Understanding of intrinsically safe systems as an end user in ship’s hazardous areas

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Abstract. Proper maintenance of the explosion protected equipment and systems on ships requires special knowledge and skills. It is worth to underline that the explosion protection properties of electrical equipment are generally different from the functional ones. It means that the electrical explosion protected equipment can lose its explosion protected properties and can still work because its functional side is in a good condition and vice versa (only for intrinsically safe solution). From the safety perspective the intrinsically safe measurement line fulfils safety requirements, but from the functional one it can introduce some additional measurement errors. To avoid such situations, the new course under discussion is proposed. The course gives a possibility to improve crewmembers’ skills, especially for intrinsically safe solutions.

1. Introduction
Ships and mobile offshore units are a specific type of industrial installation compared to ashore industry. This problem is more complicated for installations in potentially explosive areas, hereinafter referred to as hazardous areas. Risk of explosion exists due to use of flammable materials for ongoing operation, maintenance as well as their transport in large quantities, sometimes also while processing. It is mandatory to have explosion-proof equipment installed in hazardous areas. Proper maintenance of explosion-proof electrical equipment during long time of operation is a special challenge for an ETO (Electro-Technical Officer). This role requires special training, much wider than according to the requirement for ETO set in the STCW (Standards of Training, Certification and Watchkeeping for Seafarers) convention [1, 2].

2. Type of the electrical equipment explosion protection
Electrical equipment can be built according to different IEC recognized explosion-protection methods [3]. For gas hazard, they are: d - flameproof enclosures, p - pressurized enclosures, q - powder filling, o - oil immersion, e - increased safety, i - intrinsic safety, n - protection n, m - encapsulation, op - optical radiation. For dust hazard they are, respectively: tD - protection by enclosure, pD - pressurisation, iD - intrinsic safety and mD - encapsulation.

It is also worth to mention that in some regions of the word the approach to explosion protection is a bit different, e.g. in North America.

For instrumentation, measurement and automation intrinsically safe solution is the most popular as an explosion protection method [4, 5].

3. Intrinsically safe technology
According to the intrinsically safe technology there are separately classified: self-contained intrinsically safe apparatus, intrinsically safe apparatus designed for being connected to other devices and associated apparatus. The self-contained intrinsically safe apparatuses are most often portable, e.g. measurement devices or communication devices.

Usually, the intrinsically safe technology is used for wide area measurements and controlling systems, where there occurs a necessity of connecting an apparatus in the hazardous area with devices in the safe area by cables. Such mutual connecting of intrinsically safe apparatuses
creates an intrinsically safe system (figure 1). In this situation, the intrinsically safe apparatus in the hazardous area has to cooperate with the apparatus in the safe area, in which the circuits are partially intrinsically safe. The apparatus in the safe area is called an associated apparatus [5]. The concept of intrinsically safe technology consists of two aspects.

The first one means designing and finally certification of intrinsically safe apparatus. These processes are very sophisticated and adequate requirements are provided in the standards series IEC 60079 [3] while the details are given by the standard IEC 60079-11 [4]. As a result, producers and vendors offer individual apparatuses, which are certified as intrinsically safe and which can be used for different purposes.

The second one concerns use of ready, certificated intrinsically safe apparatus to design industry instrumentation, measurement or automation systems in hazardous areas. That approach is most often used to build intrinsically safe long distance measuring and control line, typical for ships' monitoring and automation systems.

4. Influence of intrinsically safe solution on metrological properties of long distance measurement lines

End user of explosion-proof equipment is essentially interested in ensuring that installation in hazardous area is safe but it has to be also functional. To achieve both conditions, especially for long distance intrinsically safe installation, it is necessary not only to assess the intrinsically safe system itself, but also to take under consideration the influence of associated apparatus on the functional property of this intrinsically safe installation.

5. Dedicated course to improve knowledge and skills related to maintenance of electrical equipment in hazardous areas

In order to make understanding of maintenance of electrical equipment placed in ships' hazardous area easier the course was divided into two parts [6]. The first one is a theoretical lecture where participants are introduced with all the aspects related to explosion protection technology. The lecture (about 15 hours) gives the students an opportunity to understand better the physical phenomena related to the subject and acquire theoretical knowledge in the fields [3, 6,
7, 8, 9, 10]: physical conditions of explosion; selected parameters of dangerous goods; classification of explosive atmospheres (explosive groups and temperature classes); classification of ships’ hazardous areas (zone classification); types of explosion protection; intrinsically safe protections; certification and marking; constructional, selection and installation requirements; repair and maintenance (spare parts, instrumentation, tools, records); differences between various approaches to explosion protection dependent on the region of the world.

The aforementioned lectures will be extended by laboratory activity in a form of workshops, being in fact a practical familiarization with intrinsically safe aspects of industrial long distance measurement and control line. During the workshops participants are trained in two aspects.

The first one concerns selection of intrinsically safe apparatus to comply with intrinsically safe measurement or control system requirements. The participants practise following adequate technical data sheet and explosion-proof certificates. During that process the students improve competency in reading and understanding adequate safety parameters given in certificates. Finally they assess according to IEC 60079-25 [5] the safety level of the whole intrinsically safe system standard and calculate the maximum admissible length of cables which can be used.

The second part concerns unique approach to the functionality of measurement or control of intrinsically safe line. The functional properties are identified for normal working conditions. During the workshops the participants make practical checks of different parameters or characteristics of some apparatuses depending on a kind of the measurement line under consideration [11, 12, 13, 14]. To estimate functional properties of measurement line sometimes it is enough to know adequate technical data from catalogue or data sheets but in many cases it is necessary to make special experimental checks because adequate technical data is not available.

All the above practical skills can be trained based mainly on intrinsically safe solution of:

1. Measurement lines in standard 4-20mA with passive or active Zener barrier, where the influence of end to end resistances of Zener barrier is checked, eg 400 Ω.
2. Measurement lines in standard 4-20mA with galvanic separator, for separators of different vendors, equivalent parameters are pointed out which have to be known for proper designing of IS measurement line under consideration. As the results the equivalent input parameters are different. It shows that replacing galvanic separators from different vendors can result in generating additional measurement error.
3. Measurement of temperature by Pt-100 sensors with passive Zener barrier, where influence of end to end resistances of Zener barrier is checked. As a result an additional error can occur (or not) for the same sensor and Zener barrier, depending on the type of connection and PLC card.
4. Measurement of temperature by TC elements (thermocouples) passive Zener barrier. As a result an additional error can occur (or not) for the Zener barrier, depending on the type of equivalent circuit of the PLC card or other measurement devices.
5. On-off measurement lines with separator and checking of connection cable according to NAMUR standard (proximity switches), where parameters of equivalent input circuit of the dedicated associated apparatus of different producers are pointed out and compared. In that case, opposite to 4-20mA separators, all input characteristics have to be similar and fulfil the standard requirements.
6. Control of solenoid valve via separator, where input characteristics of associated apparatus are pointed out to be checked with technical data. It finally gives a possibility of understanding the proper selection of the separator for the solenoid valve.
7. Electric equipment in Exe, Exd, Exn, Exm, Exq protection. In that exercise the parameters of explosion protection other than intrinsically safe solution are observed and compared with standard requirements.
During the exercises the students will practice completing different input and output lines using original factory equipment with the corresponding attests. In Gdynia Maritime University there is a laboratory appropriately equipped with the necessary instrumentation related to in the discussed subject. The basic equipment of the laboratory consist of the original ships' monitoring system in a basic version from Kongsberg (previously Norcontrol), some transducers (from Autronica, Rosemount, Emerson, Trafag) and another elements of measurement lines like separators, Zener barriers (from MTL, Stahl, Turck). It is worth to add that during the workshops the participants also have a possibility to get familiar in practice with explosion-proof protection other than intrinsically safe solutions.

6. Summary
At all kind of ships there is installed electrical explosion-proof equipment. Ships used for transport of huge quantities of flammable goods are additionally equipped with the most sophisticated intrinsically safe apparatuses used for monitoring and automation. Maintenance of these installations is a responsibility of ETO's, who as the end users, should not only understand selection of the adequate apparatus according to the safety criteria but also they should be familiar with influence of the safety solution on the functional properties.

At Gdynia Maritime University (Poland) a dedicated course for future ETOs was introduced. This course includes adequate lecturing program and practical activities in a dedicated laboratory in form of workshops. Development of that course was supported by IAMU (International Association of Maritime Universities) project FY-2004-18 “Exploitation of electrical equipment in ship hazardous areas”. Program of that course was distributed to the 21 Maritime Universities worldwide (members of IAMU). The course is currently updated following new IMO (International Maritime Organization) rules, standards as well as technological progress in the discussed field. Additionally, some elements of that course were implemented into IMO Model course for ETO 2014 edition.

7. References
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