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ELECTROMAGNETIC COMPATIBILITY AND SECURITY REQUIREMENTS IN THE CONSTRUCTION OF PROTOTYPE, LOW VOLTAGE, RESEARCH DEVICES

Key words

EMC, LVD, designers' testing, conducted emission.

Abstract

The article presents the standards harmonized with the EMC and LVD directives, and procedures leading to the fulfilment of these requirements when designing prototype, research devices. It describes the methods of limiting interferences conducted to the power supply network and ensuring proper impedance grounding. This article also shows the necessity to analyse all the problems which may arise in connection with the EMC and LVD directives at the design stage as well as the need to conduct the designers' testing during the construction of equipment.

Introduction

At the concept stage of developing a new device, designers should bear in mind that this device is intended to operate in a certain electromagnetic environment in which it can be neither a source of danger to other objects, nor too susceptible to the common unwanted effects occurring in this environment. Considering the problems of EMC should be an integral part of the design of any electronic device or circuit. It is justified from the economic perspective. Making changes related to the EMC on the finished product is not cost-effective. The device should be constructed in such a way that the levels of emitted disturbances – the conducted and radiated ones – were lower than the so-called acceptable levels specified in technical standards.

All equipment should be tested in accordance with the harmonized standards of the EMC Directive (Electromagnetic Compatibility) and LVD (Low Voltage) in order to confirm that they meet the requirements contained in these standards. One of the tests for compliance with the EMC Directive, which is mentioned in the article, is the test for disturbances conducted to the power supply in the range of 150 kHz to 30 MHz. Another study describes the measurement of radiation emitted through the power cord in the range from 30 MHz to 300 MHz. These studies are very important, because they record the disturbances generated by equipment that may have an impact on the environment and the work of other devices powered within the same network. One of the key tests for compliance with the LVD is to measure the impedance grounding of all metallic elements available to the user.

1. Requirements related to testing in accordance with the EMC and LVD directives

1.1. The study of conducted emission

The study of conducted emission spectrum is the study of the interference emitted from the power cord to the power supply network in the range of 150 kHz to 30 MHz. Such disturbances may have an adverse impact on other devices connected to the same power supply network. The process of research is described in the PN-EN 55011 [1] norm. It determines the acceptable levels of interference that a device can emit to the power supply network. Depending on the environment in which the device operates, there are two limits. For equipment intended for use in a light industry and home environment, these limits are more restrictive than for the industrial environment. For that reason, it is important to know the purpose of the device beforehand.

Table 1. Disturbance limits for the devices in the light industrial and domestic environments [1, 2, 3]

Frequency range MHz	Limits for the quasi-peak dB (µV/m)	Limits for the average value dB (µV/m)
from 0.15 to 0.5	**66** Decreases linearly with the logarithm of the frequency up to **56**	**56** Decreases linearly with the logarithm of the frequency up to **46**
from 0.5 to 5	**56**	**46**
from 5 to 30	**60**	**50**

Table 2. Disturbance limits for the devices in the industrial environment [1, 2, 3]

Frequency range MHz	Limits for the quasi-peak dB (µV/m)	Limits for the average value dB (µV/m)
from 0.15 to 0.5	79	66
from 0.5 to 30	73	60

During the measurement of interference voltage, the tested object has an unspecified resistance to interference source. Therefore, the voltage measurement may be defined only when it is measured at a specified load resistance. For this purpose, the measured object is connected with an "artificial" network, which represents a defined load resistance for a disturbance value. Additionally, it connects the test object with both the power supply network and measuring device and separates it from interference that could arise from the power supply network. The artificial networks, which are connected with the supply network at a given frequency, should have the least possible voltage drop. The value of the supply voltage cannot be less than 95% of the nominal value. The measured voltage value is also dependent on the environment in which there is the tested object. The interference produced by other interference sources (existing in the supply network or induced by external electromagnetic fields) should be at least by 20 dB lower than the lowest expected interference voltages generated by the tested device. In order to meet these requirements, the test stand consists of a measuring receiver, an artificial network, and a Faraday cage minimizing external interference, in which the test is carried out. The tested device is connected to the supply network with a cable with a length of 80 cm or longer but coiled to such a length. The measurement is carried out on both power supply bolts (the phase and neutral conductor.) During the test, the device should work as it is intended to operate nominally.

1.2. Examination in accordance with the LVD Directive

The requirements of the harmonized standards of the Directive on electrical equipment designed for use within a specified voltage range („low voltage devices") are determined to increase the safety of devices. The standards distinguish between the following types of threats:

– Electrical hazards include those associated with the possibility of a dangerous voltage on the housing of the device or the possibility to access to the components under dangerous voltage. The main issue connected with this threat is to ensure the proper circuit of protective grounding covering all accessible conductive parts of the device. Another issue is to ensure proper isolation of individual circuits.

- Mechanical hazards include those associated with the stability of equipment, the strength of the housing shielding components under dangerous voltage, or the risks arising from too sharp edges of the device.
- Thermal hazards include those resulting from excessive heating of the sub-assemblies of the device.
- Chemical hazards and others should also be distinguished.

2. The sources of interference

The main sources of interference in devices are the following:

- Fast switching power transistors and outputs with pulse width modulation (PWM) in different types of devices can produce rapid changes in voltage generated by them causing electromagnetic interference (EMI). There are two main types of EMI: conducted EMI (with a frequency range of 150 kHz – 30 MHz), caused by unwanted flow of energy through wires and connectors, and radiated EMI (30 MHz – 1 GHz), which is the result of wave propagation in space.
- Electromagnetic coils (contactors, relays) emitting magnetic field can cause interference.
- Electrical connectors generating distortion in the form of an electrical arc occurring at the contact points when switching can cause interference.

3. Ways to reduce interference

In order to suppress the unwanted emissions in the power lines and data transmission lines, it is necessary to use filters. The attenuation of filter depends on the source and load impedance. Manufacturer data are usually given for the source and load impedance equal to 50Ω, while the actual impedance is variable and largely dependent on the frequency range. Therefore, the filter selection by calculation is very difficult. Therefore, it is often made experimentally by measuring the attenuation of different filters in a given device.

Another very important issue is to provide a low impedance of connection with filters and screens' grounding. Grounding is probably the most important, but also the least understood aspect of interference. Grounding connections are often made without regard to the impedance of the grounding conductors for the required frequency range. This can result in decreased performance of the shielded housing, the shielded cable, or filter.

Proper cable routing is another very important aspect of EMC. It is common that the low-voltage signal cables are run together with an output power cable, which has a signal of several hundred volts from the PWM generator. As a result, each conductor within the system is a transmitter or receiver of interference.

In order to minimize interference, here are some recommendations:

a. Apply a broadband filter.
b. Use anti-overvoltage elements for all coils.
c. For the connections between the motor and the frequency converter, only a dedicated cable, recommended by wiring manufacturer, should be used.
d. Use pair-twisted cables and apply shielding to all cables carrying low voltage signals to prevent interference from power circuits such as motors and relays.
e. Increase the distance between the wires belonging to different circuits and limit the length at which the wires are arranged next to each other.
f. Do not create loops – use a single grounding point.
g. Equalize conductive potential of the housing of a device with a cable having small resistance.
h. Separate the measurement and control cables from the power and motor cables. Cables from different groups should be placed at right angles.
i. Use separating transformers and, if necessary, signal filters on power lines to impede the transfer of interference to other devices.

4. Consultation and designers' testing

All electrical equipment should be tested for compliance with the EMC and LVD directives before being released to the market. However, in the event of any inconsistency, it is necessary to, e.g., rebuild the device, or introduce modifications in the power supply system. Some discrepancies can be eliminated at the design stage of the device. While developing the design drawings, special attention should be paid to proper grounding of all metallic elements by attaching ground-prongs to them. Designing suitable shields helps to separate the user from the elements under tension. As for the creation of electrical schematics, it is very important to select proper electrical protection (e.g. overcurrent circuit breakers, differential switches). At this stage, the project of control cabinets is also very important. The appropriate cabling eliminates the possibility of interference emitted by power cables influencing the cables with the measuring signals. In consequence, the possibility of distortion of the measurement results is reduced. Both the proper selection of electrical equipment in the control cabinet and the use of appropriate cables have an impact on unwanted emissions and the resistance of circuits to the outside disturbance. However, it must be remembered that the applied components, even though they may have the CE label indicating that the device is safe for others and resistant to interference, in conjunction with other electrical components may no longer meet the requirements of the EMC directive. Therefore, if possible, it is advised to conduct designers' tests during the construction of the device. Such tests allow for early detection of potential non-compliance with the EMC and LVD standards and provide an opportunity to reduce the risk of a delayed product release (e.g., by having to wait for the elements needed for reconstruction, modernization or reduction of interference emitted by the device).

A climatic chamber was subject to such tests. The chamber is designed for a light industry environment. For that reason, the red lines on the graphs show the limits of acceptable interference according to Table 1. The test indicated that the interference emitted to the network exceeded acceptable levels. The result is shown in Figure 1. The blue line shows the quasi-peak value of conducted interference, while the black one shows the average value of conducted interference. For each peak exceeding the permissible level, the measurements were taken. They are presented in Table 3. The table illustrates the frequency at which the exceeding value has been recorded. The next section illustrates the level and the value by which the allowed limit was exceeded. After analysing the power supply system, it was concluded that the cause of the interference was the drive system of the pump powered by frequency inverter.

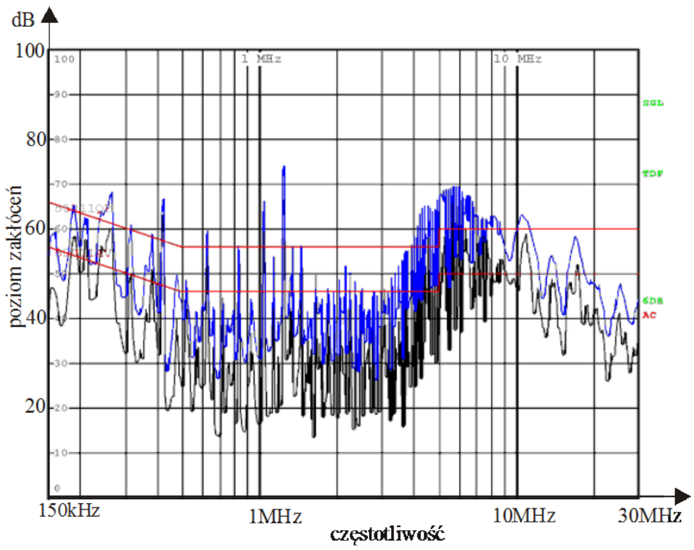


Fig. 1. The test results of climatic chamber

In order to reduce the interference it was decided to apply a filter. A number of studies with different filters mounted on the input of the device were conducted. Figure 2 shows the attenuation of the selected filter. It allowed for the reduction of interference in the whole measurement band. It is well illustrated by contrast with Fig. 3 that shows the interference emitted from the device with the line filter.

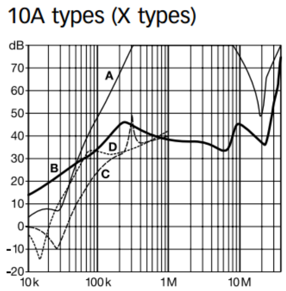


Fig. 2. Attenuation of the line filter FN 2310x-10-06 [4]

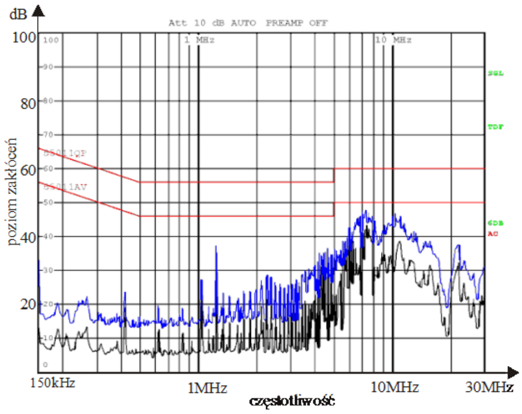


Fig. 3. Interference of the climatic chamber with the line filter

Another device that was subject to studies was a document tester. This device was designed for use in light industry. Therefore, the limits were set according to Table No. 1. Although the device was equipped with a line filter built into the power cable connection, this study showed that the permissible level was slightly exceeded and three out of four peaks were within the margin of measurement error. The results are shown in Figure 4 and Table No. 4.

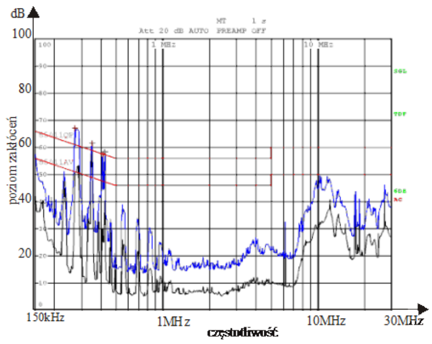


Fig. 4. Studies results

It was decided to reduce the interference so that the results did not raise any doubts. After analysing the construction of the device, it was assumed that the potential source of interference is a switching power supply used for the measuring system. Next, the level of interference, caused by the switching power supply under load, installed in the tester, was tested. Then different power supplies were subject to the same test in order to select the most appropriate one. The results are shown in Figure 5. Figure 5a) illustrates the power supply that was placed in the tester.

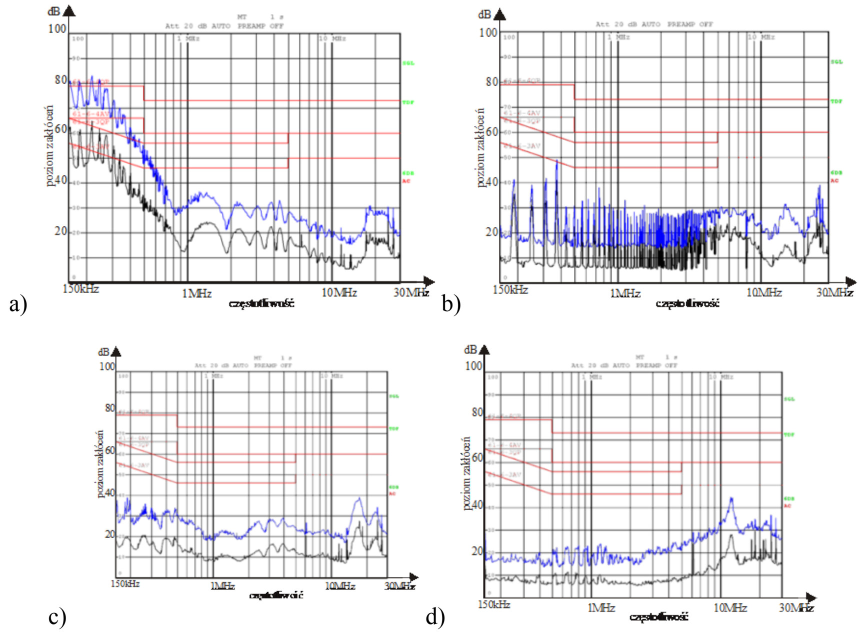


Fig. 5. Emission levels of power supplies a) the power supply installed in the tester, b), c), d) other

After analysing the test results of the power supplies, it was decided to replace the faulty power supply with a new one whose chart showing conducted disturbances is shown in Figure 5c. After re-examining the device with the new power supply, it was observed that one peak exceeds the acceptable level of 5.55 dBμV as shown in Figure 6 and Table No. 5.

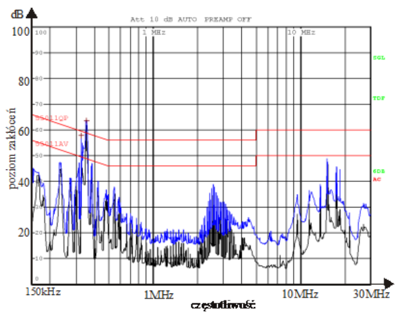


Fig. 6. The test result conducted on the tester with a new power supply

Different possible solutions were analysed with a view to minimize this peak. It was decided to add another filter that would reduce these distortions. Figure 7 shows a graph of interference obtained by testing the tester with the exchanged power supply and the added line filter.

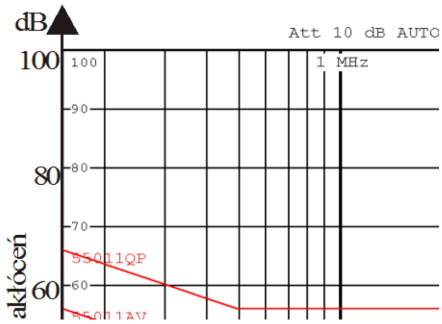


Fig. 7. The test result conducted on the tester with the new power supply and the added line filter

In the studied tribological tester, the emitted disturbance (Fig. 8) exceeded the levels in almost the entire frequency range.

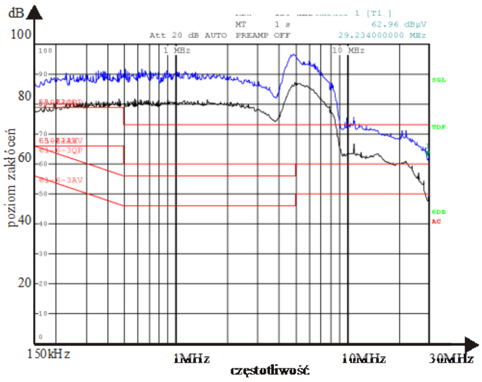


Fig. 8. The test results of the tribological tester

The reason for this situation was improper routing of the engine power cables. The drive was powered by the voltage transformer located in the control cabinet. The device was also equipped with a fan powered from the same control cabinet. In order to reduce the power supply connectors of both drives, one cabtyre, shielded cable was used. Since the cables connecting the transformer and the engine emit strong interference, they should be separated from other circuits by placing them in an isolated shielded cable where the shieldings must be connected directly to the transformer and motor. In this case, the interference from these wires strongly influenced the fan power cables. What is more, it returned to the power supply system causing high disturbance. Figure 9 illustrates the entry of the engine power cables together with the fan power cables.

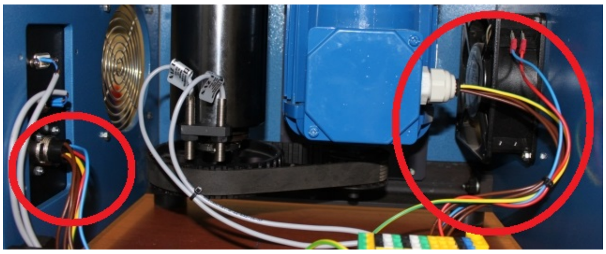
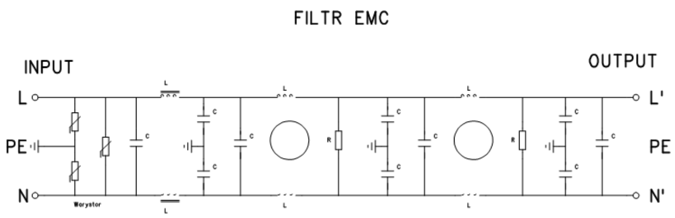


Fig. 9. Improper wiring of fan and motor power supply cables

The recommendation for the contractor was to rebuild the device by separating the circuits powering the motor from the other circuits.

During the construction of the sources of magnetron, it was decided to examine the high voltage power supply that was a potential source of interference. The test results indicated that a filter is necessary to reduce the disturbance produced. A number of filters available on the market were examined, but none of them limited the interference to the acceptable levels. It was decided to build a new filter. Filtering performance tests were conducted for each combination of the individual filter elements. The result was a broadband filter that reduced the disturbance level even below the acceptable level. The schematic diagram of the filter is shown in Figure 10. Figure 11 illustrates the levels of unwanted emissions generated by a power supply a) without a filter, and b) with a filter.



Rys. 10. The schematic diagram of a filter build for the power supply of magnetron sources

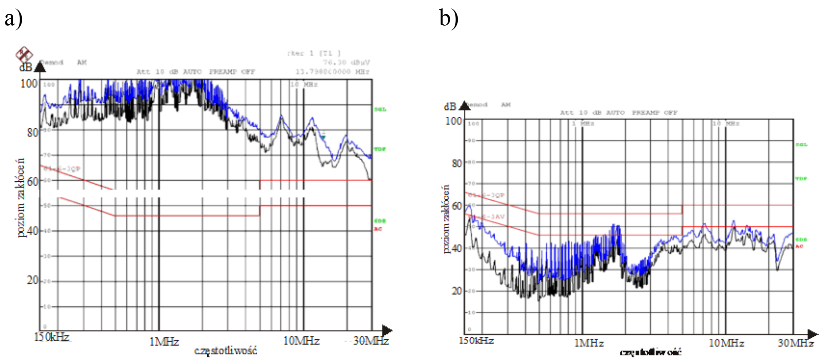


Fig. 11. Test results conducted on a power supply a) without a filter, and b) with a filter

4. Proper grounding of metal parts

Another important issue to bear in mind at the stage of designing the device is suitable grounding of all metal parts of the device including, in particular, housing. If the housing is metal, it should be connected by a protective conductor with the rest of the device as shown in Figure No. 12.

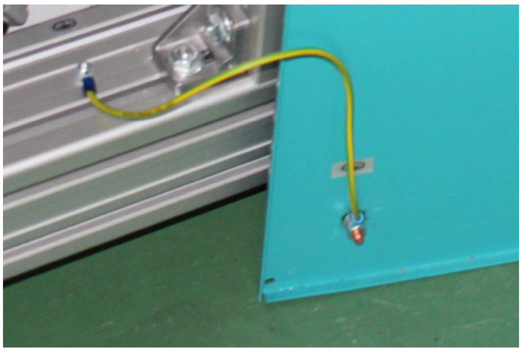


Fig. 12. Proper grounding of a metal housing

Lack of such connections puts the user at risk of electric shock in the event of failure. Such a device does not meet the requirements of the Low Voltage Directive (LVD). Making these connections when the device is ready can cause damage to the coating and the need for repainting some parts of the housing.

5. Conclusions

All electrical apparatus should be safe for the user, it should not interfere with other devices, and it must be resistant to interference coming from, e.g., the power supply system or from the outside. Designers' testing allows for the early detection of defects in the tested devices and gives the possibility to introduce improvements at the stage of construction. At the stage of designing the equipment, a proper grounding of metal parts needs to be considered and properly designed grounding pins must be planned. While creating wiring diagrams, appropriate components should be selected, the risk of interference should be estimated to consider the need for a filter. It is also very important to lead the wires and cables in the device properly and to separate the power supply circuits from the measurement systems. The above examples show that the prior consultation and designers' tests enabled saving time and the possible costs of upgrading, since there is a need to dismantle the device into components or to redevelop it in order to replace a faulty element. If the finished product is tested in an accredited laboratory, the manufacturer bears the cost of re-testing of the device in case of the need of upgrading the equipment. This, in turn, is often associated with the necessity of waiting for the next test.

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References

1. PN-EN 55011:2012 Urządzenia przemysłowe, naukowe i medyczne – Charakterystyki zaburzeń o częstotliwości radiowej – Poziomy dopuszczalne i metody pomiaru.
2. PN-EN 61000-6-3:2008P Kompatybilność elektromagnetyczna (EMC) – Część 6-3: Normy ogólne – Norma emisji w środowiskach: mieszkalnym, handlowym i lekko uprzemysłowionym.
3. PN-EN 61000-6-4:2008P Kompatybilność elektromagnetyczna (EMC) – Część 6-4: Normy ogólne – Norma emisji w środowiskach przemysłowych
4. Karta katalogowa SCHAFFNER: SINGLE-PHASE CHASSIS-MOUNTING FILTER FN 2310. www.schaffner .com
5. Duzinkiewicz K.: Wizualizacja wyników pomiarów w otwartym systemie pomiarowym zaburzeń przewodzonych i promieniowanych EMC, PAK, 2011, vol 57, nr 7, s. 717–720.
6. Sroka J.: Niepewność pomiarowa w badaniach EMC. Pomiary emisyjności radioelektrycznej. Oficyna Wydawnicza Politechniki Warszawskiej, 2009.

Wymagania kompatybilności elektromagnetycznej i bezpieczeństwa niskonapięciowego w konstruowaniu prototypowych urządzeń badawczych

Słowa klucze

EMC, LVD, badania konstruktorskie, emisja przewodzona.

Streszczenie

W artykule przedstawiono wymagania, jakie są zawarte w normach zharmonizowanych z dyrektywami EMC oraz LVD, oraz drogi prowadzące do spełnienia tych wymogów w aspekcie projektowania prototypowych urządzeń badawczych. Opisano sposoby eliminacji zakłóceń przewodzonych do sieci zasilającej oraz zapewnienia właściwej impedancji uziemienia. Uzasadniono konieczność przeanalizowania na etapie projektowania problemów wynikających z dyrektyw EMC i LVD oraz słuszność przeprowadzania badań konstruktorskich z powyższych dyrektyw w trakcie budowy urządzeń.