Aspects regarding the repair of electrical equipment designed for use in potentially explosive atmospheres

Lucian Moldovan[1*] and *Mihai* Magyari[1]

[1]INCD INSEMEX, Department for Safety of Explosionproof Equipment and Installations, 32-34 G-ral Vasile Milea street, Petrosani, Romania

Abstract. The characteristics providing protection to explosion of equipment designed for use in potentially explosive atmospheres must be preserved during their entire period of life. Repairing is defined as the action to restore faulty equipment to its fully serviceable condition complying with the relevant standard (the standard to which the equipment or parts of equipment were originally designed). Repairing of explosion-proof equipment must be performed considering the prescription of the applicable harmonized standards and the specific type of protection(s) involved. This paper is focused on some particular aspects related to repairing of explosion-proof equipment.

1 Generalities

Equipment installed in potentially explosive areas must be design and constructed such that they do not ignite the explosive atmosphere. To that, this equipment has special characteristics that must be preserved during their entire period of life [1, 2].

In time, due to various factors (operation, environment, overloads, personnel, poor maintenance etc.) these special characteristics tend to deteriorate. In this situation maintenance operations should be performed or, if maintenance operations cannot restore the complete functionality of the equipment, repairing activities shall be performed.

Repairing represents the required action to restore faulty equipment to its fully serviceable condition complying with the relevant standard (the standard according to which the equipment and individual parts were originally designed). Repair activities have the purpose of restoring functionality of an equipment due to a malfunction [3].

In the field of explosion protected equipment repair activities are separated of maintenance activities. Maintenance activities are referred in the specific standard [1] and repair activities in the standard [3].

Maintenance represents the combination of any actions carried out to retain an item in, or restore it to, conditions in which it is able to meet the requirements of the relevant specification and perform its required functions. Maintenance operations purpose is to preserve functionality of an equipment [1]. Replacement parts shall be in accordance with

* Corresponding author: lucian.moldovan@insemex.ro

the manufacturer documentation (be provided by the manufacturer or his authorized representative).

Regarding the equipment designed for use in potentially explosive atmospheres the repairing, according SR EN 60079-19 requirements, concentrates on restoring the special characteristics on which explosion protection is based.

2 Requirements for repair workshops of equipment designed for use in explosive atmospheres

The service facility (repair workshop) can be the manufacturer, user or a third-party repair shop. The requirements provided in the specific legislation or standards governing the repair or overhaul operation shall be observed [3].

In Romania, the applicable regulations regarding the repair of electrical equipment for use in potentially explosive atmospheres include NEx 01-06/2007 and SR EN 60079-19. Also, some specific aspects regarding the repair activity are also included in the ATEX 2014/34/EU Guidelines [1, 4, 5].

Repair workshops shall operate a quality management system that includes also the following [3]:

a) A competent 'responsible person' (within the management organization), shall have the responsibility and authority to ensure that the repaired equipment complies with the Ex Certificate.

b) A quality plan shall be elaborated, incorporating all aspects related to repair (inspection, diagnostic, test and check)

c) Procedures/work instructions ensuring that repairs meet the requirements of applicable standards and regulations shall be implemented in the quality system of the repairer. Schedule drawings must be consulted to confirm that the equipment can be re-installed in a hazardous area.

d) Test and measurement capabilities for the repair workshop and their limitations related to the repair and overhaul of Ex equipment must be provided together with a calibration system for measuring equipment (records, providing traceability of measured results to calibrated instruments shall be stored and maintained).

e) Dimensional and electrical measurements shall be recorded in the reports, for the initial values “as found” and final values “as left”.

f) An internal audit programme shall be established (to check that the quality management system is effective and meets the specific requirements, including SR EN 60079-19).

g) If the integrity of a Type of Protection cannot be verified after repair (due to the repair process specifics), that specific process must be measured and monitored (in order to demonstrate compliance with required parameters).

h) When tests are required, these shall be performed considering the type of protection and the repair operation performed (according to SR EN 60079-19, or to other relevant standards).

i) In case of non-conforming equipment, the service facility determines any remedial operation required. Also, records shall be maintained to identify the user and full details of the remedial operations taken.

j) The repair workshop shall possess adequate facilities and equipment, trained personnel (with the required competency and authority) to carry out the repair activities, taking into account the specific type(s) of protection.

k) The repair workshop shall assess the equipment and agree with the beneficiary regarding the status of the equipment after repair. The scope of work to be performed shall be also agreed.

l) After an overhaul or repair all characteristics providing protection to explosion (relating to the type of protection) have to be verified in order to check conformity against the schedule drawings and/or relevant standards (including the Specific Conditions of Use).

m) The assessment must consider the repair standard [3], the relevant type(s) of protection standards and has to be included in the job report to the user (this shall be conducted by the responsible person and supported by appropriate operatives considering their competencies on appropriate types of protection).

n) External (to the repair workshop facility) overhaul and repair operations can only be performed if the quality management system allows it.

All necessary information and data regarding the equipment to be repaired are to be obtained by the repair workshop from the user or manufacturer. This information includes [3]:

a) technical specification;

b) technical drawings;

c) standards for the relevant Type(s) of Protection;

d) operating conditions (such as environment, supply (inverter), lubricants, duty, etc.);

e) instructions (for dismantling and assembly);

f) Ex Certificate and schedule drawings with Specific Conditions of Use, where specified;

g) marking (including Ex marking);

h) recommended methods of installation, operation, maintenance, repair or overhaul for the equipment;

i) list of spare parts;

j) summary of previous history of the repaired product.

When finalizing the repair work, a job report must be sent to the user. The user must include it in its verification dossier. The job report must contain (as a minimum) [2]: details related to the identified fault(s); full details of repair and overhaul; list of replaced or reclaimed parts; results of all checks and tests (in sufficient detail to be useful, if required, by the next repairer); a comparison of the results against the criteria that have been used to determine compliance; a copy of the user contract or order; and a recapitulation of the marking applied to recognise the repaired equipment.

The job reports of repairs or overhauls shall be retained for a period of time as agreed with the user [3].

If the repair was undertaken and the Ex Certificate and schedule drawings are not available, at least the following items must be included in the repair report [3]:

- a statement of the repair workshop, that the repair is made considering the manufacturer's instructions or the applicable requirements of the standard for the Type(s) of Protection used for the certification of equipment;
- a statement that the repair workshop has insufficient evidence regarding the full compliance with the Ex Certificate and schedule drawings;
- a statement referring to the Specific Conditions of Use (that these conditions have been analysed and considered in the repair or overhaul process).

The repair workshop shall retain at least the following records for minimum ten years (or as agreed with the user) [3]:

1. actual and past copies of relevant technical standards (supplementary to the explosion protection standards);
2. assessment of repair workshop quality standard (details of repair workshop quality assessment scheme, calibration of test instrument, records regarding competency and training of personnel, purchasing system, customer complaints, internal and external audit documents, management review, control procedures for processes, documented information regarding the manufacturer's drawings).

3. job records (including the steps taken to obtain the Ex Certificate and schedule drawings, inspection records regarding the compliance with the specific relevant standards and traceability for measuring instruments used plus pass/fail criteria, defect identification, electrical test records before and after repair, conformity attestation for any replaced part, procedure for recovery of repaired components, records of evaluation made by the responsible person and justification for decisions taken, record of inspections during assembly and upon completion, record operations performed by the repair workshop, record of replacement parts made by the repairer).
4. repaired component records (including identification of the component part, a detailed justification for the carried-out work, options considered, technical parameters, etc.).

The main role of a repair workshop is to maintain, or return equipment to, its originally certified condition[3].

Where alteration work is made in the repair process, then, in addition to the requirements of for repairs and overhauls, the following also apply [3]:

a) alteration can be made only if is permitted in the Ex Equipment Certificate and schedule drawings; and

b) where schedule drawings are not available, the proposed alteration work can only be made if it is confirmed in writing by the manufacturer to be permitted by the Ex Equipment Certificate.

If a modification is proposed (and the equipment will no longer conform to the schedule drawings or the certification standards), the user shall be informed in writing and the user shall provide written instructions on how to proceed. Additional assessment must be performed to check if the equipment can be used in an explosive atmosphere and a new Ex Certificate shall be obtained (for the new configuration of equipment). The marking label shall be removed or altered (to give a clear indication that the equipment does not conform to the Ex Equipment Certificate) in case the modification was made, but additional assessment was not performed. In addition, the report to the user shall clearly state the engineering characteristics of the modification and that the equipment is not suitable for use in an explosive atmosphere without additional assessment [3].

According the ATEX Guidelines, a repaired equipment represents a product whose functionality was restored (following a defect) without any other modification (including the adding of new features) [5]. Because this operation occurs after the product was placed on the market (the product is not going to be sold as a new product), in this case, the requirements of ATEX Directive 2014/34/EU does not apply. But still, national regulations of the Member States can be applied for the assessment of the repaired product [4, 5, 6].

If, during repair, a substantial modification is made (that is any modification affecting one or more health and safety characteristics that is covered by essential health and safety requirements or the integrity of a type of protection) Directive 2014/34/EU has to be applied. This does not preclude that other relevant EU legislation to be applied, if it is the case [5, 6].

In this case Directive 2014/34/EU re-applies to a modified product (where the modification is substantial and if it is intended to be placed again on the EU market for distribution and/or use or to be used for own purposes) [5, 6].

According the Normative NEx 01-06/2007, the organisation performing specific repair activities must have a quality system in which specific procedures (for repair activities) are implemented. Also, another requirement is that the personnel involved in specific activities (including repair) to be authorized by INSEMEX Petroșani. The organisation capability is attested to be able to perform specific repairing activities related to equipment/installations operating in potentially explosive atmospheres [4].

A specific diagram for repairing an equipment designed for use in potentially explosive atmospheres is presented in fig. 1.

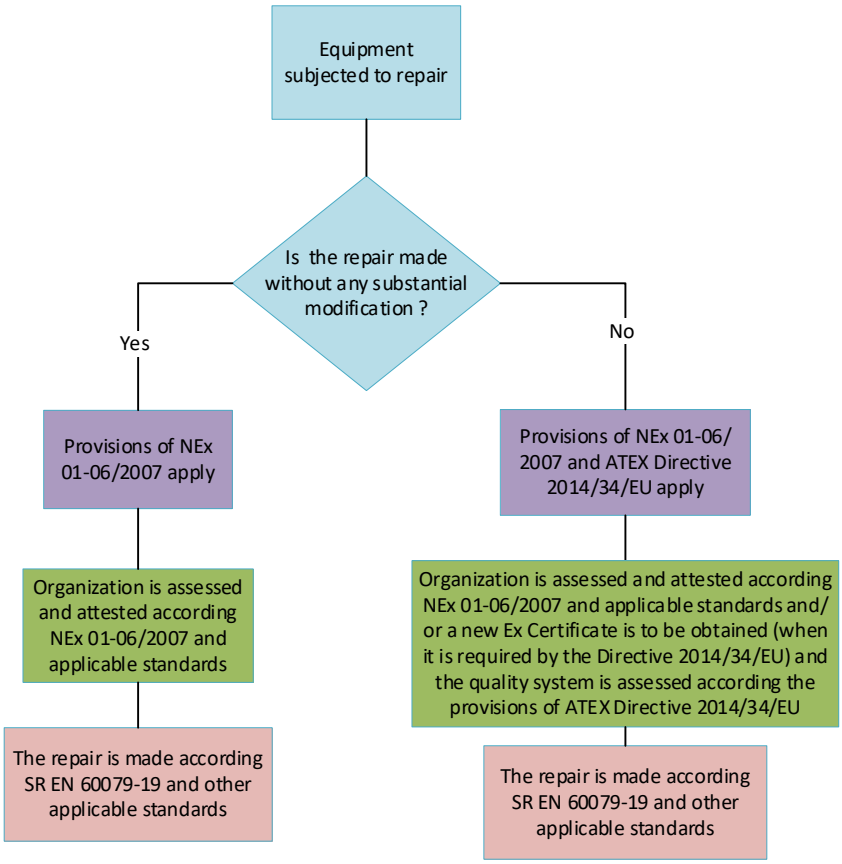

Fig. 1 Specific diagram for repairing an equipment designed for use in potentially explosive atmospheres

3 Examples of specific repair operations related to electrical equipment designed for use in explosive atmospheres

The specific technical requirements for repairing of electrical equipment designed for use in potentially explosive atmospheres are comprised in SR EN 60079-19 [3].

In this paper are considered the important aspects related to the repair of equipment with types of protection flameproof enclosure “d” and increased safety “e”.

In the repair process it is always preferable to obtain the appropriate (new) parts from the manufacturer. The spare parts must be identified [3].

Where the original manufacturer is not supplying the components, the repairer may manufacture itself replacement component parts, or source through a subcontractor, provided that [3]:

a) the full specification for the component is available; and

b) the repair workshop’s quality scheme permits.

Records of such replacement component parts shall be retained and provided to the user [3].

In the specific repairs and reclamations category, for equipment designed for use in potentially explosive atmospheres, are also included those presented below.

3.1 Threaded holes for fasteners

Recovered threaded holes must be according the requirements for the type of protection standards. Damaged threads may be reclaimed (depending upon the type of protection) by one of the following means [3]:

a) oversize drilling and re-tapping;

b) oversize drilling, re-tapping and the fitting of a proprietary thread insert which passes the appropriate pull test as specified by the thread insert manufacturer;

c) oversize drilling, plugging, re-drilling and re-tapping;

d) oversize drilling and tapping, insert solid threaded plug, re-machine (as required);

e) plugging, re-drilling and tapping elsewhere;

f) plug-welding, re-drilling and tapping.

3.2 Electric machines. Removal of damaged windings

The general (industrial) requirements in SR EN CEI 60034-23, covering the procedures of overhaul and repair of all electric machines (covered by SR EN CEI 60034 - all parts), are applicable for electric machines intended to be installed in non-hazardous areas. The additional requirements in SR EN 60079-19 supplement the requirements of SR EN CEI 60034-23 in case of Ex Equipment installed in hazardous areas [3].

To remove damaged windings, softening the impregnating varnish of windings with solvents before stripping is accepted [3].

Also, an alternative procedure using the application of heat to facilitate the removal of windings is accepted. Using heat on windings removal for equipment with increased safety "e" and equipment with any Type of Protection having temperature class T6, T5 or T4 requires particular caution (open flames shall be applied to the core only with continuous monitoring of core temperature due to the possibility of insulation damage between laminations that leads to increased core losses that can also affect increased safety "e" parameters or conduct to exceeding the temperature class) [3].

The repair workshop shall confirm, that on completion of the reclamation/repair the equipment is in a fully serviceable condition (also that the equipment can be used in potentially explosive atmospheres) and complies with the standard(s) for the relevant type(s) of protection [3].

After repair, windings, have to be subjected (preferably with the equipment assembled), to some specific tests, as applicable: winding resistance measurement, insulation resistance test (to measure the resistance between the windings and earth, between windings where possible, between windings and auxiliaries, and between auxiliaries and earth), high-voltage test (between windings and earth, between windings where possible, and between windings and auxiliaries attached to the windings). In case of a transformer or similar equipment this should preferably be energized at rated supply voltage (the supply current, secondary voltage and current shall be measured and compared with that derived from the manufacturer's data, and in polyphase systems shall be balanced in all phases, as far as is reasonable). High-voltage (1 000 V AC_{RMS}/1 500 V DC and above) and other special equipment may require additional tests (according the repair or overhaul contract) [3].

Supplementary to the above tests, electric machines shall be subjected to the following tests (as far as is reasonably practicable) [3]:

a) The machine shall be run at rated speed and rated voltage (to verify bearing temperature, noise or vibration and no-load current values).

b) The stator windings of cage machines, shall be energized (with the rotor locked) at an appropriate reduced voltage, to obtain between 75 % and 125 % of full-load current and to check balance on all phases.

d) High-voltage (1 000 V AC_{RMS}/1 500 V $_{DC}$, and above) and non-cage machines may require alternative or additional tests (subject of the repair or overhaul contract).

3.3 Ex "d" equipment

The first option is to obtain new parts from the manufacturer. In case of flameproof enclosures, the correct assembly of flameproof enclosures after repair or overhaul shall be observed (to ensure that the flameproof joints comply with the requirements of the relevant standard and, where appropriate, with the schedule drawings) [3].

If flameproof joints are not gasketed (and the manufacturer's documentation does not specifically address joint protection) then non-setting grease without evaporating solvents or anti-corrosive agents without evaporating solvents can be used together with other methods of protection in accordance with SR EN 60079-14 [3, 7]. Corrosion or deformation of parts must be assessed to ensure any original openings or gaps in the enclosure have not exceeded the limits of surface finish and the flamepath gap [3].

Where gaskets which are not part of the flamepath are incorporated into the flameproof joints, replacements shall be of the same materials and dimensions as the original [3].

The drilling of holes into an enclosure is a modification and shall not be carried out without reference to the schedule drawings (if the manufacturer has discontinued trading, to the certificate issuer) [3].

When changing surface finish, paint, etc. care should be taken, as this could affect the surface temperature of the enclosure [6] and thus the temperature class [3].

Where enclosure has suffered structural repairs (or the integrity of the enclosure is questionable), an over-pressure test shall be conducted (at 1,5 times the reference pressure or the routine pressure value as stated in equipment documentation, and held for at least 10 s). Where the reference pressure is not stated, tests shall be conducted at 1000 kPa (Group I enclosures), 1500 kPa (IIA and IIB enclosures) and at 2000 kPa (Group IIC enclosures) [3, 8].

In case of flameproof enclosures entries, these shall conform, after repair or overhaul, to the conditions in the appropriate equipment standard(s) and Ex Equipment Certificate and schedule drawings where applicable [3].

Machining of damaged or corroded flameproof joints faces can be performed (after consultation with the manufacturer wherever possible) only if the joint gaps are according the schedule drawings. If the schedule drawings are not available, guidance must be taken from Annex C of SR EN 60079-19 [3]. Non-metallic flameproof joints shall not be recovered [3].

Recondition of flameproof joints by using welding, electroplating and re-machining is permissible, but considering the limitations of the technique. The use of metal-spraying techniques is permissible provided the bond strength is greater than 40 MPa [3].

Addition of metal must be used in case of spigot joints before machining, thus ensuring the compliance of flameproof joints dimensions to the equipment standard, and where appropriate, the schedule drawings. The accepted techniques for addition of metal are electroplating, sleeving or welding (spraying techniques with a bond strength lower than 40 MPa are not recommended) [3].

In case of threaded joints of cable and conduit entries the threaded damaged male parts are not to be reclaimed; new components shall be used. Female threaded parts are accepted to be reclaimed by using MMA, MIG and TIG welding techniques [3].

MMA, MIG and TIG welding techniques can be used in the reclamation of threaded covers and the associated housing [3].

Reclaiming the damaged threads of holes for fasteners may be performed by one of the following [3]:

a) oversize drilling, re-tapping and the fitting of a proprietary thread insert which passes the appropriate pull test as specified by the thread insert manufacturer;

b) oversize drilling, plugging, re-drilling and re-tapping;

c) oversize drilling and tapping, insertion of solid threaded plug, re-machining (as required); or

d) plug-welding, re-drilling and tapping.

Electroplating, metal spraying, sleeving or welding techniques may be used in case of shafts and bearing housings, including flameproof joints. MMA techniques are not accepted [3].

When reclaiming damaged rotors and stators by skimming, the repairer must proceed with care, due to the fact that the increased air gap resulted between rotor and stator can produce a change in the characteristics providing protection to explosion (change in pressure piling characteristics or higher external surface temperatures exceeding the temperature class of the machine). A "flux test" conducted at not less than 1,5 Tesla shall be performed to ensure that no hot spots occurred after the skimming operation [3].

Other specific repairs or reclamations in case of flameproof equipment are considered machining of threaded joints and threaded holes for fasteners, skimming of stator and rotors etc. [3].

3.4 Ex “e” equipment

The type of protection “e” is dependent on the IP rating and shall be maintained after repair [3, 9]. Thus, gaskets and seals are critical and should only be replaced with gaskets and seals of identical materials and identical construction [3].

Adequate clearance shall be maintained between stationary and rotating parts in accordance with the equipment standard (according manufacturer’s certification drawings or, in the absence of these, the minimum clearance as required by SR EN 60079-7) [3, 9].

The effects of surface finishes, paint etc., on the temperature class of enclosures shall be considered (only those specified by the manufacturer or equivalent can be applied) [3, 10, 11].

If terminals are to be repaired, in terms of the materials and construction used, the creepage and clearance distances and the CTI of termination insulation shall be considered (these are normally provided in the schedule drawings). The manufacturer shall provide replacement parts or his advice must be sought for other acceptable alternatives [3].

In case of internal connections, the insulation on such connections shall not be inferior (electrically, thermally or mechanically) to that originally supplied [3].

In case of electric machines is critical that the repairer shall be in possession of all the necessary information and repair equipment. The winding should be restored to the original condition, except that, where practicable, a partial winding replacement may be possible on formed coil winding [3].

In case of electrical machines with a rated voltage lower than 1000V only some repair techniques are accepted (regarding the replacement of stator windings) [3]:

- stator windings replaced with those provided by the manufacturer or replaced based on manufacturer’s winding data; and
- copy winding techniques.

To repair the stator winding and maintain the original t_E data related to the original winding are required (type of winding – for example, single-layer, double-layer; winding diagram; number of turns or conductors per slot, parallel paths per phase; interphase connections; conductor size; insulation system, including slot insulation and the generic varnish system or process such as vacuum pressure impregnation (VPI) or trickle; resistance per phase or between terminals; coil pitch; winding projection, including

clearance between coils and enclosure etc.). It is important to know any failure of any electric machine in service, with type of protection "e", due to winding over temperature (an analysis shall be made to determine the cause) [3].

Light-transmitting parts shall not be repaired or re-cemented. Only complete replacement assemblies, as specified by the manufacturer, shall be used. Light-transmitting or other parts made from plastics shall not be cleaned with solvents. Household detergents are recommended for this purpose [3].

4 Marking of repaired equipment

Repaired and overhauled equipment shall be marked on the main part in a visible place. This marking shall be legible and durable taking into account all relevant environmental conditions [3].

The marking shall include [3]:

a) the relevant symbol:

- Repair in accordance with schedule drawings or manufacturer's specification (fig. 2)

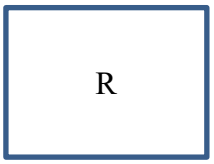

Fig. 2 Symbol to be placed on the marking label when repair is in acoordance with schedule drawings or manufacturer specifications

- Repair in accordance with the Type of Protection standards but not the schedule drawings (fig. 3)

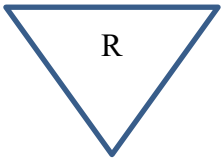

Fig. 3 Symbol to be placed on the marking label when repair is in acoordance with the type of protection standards but not in accordance with schedule drawings or manufacturer specification

b) the standard number "SR EN CEI 60079-19";

c) the name of the repairer or his registered trade mark (and service facility third party accreditation, if any);

d) the repairer's reference number (for the repair); and

e) the date (of the repair).

The marking may be on a plate permanently attached to the repaired equipment.

Also, if during the repair, an equipment was substantially modified (according the provisions of the ATEX Guidelines), the marking provided by the ATEX Directive and applicable standards shall be considered [3, 5, 6].

Equipment which, after repair or reclamation, does not conform to the situations mentioned above (repair in accordance with schedule drawings or manufacturer's specification or repair in accordance with the type of protection standards but not the schedule drawings) should have its original manufacturer's label removed or altered to give a clear indication that the equipment is not in compliance with the Ex Equipment Certificate [3].

5 Conclusions

In this scientific paper were presented multiple aspects related to the repair of electrical equipment designed for use in potentially explosive atmospheres.

In the first part of the paper, the importance of the repairing activities was underlined. In the second part, the aspects related to conditions that organisations providing repair services has to be fulfilled, in order to perform these operations. The next part considered some examples of repair operations for electrical equipment with type of protection flameproof enclosure "d" and increased safety "e" designed for use in potentially explosive atmospheres.

The last part of the paper presented the information to be considered when marking a repaired equipment designed for use in potentially explosive atmospheres.

This paper presents a particular importance to the repairers, users and for maintenance organisations related to equipment designed for use in potentially explosive atmospheres because it clarifies many aspects related to the repair activity.

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