
        Catch ex As Exception
            Exit Sub
        End Try
        Dim causes() As DataRow = causesDT.Select()
        Dim cause As DataRow
        Dim min As Integer = 1000
        Dim min2 As Integer = 1000
        Dim score10 As Integer
```

```
        Dim score19 As Integer

        For Each cause In causes
            Dim score As Integer = cause.Item(1)

            If cause.Item(0) = "Intercooler failure" Then
                score10 = score
                If cause10highest Then
                    score = 2
                    score10 = 2
                Else
                    score = 14
                    score10 = 14
                End If
            ElseIf cause.Item(0) = "Insufficient ventilation" Then
                score19 = score
                If cause19highest Then
                    score = 1
                    score19 = 1
                Else
                    score = 14
                    score19 = 14
                End If
            End If
            causeslist.Add(cause.Item(0))
            If score < min Then
                min2 = min
                min = score
            ElseIf score < min2 Then
                min2 = score
            End If
        Next
        ReportForm.causes = ""
        For Each cause In causes
            Dim score As Integer = cause.Item(1)

            If cause.Item(0) = "Intercooler failure" Then
                score = score10
            ElseIf cause.Item(0) = "Insufficient ventilation" Then
                score = score19
            End If

            If score = min Then
                dominanCause.Add(cause.Item(0))
                If dominanCauseNum.Count > 0 Then
                    ReportForm.causes &= Environment.NewLine
                End If
                ReportForm.causes &= dominanCauseNum.Count + 1 & ". " &
cause.Item(0) & Environment.NewLine & "    " & cause.Item(2)
                dominanCauseNum.Add(dominanCauseNum.Count + 1 & ". " &
cause.Item(0))
            End If
```

```
        Next
        For Each cause In causes
            If dominanCause.Count >= 2 Then
                Return
            End If
            If cause.Item(1) = min2 Then
                dominanCause.Add(cause.Item(0))
                If dominanCauseNum.Count > 0 Then
                    ReportForm.causes &= Environment.NewLine
                End If
                ReportForm.causes  &=  dominanCauseNum.Count  +  1  &  ".  "  &
cause.Item(0) & Environment.NewLine & "    " & cause.Item(2)
                dominanCauseNum.Add(dominanCauseNum.Count  +  1  &  ".  "  &
cause.Item(0))
            End If
        Next
    End Sub

    Private Function troubleshoot()
        Dim SQL As String

        Access = New SQLControl
        SQL = buildTroubleshootQuery()
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show("No  troubleshoot",  "Troubleshoot  Not  Found",
MessageBoxButtons.OK, MessageBoxIcon.Warning)
            Return False
        End If
        If Access.RecordCount < 1 Then Return False

        Dim tsDT As DataTable
        Try
            tsDT = Access.SQLDS.Tables(0)
        Catch ex As Exception
            Return False
        End Try
        Dim tss() As DataRow = tsDT.Select()
        Dim ts As DataRow
        contact = False
        ReportForm.troubleshoot = ""
        For Each ts In tss
            troubleshootlist.Add(ts.Item(3))
            If troubleshootlistNum.Count > 0 Then
                ReportForm.troubleshoot &= Environment.NewLine
            End If
            ReportForm.troubleshoot &= troubleshootlistNum.Count + 1 & ". " &
ts.Item(3)
            troubleshootlistNum.Add(troubleshootlistNum.Count  +  1  &  ".  "  &
ts.Item(3))
            If ts.Item(4) = True Then
                contact = True
```

```
            End If
        Next
        Return True
    End Function

    Private Function buildTroubleshootQuery()
        Dim SQL As String

        SQL = "SELECT Problems.PROBLEM_TITLE, Problems.LOCATION, " _
              &          "Causes.CAUSE_TITLE,          Causes.TROUBLESHOOTING,
Causes.CONTACT_MANUFACTURER, Causes.CAUSE_ID " _
              & "FROM Causes, Causing, Problems " _
              & "WHERE ("
        For i As Integer = 0 To causeslist.Count - 1
            If Not i = 0 Then
                SQL = SQL & "OR "
            End If
            Access.AddParam("@cause" & i, causeslist.Item(i))
            SQL = SQL & "Causes.CAUSE_TITLE = @cause" & i & " "
        Next
        Access.AddParam("@problem", problem)
        SQL = SQL & ") AND Causes.CAUSE_ID = Causing.CAUSE_ID " _
              & "AND Causing.PROBLEM_ID = Problems.PROBLEM_ID " _
              & "AND Problems.PROBLEM_TITLE = @problem "
        Return SQL
    End Function

    Private Sub Summarize()
        Dim SQL As String

        Access = New SQLControl
        SQL = buildSummaryQuery()
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then Exit Sub
        If Access.RecordCount < 1 Then Exit Sub
        goToSummary()
    End Sub

    Private Function buildSummaryQuery()
        Dim SQL As String

        If dominanCause.Count < 1 Then
            Return ""
        End If
        Access.AddParam("@cause", dominanCause.Item(0))
        Access.AddParam("@problem", problem)
        SQL = "SELECT Problems.PROBLEM_TITLE, Problems.LOCATION, " _
              &          "Causes.CAUSE_TITLE,          Causes.TROUBLESHOOTING,
Causes.CONTACT_MANUFACTURER, Causes.CAUSE_ID " _
              & "FROM Causes, Causing, Problems " _
              & "WHERE Causes.CAUSE_TITLE = @cause " _
              & "AND Causes.CAUSE_ID = Causing.CAUSE_ID " _
```

```
                & "AND Causing.PROBLEM_ID = Problems.PROBLEM_ID " _
                & "AND Problems.PROBLEM_TITLE = @problem "
        Return SQL
    End Function

    Private Sub goToSummary()
        Dim rows() As DataRow = Access.SQLDS.Tables(0).Select()
        Dim row As DataRow

        For Each row In rows
            SummaryForm.ProblemTextBox.Text = row.Item(0)
            SummaryForm.LocationTextBox.Text = row.Item(1)
            SummaryForm.causeid = row.Item(5)
        Next
        SummaryForm.contact = contact
        SummaryForm.CausesList.Items.AddRange(dominanCauseNum.ToArray)

SummaryForm.TroubleshootList.Items.AddRange(troubleshootlistNum.ToArray)
        SummaryForm.listdominanCause = dominanCause
        SummaryForm.listTroubleshoot = troubleshootlist

ReportForm.TroubleshootList.Items.AddRange(troubleshootlistNum.ToArray)
        SummaryForm.Show()
        Me.Close()
    End Sub

    Private Sub BackButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BackButton.Click
        ProblemForm.Show()
        Me.Close()
    End Sub

    Private Sub HomeButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles HomeButton.Click
        BackToSearch()
        Me.Close()
    End Sub
End Class
```

10. SummaryForm

```
Imports System.IO
Imports System.Drawing

Public Class SummaryForm
    Dim Access As SQLControl
    Public listDominanCause As ArrayList = New ArrayList()
    Public listTroubleshoot As ArrayList = New ArrayList()
    Public contact As Boolean
    Public causeid As Integer
    Dim image As Image
    Dim ratio As Double = 1.0
```

```
    Private Sub SummaryForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        Access = New SQLControl
        Me.CausesList.Select()
        Me.CausesList.SelectedIndex() = 0
        If contact = True Then
            ContactLabel.Visible = True
        End If
        showCauseDetails()
    End Sub

    Private Sub showCauseDetails()
        Dim SQL As String
        Dim problem As String = DataForm.problem

        Access.AddParam("@problem", problem)
        Access.AddParam("@causeid", causeid)
        SQL     =     "SELECT     Causing.PROBLEM_ID,     Causing.DESCRIPTION,
Causes.CAUSE_TITLE " _
             & "FROM Causes, Causing, Problems " _
             & "WHERE Problems.PROBLEM_TITLE = @problem AND Causes.CAUSE_ID
= @causeid " _
             &    "AND    Causing.PROBLEM_ID    =    Problems.PROBLEM_ID    AND
Causing.CAUSE_ID = Causes.CAUSE_ID "
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show(Access.Exception)
            Exit Sub
        End If
        If Access.RecordCount < 1 Then Exit Sub
        Dim descDT As DataTable = Access.SQLDS.Tables(0)
        Dim descs() As DataRow = descDT.Select()
        Dim desc As DataRow
        For Each desc In descs
            Dim source As String = Path.GetFullPath(Path.Combine("Resources",
"p" & desc.Item(0) & "-c" & causeid & ".jpg"))
            enableZoom()
            PictureBox1.Load(source)
            image = PictureBox1.Image
            ratio = 0.4
            PictureBox1.Image    =    zoom(New    Size(image.Width    *    ratio,
image.Height * ratio))
        Next
    End Sub

    Private Sub TroubleshootList_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles TroubleshootList.Click
        Dim SQL As String
        Dim index As Integer = TroubleshootList.SelectedIndex

        If index < 0 Then Exit Sub
```

```
        Dim troubleshoot As String = listTroubleshoot.Item(index)
        SQL = buildQuery(troubleshoot)
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show(Access.Exception)
            Exit Sub
        End If
        If Access.RecordCount < 1 Then Exit Sub
        Dim idDT As DataTable = Access.SQLDS.Tables(0)
        Dim ids() As DataRow = idDT.Select()
        Dim id As DataRow
        For Each id In ids
            Dim source As String = Path.GetFullPath(Path.Combine("Resources",
"ts" & id.Item(0) & ".jpg"))
            enableZoom()
            PictureBox1.Load(source)
            image = PictureBox1.Image
            ratio = 0.4
            PictureBox1.Image    =    zoom(New    Size(image.Width    *    ratio,
image.Height * ratio))
        Next
    End Sub

    Private Function buildQuery(ByVal troubleshoot As String)
        Dim SQL As String

        Access.AddParam("@troubleshoot", troubleshoot)
        SQL = "SELECT Causes.CAUSE_ID " _
              & "FROM Causes " _
              & "WHERE Causes.TROUBLESHOOTING = @troubleshoot "
        Return SQL
    End Function

    Private Sub CausesList_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles CausesList.Click
        Dim SQL As String
        Dim index As Integer = CausesList.SelectedIndex

        If index < 0 Then Exit Sub

        Dim cause As String = listDominanCause.Item(index)

        SQL = buildCauseQuery(cause)
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show(Access.Exception)
            Exit Sub
        End If
        If Access.RecordCount < 1 Then Exit Sub
        Dim descDT As DataTable = Access.SQLDS.Tables(0)
        Dim descs() As DataRow = descDT.Select()
```

```
        Dim desc As DataRow
        For Each desc In descs
            Dim source As String = Path.GetFullPath(Path.Combine("Resources",
"p" & desc.Item(0) & "-c" & desc.Item(1) & ".jpg"))
            enableZoom()
            PictureBox1.Load(source)
            image = PictureBox1.Image
            ratio = 0.4
            PictureBox1.Image    =    zoom(New    Size(image.Width    *    ratio,
image.Height * ratio))
        Next
    End Sub

    Private Function buildCauseQuery(ByVal cause As String)
        Dim SQL As String
        Dim problem As String = DataForm.problem

        Access.AddParam("@problem", problem)
        Access.AddParam("@cause", cause)
        SQL = "SELECT Causing.PROBLEM_ID, Causing.CAUSE_ID " _
              & "FROM Causes, Causing, Problems " _
              &     "WHERE     Problems.PROBLEM_TITLE     =     @problem     AND
Causes.CAUSE_TITLE = @cause " _
              &    "AND    Causing.PROBLEM_ID    =    Problems.PROBLEM_ID    AND
Causing.CAUSE_ID = Causes.CAUSE_ID "
        Return SQL
    End Function

    Private Sub PrintButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles PrintButton.Click
        ReportForm.listTroubleshoot = listTroubleshoot
        ReportForm.Show()
    End Sub

    Private Sub disableZoom()
        ZoomInButton.Enabled = False
        ZoomOutButton.Enabled = False
    End Sub

    Private Sub enableZoom()
        ZoomInButton.Enabled = True
        ZoomOutButton.Enabled = True
    End Sub

    Private Sub ZoomInButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ZoomInButton.Click
        If ratio >= 1.0 Then Exit Sub
        ratio += 0.1
        PictureBox1.Image = zoom(New Size(image.Width * ratio, image.Height *
ratio))
    End Sub
```

```
    Private Sub ZoomOutButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ZoomOutButton.Click
        If ratio <= 0.2 Then Exit Sub
        ratio -= 0.1
        PictureBox1.Image = zoom(New Size(image.Width * ratio, image.Height *
ratio))
    End Sub

    Private Function zoom(ByVal size As Size)
        Return New Bitmap(image, size)
    End Function

    Private Sub CausesList_Leave(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles CausesList.Leave
        CausesList.ClearSelected()
    End Sub

    Private Sub TroubleshootList_Leave(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles TroubleshootList.Leave
        TroubleshootList.ClearSelected()
    End Sub

    Private Sub BackButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BackButton.Click
        DataForm.problemForm = False
        GenerateDiagnose()
        Me.Close()
    End Sub

    Private Sub HomeButton_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles HomeButton.Click
        BackToSearch()
        Me.Close()
    End Sub
End Class
```

11. ReportForm

```
Imports System.IO
Imports Microsoft.Reporting.WinForms

Public Class ReportForm
    Dim Access As SQLControl
    Public causes As String
    Public troubleshoot As String
    Public listTroubleshoot As ArrayList = New ArrayList()

    Private Sub ReportForm_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        Access = New SQLControl
        Dim contactString As String
        If SummaryForm.contact = True Then
```

```
            contactString = "*It is necessary to contact turbocharger
manufacturer"
        Else
            contactString = " "
        End If
        Dim username As New ReportParameter("username", DataForm.user)
        Dim problem As New ReportParameter("problem",
SummaryForm.ProblemTextBox.Text)
        Dim location As New ReportParameter("location",
SummaryForm.LocationTextBox.Text)
        Dim cause As New ReportParameter("cause", causes)
        Dim troubleshooting As New ReportParameter("troubleshooting",
troubleshoot)
        Dim contact As New ReportParameter("contact", contactString)
        ReportViewer.LocalReport.SetParameters(username)
        ReportViewer.LocalReport.SetParameters(problem)
        ReportViewer.LocalReport.SetParameters(location)
        ReportViewer.LocalReport.SetParameters(cause)
        ReportViewer.LocalReport.SetParameters(troubleshooting)
        ReportViewer.LocalReport.SetParameters(contact)
        Me.ReportViewer.RefreshReport()
    End Sub

    Private Function buildQuery(ByVal troubleshoot As String)
        Dim SQL As String

        Access.AddParam("@troubleshoot", troubleshoot)
        SQL = "SELECT Causes.CAUSE_ID " _
              & "FROM Causes " _
              & "WHERE Causes.TROUBLESHOOTING = @troubleshoot "
        Return SQL
    End Function

    Private Sub TroubleshootList_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles TroubleshootList.Click
        Dim SQL As String
        Dim index As Integer = TroubleshootList.SelectedIndex

        If index < 0 Then Exit Sub

        Dim troubleshoot As String = listTroubleshoot.Item(index)
        SQL = buildQuery(troubleshoot)
        Access.ExecQuery(SQL)
        If Not String.IsNullOrEmpty(Access.Exception) Then
            MessageBox.Show(Access.Exception)
            Exit Sub
        End If
        If Access.RecordCount < 1 Then Exit Sub
        Dim idDT As DataTable = Access.SQLDS.Tables(0)
        Dim ids() As DataRow = idDT.Select()
        Dim id As DataRow
        For Each id In ids
```

```
            Dim source As String = Path.GetFullPath(Path.Combine("Resources",
"tc" & id.Item(0) & ".pdf"))
            Process.Start(source)
        Next
    End Sub
End Class
```

Lain-lain

1. SQLControl

```
Imports System.Data.SqlServerCe

Public Class SQLControl
    ' CONNECTION
    Private SQLCon As New SqlCeConnection("Data Source=KnowledgeDatabase.sdf")
    Private SQLCmd As SqlCeCommand

    ' SQL DATA
    Public SQLDA As SqlCeDataAdapter
    Public SQLDS As DataSet

    ' QUERY PARAMETERS
    Public Params As New List(Of SqlCeParameter)

    ' QUERY STATISTICS
    Public RecordCount As Integer
    Public Exception As String

    Public Sub ExecQuery(ByVal Query As String)
        ' RESET QUERY STATISTICS
        RecordCount = 0
        Exception = ""

        Try
            SQLCon.Open()

            ' CREATE SQL COMMAND
            SQLCmd = New SqlCeCommand(Query, SQLCon)

            ' LOAD PARAMETERS INTO SQL COMMAND
            Params.ForEach(Sub(p) SQLCmd.Parameters.Add(p))

            ' CLEAR PARAMETER LIST
            Params.Clear()

            ' EXECUTE COMMAND AND FILL DATASET
            SQLDS = New DataSet
            SQLDA = New SqlCeDataAdapter(SQLCmd)
            RecordCount = SQLDA.Fill(SQLDS)
```

```
            SQLCon.Close()
        Catch ex As SqlCeException
            Exception = ex.Message
        End Try

        If SQLCon.State = ConnectionState.Open Then SQLCon.Close()
    End Sub

    Public Sub AddParam(ByVal Name As String, ByVal Value As Object)
        Dim NewParam As New SqlCeParameter(Name, Value)
        Params.Add(NewParam)
    End Sub
End Class
```

2. DataForm

```
Public Class DataForm
    Public role As String
    Public user As String
    Public problem As String
    Public ProblemList As DataTable
    Public CauseList As DataTable
    Public rows() As DataRow
    Public problemForm As Boolean
    Public slow As Boolean = False
    Public med As Boolean = False
    Public high As Boolean = False
    Public questionsNumber As Integer
End Class
```

3. Module1

```
Module Module1

    Sub BackToSearch()
        SearchForm.Show()
        SearchForm.SearchTextBox.Select()
    End Sub

    Public Function GenerateDiagnose() As Boolean
        Dim rows() As DataRow = DataForm.rows
        Dim row As DataRow
        Dim left As Integer
        Dim top As Integer
        Dim yesBtn As Button
        Dim noBtn As Button
        Dim textBox As TextBox
        Dim counter As Integer
        top = 260
        counter = 0
```

```
        ProblemForm.DiagnoseTableAdapter.Delete()

        Dim count93 As Integer = 0

        ' ==============================

        Dim q1 As Boolean
        Dim q2 As Boolean
        Dim q3 As Boolean
        Dim problem As String = DataForm.problem
        Dim noId As ArrayList = New ArrayList()

        If problem = "Turbine - Damaged Turbine Wheel" Or problem = "Compressor
- Damaged Compressor Wheel" Then
            Dim result As DialogResult = MessageBox.Show("Has your
turbocharger ever been overhauled and dismantled?", "",
MessageBoxButtons.YesNo, MessageBoxIcon.Question)
            If (result = DialogResult.Yes) Then
                q1 = True
            Else
                q1 = False
            End If
            If q1 = False Then
                noId.Add(20)
                noId.Add(35)
                noId.Add(90)
                noId.Add(22)
                If problem = "Compressor - Damaged Compressor Wheel" Then
                    noId.Add(24)
                    noId.Add(76)
                End If
            End If
        ElseIf problem = "Turbocharger - Fail to Start (Jammed)" Then
            Dim result As DialogResult = MessageBox.Show("Has your
turbocharger ever been overhauled and dismantled?", "",
MessageBoxButtons.YesNo, MessageBoxIcon.Question)
            If (result = DialogResult.Yes) Then
                q1 = True
            Else
                q1 = False
            End If
            result = MessageBox.Show("Does your turbocharger slow to rotate
and followed by abnormal noises?", "", MessageBoxButtons.YesNo,
MessageBoxIcon.Question)
            If (result = DialogResult.Yes) Then
                q2 = True
            Else
                q2 = False
            End If
            result = MessageBox.Show("Is there any sudden decrease of pressure
followed by abnormal noises?", "", MessageBoxButtons.YesNo,
MessageBoxIcon.Question)
```

```
            If (result = DialogResult.Yes) Then
                q3 = True
            Else
                q3 = False
            End If
            If q1 = True And q2 = True And q3 = True Then
                MessageBox.Show("Your engine/turbocharger is having major
damages! Please send to repair facility or service stations immidiately.",
"WARNING", MessageBoxButtons.OK, MessageBoxIcon.Warning)
                Return False
            End If
            If q1 = False And q2 = False And q3 = False Then
                MessageBox.Show("Please check your answers.", "WARNING",
MessageBoxButtons.OK, MessageBoxIcon.Warning)
                Return False
            End If
            If q1 = False Then
                noId.Add(20)
                noId.Add(35)
                noId.Add(90)
                noId.Add(22)
                noId.Add(97)
            End If
            If q2 = False Then
                noId.Add(34)
                noId.Add(5)
                noId.Add(24)
                noId.Add(79)
            End If
            If q3 = False Then
                noId.Add(10)
                noId.Add(12)
                noId.Add(1)
                noId.Add(19)
                noId.Add(14)
                noId.Add(47)
                noId.Add(105)
            End If
        End If

        ' ==============================

        DataForm.questionsNumber = 0
        For Each row In rows

            Dim question As String = row.Item(1)
            Dim prevQuestion As String = ""

            Dim id As Integer
            Dim previousId As Integer

            If TypeOf row.Item(0) Is Integer Then
```

```
                id = DirectCast(row.Item(0), Integer)
            End If
            previousId = -1
            If counter <> 0 Then
                If TypeOf rows(counter - 1).Item(0) Is Integer Then
                    previousId   =   DirectCast(rows(counter   -   1).Item(0),
Integer)
                End If
            End If

            Dim cont As Boolean = False
            For i As Integer = 0 To counter - 1
                Dim tb As TextBox = CType(DiagnoseForm.Controls("TextBox" &
i), TextBox)
                If Not tb Is Nothing Then
                    prevQuestion = tb.Text
                    If question = prevQuestion Then
                        ProblemForm.DiagnoseTableAdapter.Insert(counter,
row.Item(0), False)
                        DiagnoseForm.notyet.Add(counter)
                        DiagnoseForm.question.Add(question)
                        counter = counter + 1
                        cont = True
                        Exit For
                    End If
                End If
            Next
            If cont Then
                Continue For
            End If

            Dim slow As Boolean = DataForm.slow
            Dim med As Boolean = DataForm.med
            Dim high As Boolean = DataForm.high
            If id = 93 Then
                If count93 = 0 Then
                    If DataForm.problemForm Then
                        SpeedTypeForm.question = question
                        Dim       result       As       DialogResult       =
SpeedTypeForm.ShowDialog()
                    End If
                    count93 = count93 + 1
                    Continue For
                Else
                    If ((count93 = 1 And slow = True) OrElse (count93 = 2 And
med = True) OrElse (count93 = 3 And high = True)) Then
                        count93 = count93 + 1
                    Else
                        count93 = count93 + 1
                        Continue For
                    End If
                End If
```

```
End If

' ==============

Dim idno As Integer
Dim contfor As Boolean = False
For Each idno In noId
    If id = idno Then
        contfor = True
    End If
Next
If contfor = True Then
    Continue For
End If

' ==============

left = 59
textBox = New TextBox
With textBox
    .Width = 590
    .ReadOnly = True
    .BackColor = Color.FromArgb(211, 3, 68)
    .ForeColor = Color.White
    .Font = New Drawing.Font("Calibri", 14, FontStyle.Bold)
    .BorderStyle = BorderStyle.None
    .Text = question
    .Left = left
    .Top = top
    .Tag = counter
    .Name = "TextBox" & counter
End With

left = left + 595
yesBtn = New Button
With yesBtn
    .Width = 65
    .Height = 30
    .Text = "Yes"
    .Left = left
    .Top = top - 5
    .Tag = counter
    .Name = "YesBtn" & counter
    .Cursor = Cursors.Hand
    .BackColor = Color.Gainsboro
    .ForeColor = Color.White
    .FlatStyle = FlatStyle.Flat
    .FlatAppearance.BorderSize = 0
    .Font = New Drawing.Font("Calibri", 14, FontStyle.Bold)
End With
AddHandler yesBtn.Click, AddressOf DiagnoseForm.YesBtn_Click
```

```
            left = left + 65
            noBtn = New Button
            With noBtn
                .Width = 65
                .Height = 30
                .Text = "No"
                .Left = left
                .Top = top - 5
                .Tag = counter
                .Name = "NoBtn" & counter
                .Cursor = Cursors.Hand
                .BackColor = Color.Red
                .ForeColor = Color.White
                .FlatStyle = FlatStyle.Flat
                .FlatAppearance.BorderSize = 0
                .Font = New Drawing.Font("Calibri", 14, FontStyle.Bold)
            End With
            AddHandler noBtn.Click, AddressOf DiagnoseForm.NoBtn_Click
            ProblemForm.DiagnoseTableAdapter.Insert(counter,     row.Item(0),
False)

            top = top + 40
            counter = counter + 1
            DiagnoseForm.Height = DiagnoseForm.Height + 40
            DiagnoseForm.NextButton.Top = DiagnoseForm.NextButton.Top + 40
            DiagnoseForm.Controls.Add(textBox)
            DiagnoseForm.Controls.Add(yesBtn)
            DiagnoseForm.Controls.Add(noBtn)
            DataForm.questionsNumber = DataForm.questionsNumber + 1
        Next

        DiagnoseForm.Height = DiagnoseForm.Height + 40
        DiagnoseForm.NextButton.Top = DiagnoseForm.NextButton.Top + 30
        DiagnoseForm.counter = counter - 1
        DiagnoseForm.Show()
        Return True
    End Function
End Module
```

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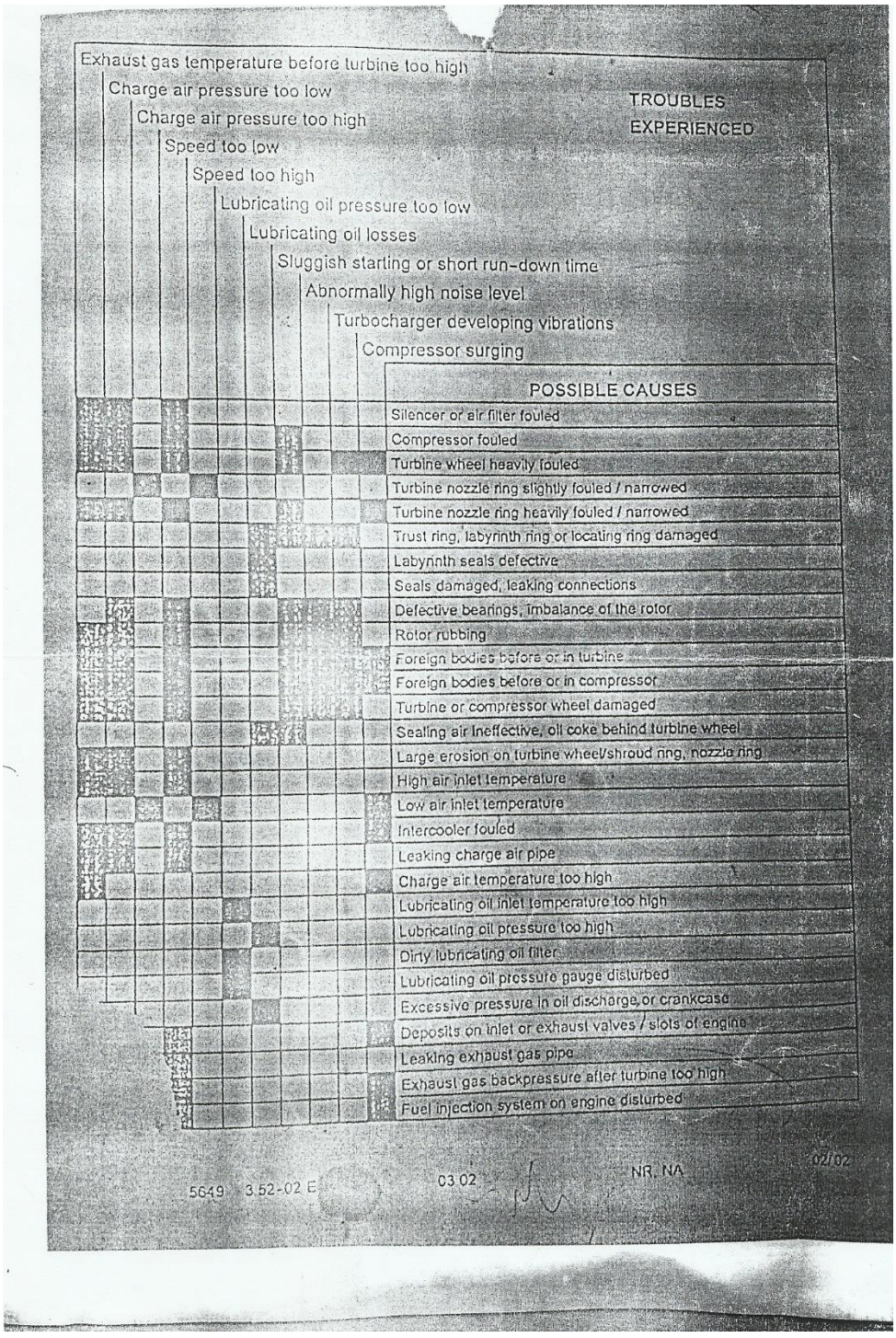
Annex B
Turbocharger Diagnostic Matrix

Trouble	Location	Cause	Remedy	see
Vibrations	Turbocharger	- rotor unbalance due to heavy contamination of compressor / turbine	- remove and clean, call service station	Chap. 5
		- turbine blades or damping wire damaged	- replace rotor	Chap. 5
		- bearing defect	- replace bearing, seek possible cause	Chap. 5
Noises on running down, time too short, reluctant starting	Turbocharger	- bearing damaged	- replace bearing	Chap. 5
		- rotor rubbing	- call service station	Chap. 8
		- dirt in turbocharger	- clean	Chap. 3
		- foreign bodies in the turbocharger	- call service station, replace damaged parts	Chap. 8
Leaks in the casing	Turbocharger	- cracks due to thermal tension: insufficient ventilation	- replace casing - provide better ventilation	
		insufficient cooling water	- check and top up	
		dirt in cooling water space	- clean	Chap. 3
Loss of lubrication oil	Turbocharger	- sealing bushes (505[VTR321]/506 [VTR201,251]/5061[VTR161]/725) damaged	- replace sealing bushes	Chap. 5
		- compensation ducts X and Z obstructed	- clean	Chap. 3
		- gasket of bearing space cover leaking	- replace gasket	Chap. 5
Conpressor surge of the turbocharger	Turbocharger	- increased flow resistance due to:		
		- dirt in the chargeair cooler or silencer	- clean	Chap. 3
		- heavy deposits of dirt in the compressor / turbine	- clean	Chap. 3
	Engine	- defective check valves in two-stroke engines	- replace valves	
		- exhaust gas pressure increased after the turbine, because the boiler or the exhaust gas silencer are dirty	- clean	
		- grid dity	- clean	

Call the service station or representative if the cause of the surging cannot b detected.

1
Troubles, causes, remedies

Trouble	Location	Cause	Remedy	see
Exhaust gas temperature too high engine power and speed unaltered	Engine	- faults in injection system	- repair or consult engine manufacturer	
	Turbocharger	- lack of air, e.g. filter blocked by dirt	- clean	Chap. 3
		- compressor / turbine contaminated	- clean	Chap. 3
		- Exhaust gas back pressure too high	- clean or repair boiler	
		- turbine blade damaged or eroded	- replace the rotor	Chap. 5
		- cover ring eroded	- replace	Chap. 5
	Charge-air cooler	- dirt in the cooler	- clean	
		- insufficient cooling water	- check/clean cooling system	
		- cooling water inlet temperature too high	- check/clean cooling system	
		- insufficient ventilation	- improve ventilation	
Charge air pressure too low engine power and speed unaltered; air intake normal	Engine	- leak in the air receiver	- repair	
		- leak in the gas duct between engine and turbine	- repair	
		- injection incorrectly adjusted	- adjust correctly	
	Turbocharger	- manometer indication defective	- replace manometer	
		- leaks in the line to the manometer	- repair leak	
		- dirt in the air filter causing, excessive pressure loss	- clean	Chap. 3
		- dirt in the compressor / turbine	- clean	Chap. 3
		- labyrinth seal damaged	- consult service station for replacement	Chap. 8
		- turbine / compressor blades damaged	- replace the rotor	Chap. 5
		- nozzle ring damaged	- replace	Chap. 5
		- cover ring eroded	- replace	Chap. 5
		- exhaust gas back pressure too high	- clean boiler or exhust gas silencer	
Charge air pressure too high engine power and speed unaltered	Engine	- faults in the injection system	- adjust correctly	
		- engine performance higher than assumed	- check engine performance	
		- injection system incorrectly adjusted	- adjust correctly	
	Turbocharger	- manometer indication incorrect	- replace manometer	
		- nozzle ring dirty or partly obstructed	- clean	Chap. 3


Exhaust gas temperature before turbine too high
Charge air pressure too low
Charge air pressure too high
Speed too low
Speed too high
Lubricating oil pressure too low
Lubricating oil losses
Sluggish starting or short run-down time
Abnormally high noise level
Turbocharger developing vibrations
Compressor surging
TROUBLES EXPERIENCED
POSSIBLE CAUSES
Silencer or air filter fouled
Compressor fouled
Turbine wheel heavily fouled
Turbine nozzle ring slightly fouled / narrowed
Turbine nozzle ring heavily fouled / narrowed
Trust ring, labyrinth ring or locating ring damaged
Labynnth seals defective
Seals damaged, leaking connections
Defective bearings, imbalance of the rotor
Rotor rubbing
Foreign bodies before or in turbine
Foreign bodies before or in compressor
Turbine or compressor wheel damaged
Sealing air ineffective, oil coke behind turbine wheel
Large erosion on turbine wheel/shroud ring, nozzle ring
High air inlet temperature
Low air inlet temperature
Intercooler fouled
Leaking charge air pipe
Charge air temperature too high
Lubricating oil inlet temperature too high
Lubricating oil pressure too high
Dirty lubricating oil filter
Lubricating oil pressure gauge disturbed
Excessive pressure in oil discharge or crankcase
Deposits on inlet or exhaust valves / slots of engine
Leaking exhaust gas pipe
Exhaust gas backpressure after turbine too high
Fuel injection system on engine disturbed
5649 3.52-02 E
03.02
NR. NA
02/02

Turbocharger diagnostic matrix

Maintenance and care

Turbochargers are designed to last for the service life of the engine. Monitoring is restricted to a few periodic checks that should be performed during every engine service. One condition for achieving longevity, however, is exact compliance with the engine manufacturer's servicing specifications – such as oil change intervals, oil-filter system maintenance, oil-pressure checks, cleaning of all filter systems, and regular, professional filter changes.

Power losses and faults – the causes are frequently not inside of the turbocharger

It is crucial to analyze an detect why the turbocharger has failed. Please use the diagnostic table below to find your cause.

- This matrix is intended to help pinpoint the causes of damage or failure.
- Such causes must be eliminated before the turbocharger is replaced.
- If the true causes of damage or failure are not found and corrected, they will probably recur with a new turbocharger.
- Please do not disassemble any part of the turbocharger.

Possible Causes / Problem	Compressor/turbine wheel defective	Low power/boost pressure too low	Boost pressure too high	Black smoke	Blue Smoke	Turbocharger is noisy	High oil consumption	Oil leakage at compressor	Oil leakage at turbine
Dirty air filter system		•		•	•		•	•	
Air-intake and pressure line distorted or leaking		•		•		•			
Excessive flow resistance in exhaust system/ leakage upstream of turbine		•		•	•	•	•	•	
Oil feed and drain lines clogged, leaking or distorted					•		•	•	•
Crankcase ventilation clogged or distorted					•		•	•	•
Coke or sludge in turbocharger bearing housing					•		•	•	•
Fuel system/injection system defective or improperly adjusted		•	•	•					
Valve guide, piston rings, engine, or cylinder liners worn/increased blow-by		•		•	•		•	•	•
Dirty compressor or charge air cooler		•		•	•	•	•	•	
Boost pressure control swing valve/poppet valve does not close		•		•					
Boost pressure control swing valve/poppet valve does not open			•						
Control line to swing valve/poppet valve defective		•	•						
Piston ring seals defective					•		•	•	•
Turbocharger bearing damage	•	•		•	•	•	•	•	•
Foreign-body damage to compressor or turbine	•	•		•		•			
Exhaust gas leakage between turbine outlet and exhaust pipe						•			
Engine air collector cracked/missing, loose gaskets		•		•		•			
Turbine housing/swing valve damaged	•	•		•		•			
Insufficient oil supply to turbocharger	•	•		•		•			

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HOLSET®
TURBOCHARGERS

Turbocharger Failure Diagnosis

Turbocharger Failure Diagnosis

Loss of power, excess smoke, high fuel consumption, overheating, high exhaust temperatures and oil leakages from the turbocharger are all symptoms that could indicate turbocharger malfunction. However, these faults are often wrongly attributed to the turbocharger because defects in other components can produce the same symptoms. The turbocharger performance can only be impaired by mechanical damage or blockage caused by dirt.

This checklist provides a comprehensive list of the most common symptoms related to turbocharger failure. BEFORE replacing a turbocharger, verify the problem by consulting the chart below. If after taking the appropriate action, problems still persist, please contact your nearest authorised Holset distributor for advice.

	Engine Running Hot	Poor Transient Response	Smoke	Engine Lacks Power	Black Exhaust Smoke	Blue Exhaust Smoke	High Oil Consumption	Turbocharger Noisy	Cyclic Sound from the Turbocharger	Oil Leak from Compressor Seal	Oil Leak from Turbine Seal
Dirty air cleaner Clean or replace element according to manufacturer's recommendations	●	●	●	●	●	●	●			●	
Restricted compressor intake duct Remove restriction or replace damaged parts as required	●	●	●		●	●	●	●	●	●	
Restricted air duct from compressor to intake manifold Replace seals, gaskets or tighten fasteners as required	●	●		●	●			●			
Restricted intake manifold Refer to engine manufacturer's manual and remove restriction	●	●		●	●			●			
Air leak in feed from air cleaner to compressor Replace seals, gaskets or tighten fasteners as required								●			
Air leak in feed from compressor to intake manifold Replace seals, gaskets or tighten fasteners as required	●	●	●	●	●	●	●	●			
Air leak between intake manifold and engine Refer to engine manufacturer's manual and replace gaskets or tighten fasteners as required	●		●	●	●	●	●	●			
Foreign object in exhaust manifold (from engine) Refer to engine manufacturer's manual and remove obstruction				●	●	●	●	●		●	
Restricted exhaust system Remove restriction or replace damaged parts as required	●			●	●					●	
Exhaust manifold cracked, gaskets blown or missing Refer to engine manufacturer's manual and replace gaskets or damaged parts as required		●	●	●	●			●			
Gas leak at turbine inlet/exhaust manifold joint Replace gasket or tighten fasteners as required		●	●	●	●			●			
Gas leak in ducting after turbine outlet Refer to engine manufacturer's manual and repair leak		●						●			
Restricted turbocharger oil drain line Remove restriction or replace damaged parts as required						●	●			●	●
Restricted engine crankcase breather Refer to engine manufacturer's manual, clear restriction						●	●			●	●
Turbocharger bearing housing sludged or coked Change engine oil and oil filter, overhaul or replace turbocharger as required						●	●			●	●
Fuel injection pump or fuel injectors incorrectly set Refer to engine manufacturer's manual and replace or adjust faulty components as required		●	●	●	●						
Engine valve timing incorrect Refer to engine manufacturer's manual for correct settings and adjust as required				●	●						
Worn engine piston rings or liners Refer to engine manufacturer's manual and repair as required				●	●	●	●			●	●
Burnt valves and/or pistons Refer to engine manufacturer's manual and repair as required				●	●	●	●			●	●
Excessive dirt build-up on impeller and/or diffuser vanes Clean in accordance with the appropriate Holset repair manual				●	●	●	●	●	●	●	●
Turbocharger damaged Find and correct cause of failure, repair or replace turbocharger as necessary				●	●	●	●	●		●	●
Failed diaphragm Replace using correct Actuator Service Kit	●							●			
Siezed valve Free valve/replace complete turbine housing sub-assembly	●	●									
Leaking hose Replace hose and clips	●							●			
Wastegate mechanism set incorrectly Contact nearest Holset distributor for correct setting details	●	●	●	●				●			

TURBOCHARGER TROUBLESHOOTING

■ PROBABLE CAUSE □ NOT A PROBABLE CAUSE

POSSIBLE CAUSE	Engine Lacks Power	Excessive Oil Consumption	Black Smoke	Blue Smoke	Excessive Oil - Compressor End	Noise	Excessive Oil - Turbine End	Drag or Bind in Rotating Assembly	Excessive Rotating Assembly Play	Damaged Compressor Wheel	Damaged Turbine Wheel	SOLUTIONS
Dirty air cleaner element	■	■		■	■	■						Clean or replaced filter element
Plugged crankcase breathers			■			■	■					Clear obstruction per manufacturer's manual
Air cleaner element missing, leaking or loose connections to turbo					■			■		■		Replace, repair or reconnect air cleaner element per manufacturer's manual
Collapsed or restricted air pipe before turbocharger	■	■		■	■	■						Inspect pipe for damage or obstructions, replace or repair
Restricted or damaged crossover pipe turbo to inlet manifold	■	■			■	■						Inspect pipe for damage or obstructions, replace or repair
Foreign object between cleaner and turbocharger	■	■			■	■		■	■	■		Inspect air intake piping, remove foreign object
Foreign object in exhaust system (from engine, check engine)	■	■			■		■	■	■		■	Inspect exhaust piping ONLY when engine is NOT running and cold, remove foreign object
Turbocharger flanges, clamp or bolt loose	■	■	■	■	■	■	■	■	■	■	■	Inspect all connecting hardware for damage, ensure tight fits per installation instructions
Inlet manifold cracked, gaskets loose or missing, connections loose	■	■		■	■	■						Remove and inspect inlet manifold for damage to castings and gaskets, replace if needed
Exhaust manifold cracked, burned, gasket loose, blown or missing	■	■			■							Remove exhaust manifold ONLY when engine is cold and NOT running and inspect for damage to castings and gaskets, replace if needed
Restricted exhaust system					■							Inspect exhaust system ONLY when engine is cold, NOT running, remove obstruction
Oil lag at start-up								■	■			Inspect lubrication system lines, filters, and oil for obstruction, remove obstruction
Insufficient lubrication								■	■			Inspect lubrication system lines, filters, and oil for obstruction, remove obstruction
Lubricating oil contaminated with dirt or other material								■	■			Replace all filters and lubricating oil with new per manufacturer's manual
Improper lubricating oil type used								■	■			Replace lubricating oil with correct grade
Restricted oil feed line							■	■	■	■		Remove and inspect oil line, remove obstruction
Restricted oil drain line			■					■				Remove and inspect oil line, remove obstruction
Turbine housing damaged or restricted	■	■			■						■	Remove turbine housing, inspect for cracks or wear, replace if needed
Turbocharger seal leakage			■	■		■	■					Inspect for proper oil feed / drain line installation. Contact the number on the front of this brochure for a rebuild.
Worn jounal bearing	■	■	■		■	■	■	■	■	■	■	Contact the number on the front of this brochure
Excessive dirt build-up behind turbine wheel	■	■		■	■	■		■		■	■	Inspect air cleaner element and intake piping for damage or leaks, replace if needed. Clean compressor wheel and housing
Excessive carbon build-up behind turbine wheel	■	■		■	■		■	■			■	Inspect crankcase ventilation system
Too fast acceleration at initial start									■	■		Decrease acceleration at initial start
Too little warm-up time									■	■		Extend warm-up period
Fuel pump malfunction	■	■										Refer to engine manufacturer's manual and replace if needed
Worn or damaged injectors	■	■										Inspect injectors for damage and replace if needed
Valve timing	■	■										Refer to engine manufacturer's manual and adjust as needed
Burned valves	■	■										Refer to engine manufacturer's manual and replace if needed
Worn piston rings	■	■										Refer to engine manufacturer's manual and replace if needed
Burned pistons	■	■										Refer to engine manufacturer's manual and replace if needed
Leaking oil feed line									■	■		Remove and inspect oil line, remove obstruction
Excessive engine pre-oil				■			■					Refer to engine manufacturer's manual and adjust as needed
Excessive engine idle			■	■		■	■					Refer to engine manufacturer's manual and adjust as needed
Coked or sludged center housing			■	■			■	■			■	Contact the number on the front of this brochure
Oil pump malfunction									■			Refer to engine manufacturer's manual and replace if needed
Oil filter plugged			■	■		■	■	■	■	■	■	Refer to engine manufacturer's manual and replace if needed
Oil bath air cleaner: air inlet screen restricted / dirty air cleaner	■	■	■	■	■							Repair air inlet screen
Oil bath air cleaner: oil pull-over / oil viscocity too low or high	■	■	■	■	■							Replace lubricating oil with correct grade
Boost control malfunction: wastegate	■	■	■	■	■	■	■		■	■	■	Inspect for damage, leaks or obstructions; replace or repair if needed
Boost control malfunction: VNT	■	■	■	■	■	■	■		■	■	■	Contact the number on the front of this brochure
Boost control malfunction: engine management system	■	■	■	■	■	■	■		■	■	■	Refer to engine manufacturer's manual and adjust as needed

Turbocharger Troubleshooting

If the problem occurred during operation is not resolved by means of the action(s) recommended in the table below, or if turbocharger overhaul cannot be performed, consult with MHI or authorized repair agents.

1 Compressor Surging

Immediate action	Cause	Remedy
• Reduce speed to load at which surging stops. • If necessary, open the air cooler inspection hole to stop surging (be careful of elevated exhaust temperature).	Air filter fouling	Remove and clean air filter
	Turbine side fouling	Overhaul and clean turbine side
	Turbine blade wear damage	Replace turbine blades (consult with MHI or Authorized repair agents)
	Air cooler fouling	Refer to engine manual.
	Exhaust gas protection grill blockage	Refer to engine manual.
	Problem with fuel pump	Refer to engine manual.
	Exhaust gas boiler contamination	Refer to vessel manual.
	Problem with engine room ventilation	Check ventilation fan operation.

2 Oil leakage from Main Unit and/or Oil Mist Mixed with Discharged Air

Immediate action	Cause	Remedy
• Check whether there is any abnormal vibration. • If so, reduce speed to load at which vibration is alleviated, and immediately overhaul turbocharger.	Excessive inlet lubricant pressure	Adjust oil pressure at orifice, etc. 0.6-1.5 [bar]
	Problem with air bleeder piping	Check size of air bleeder piping. Check that there is no inclination where oil has accumulated.
	Loose impeller	Check whether impeller is tightened at specified pressure.
	Vacuum breaker sticking	Overhaul vacuum breaker.
	Oil labyrinth damage	Overhaul turbocharger, inspect parts, and clean channels.
	Bearing damage	Overhaul turbocharger, inspect parts, and clean channels. Inspect or clean L.O. filter for turbocharger.
	Sealing air channel blockage	Overhaul turbocharger, inspect parts, and clean channels.
	Problem with oil return tubing	Check whether interim valves are closed. Check size of oil return tubing.

3 Exhaust Gas (or oil) mixed with released air from bearing pedestal side

Immediate action	Cause	Remedy
• If amount of exhaust gas is low, continue using turbocharger until next overhaul. • If amount is high, and gas is ingested from the turbocharger silencer such that intake air temperature is higher than the engine room temperature by 10˚C or more, reduce speed of engine immediately and overhaul turbocharger as soon as possible.	Gas sealing ring wear/damage	Remove rotor and replace sealing ring.
	Oil leakage from compressor side (when the oil mist is mixed with air)	Remove impeller and check the ljournal bearing & oil labyrinth (refer chapter 2).

4 Abnormal Vibration and/or Noise from Main Unit

Immediate action	Cause	Remedy
Reduce speed to load at which vibration is alleviated, and overhaul turbocharger as soon as possible.	Turbine blade and/or compressor impeller damage	Overhaul turbocharger
	Bearing damage	Remove rotor and inspect bearing
	Over the maximum acceptable value of Rotor deflection MET22-90 size: 0.1[mm] Met18 size: 0.05	Remove silencer and confirm the rotor deflection. When the value is over the limit, remove the silencer and check the surface of impeller clutch.
	Loose impeller	Check whether impeller is tightened at specified pressure.

5 Abnormally High Turbocharger Speed, Speed Increases Regardless of Engine Load

Immediate action	Cause	Remedy
• If both scavenge air pressure and exhaust gas temperature are high, or if exhaust temperature is abnormally high, reduce engine load and inspect turbocharger and engine as soon as possible. • Do not approach turbocharger.	Abnormal engine combustion	Stop engine and inspect according to engine manual.
If scavenge air pressure and exhaust gas temperatures are normal, reduce engine load and test output signal from turbocharger tachometer.	Abnormality with tachometer	Check rpm from frequency of signal in tachometer junction box near turbocharger. Identify problem point and replace part(s).

6 High Exhaust Gas Temperature

Immediate action	Cause	Remedy
Reduce engine load to point at which engine reaches allowable temperature, and inspect engine.	Turbocharger internal fouling	Overhaul turbocharger and clean
	Substantial scavenge air leakage	Identify location of scavenge air leakage and perform countermeasures.
	Bigger tip clearance by miss assembling	Check the clearance “A” “B” and “L” In case of MET SR series, “W” should be checked instead of “L”

7 Failure of Turbocharger to Start Up

Immediate action	Cause	Remedy
Inspect turbocharger.	Blockage due to combustion residue on turbine blade tips	Clean turbine side.
	Blind plate for turbocharger shutdown extending into gas inlet	Remove blind plate.

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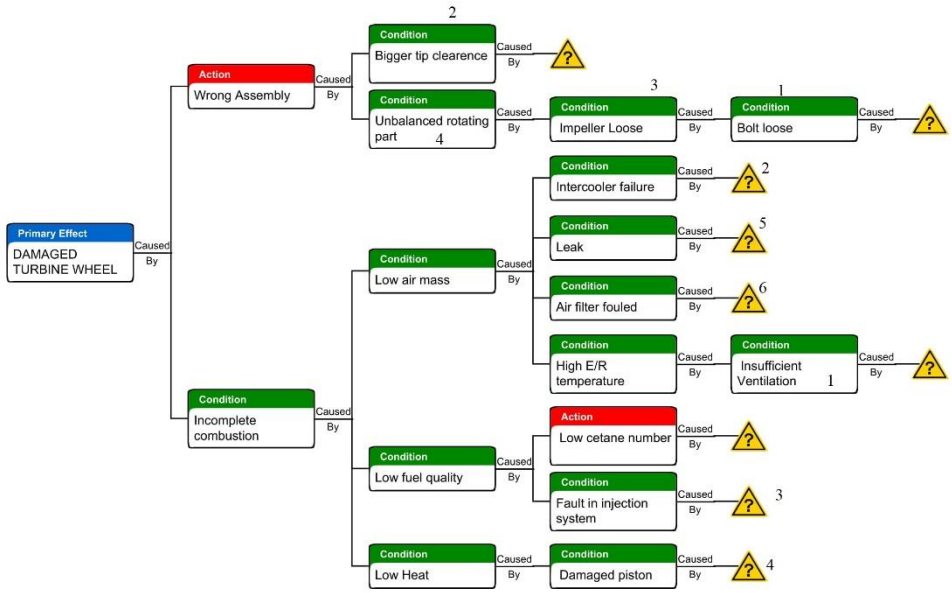
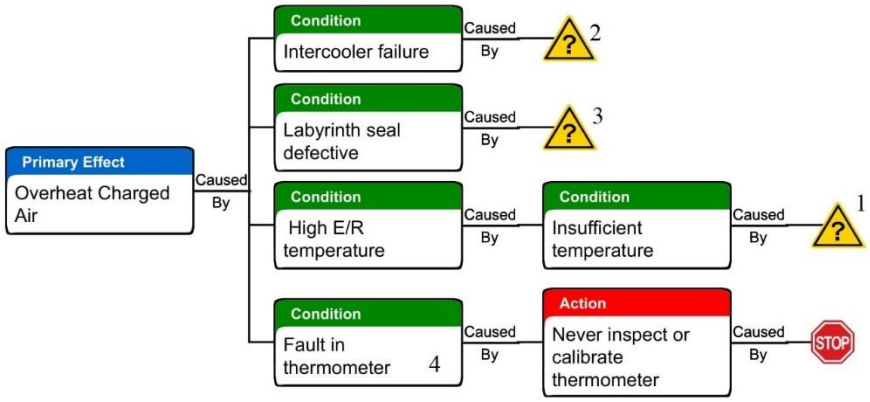
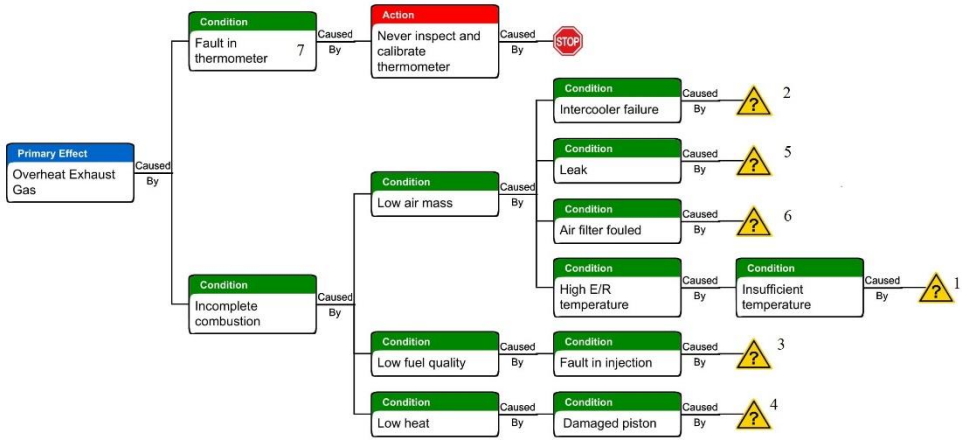
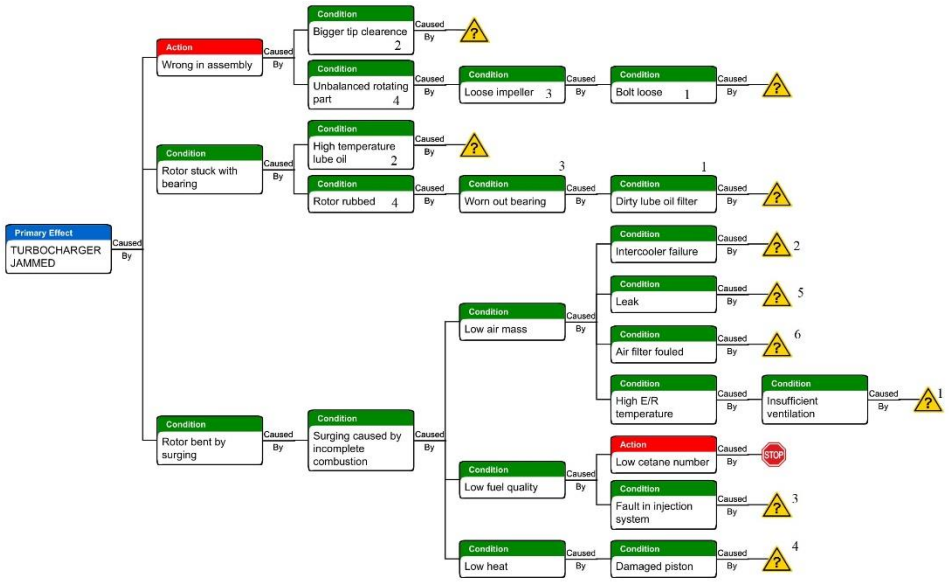
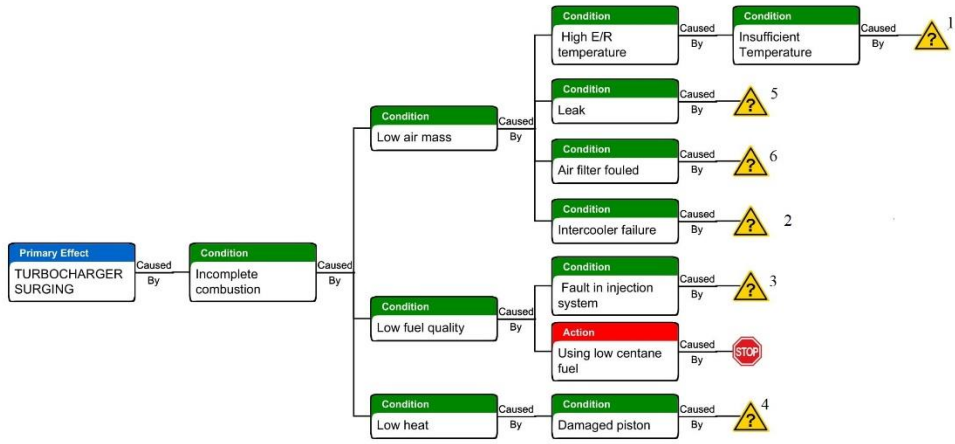
Annex C
Root Cause Analysis and Cause Scoring






Primary Effect
Overheat Exhaust Gas
Caused By
Condition
Fault in thermometer
7
Caused By
Action
Never inspect and calibrate thermometer
Caused By
STOP
Condition
Incomplete combustion
Caused By
Condition
Low air mass
Caused By
Condition
Intercooler failure
Caused By
2
Condition
Leak
Caused By
5
Condition
Air filter fouled
Caused By
6
Condition
High E/R temperature
Caused By
Condition
Insufficient temperature
Caused By
1
Condition
Low fuel quality
Caused By
Condition
Fault in injection
Caused By
3
Condition
Low heat
Caused By
Condition
Damaged piston
Caused By
4


Primary Effect
TURBOCHARGER JAMMED
Caused By
Action
Wrong in assembly
Caused By
Condition
Bigger tip clearance
2
Caused By
Condition
Unbalanced rotating part
4
Caused By
Condition
Loose impeller
3
Caused By
Condition
Bolt loose
1
Caused By
Condition
Rotor stuck with bearing
Caused By
Condition
High temperature lube oil
2
Caused By
Condition
Rotor rubbed
4
Caused By
Condition
Worn out bearing
3
Caused By
Condition
Dirty lube oil filter
1
Caused By
Condition
Rotor bent by surging
Caused By
Condition
Surging caused by incomplete combustion
Caused By
Condition
Low air mass
Caused By
Condition
Intercooler failure
Caused By
2
Condition
Leak
Caused By
5
Condition
Air filter fouled
Caused By
6
Condition
High E/R temperature
Caused By
Condition
Insufficient ventilation
Caused By
1
Condition
Low fuel quality
Caused By
Action
Low cetane number
Caused By
STOP
Condition
Fault in injection system
Caused By
3
Condition
Low heat
Caused By
Condition
Damaged piston
Caused By
4


Primary Effect
TURBOCHARGER SURGING
Caused By
Condition
Incomplete combustion
Caused By
Condition
Low air mass
Caused By
Condition
High E/R temperature
Caused By
Condition
Insufficient Temperature
Caused By
1
Condition
Leak
Caused By
5
Condition
Air filter fouled
Caused By
6
Condition
Intercooler failure
Caused By
2
Condition
Low fuel quality
Caused By
Condition
Fault in injection system
Caused By
3
Action
Using low centane fuel
Caused By
STOP
Condition
Low heat
Caused By
Condition
Damaged piston
Caused By
4

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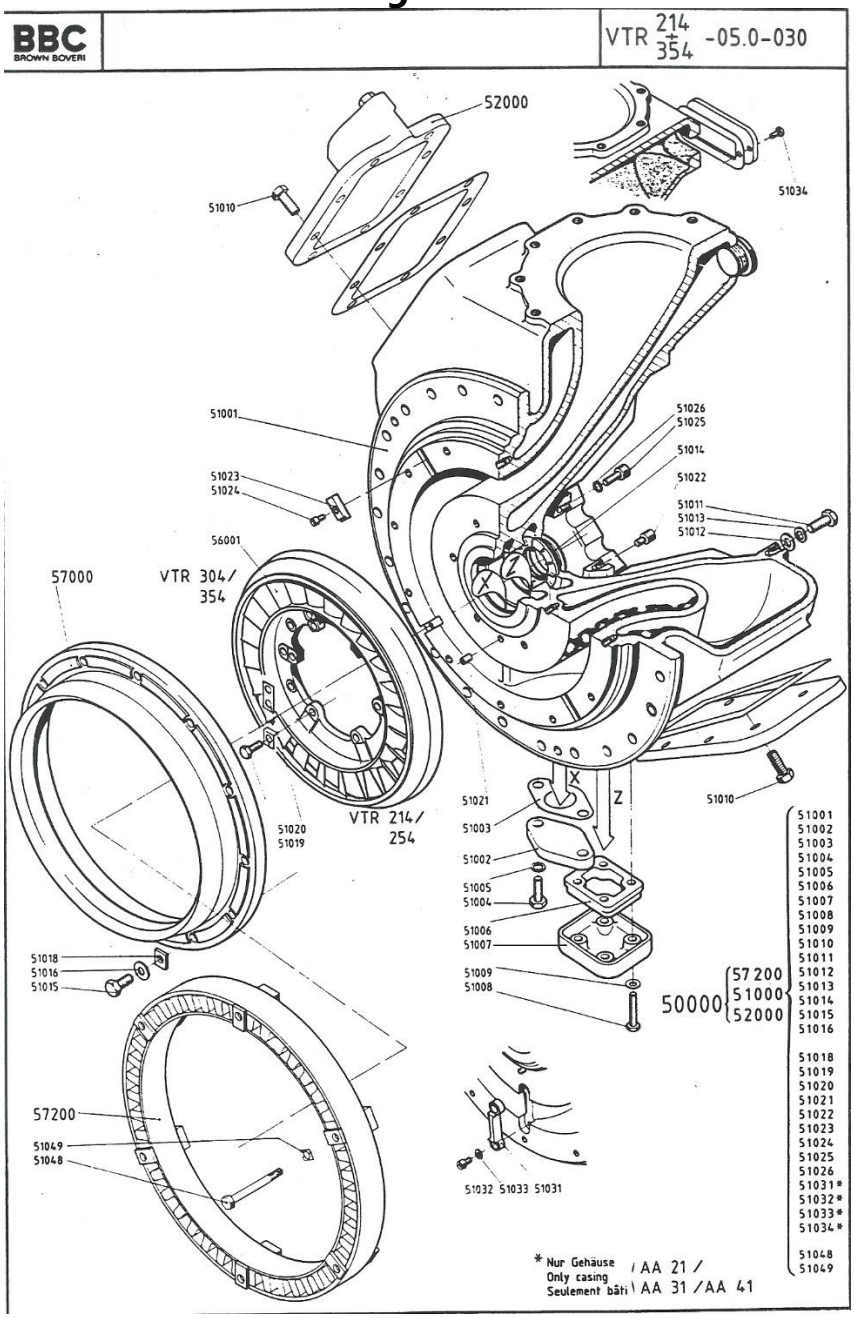
Annex D
Detail Troubleshooting



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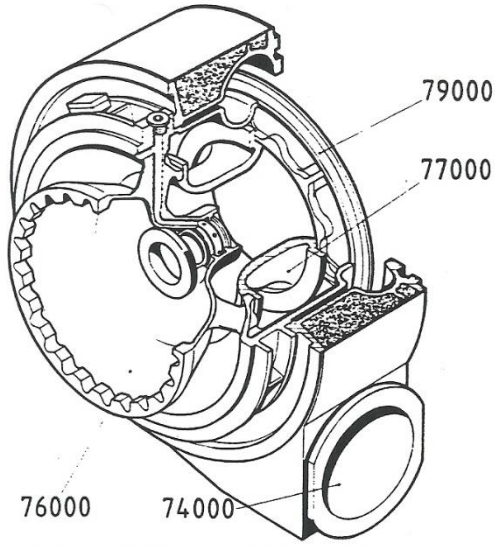

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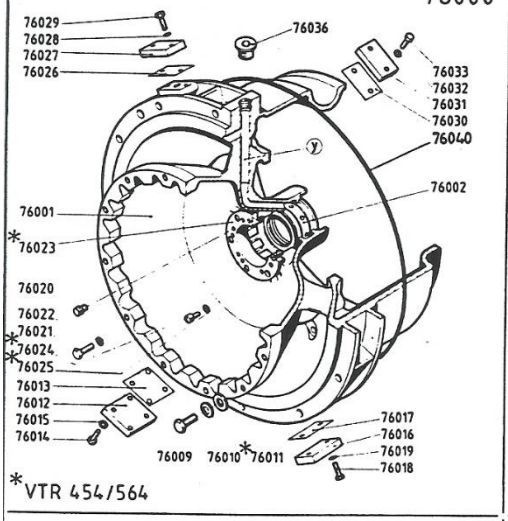

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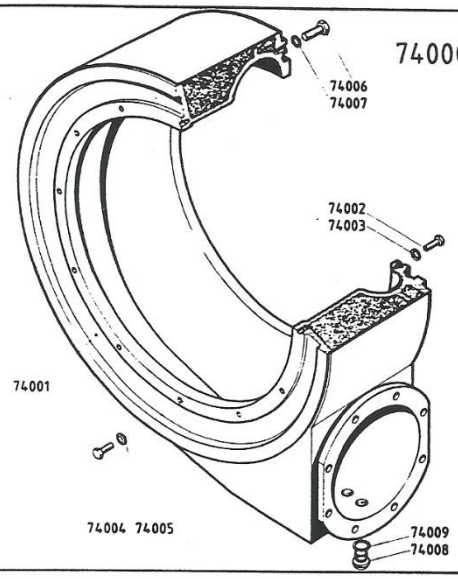

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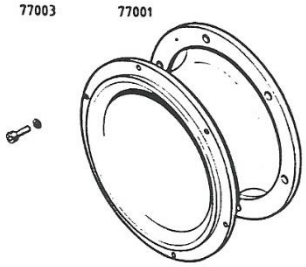

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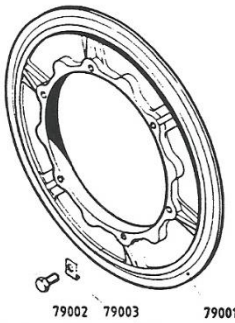

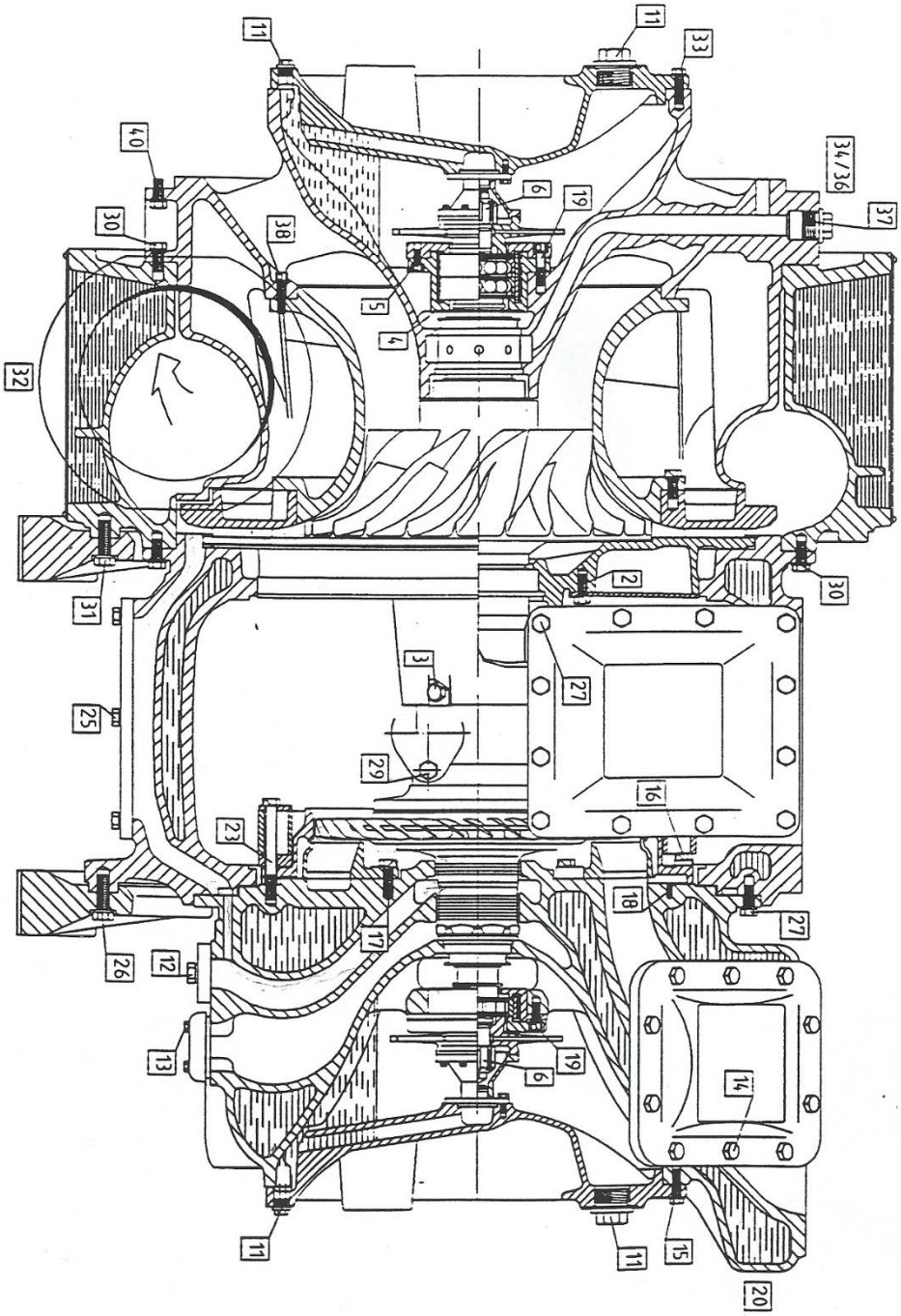
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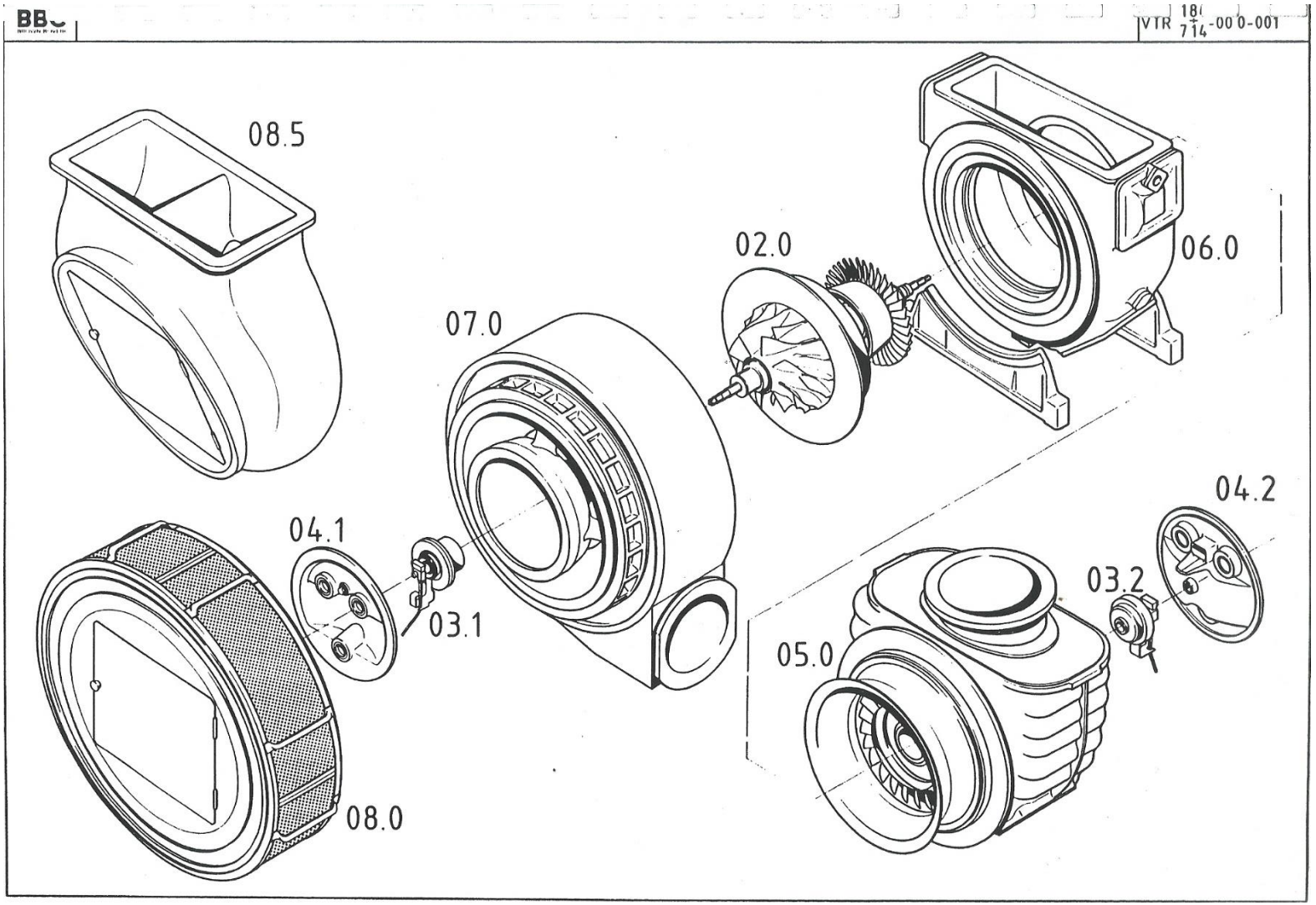
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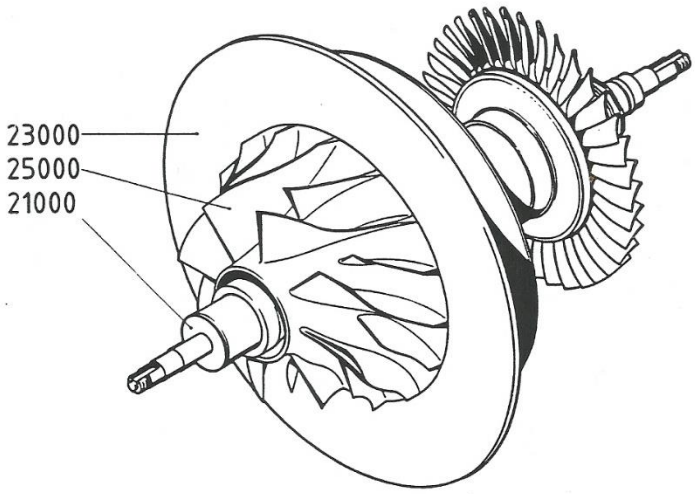

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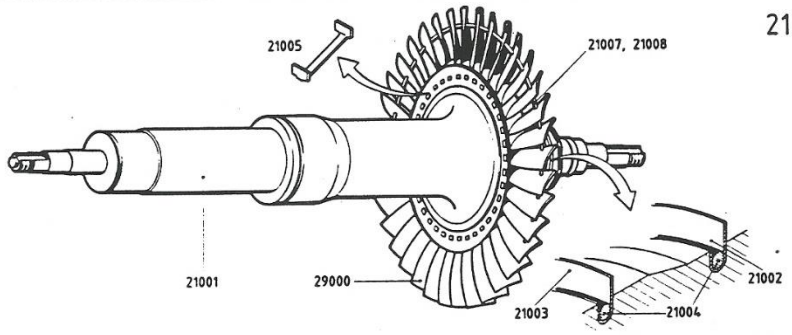

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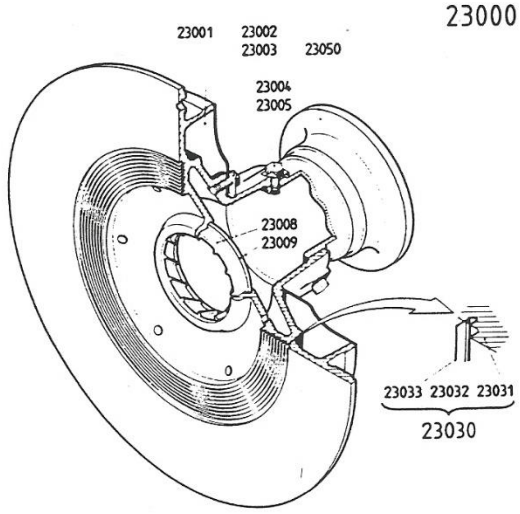

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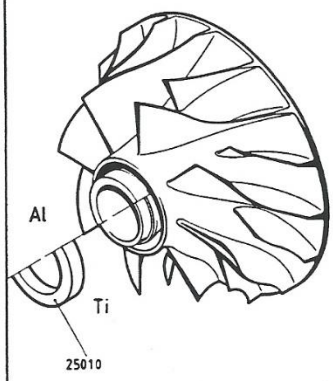

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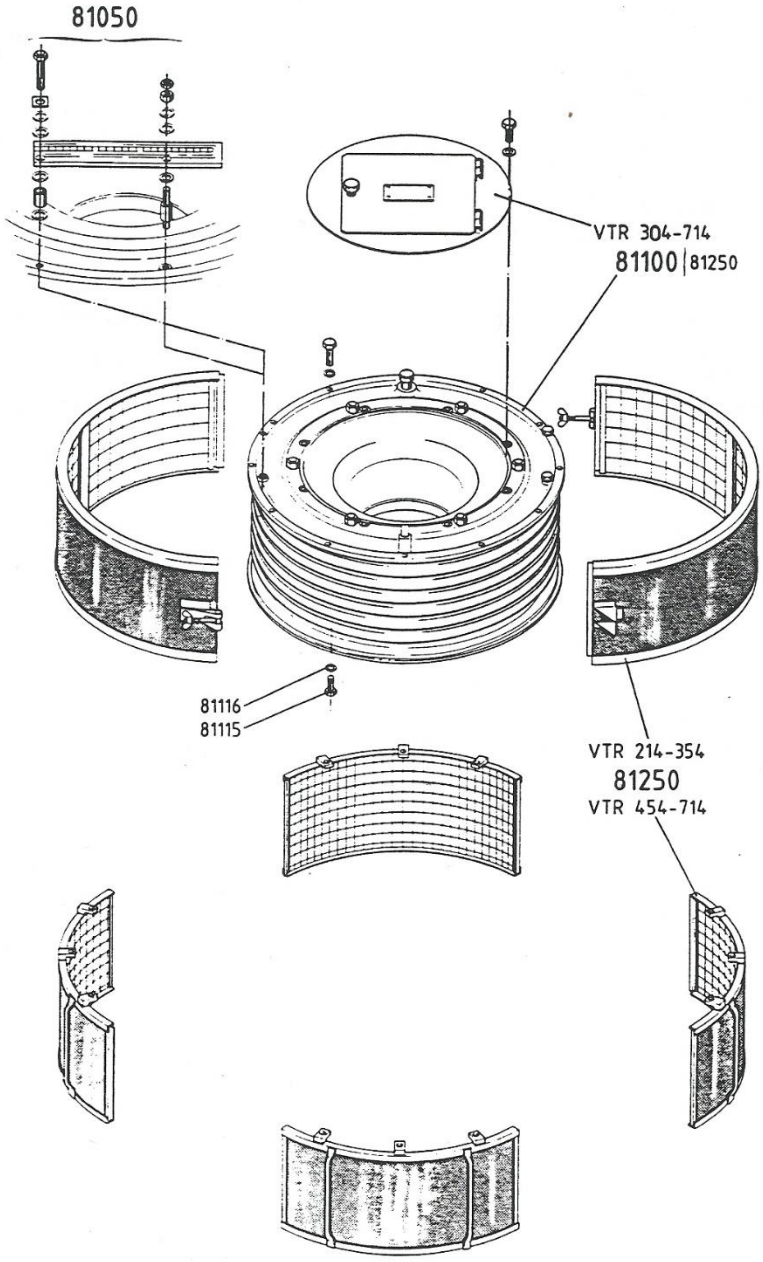

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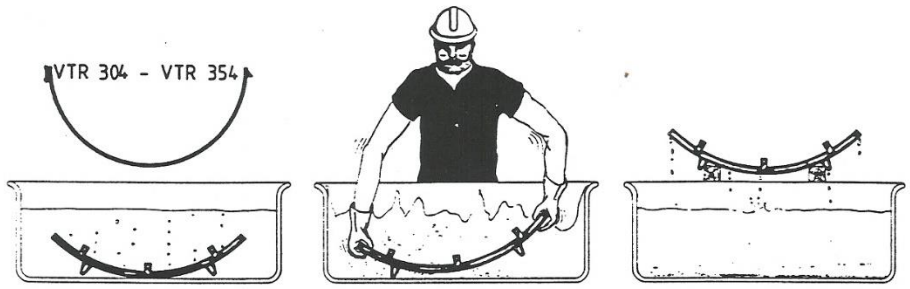

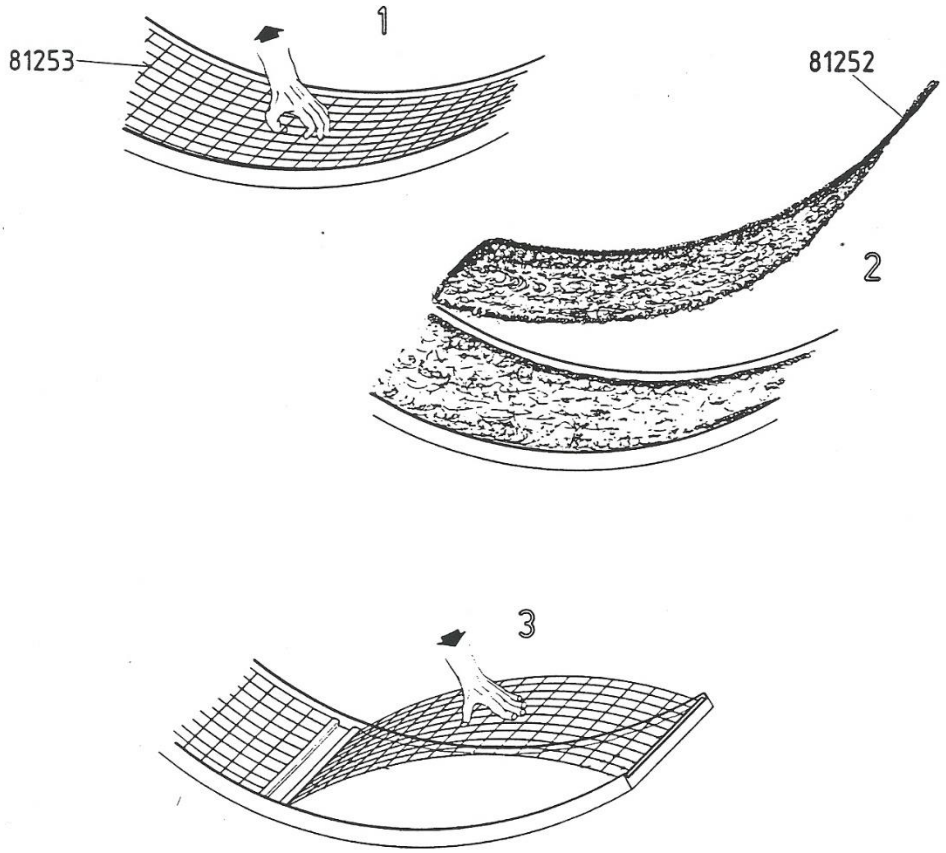

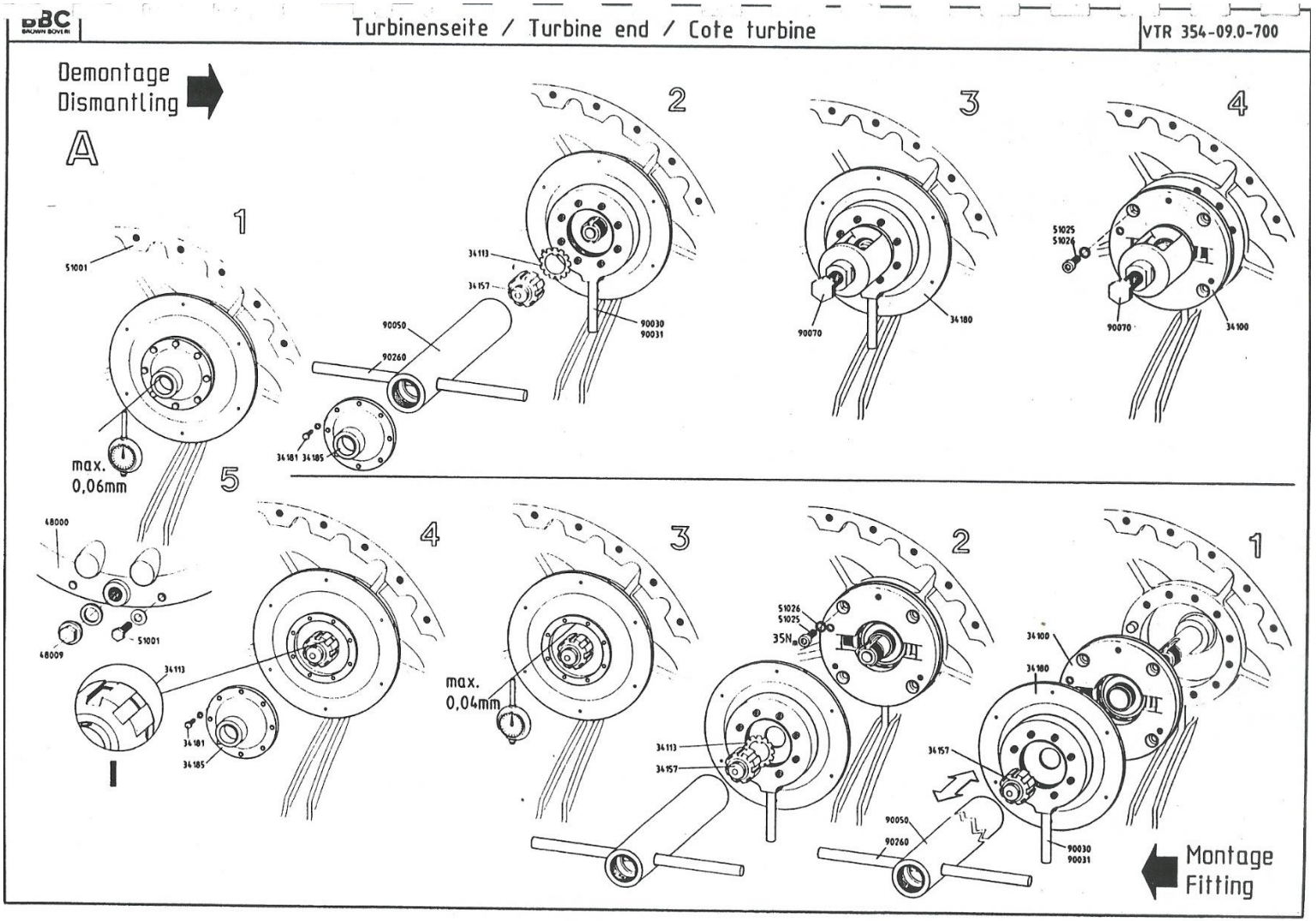
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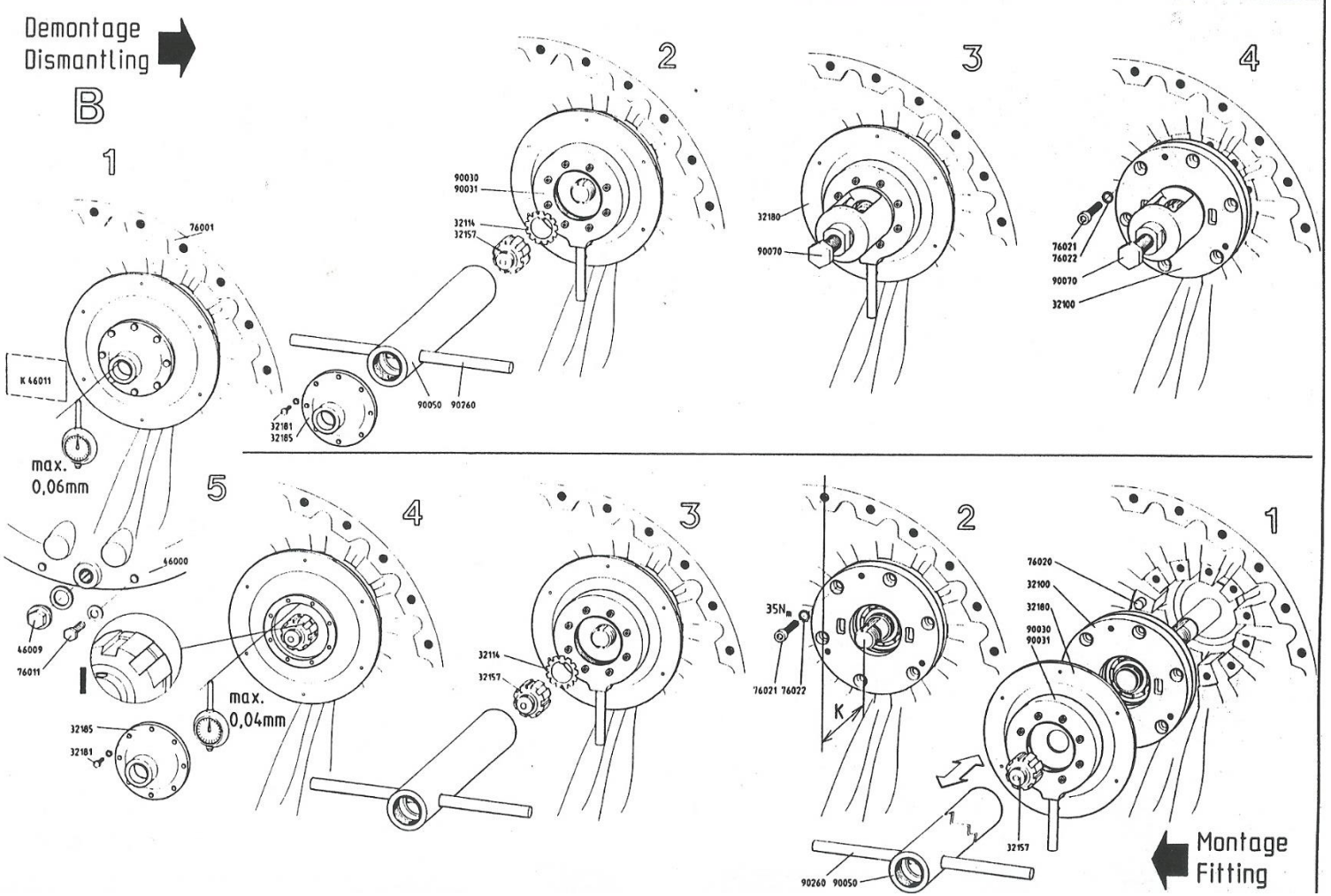

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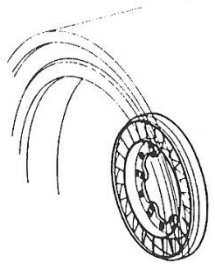

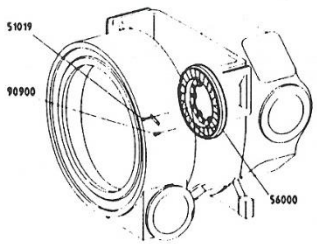

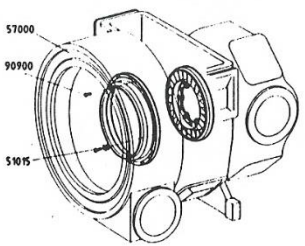

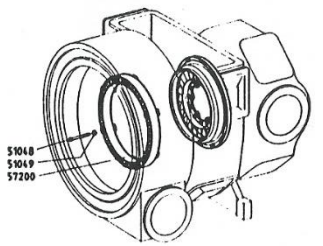

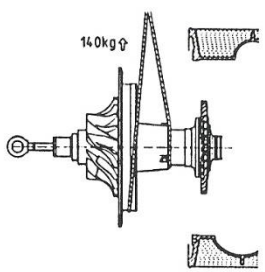

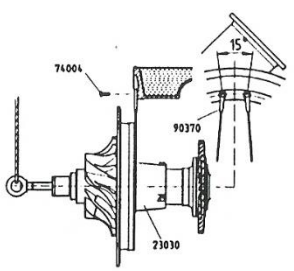

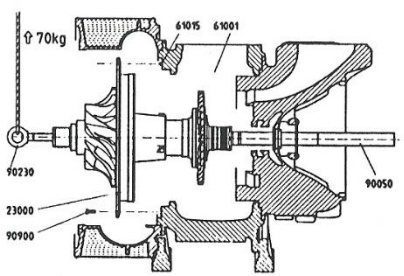

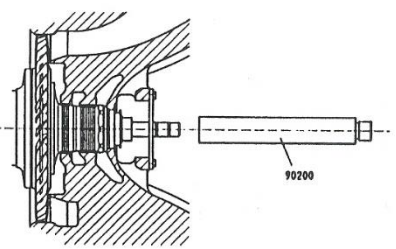

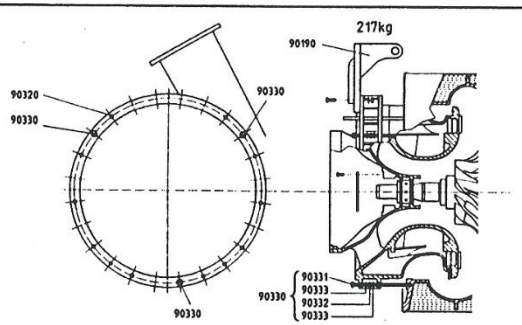

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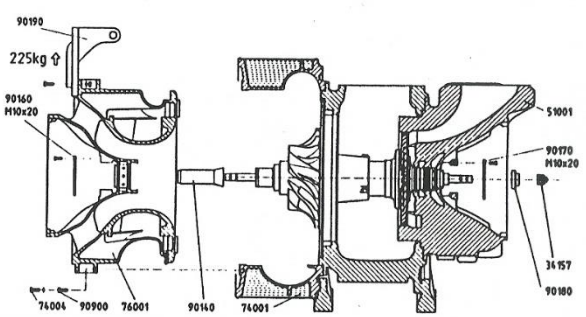
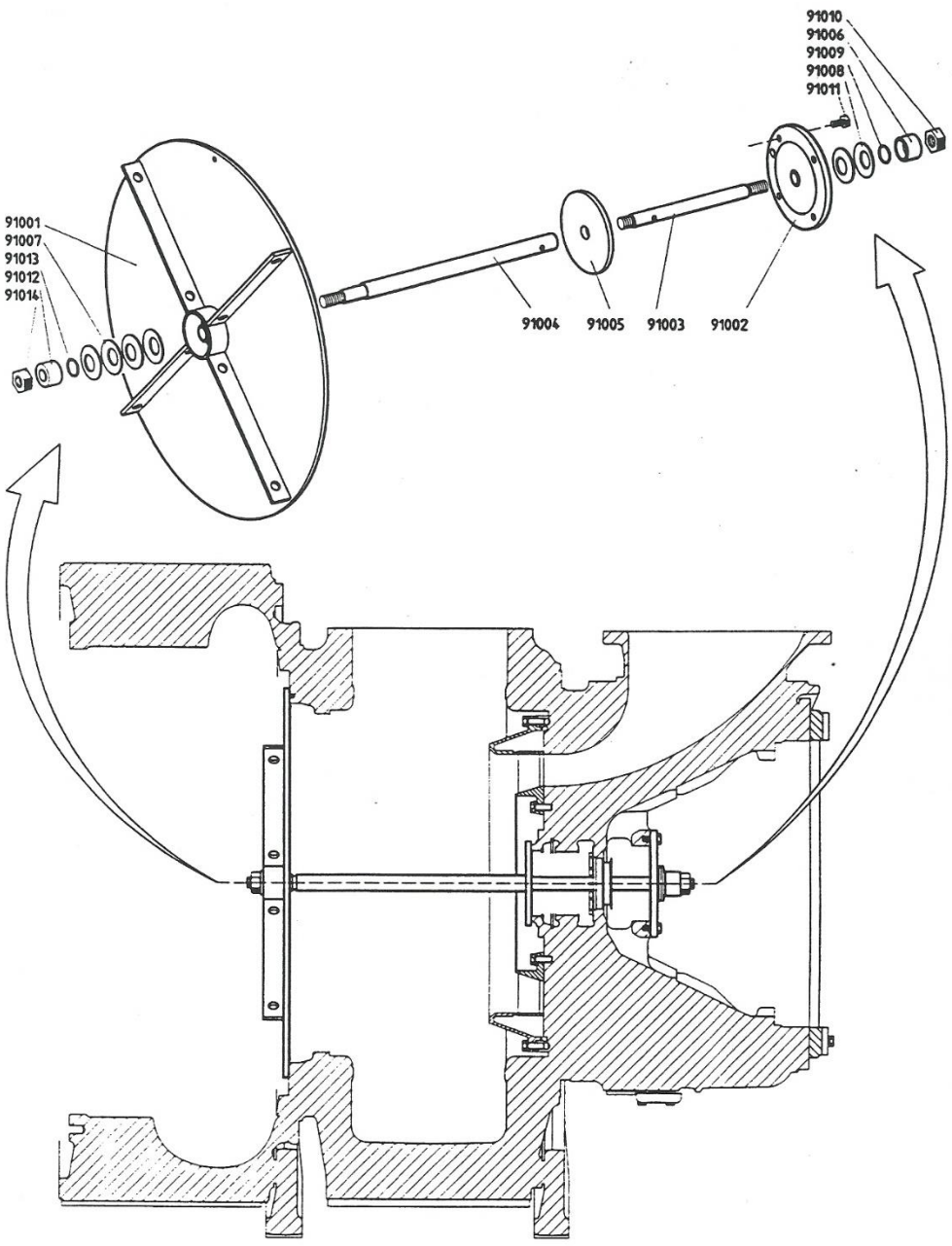
Gehäuse - Stellung
Position bati
Arrangement casing

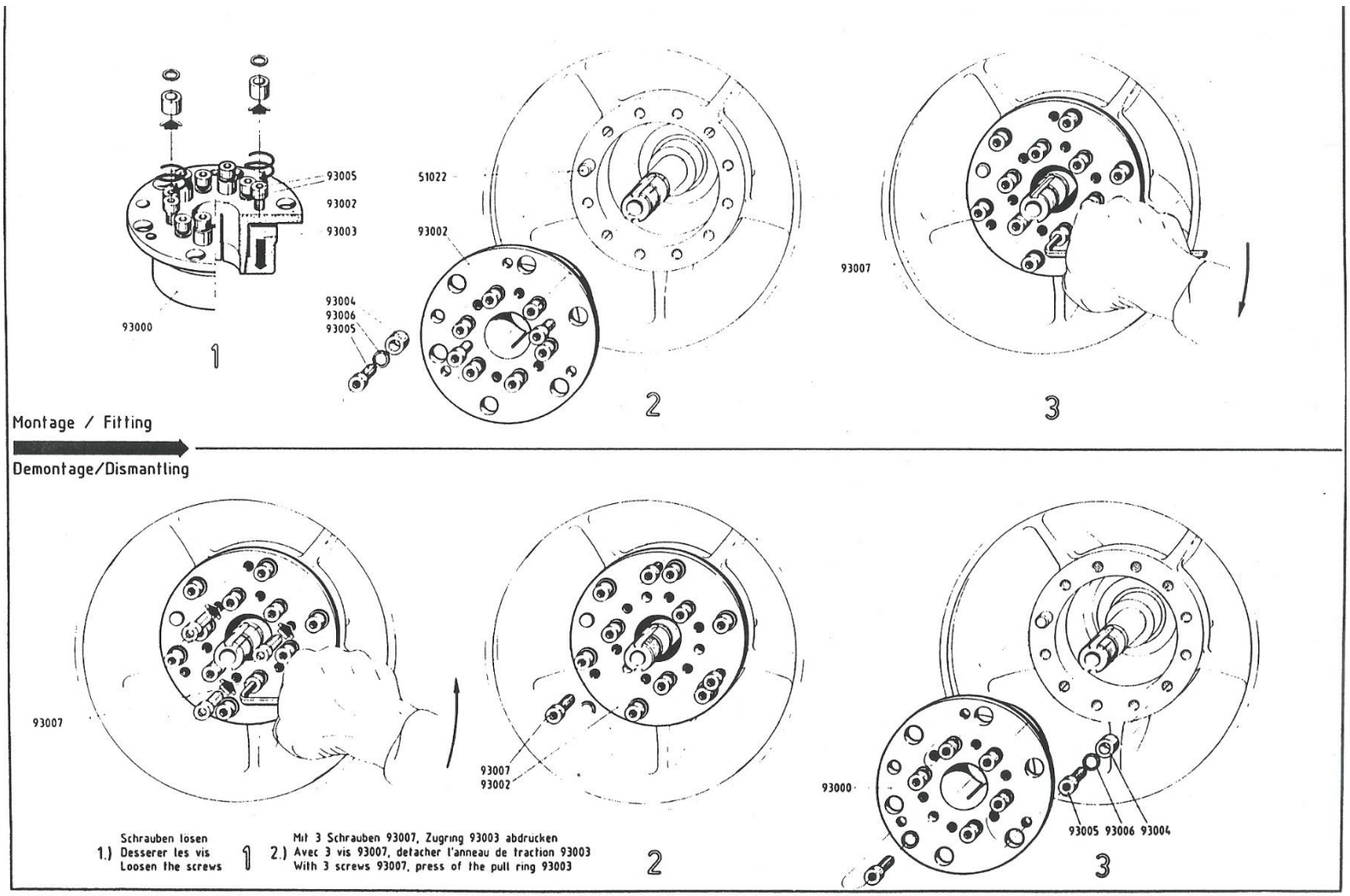


BBC BROWN BOVERI

VTR 184/714 -09.1-001.05

91000



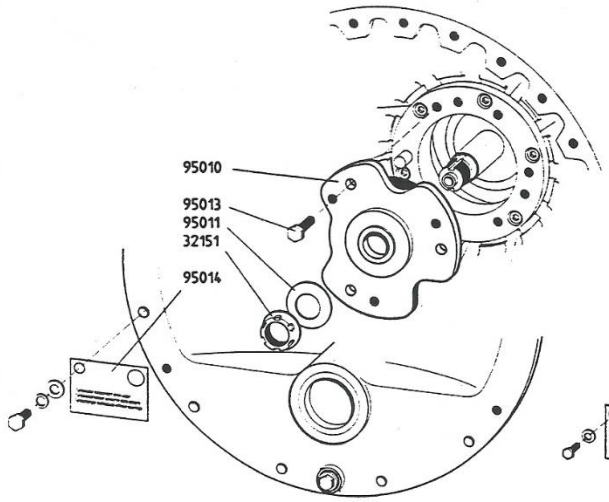

93005
93002
93003
93000
1
51022
93002
93004
93006
93005
2
93007
3
Montage / Fitting
Demontage/Dismantling
93007
93007
93002
93000
93005 93006 93004
1.) Schrauben losen
Desserer les vis
Loosen the screws
1
2.) Mit 3 Schrauben 93007, Zugring 93003 abdrucken
Avec 3 vis 93007, detacher l'anneau de traction 93003
With 3 screws 93007, press of the pull ring 93003
2
3

BBC BROWN BOVERI

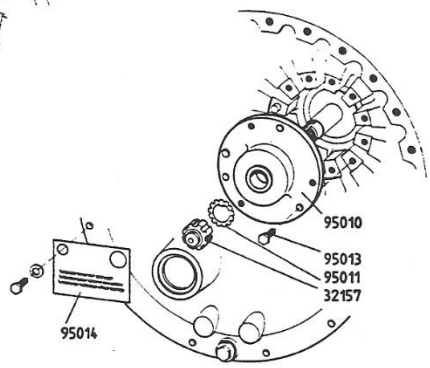
VTR $\frac{184}{714}$ -09.5-001.03

VTR 454 - VTR 714

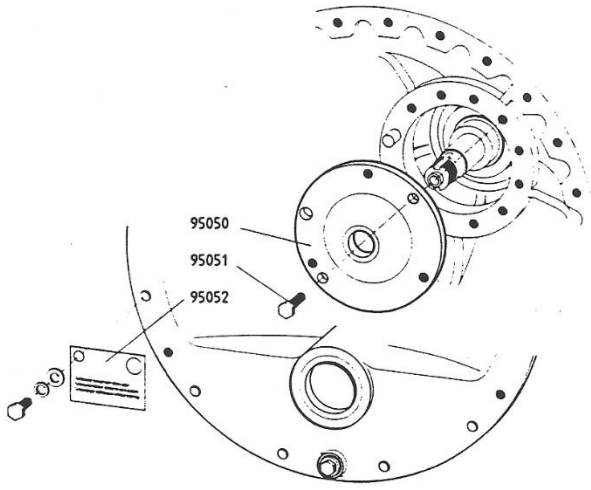
95000



VTR 184 - VTR 354



Verdichterseite / Compressor end / Cote compresseur



Turbinenseite / Turbine end / Cote turbine

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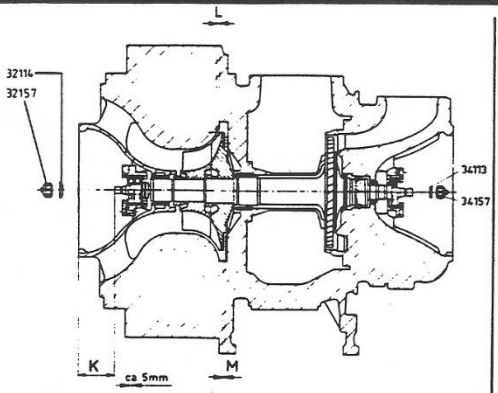
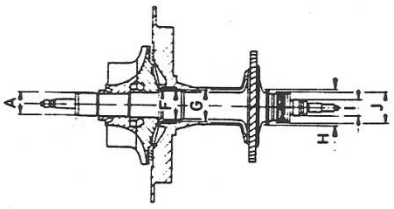
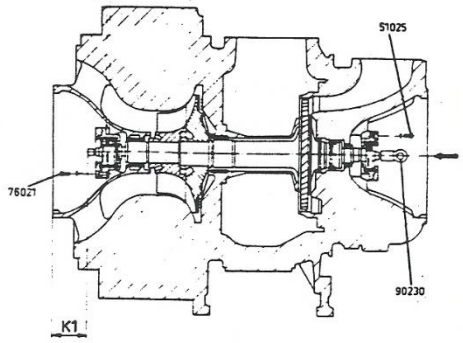
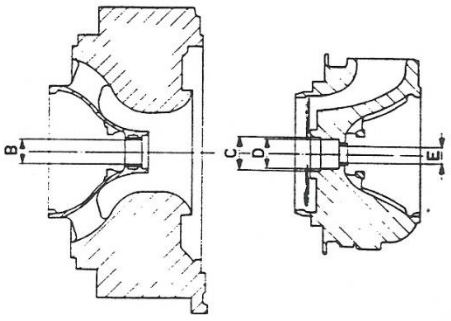
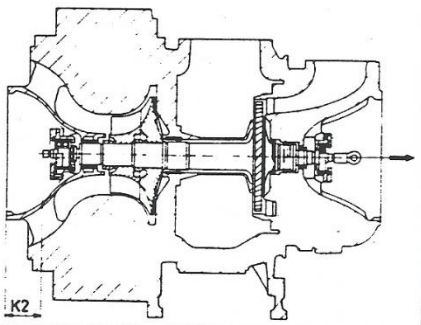
VTR $\frac{184}{354}$ -09.7-001.07

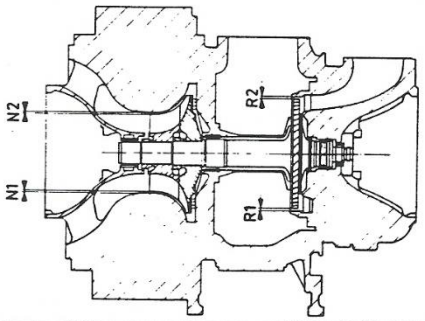












VTR	184	214	254	304	354
L	0,54...1,28	0,55...1,27	0,58...1,35	0,68...1,50	0,79...1,70
M	0,20...1,02	0,19...1,21	0,19...1,26	0,20...1,30	0,20...1,37

Leistungsschild Rating plate Plaque signalétique

BBC BROWN BOVERI

Abgasturbolader
Exhaust-Gas Turbocharger
Turbocompresseur de suralimentation

Typ VTR	$n_{max.}$ t
No. HT	t_{max} °C
Specification	
V	R H
W.....	E U
L	T

HTLT 411 795 P2

Siehe
See
Voir

VTR	184	214	254	304	354
A	39,8±0,05	47,3±0,05	56,2±0,05	66,8±0,05	79,4±0,05
B	40,3+0,1/-0	47,8+0,1/-0	56,7±0,05	67,4±0,05	80,1±0,05
C	52,0±0,05	61,2±0,05	72,6+0,1/-0	86,3+0,1/-0	103+0,1/-0
D	50,3±0,05	59,3±0,05	70,3+0,1/-0	83,6+0,1/-0	100+0,1/-0
E	28,4±0,05	33,6±0,05	39,8+0-0,05	47,2+0,1/-0	56,1+0,1/-0
F	60,0±0,05	71,5±0,05	85±0,05	101±0,05	120±0,05
G	-	72,2+0,05/-0	85,8+0,05/-0	101,9+0,05/-0	121±0,05
H	51,5+0/-0,1	60,7+0/-0,1	72,2+0/-0,1	85,8+0/-0,1	102,4+0/-0,1
I	27,9+0/-0,1	33,1+0/-0,1	39,3+0/-0,1	46,7+0/-0,1	55,5+0/-0,1
J	49,8+0/-0,1	58,8+0/-0,1	69,9+0/-0,1	83,1+0/-0,1	99,4+0/-0,1
N1	0,22...0,55	0,29...0,81	0,31...0,84	0,29...0,84	0,36...0,74
N2	0,49...0,82	0,57...0,89	0,61...0,94	0,61...0,96	0,71...1,09
R1	0,13...0,44	0,13...0,47	0,14...0,49	0,18...0,56	0,26...0,67
R2	0,40...0,71	0,41...0,75	0,44...0,79	0,50...0,88	0,61...1,02
R1	0,25...0,56	0,27...0,81	0,31...0,66	0,38...0,76	0,50...0,91
R2	0,52...0,83	0,55...0,89	0,61...0,96	0,70...1,08	0,85...1,26
R1		0,34...0,88	0,39...0,74		
R2		0,62...0,96	0,69...1,04		
R1		0,48...0,82	0,56...0,91		
R2		0,76...1,10	0,86...1,21		

WC1/WC2	R1
WG04/08/08	R2
WC1/WC2	R1
WG10	R2
WC3	R1
WG04/08/08	R2
WC3	R1
WG10	R2

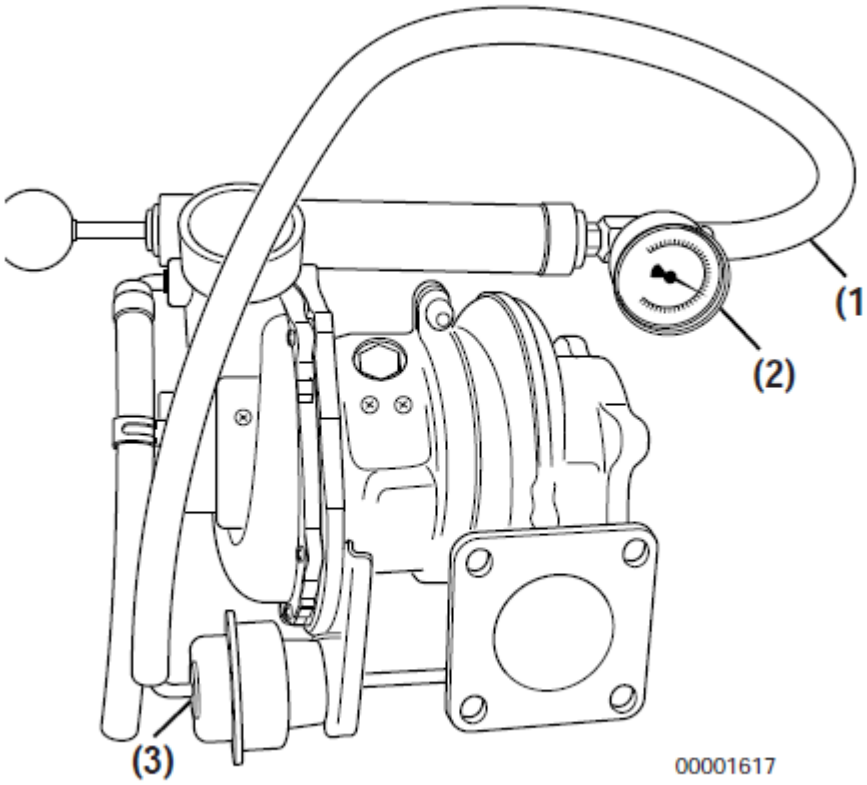


Figure 10-6

Checking Fuel Injection Timing

Note: Some fuel may drain from the fuel injection pump during this process. Make provisions to contain any such spillage.

1. Turn off the fuel valve in the fuel supply hose and the fuel return hose.
2. Clamp shut the fuel injection pump fuel return hose leading to fuel filter **(Figure 7-41, (1))**.

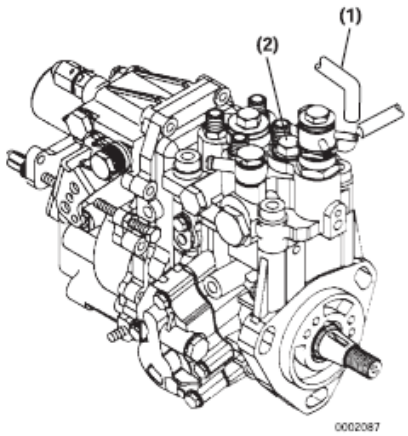


Figure 7-41

IMPORTANT

Clean the top of the fuel injection pump to prevent any contamination when the fuel injection pump plunger plug is removed.

3. Remove the forward fuel injection pump plunger plug **(Figure 7-41, (2))** on the top of the fuel injection pump.
4. Install a dial indicator adapter and clamp into the pump plunger opening.

Note: Use the Yanmar part no. 158090-51831 M14 adapter for the MP2 fuel injection pumps (TNV82 - 88 model engines) or Yanmar part no. 158090-51841 for the M16 adapter used on the MP4 fuel injection pumps (TNV94 - 106 model engines) and Yanmar part no. 23000-013000 plunger adapter clamp **(Figure 7-42,** (1)).

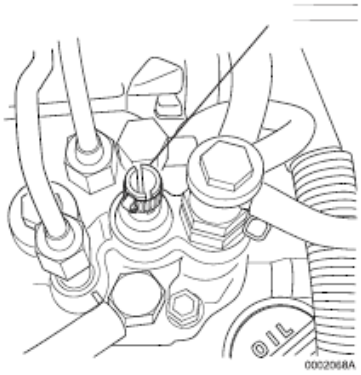


Figure 7-42

5. Install a dial indicator **(Figure 7-43, (1))**, Mitutoyo No. 2050SB or equivalent, with a 30 mm extension, Yanmar part no. 158090-51870 or Mitutoyo No. 303613, into the adapter. Secure with the Yanmar part no. 23000-013000 plunger adapter clamp **(Figure 7-42,** (1)) at approximately the mid-point of its travel.

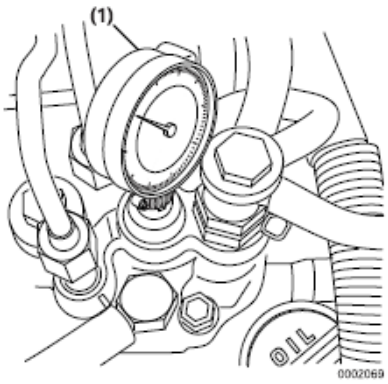


Figure 7-43

Note: The following references to the direction-of-rotation are facing the coolant pump end of the engine and are adjusted by turning the crankshaft pulley.

6. Using a wrench on the crankshaft pulley bolt, rotate the crankshaft in a clockwise direction while looking through the flywheel inspection port **(Figure 7-44, (1))**. Rotate the crankshaft until the injection timing marks on the flywheel are visible.

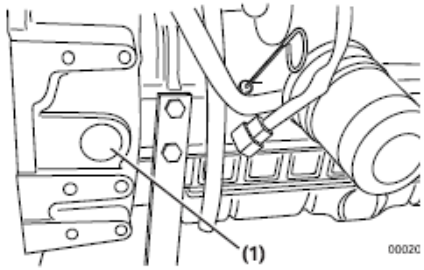
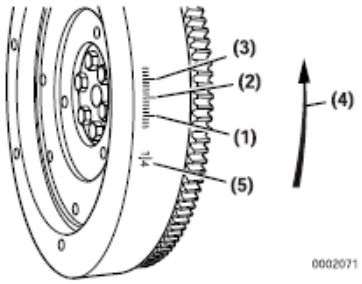


Figure 7-44

7. Typical flywheel markings are as shown in **(Figure 7-45, (1))**.

Note: A typical flywheel will have multiple timing grids depending on the number of cylinders. Any grid can be used to check the fuel injection timing.

The flywheel shown in **Figure 7-45** is for a Yanmar "Standard Specification" DI engine. Flywheels used on some "OEM Specific" DI engines may be marked differently. You should contact that specific OEM for information on the identification of the timing marks.



1 – 10° BTDC (Before Top Dead Center)
2 – 15° BTDC
3 – 20° BTDC
4 – Direction of Rotation
5 – TDC (Top Dead Center)

Figure 7-45

Note: The TDC (Top Dead Center) mark can be identified by the cylinder numbers stamped near the TDC mark on the flywheel.

If you are uncertain as to the timing degree designation of the timing marks on the flywheel timing grid, you can determine the timing degree designation by measuring the timing grid.

- First measure the distance between two of the "longer" marks on the timing grid. (They are 5° apart.) Then measure the distance from the TDC mark to the first "longer" mark on the timing grid. Divide that measurement by the distance between the two "longer" marks. The resulting answer will tell you how many degrees there are between the TDC mark and the first "longer" mark.

- EXAMPLE: If the distance between the two "longer" marks is approximately 2.0 cm and the distance from the TDC mark is approximately 4.0 cm, the answer is approximately 2. This indicates there is 10° (2 x 5°) between the TDC mark and the first "longer" mark on the timing grid. That means the first "longer" mark on the timing grid indicates 10° BTDC, the second "longer" mark indicates 15° BTDC and the third timing mark indicates 20° BTDC. If the answer is 3, that indicates there is 15° (3 x 15°) between the TDC mark and the first "longer" mark and that the first "longer" mark indicates 15° BTDC with the second and third "longer" marks indicating 20° BTDC and 25° BTDC respectively.

8. Highlight the timing reference mark **(Figure 7-46, (2))** on the flywheel housing or engine back plate **(Figure 7-47, (2))**. Highlight the TDC (Top Dead Center) mark **(Figure 7-46, (1))** on the flywheel.
9. Highlight the target timing mark **(Figure 7-47, (1))** on the flywheel as calculated in *Determining the Fuel Injection Timing Specification on page 7-27*.

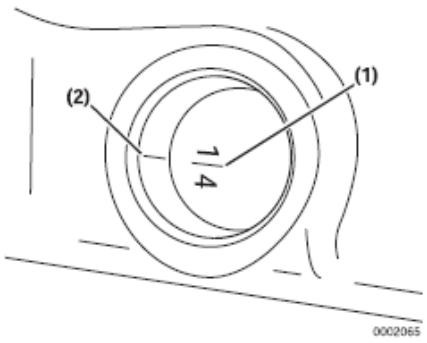
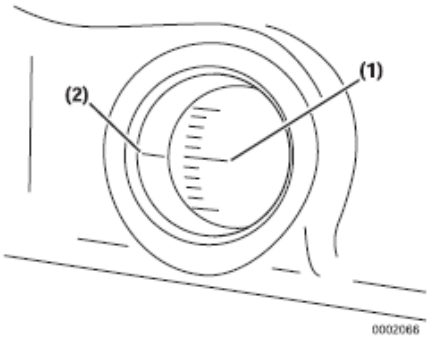


Figure 7-46



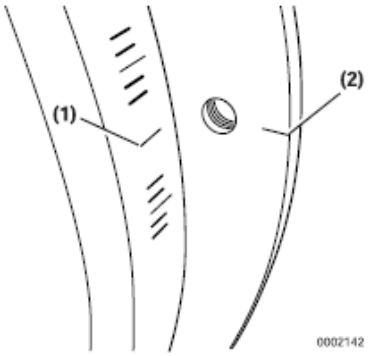


Figure 7-47

10. Rotate the crankshaft counter-clockwise until the dial indicator shows that the injection pump plunger is at the bottom of its stroke. Rock the crankshaft back and forth slightly to confirm a point where the dial indicator shows no movement. Zero the dial indicator.
11. Slowly rotate the crankshaft clockwise until the dial indicator shows a pump plunger lift of 2.5 mm (0.098 in.).
12. Check the position of the flywheel target timing mark (previously determined) **(Figure 7-47, (1))** in relation to the timing reference mark **(Figure 7-47, (2))** on the flywheel housing or engine back plate. If the two marks are aligned, the fuel injection timing is correct. If the marks do not align, the fuel injection timing must be adjusted. *See Adjusting Fuel Injection Timing on page 7-31.*

13. If the injection timing is correct, remove the dial indicator and adapter. Replace the pump plunger plug and its copper gasket and tighten to specifications. Replace the flywheel inspection port cover. Open the fuel supply valve and remove the clamp from the fuel supply hose and the fuel return hose.
14. Prime the fuel system. Operate the engine and check for leaks.

Adjusting Fuel Injection Timing

If the timing marks did not align when performing the *Checking Fuel Injection Timing on page 7-28*, the following steps must be performed to properly time the engine.

1. Leave the dial indicator installed in the fuel injection pump. Do not disturb the reading on the dial indicator.
2. Rotate the flywheel until the target timing mark **(Figure 7-48, (1))** and the timing reference mark **(Figure 7-48, (2))** on the flywheel housing or back plate are aligned.

IMPORTANT

Do not rotate the crankshaft during the remainder of this procedure.

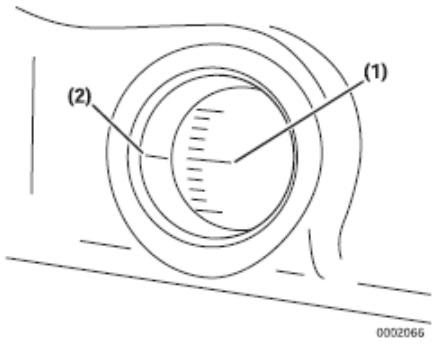


Figure 7-48

3. Note the reading on the dial indicator **(Figure 7-49, (1))**. If the reading is less than 2.5 mm (0.098 in.), the fuel injection timing is "retarded." If the dial indicator reading is greater than 2.5 mm (0.098 in.), the fuel injection timing is "advanced."

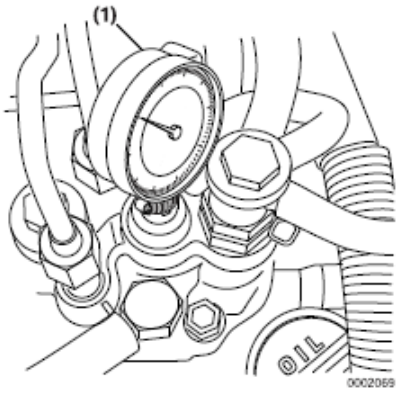


Figure 7-49

Note: Some model engines require the intake manifold and fuel injection pump insulator be removed to access the inner fuel injection pump retaining nuts.

4. Loosen the nuts fastening the fuel injection pump to the gear case or front plate. Loosen the rear bracket(s) on the fuel injection pump.

Note: Loosening the high-pressure injection line nuts on the fuel injection pump may make rotating the pump easier.

5. Rotate the fuel injection pump until the dial indicator reads 2.5 mm (0.098 in.).
6. To "advance" the injection timing, rotate the top of the fuel injection pump away from the engine.
7. To "retard" the injection timing, rotate the top of the fuel injection pump toward the engine.
8. When the dial indicator reads 2.5 mm (0.098 in.) of pump plunger lift and the target timing mark on the flywheel aligns with the reference mark on the flywheel housing or engine back plate, the injection timing is correct.

9. Tighten the fuel injection pump mounting nuts and rear bracket(s).
10. Remove the dial indicator and adapter. Replace the plug in the pump plunger opening and tighten it to specification. If removed, install the intake manifold and pump insulator. Tighten the high-pressure injection line nuts to specification. Open the fuel supply valve, remove the clamp from the fuel return line and prime the fuel system. Operate the engine and check it for leaks.

FUEL INJECTORS

Removal of Fuel Injectors

2-Valve Cylinder Head

1. Close any fuel valves in the fuel supply line.
2. Remove the high-pressure fuel injection lines as an assembly **(Figure 7-50, (1))**.

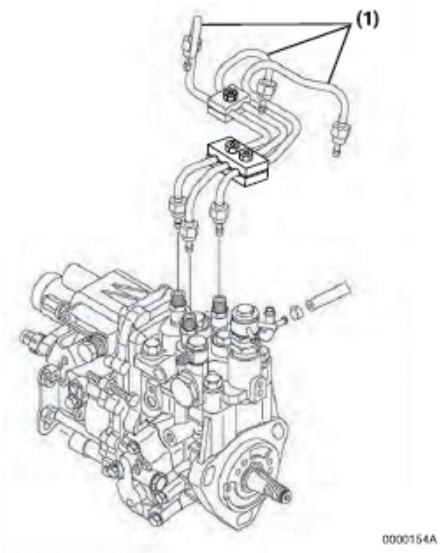


Figure 7-50

Note: To prevent "rounding" the fuel line nuts always use a "line" or "flare nut" wrench. When loosening the fuel line nuts, always hold the fuel injection pump delivery valves with a "back up" wrench to prevent loosening.

- Loosen the fuel line nuts at the fuel injectors and then at the fuel injection pump.

NOTICE

Remove or install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

- Finish loosening all the fuel line nuts and remove the high-pressure fuel lines as an assembly being careful not to bend any of the fuel lines. Be sure to protect the fuel system from contamination by covering all open connections.

3. Remove the return fuel hoses **(Figure 7-51, (1))** from one side of each fuel injector.
4. Remove the bolts and washers that secure the fuel injector retainers **(Figure 7-51, (2))** to the cylinder head.
5. Remove the fuel injector retainer.

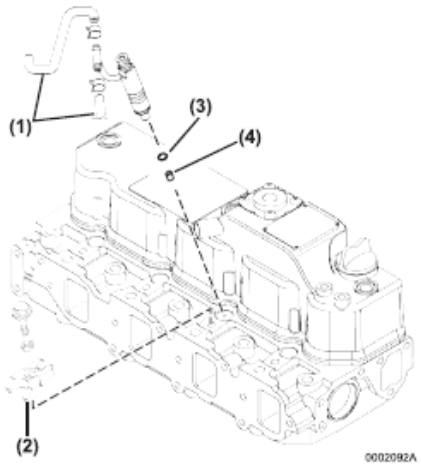


Figure 7-51

6. Remove the fuel injector.

Note: The fuel injectors can usually be removed by manually pulling them out of the fuel injector wells. If the fuel injectors cannot be manually removed, use the fuel injector removal tool, Yanmar Part No. 129470-92305, and a slide-hammer puller **(Figure 7-52)**.

- Attach a slide-hammer puller to the fuel injector removal tool using a 3/8-16 puller rod.

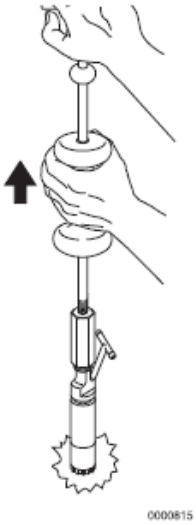


Figure 7-52

- Tap the fuel injector out of the cylinder head using the slide hammer.

7. Remove the injector nozzle protector **(Figure 7-51, (3))** and seat **(Figure 7-51, (4))** from the cylinder head.
8. Repeat the steps to remove the remaining fuel injectors.

4-Valve Cylinder Head

1. Close any fuel valves in the fuel supply line.
2. Remove the valve cover. *See Removal of Valve Cover on page 6-35.*
3. Remove the injector return line **(Figure 7-53, (1))**. Be careful not to bend the line.
4. Remove the fuel injector mounting clamp bolts **(Figure 7-53, (2))**. Lift the injector mounting clamps **(Figure 7-53, (3))** away from injector.
5. Remove the fuel injector **(Figure 7-53, (4))** from the cylinder head.

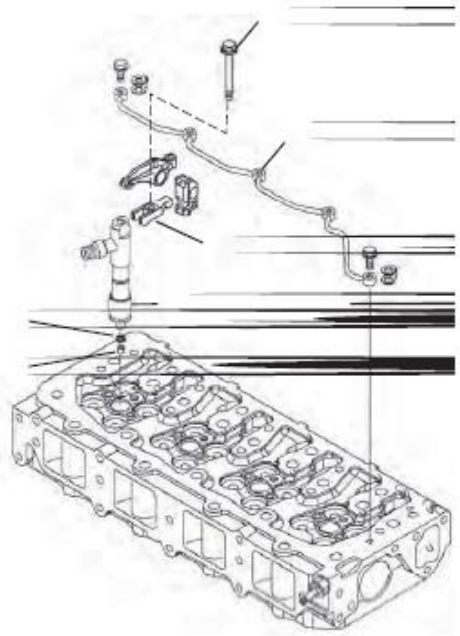


Figure 7-53

Note: The fuel injectors can be removed by manually pulling them out of the fuel injector wells.

6. Remove the injector nozzle protector **(Figure 7-53, (5))** and seat **(Figure 7-53, (6))** from the cylinder head. Discard both items.
7. Repeat steps to remove the remaining fuel injectors.

Testing of Fuel Injectors

NOTICE

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Thoroughly clean the fuel injector nozzle using clean diesel fuel and a brass wire brush.
2. Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean, repair or replace as necessary.

Note: For testing the fuel injector using an injection nozzle tester. Operate the tester following the information provided by the tester manufacturer. Use clean, filtered fuel or FIE calibration fluid for the test.

3. Using the correct adapter, connect a fuel injector to a nozzle tester. Aim the fuel injector into a suitable container to catch the fuel spray.

⚠ WARNING

- **Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.**
- **Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.**

⚠ CAUTION

FLYING OBJECT HAZARD!

- **ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.**
- **Failure to comply may result in minor or moderate injury.**

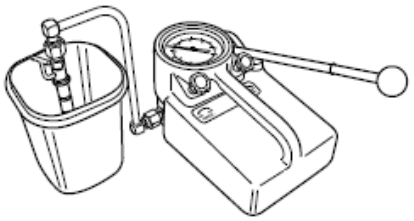


Figure 7-54

4. Pump the operating lever of the tester slowly, observing the pressure reading at the point where the fuel injector begins spraying fuel **(Figure 7-54).**

   See **Figure 7-57** for injector ID location.

   See Test and Adjustment Specifications on page 7-8 for correct pressure readings.

Note: The opening pressure of a new fuel injector will be approximately 725 psi (5 MPa; 51 kgf/cm²) higher than one that has been operated for five hours or longer.

5. Pump the operating lever slowly to hold the pressure steady at a point just below the opening pressure and hold it for 5 seconds. Observe the injector to see that it is sealing properly and is not "dripping". If fuel leaks from the return line fitting, check that the nozzle case nut is tight. Service or replace the injector if fuel continues to leak from either the return line fitting or nozzle.
6. Pump the operating lever more rapidly to repeatedly "pop" the injector and observe the spray pattern. The pattern should be a very fine uniform spray **(Figure 7-55).** If a dripping or an uneven pattern is seen **(Figure 7-56)**, service or replace the injector.

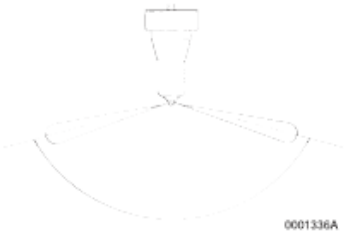


Figure 7-55

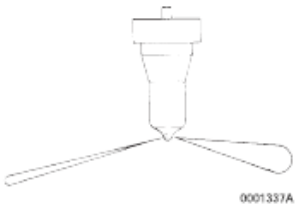


Figure 7-56

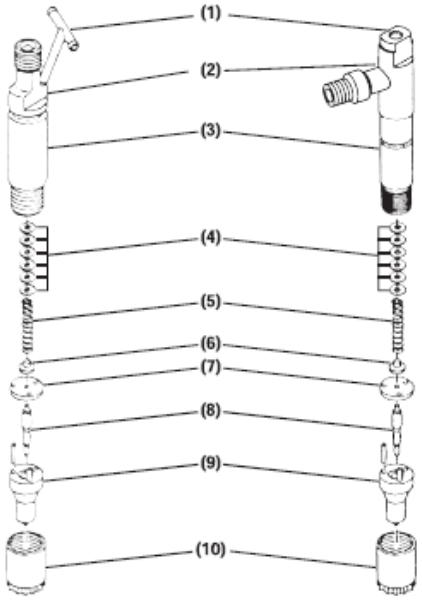
If the fuel injector fails any of these tests, it should be serviced or replaced as necessary. If the pressure is outside specified limits, adjust the pressure. *See Adjusting Fuel Injector Pressure on page 7-37.*

Disassembly and Inspection of Fuel Injectors

NOTICE

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Clean carbon from used injectors using clean diesel fuel. Hardened deposits or varnish can be cleaned using a brass wire brush.



1 – Fuel Return Passage
2 – Injector ID Location
3 – Injector Body
4 – Pressure Adjusting Shims
5 – Spring
6 – Spring Seat
7 – Valve Stop Spacer
8 – Nozzle Valve
9 – Nozzle Body
10 – Nozzle Case Nut

Figure 7-57

2. Place the fuel injector in a soft-jawed vise with the nozzle pointing up.
3. Remove the nozzle case nut.
4. Carefully remove the injector from the vise.
5. Turn the injector over and remove the nozzle body, nozzle valve, valve stop spacer, nozzle spring seat, nozzle spring, and shims.

6. Inspect the sealing surfaces **(Figure 7-58, (2))** between the valve stop spacer and nozzle body for nicks or scratches. Check the contact area between the valve stop spacer and the nozzle valve **(Figure 7-58, (1))** for scoring, or pitting. Use a magnifier glass to inspect the area.

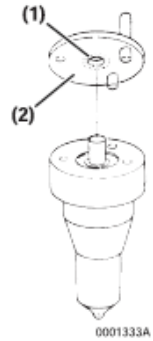


Figure 7-58

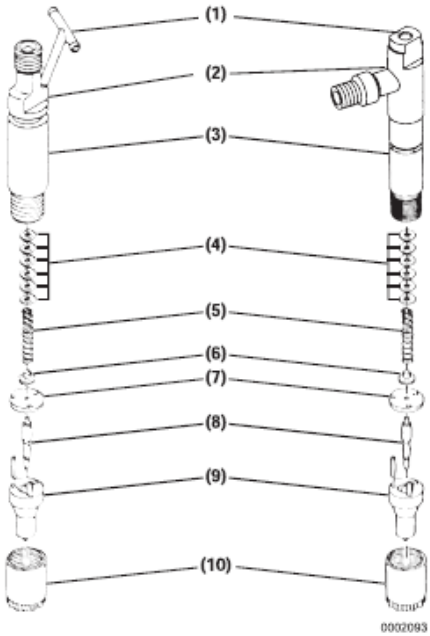
7. Perform a nozzle valve slide test:
   (a) Wash nozzle body and valve in clean diesel fuel.
   (b) While holding the nozzle body vertical, pull the nozzle valve about 2/3 of the way out **(Figure 7-59)**.
   (c) Release the valve. It should fall smoothly to its seat by it's own weight.

Figure 7-59

8. Replace the fuel injector assembly if it fails any inspection.

Adjusting Fuel Injector Pressure

The fuel injectors open when pressure reaches a predetermined pressure threshold. They close when the pressure is reduced below that threshold. The pressure threshold can be adjusted by adding or removing shims **(Figure 7-60, (3))**.



1 – Fuel Return Passage
2 – Injector ID Location
3 – Injector Body
4 – Pressure Adjusting Shims
5 – Spring
6 – Spring Seat
7 – Valve Stop Spacer
8 – Nozzle Valve
9 – Nozzle Body
10 – Nozzle Case Nut

Figure 7-60

The injection pressure will change by approximately 275 psi (1.9 MPa; 19 kgf/cm^2) for every 0.1 mm (0.004 in.) in shim thickness.

See the parts catalog for available shims.

NOTICE

Each pressure adjusting shim removed or added changes the pressure threshold by approximately 275 psi (1.9 MPa, 19 kgf/cm²). Adding adjusting shims increases the threshold pressure. Removing adjusting shims reduces the pressure threshold.

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1. Disassemble the fuel injector assembly. *See Disassembly and Inspection of Fuel Injectors on page 7-36.*
2. Remove or add adjusting shims as needed.
3. Reassemble the fuel injector assembly. *See Reassembly of Fuel Injectors on page 7-38.*
4. Retest the fuel injector. *See Testing of Fuel Injectors on page 7-35.* If the injector cannot be adjusted to the appropriate pressure, discard the fuel injector.

Reassembly of Fuel Injectors

1. Secure the injector in a soft-jawed vise with the nozzle end up.
2. Reinstall the shims, nozzle spring, nozzle spring seat, valve stop spacer, nozzle valve, and nozzle body.
3. Reinstall the nozzle case nut. Tighten it to specification. *See Special Torque Chart on page 7-7.*

Installation of the Fuel Injectors

2-Valve Cylinder Head

1. Reinsert a new nozzle seat **(Figure 7-61,** (4)) and nozzle protector **(Figure 7-61,** (3)) in the cylinder head for each injector.
2. Reinstall a O-ring on to each injector body.
3. Reinsert each fuel injector into the cylinder head.
4. Reinstall the fuel injector retainers **(Figure 7-61,** (2)) and torque the retaining bolts to specification.
5. Reinstall the fuel return hoses **(Figure 7-61,** (1)), one on each side of each injector.
6. Reinstall the fuel high-pressure fuel line assembly and tighten the nuts using a "line" or "flare nut" wrench.

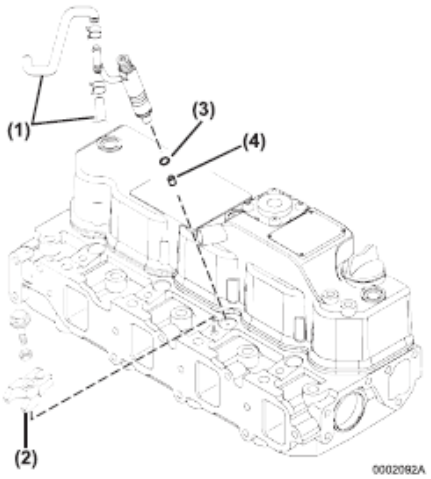


Figure 7-61

7. Prime the fuel system. *See Priming the Fuel System on page 4-18.*
8. Operate the engine and check for fuel and coolant leaks.

4-Valve Cylinder Head

1. Reinsert a new nozzle seat **(Figure 7-62,** (6)) and nozzle protector **(Figure 7-62,** (5)) in the cylinder head for each injector.
2. Reinstall a O-ring on to each injector body.
3. Reinsert each fuel injector **(Figure 7-62,** (4)) into the cylinder head.
4. Reinstall the fuel injector retainers **(Figure 7-62,** (3)) and torque the retaining bolts **(Figure 7-62,** (2)) to specification.
5. Reinstall the fuel injector return line assembly using new gaskets on each side of the injector line screws.
6. Reinstall the fuel high-pressure fuel lines to each injector and tighten the nuts using a "line" or "flare nut" wrench.

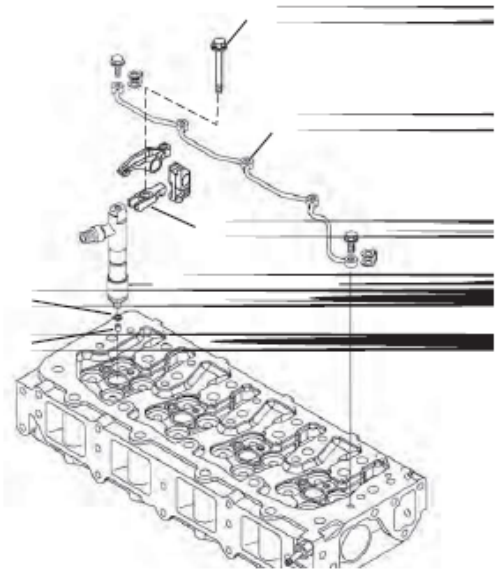


Figure 7-62

7. Prime the fuel system. *See Priming the Fuel System on page 4-18.*
8. Operate the engine and check for fuel and coolant leaks.

Fuel injection system (for a four-valve cylinder head)

The fuel injection system for a four-valve cylinder head is different, not only in the nozzle valve specifications, but also in the nozzle holder specifications. Therefore, it is marked as follows; take care not to install a wrong part when replacing it with new one.

Identifying the fuel injector assembly

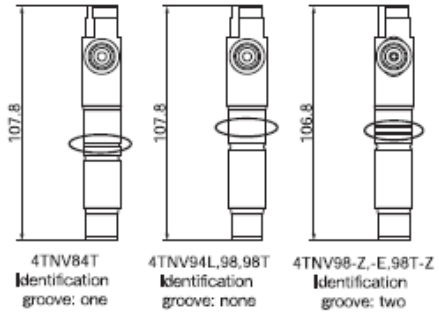


Figure 7-63

Lubricating oil system

■ Oil level checking

Check the oil level with the dipstick. Oil level must be maintained between the upper and lower level marks on the dipstick. Add the recommended oil up to the upper level mark, if necessary.

Service period	Daily (prior to operation)

■ Oil filter deposit draining

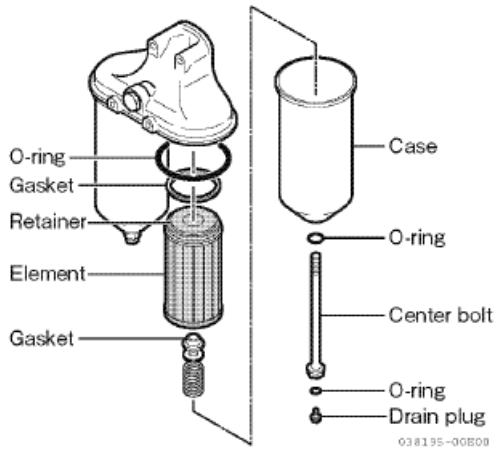
Remove the drain plug from the center bolt of the filter drain water and sediment.

Service period	Every 250 hours

■ Oil filter replacement

Loosen the bolt in the center of the fuel filter and remove the filter case and element.
Replace the element with a new one.
When installing the new element and case, use new O-rings; tighten the center bolt securely.

Oil filter



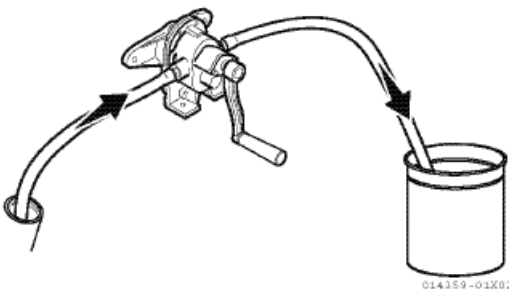
NOTICE

- Before installing the element, clean the inside of the filter case.
- Do not forget to install the spring, retainer, O-rings and gaskets.
- After replacing the element, check for oil leakage during operation.

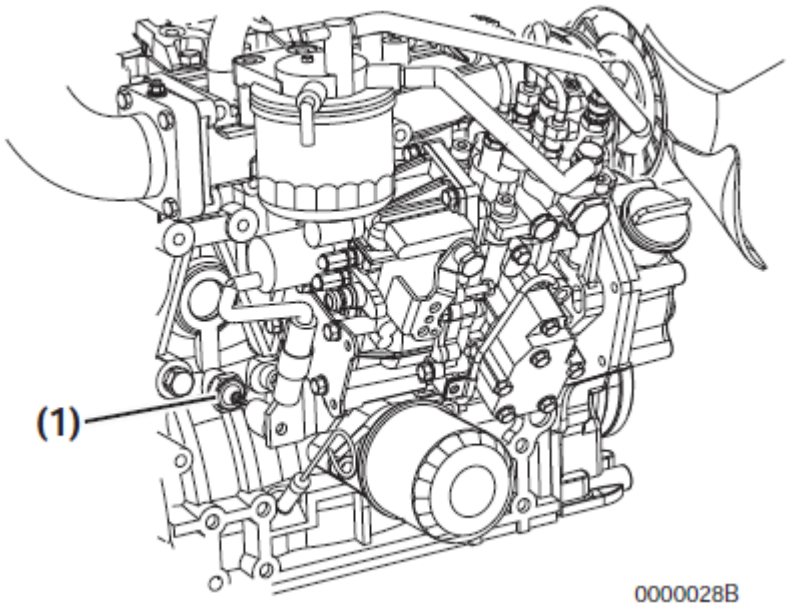
Service period	1st time	50 hours
	2nd time and after	Every 500 hours

■ Engine oil change

Wait for about one to two hours after stopping the engine, connect the end of the rotary pump rubber hose to the oil drain port, and drain oil. Fill the oil pan with recommended oil.



Service period	1st time	50 hours
	2nd time and after	Every 250 hours (Sulfur content 0.5%-1.0%)
		Every 500 hours (Sulfur content ≤ 0.5%)


(1)
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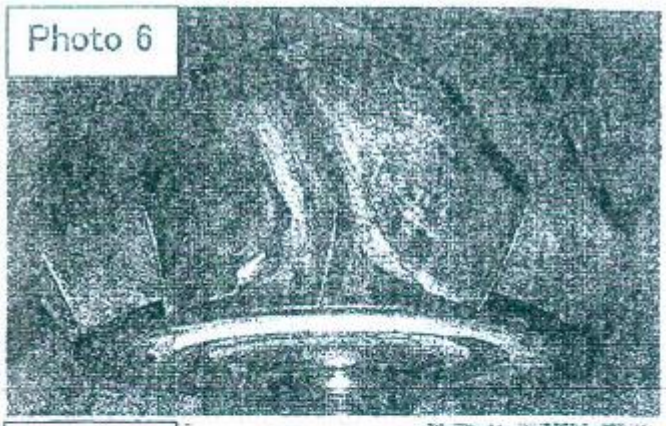


Photo 6

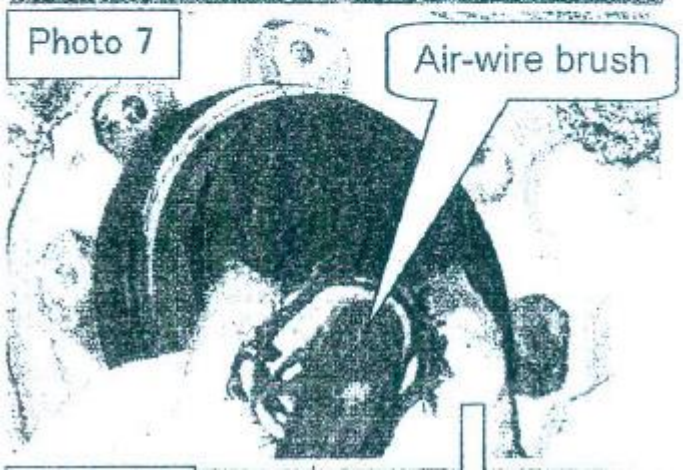


Photo 7
Air-wire brush

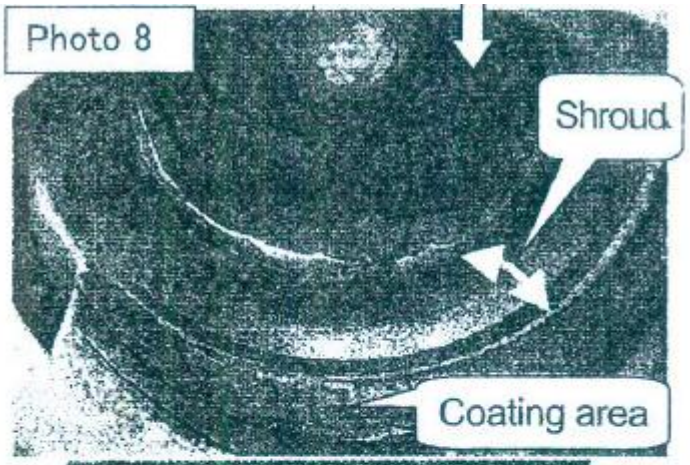


Photo 8
Shroud
Coating area

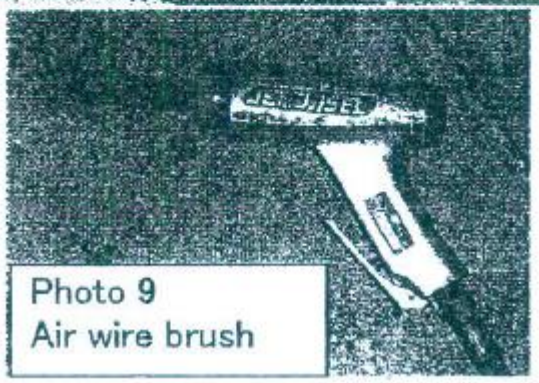
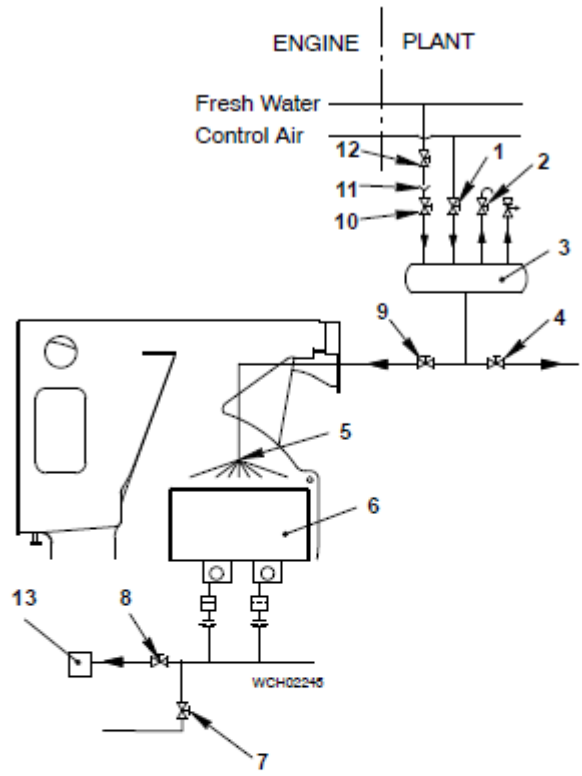


Photo 9
Air wire brush


ENGINE
PLANT
Fresh Water
Control Air
12
1
2
11
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WCH02245
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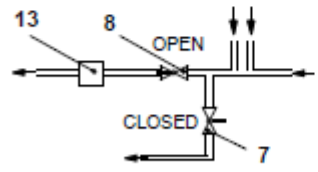
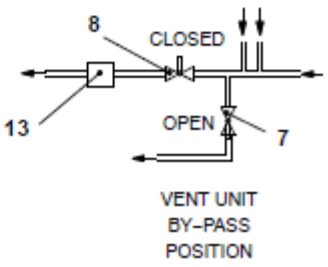

13
8
OPEN
CLOSED
7
USUAL
OPERATION
POSITION


8
CLOSED
13
OPEN
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VENT UNIT
BY-PASS
POSITION

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BIOGRAPHY

The author's name is Robby Rachmat Susilo and was born on June 22nd, 1996 in Jakarta, Indonesia. Born to be the only son derived from a couple with father named Dulimin Bagio and mother named Sudjinah. The author had completed the formal studies at SDI Al-Azhar 8 Kembangan (2002-2008) for elementary school, SMPI Al-Azhar 10 Kembangan (2008-2011) for junior high school, and SMAN 78 Jakarta, Cambridge Curriculum (2011-2014) for senior high school. Graduated from senior high school with additional certificate from Cambridge Curriculum, IGCSE and A-Level. In 2014, the author started to continue the study in Marine Engineering Department of Institut Teknologi Sepuluh Nopember (Double Degree Program with Hochschule Wismar) and specialized in Marine Operation and Maintenance. During the college study, the author had involved as member in student organization, Himpunan Mahasiswa Teknik Sistem Perkapalan ITS and also the Society of Petroleum Engineer ITS. On the second year of college, the author participated in On Job Training Program of PT Dok & Perkapalan Kodja Bahari Jakarta. On the third year of college, the author participated in On Job Training Program of PT. Samudera Indonesia Ship Management as Technical Support of Fleet Department and On Job Training Program of PT. Pertamina Shipping as Technical Support of Technical Fleet I. In final year, the author focused as the member of Marine Operation and Maintenance Laboratory. For further discussion and suggestion regarding to this research, the author can be reached through email stated as below.

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Motto : "No legacy is so rich as honesty"