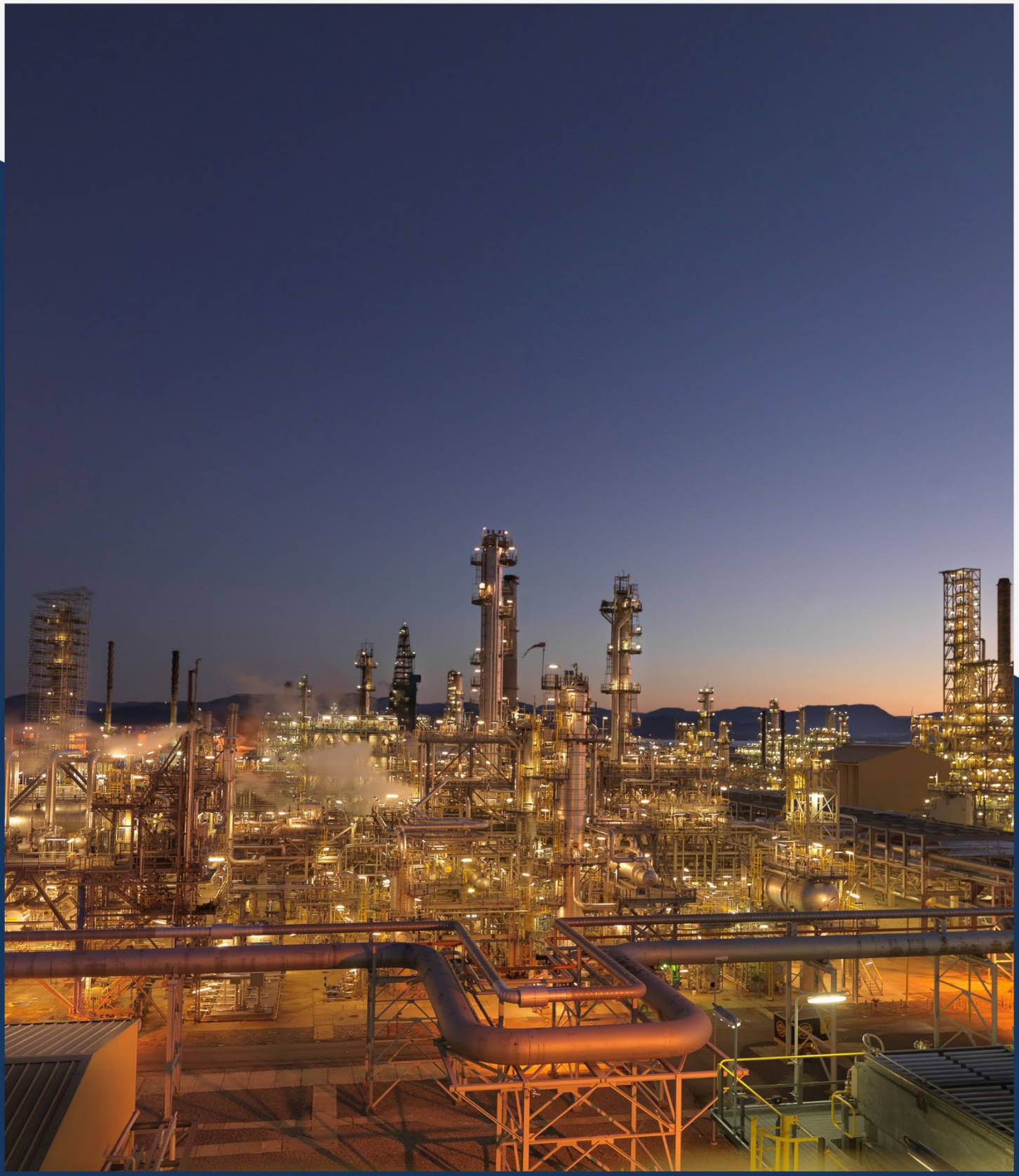
IEC Subcommittee 31J

Background to flameproof cable gland requirements in IEC 60079-14



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1 Abstract

Flameproof equipment for hazardous areas uses either a cable gland sealed with a setting compound (commonly called a “barrier” gland) or a compression type cable gland to prevent flame transmission via the cable entry in the event of an explosion internal to the flameproof enclosure. The “barrier” type cable gland provides protection from flame transmission through a cable. The need for a barrier type gland is based on several factors related to the application details of a Flameproof (Ex “d”) enclosure and the types of cables.

This paper reviews the history and technical factors associated with cable gland selection for flameproof (Ex “d”) enclosures as background to the selection criteria in IEC 60079-14. A wide range of available test results are included to assist in understanding this background.

The publication of IEC 60079-14:2013 edition 5.0 introduced a different approach to cable gland selection for flameproof (Ex “d”) enclosures from editions 2.0, 3.0 and 4.0 of IEC 60079-14 which had been in place since the end of 1996. This new approach raised concerns in some sectors around the validity of the approach and reasons for the change.

2 Introduction

Cable glands for hazardous area installations provide an essential function in maintaining enclosure integrity and environmental protection (e.g. IP rating) requirements. This is common for all enclosures for all explosion protection techniques. As a result, cable glands that are suitable for hazardous areas tend to be more robust and offer superior sealing of the cable entry than typical industrial grade cable glands.

To maintain the integrity of flameproof (Ex “d”) enclosures it is critical that, in the event of an explosion inside an enclosure, the combination of the cable and cable gland is capable of preventing any ignition capable hot gasses or flames from reaching the outer atmosphere.

A third, and optional function of the cable gland, is that sometimes a gland may be selected to reduce possible migration of liquid or gas, through the cable. For example, due to breakdown of a process seal in the equipment to which the cable is connected. This blocking function is completely independent of the flame proofing function but may be enhanced by the selection of a suitable cable gland.

This paper is limited to the selection of cables and cable glands to prevent flame transmission in case of an explosion inside a flameproof enclosure.

The concern with flame transmission through a cable was raised in the 1970’s which led to specific requirements for flameproof cable glands being introduced in the 1980’s. With ongoing changes in materials, technologies and manufacturing it should not be regarded as unusual that the requirements of this era are reviewed and even challenged. Such reviews are common in many industries to validate both ongoing requirements and the possibility of new issues being created.

It is not the purpose of this paper to detail all the changes to product standards and technologies related to cables and cable glands. This paper is intended to assist National Committees in understanding the changes in IEC 60079-14 with respect to cable and cable gland selection for flameproof enclosures.

3 Pathways for flame transmission

There are two main pathways for flame transmission associated with cables and glands into a flameproof enclosure. These are:

- via the cable gland seal (or seals) which makes contact to the cable, or,
- through the cable itself, i.e. due to gaps in the cable construction associated with the individual conductors and any fillers.

Either of these pathways may also be further compromised due to damage to the cable. If an explosion occurs in a flameproof enclosure, cable damage may be caused by either the increased pressure or the heat of combustion.

A possible third pathway via the threaded connection for the cable gland into the enclosure is not addressed in this paper. This interface is defined and tested in accordance with the relevant standards (IEC 60079-0 and IEC 60079-1).

It should be recognized that damage to a cable can take several forms and not all forms of damage may lead to flame transmission. For example, degradation of individual cores or the inner sheath up to the cable gland seal may not result in flame transmission whereas damage to an inner or outer sheath or under the cable gland seal might lead to flame transmission as a result of subsequent ignitions inside an enclosure.

While flame transmission has been demonstrated through cables with large gaps between the cable cores, there is insufficient evidence to suggest that flame transmission could occur through the gaps between strands in an individual cable conductor. The theory here is that the metal conductors act like a flame arrestor and quench any flame.

Flame transmission is also fundamentally different to gas or liquid transmission and the two issues must be clearly differentiated. While the type of cable gland may be able to influence the degree of gas or liquid transmission through a cable, the requirement for a flameproof enclosure (and cable gland) is to control flame transmission and not gas or liquid transmission. In some cases, gas or liquid transmission could occur even through the strands of an individual conductor.

4 Approval and testing of flameproof enclosures to IEC 60079-1

Flameproof enclosures that are tested for flame transmission must pass multiple ignition tests without flame transmission to be certified for use. Either three or five explosion tests are conducted on an enclosure, depending on the gas group, to ensure proper validation of the test results.

IEC 60079-1 provides options for how flame transmission testing is carried out according to the enclosure and testing preferences or limitations that may be applicable. The commonly applied number of tests and the explosive mixture used, in volumetric ratio with air and at atmospheric pressure, are:

- electrical equipment of Group I: three tests with (9,8 ± 0,5)% Methane;
- electrical equipment of Group IIA: three tests with (4,6 ± 0,3)% Propane;
- electrical equipment of Group IIB: three tests with (8 ± 0,5)% Ethylene;
- electrical equipment of Group IIC: five tests with (14 ± 1)% Acetylene and five tests with (31 ± 1)% Hydrogen.

In these tests, either the flame path gap is increased or the initial pressure inside the enclosure is increased to ensure a factor of safety in the test results.

For group IIC enclosures a common option is to use Oxygen enrichment with the test gas, rather than increasing the flame gap, to provide the safety factor. In this case the test mixtures used consist of the following volumetric ratios at atmospheric pressure:

- (40 ± 1)% Hydrogen, (20 ± 1)% Oxygen and the rest Nitrogen; and
- (10 ± 1)% Acetylene, (24 ± 1)% Oxygen and the rest Nitrogen.

It is critical to appreciate here that the pressure and thermal behaviour of different gases during the combustion process are different and conditions at a specific point in the enclosure may also vary depending on the location of the ignition source. Testing with gases other than Hydrogen will give higher thermal conditions, not necessarily due to higher temperatures but due to longer burning time (or slower flame speeds) which increases the thermal transfer behaviour. In particular, the thermal conditions at any point in the enclosure under test may also vary based on the behaviour of the flame and pre-compression as part of the combustion process in a closed chamber. Thus, these tests are based on generic safety factors.

5 Approval and testing of flameproof cable glands to IEC 60079-1

There are two critical distinctions in testing flameproof cable glands compared to flameproof enclosures.

1) IEC 60079-1 does not require testing of individually certified cable glands for flame transmission. Cable glands are instead tested by assembly onto a metal rod with hydraulic pressure applied to test the cable gland seal onto the rod. If the seal withstands the required pressure without leaking, the cable gland is deemed to have passed.

2) The reference pressure for the hydraulic test is only distinguished between group I and group II. All group II cable glands are accepted as suitable for gas groups IIA, IIB or IIC.

Clearly, this form of cable gland testing is only able to assess the interface between the cable and the cable gland and not any issues that may be relevant to the gaps between the cores in a cable. For example, between the individual conductors or the type of fillers used.

This form of testing does not replicate factors such as:

- the possible influence of deformation of a cable sheath by the cable gland, either as initial deformation, long-term deformation or installation factors,
- any influence on the cable from high temperatures due to the products of combustion or heating of a cable while in use.

There is an option to certify cable glands as part of an assembly in which case additional testing to IEC 60079-1 may be completed but such testing is not the subject of this paper. Several test reports provided in this paper are based on such testing as these reports provide useful information.

6 Defining the problem

In hazardous areas many details for equipment to control relevant aspects to prevent the specific type of equipment from becoming an active ignition source are defined and tested. The one thing we don't define well is the cable that is used to connect the numerous items of equipment together. Cable requirements in IEC 60079-14 are only described in general terms. For example, cables must be, circular, sheathed, and, "compact". The last point, especially, is very rarely controlled in the field and is not defined in any cable standard. In the absence of third-party approvals, identifying and verifying "acceptable cable" becomes the users' responsibility and is subjective.

Defining the requirements for cable construction is an issue due to several practical limitations:

1) Cables are available in multiple forms of construction, materials, and configurations, to suit specific applications. Cable construction continues to evolve as new applications emerge and technology evolves.

2) The various cable standards are developed globally, regionally or even locally with little coordination or market control. Industries may decide independently which standards are appropriate for their applications.

3) The detail in cable standards do not address the requirements for explosion safety.

4) Cable gland and cable designs construction are not coordinated. The expectation is that a cable gland would compensate for variations in cable construction.

5) Cable parameters relevant to the flame transmission performance, such as the extent of voids between cores, can vary greatly and even extend to differences between factories operated by the same company producing the "same" cable.

The problem is then defined as: how to simply specify cable and cable gland combinations that will reliably prevent flame transmission from a flameproof (Ex “d”) enclosure that can be applied to all possible combinations of cables, cable glands, and enclosure applications, around the world.

7 Initial flame transmission testing – 1976 ERA report 3051/85

In the early 1970’s a change occurred in some parts of the world with the introduction of alternatives for glanding cables into flameproof enclosures. These alternatives allowed glands without the use of compound filling or seals between the individual cores in a cable. Background discussion in the ERA report indicates the changes were opposed by some and that limitations for the alternative glanding approach were proposed. The 2-litre enclosure size limit for glands without compound filling was accepted as a final recommendation from the ERA report although the ERA report noted that this might be conservative and considering limitations of the testing conducted.

Given this change in cable glanding options and the increasing use of tape-bedded cables due to limitations in cable supplies at the time, concerns were raised about the reliability to prevent flame transmission for all combinations of cable types and flameproof enclosures. Ultimately a range of tests were carried out in the UK which led to a confidential test report, ERA report 3051/85, *Flameproof Enclosures: The Integrity of Cable/Cable Gland Inlet Assemblies*, in April 1976.

The UK ERA report tested several cables with different cable glands, test gases and enclosure sizes to examine the possibility of flame transmission with different combinations. It is fair to say the testing was limited, as has all testing been since then, due to the cost and time involved in testing what would be several combinations to cover all variables.

Points arising from the 1976 UK ERA report are summarized below:

- The initial focus was on tape-bedded cables and cable glands that are no longer made and may not reflect current standards or current products. The research project was then extended to include extruded bedded cables.
- There are no reported tests for flame transmission using less than 60-litre enclosures. Tests in smaller enclosures were assessed based on cable damage.
- Those involved at the time took the view that if the bedding suffered severe damage under the gland seal, then flame transmission might occur at some point in the life of the installation.
- The testing modified the flameproof enclosure assembly by taping over flame paths to restrict the flame path to be solely via the cable and cable gland.
- Flame transmission was not tested for small diameter cables such as multicore control cables. The tests showed severe damage to cable cores and disruption to bedding under the cable gland seal could occur in such cables due to the high temperatures from internal explosions.
- Flame sensitivity tests with Ethylene using a 30-litre enclosure with a 37-core cable resulted in the cable being destroyed after 7 tests. Using a 2-litre enclosure resulted in no discernible thermal deterioration after 10 tests. The 37-core cable was selected as the most sensitive cable that had been tested to thermal deterioration in the 60-litre tests.
- Testing used multiple explosions to “stress the cables” and cable glands. Test gases used included Hydrogen to give a high pressure and Propane to give higher thermal conditions. The number of tests applied was different to the number used for flameproof enclosures but did establish a point of reference even though the need for repeated tests may have had a different basis.

The UK ERA report demonstrated failures (flame transmission) in the following three cases with cables extending approximately 0,5 m outside the enclosure:

- 4c, 95 mm^2, Al, PVC/SWA/PVC cable with tape bedding but only with the gland inner seal onto the cable cores (not inner bedding) and when tested with Ethylene (2 tests) and 1 test with a 40%

Hydrogen+10% Oxygen/50% air mixture. This gas mixture does not match any reference mixture in IEC 60079-1 for testing flameproof enclosures but was in accordance with the BASEEFA certification of flameproof equipment in the 1970's.

- 4c, 240 mm^2, Al, PVC/SWA/PVC cable with tape bedding. However, this was after 7 Ethylene ignitions for flame sensitivity and 1 Hydrogen for flame transmission. The cable was not glanded correctly as the test used multiple layers of PVC tape to make up the bedding diameter to suit the cable gland.
- 3½ C, 95 mm^2, Cu, PVC/SWA/PVC, cable with extruded bedding and hollow tube fillers. This test was carried out with 2 Ethylene ignitions followed by 1 with Hydrogen.

The UK ERA report also established several significant aspects for testing which included:

- Sensitivity to thermal issues leading to cable deterioration.
- Indication that testing with both hydrogen and ethylene or propane may be necessary to validate cable entry system performance, i.e. assess for both pressure and thermal conditions. Both conditions could be experienced in practice. For example, where an area is classified as IIC and IIA or IIB gases may also be present.
- Identification that elevated cable and gland temperatures (operating cable temperature and not limited to ambient temperature) as a possible issue to consider. The UK ERA report included testing of power cables operating at maximum rated core temperatures and noted that reducing core temperatures did not result in a significant change to the potential damage to the inner sheath of the cables tested. However, temperature factors were not fully investigated for all cables and have not been considered in any tests since then.

The UK ERA report made a critical assumption that was not fully examined at the time. That assumption was, that severe damage to a cable or emission of smoke through the cable was sufficient evidence to indicate that flame transmission could be possible. It appears that from this assumption the ultimate requirements for cable glands were first presented in IEC 60079-14:1996 edition 2.0.

8 IEC 60079-14:1996 requirements for flameproof cable gland application

IEC 60079-14:1984 edition 1.0 did not include requirements for a compound seal cable gland with flameproof (Ex "d") enclosures. IEC 60079-14:1996 edition 2.0 introduced requirements for a compound seal cable gland with flameproof (Ex "d") enclosures based on the enclosure size, gas group, zone and nature of the application. The criteria were largely based on input from the UK considering the 1976 ERA report 3051/85 and were also likely influenced by others at the time who had first suggested 2-litre enclosures as a factor in the safety parameters.

The selection criteria were detailed in a flow chart in IEC 60079-14:1996 which became the basis for the selection of cable glands for flameproof enclosures until the 5th edition of IEC 60079-14 in 2013. The principal details of the flow chart, with some minor changes for explanations, are shown in Figure 1.

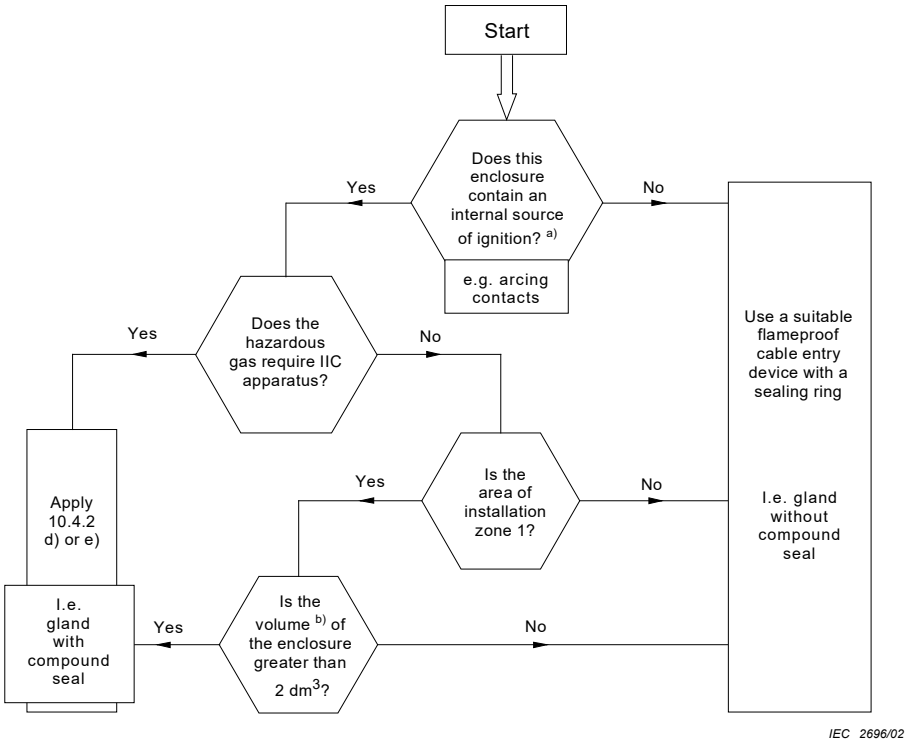

Figure 1 – Flameproof gland selection chart from IEC 60079-14:2007 with additional notes for explanation

9 Development of IEC 60079-14:2013 edition 5.0

The 40 years from the 1970's to 2013 were characterized by the traditional development of standards and equipment. Such development is commonly experienced in many industries.

For flameproof applications these developments included:

- New constructional and testing requirements for cable glands
- New cable standards, designs and materials
- Cables from new manufacturers and regions
- More countries adopting IEC Standards for hazardous areas (which influenced markets, installation practices, equipment designs and other factors.)

Given new cable and cable gland developments and with key assumptions and issues arising from the previous UK ERA report further testing on various cables and enclosure combinations took place. This testing was carried out by PTB and Dekra using a large sample of smaller cables and a 40-litre enclosure. The test configuration was different to that used for the UK ERA report but did apply multiple tests for ignitions comparable to those used for group IIC flameproof enclosures.

The PTB and Dekra tests were not able to replicate the issues and failure conditions reported in the earlier UK ERA report or through the use of the flowchart in IEC 60079-14:1996. These latter tests suggested the extent of "gaps" in a cable was the prime criterion relevant to flame transmission and that damage to cables did not occur as suggested in the UK ERA report. The assessment of the "gaps" in a cable is a poorly defined parameter and so the ability of a cable to "breathe" as indicated by a simple overpressure test was proposed.

The 5th edition of IEC 60079-14 in 2013 removed the previous cable gland selection chart in favour of other criteria related to cable construction, independent of the size of an enclosure or other application factors. The criteria from the 5th edition of IEC 60079-14 applied to the openness of the cable, that is, the extent of gaps between cores in a cable that could lead to propagation of flame and the length of the cable (to quench a possible flame). This assessment of cable properties is included in Annex E of IEC 60079-14:2013 edition 5.0. While this assessment is rather basic, it tried to be conservative and was developed since other criteria are not able to be defined by reference to any standards for cable construction. It is noted that the pressure breathing test in Annex E of IEC 60079-14:2013 edition 5.0 could be approximated by a person trying to simply blow through a cable (like a straw) to determine if bubbles appear in a container of water.

The testing by PTB and Dekra demonstrated that quite short lengths of cable may be sufficient to control flame transmission, but this is dependent on the degree of openness of a cable. The requirement from IEC 60079-14:2013 edition 5.0 for a minimum length of 3 m was proposed as being conservative and possibly many times the minimum cable length required to control flame transmission.

The combination of the two key criteria in IEC 60079-14:2013 edition 5.0 for cable breathing and minimum cable length was considered to provide for adequate safety margins and allow for reasonable ambiguity in the assessment of a cable type to meet the criteria from Annex E of IEC 60079-14:2013 edition 5.0.

10 Flame transmission testing summary

Testing of the flame transmission performance of cables and cable gland combinations has only been carried out by relatively few parties. Most of the tests have not been made available to the public and many tests are known only to the individuals or companies involved. Many test results are also confidential since they have been carried out by companies for product certification or product development reasons.

Test results that have been able to be obtained for this report are presented in the table in Annex A of this report. The results presented includes data from:

- the original UK ERA report, which formed the basis of requirements in earlier editions of IEC 60079-14,
- PTB and DEKRA reports which were initially used as the basis for later development of IEC 60079-14,
- testing by Intertek UK to replicate some of the original UK ERA tests and investigate testing using Propane, Hydrogen and Acetylene, and,
- reports of tests carried by various other parties. These other reports include both formal and informal data sources, such as Ex test bodies, cable gland manufacturers and other sources.

The test results included in this report have been confirmed as accurate by those who provided the data and a working group within IEC MT 60079-14.

In several tests, other than the original UK ERA report, it is evident that damage to cables has occurred, but this has not necessarily led to flame transmission. Many test reports also do not provide information of cable damage as this was not the focus of those carrying out the tests. Where cable damage is reported, this often does not have an associated flame transmission.

Many test reports only provide factual information such as the test configuration and pass or fail results. Photographs in the test reports often show some form of damage to the cables from the tests but then do not provide further detail and do not report on other factors that may be of interest.

Several names are withheld for confidentiality reasons and a number of details are truncated to simplify presentation in this paper. Only the key criteria with respect to test configuration and flame

transmission performance are summarized. In nearly all cases the tests are based on ambient temperatures for the test gas, cable and cable gland.

10.1 Test photographs

Examples of photographs from various tests are provided for information.

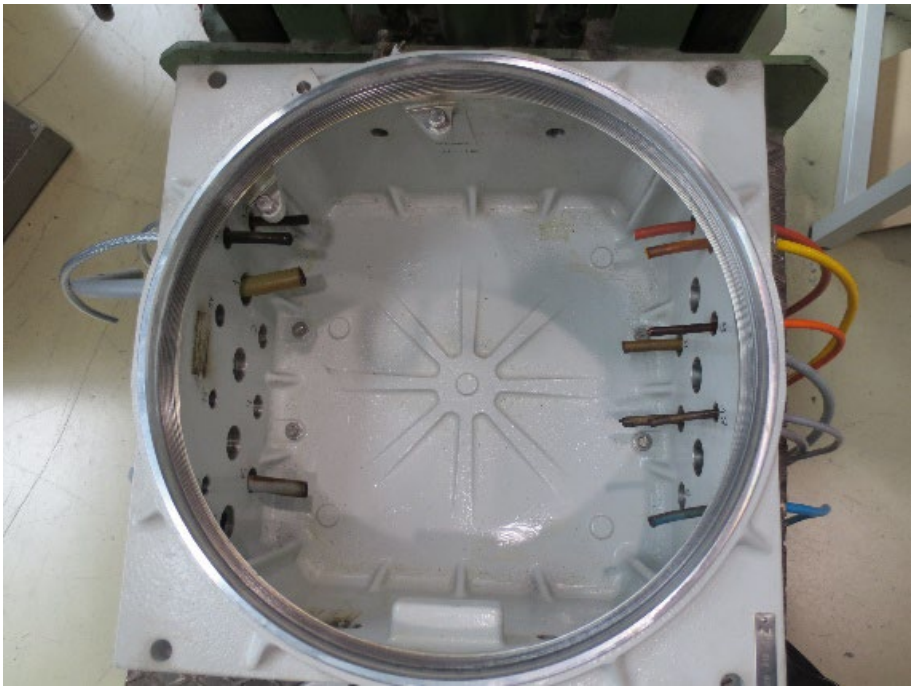

Figure 2 – Dekra 2016 test configuration

Figure 3 – Testsafe 2016 – Damage to the exposed cable end, but with no flame transmission

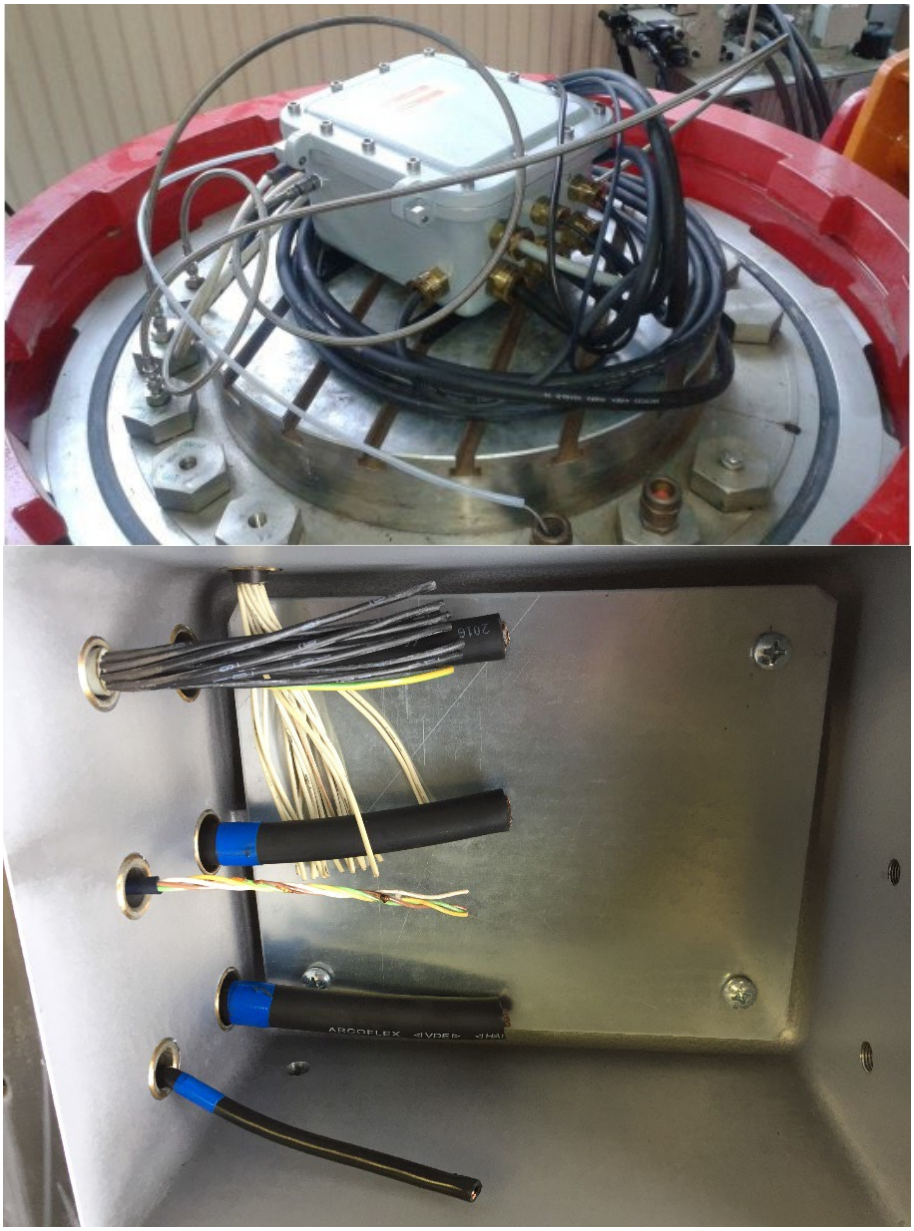

Figure 4 – KIWA 2017 test configuration showing variances in cable entries

Note: minor damage to cable cores in the bottom photo as a result of the testing, but without flame transmission.

11 Relationship to other parts of the IEC 60079 series

It is important to understand that the IEC 60079 series is a suite of documents that work together. No single document should be taken in isolation. This is highlighted in this paper with the relationship to IEC 60079-1.

The testing for flame transmission has identified the possibility of cable damage due to the thermal conditions. In many of the tests flame transmission only occurred after multiple internal explosions. However, the potential for damage is not the focus of the tests in IEC 60079-1 where multiple tests are done to validate test results on a single enclosure. While benchmark testing to align IEC 60079-1 can be followed to give a level of conservatism, the need to follow the same guidance in simulating

an end user installation for testing of the flameproof properties of cables and cable glands is something that should be considered.

For end users there is another important relationship between IEC 60079-14 for initial installation and IEC 60079-17 for ongoing inspections and maintenance. By following IEC 60079-17 the possible damage to a cable from an explosion internal to a flameproof enclosure might be identified after any number of explosion events resulting in replacement of the affected cable or cable gland. In this case the cable might also be replaced if damaged for functional integrity reasons, and not just for explosion protection reasons. Such remedial action would lead to reinstatement of the original integrity. However, it is acknowledged that damage due to an ignition inside a flameproof enclosure might not be identified when following IEC 60079-17.

12 Issues and discussion

12.1 Issues

There are numerous points that are raised through this history and the testing of cable glands and cables into flameproof enclosures. These include:

a) The original cable selection flowchart in IEC 60079-14:1996 was based on one test report, and that had many details that are worthy of review in the light of changes to standards, cable glands and cable constructions.

b) The 1976 UK ERA tests and 2015 UK EEUMA tests both included Propane as a test gas since this increases the thermal conditions from the flame compared to Hydrogen (and cable damage inside the enclosure). The establishment of different conditions for the gas groups and possible variances in either direct flame transmission or consideration of damage to the cables or cable glands is an important point to be considered.

c) The 1976 UK ERA testing assumed that damage to a cable was an indicator of flame transmission even though testing of this assumption was specifically excluded from the ERA investigations. It is reasonable to consider that flame transmission might occur on subsequent ignitions where the bedding is damaged depending on the nature of the damage and installation factors, for example cable length and bedding material. Damage to conductor insulation is not likely to be a significant factor for flame transmission.

d) All of the cables used in tests from the UK ERA and EEMUA investigations would also have failed the limited cable breathing test in Annex E of IEC 60079-14:2013 edition 5.0. In this case sealing glands would have been required for all the cables that otherwise have been indicated as a possibility for flame transmission in the original UK ERA report, irrespective of which edition of IEC 60079-14 is applied.

e) Several of the more recent tests have demonstrated that in certain cases short lengths of cable may prevent flame transmission. The tests by Dekra and others investigating the influence of cable length have also demonstrated that cable length is a factor, and all such testing indicates that a 3 m length of cable external to the enclosure provides a conservative basis for the safety of cables that might otherwise fail the flame transmission test without a gland that would seal around the individual cores.

f) Many of the tests, across all test reports, have provided an indication that the selection of cable glands based on IEC 60079-14:2013, based on cable construction and minimum length, would provide a conservative basis for safety.

g) Many of the tests were based on IEC 60079-1 requirements for enclosures and used Hydrogen as the test gas. These tests do not test for higher thermal transfer conditions associated with group IIB or IIA gases. The indication is that the use of equivalent testing for enclosures may not necessarily be a good basis for testing cable glands.

h) In addition to any cable or cable gland details there are differences in installation practices that may be important or need to be accounted for. For example, in some parts of the world an armoured cable would normally be terminated with the armour in the cable gland, implying two seals on the cable for the inner and outer sheath, and in other parts of the world the armour is normally terminated inside the flameproof enclosure implying a single seal from the cable gland is used on the outer sheath.

i) Despite any concerns in its development, the cable selection flowchart in IEC 60079-14:1996, has a long track record of safety in field installations.

j) The cable gland selection basis from IEC 60079-14:2013 has similar results validated through recent testing and field experience.

k) Except for the original UK ERA report, none of the tests have investigated a range of possible factors in the cable and cable gland application such as, the influence of cable or cable gland temperature and cable fit off details. Where such factors in cable and cable gland details are investigated, there is insufficient testing to arrive at a clear conclusion.

Other concerns include:

l) None of the tests carried out use a standardized methodology or test sequence. Such testing is not identified in any IEC or other standard.

m) The diversity of test methods makes it difficult to draw direct comparisons between the test records and only general conclusions can be suggested.

n) To test the multitude of cables, cable glands and enclosure combinations would be expensive, time consuming and difficult, if not impossible.

At best, the requirements for cable gland selection can be used as an attempt to suggest a safe approach that seems to work, with a suitable safety factor. This applies to the previous and current editions of IEC 60079-14 and likely future editions of IEC 60079-14.

Given all of these issues, there is likely to be an ongoing need for more tests, monitoring and adjusting the requirements of various cable gland, cable, and installation standards in future editions of the respective IEC Standards.

12.2 Performance testing of cables and cable glands

It should be pointed out that the performance tests in the IEC Standards (IEC 60079-1 and IEC 60079-14) related to cables and cable glands are not true functional tests for flame transmission and are not intended as such. All that is suggested is that there is sufficient evidence to indicate that if a cable or cable gland passes the respective test then an associated ability with respect to flame transmission performance may be assumed in the site installation. If this principle is questioned, then every cable gland on the market could be questioned and so far, there is no compelling evidence to raise this as a concern.

The “restricted breathing” test which was applied in Annex E of IEC 60079-14:2013 edition 5.0 was suggested as a simple means to benchmark likely cable performance. During testing by Dekra, it was observed that the performance of a cable varies based on cable construction and may vary even for cables from the same manufacturer and with same catalogue number but from different manufacturing plants. The need for some form of test rather than other criteria is then apparent.

While the test description in IEC 60079-14:2013 edition 5.0 was suggested, it is also clear that the expression and technical details were not well expressed. As such, the test details and form of expression for this restricted cable breathing test are being reviewed for improvement in the next edition of IEC 60079-14.

13 Future directions

IEC 60079-14:2013 edition 5.0 introduced a significant change for cable gland selection criteria to previous editions of IEC 60079-14. Through discussion with end users, it is clear there is some ambiguity in the interpretation of the 2013 edition. Improvements in the expression and requirements for flameproof cable glands are being considered in the drafting for the next edition of IEC 60079-14.

The future of cable gland flame transmission testing is also being discussed in an attempt to try and standardize a test approach and investigate applicable factors further. Such a test approach is unlikely to become part of an IEC Standard since IEC Standards will not form the basis of any product approval using these tests. It is hoped that Ex CBs and cable gland manufacturers will pick up the proposed test method and enable more open reporting of findings to support future considerations of this important topic.

If any other testing has been carried out or is contemplated it would be appreciated if the results can be shared with the Chair of IEC SC 31J to improve the understanding of this topic.

14 Conclusions

Many records have gaps in detail that may have been useful to have been closed, and testing conducted thus far lacks consistency in the testing approach to cover all factors that may be relevant. Notwithstanding these limitations, the available test results provide some important indicators for safety performance when considering the necessity for barrier or sealing glands for flameproof enclosures.

The approach from early editions of IEC 60079-14 is certainly worthy of examination given product changes since it was first developed and the background of the testing details. The approach from more recent editions of IEC 60079-14 needs more improvement which is being considered for the next edition of IEC 60079-14 (edition 6.0). While the various editions of IEC 60079-14 tackle the issue of preventing flame propagation from different approaches the testing indicates that neither approach is suggested as unsafe. Both approaches also include criteria which are intended to provide reasonable safety factors.

A lot more investigative testing would help. However, this takes significant time and financial support to consider what may be a large range of variables. Such further testing would help our understanding and could yet suggest further refinements in the requirements from IEC 60079-14 or other parts of the IEC 60079 series.

It is unlikely that cables, as a key component of all wiring systems, will ever come under a common standard. As such there will always be some level of uncertainty that must be accounted for and the criteria for the selection of Ex “d” cable glands are only ever likely to be that of, what is practical rather than what is perfect.

15 Acknowledgements

Several individuals and organizations from IEC Technical Committee 31 and related IECEx certification bodies are acknowledged as having provided invaluable input and test results in support of this paper. These include:

- Peter Thurnherr (Thuba Ltd) – Convenor of IEC SC 31J MT60079-14
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- Karel Neleman (Bartec)

- PTB (Germany)
- Dekra (Germany)
- Testsafe (Australia)
- TUV (Australia)
- Confidential - cable gland manufactures

Annex A Test results summary

Cable Details							Test Details							
Line ref.	Conductors (No. X mm^2)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
ERA - 1976														
1	4 x 95	PVC/SWA/PVC tape bedding	No (assumed)	500	300	stripped back to gland to expose indivivdual cores	60	Hydrogen 27.5%	Unknown (assumed atmospheric)	1	Inner gland seal to the cable bedding	No	ERA Report 3051-85	No significant thermal damage to the tape bedding
2	4 x 95	PVC/SWA/PVC tape bedding	No (assumed)	500	300		60	Hydrogen 27.5% + Oxygen 10% mix		1		No	ERA Report 3051-85	No significant thermal damage to the tape bedding
3	4 x 95	PVC/SWA/PVC tape bedding	No (assumed)	500	300	stripped back bedding into gland	60	Hydrogen 27.5%		1	Inner gland seal to the cable cores - tape bedding stripped back into the gland to simulate field installation difficulty in making off	No	ERA Report 3051-85	
4	4 x 95	PVC/SWA/PVC tape bedding	No (assumed)	500	300		60	Hydrogen 27.5% + Oxygen 10% mix		1		Yes	ERA Report 3051-85	The gland was prepared to simulate conditions met in practice at that time and not current permitted practice. The test had Oxygen enrichment. Severe thermal damage under the gland seal and beyond.
5	4 x 95	PVC/SWA/PVC tape bedding	No (assumed)	500	300	stripped back to gland to expose indivivdual cores	60	Ethylene 6.5%		5	Tape bedding removed. Cores covered with thermo-plastic tape and heat shrink sleeving applied over the thermo-plastic tape.	No	ERA Report 3051-85	No marked deterioration of core insulation
6	4 x 95	PVC/SWA/PVC tape bedding	No (assumed)	500	300		60	Ethylene 6.5%		10		Not tested	ERA Report 3051-85	No significant deterioration of core insulation or sleeving Not tested for flame transmission

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
7	4 x 240	PVC/SWA/PVC tape bedding	No (assumed)	500	300		60	Ethylene 6.5%		4	Cores covered with thermo-plastic tape and heat shrink sleeving applied over the thermo-plastic tape.	No	ERA Report 3051-85	Severe thermal deterioration of the filler material (PVC string) and core insulation under the sleeving. Severe deterioration of the tape bedding beyond the cable gland seal.
8	4 x 240	PVC/SWA/PVC tape bedding	No (assumed)	500	300		60	Ethylene 6.5%		8	Ten layers of PVC tape added to the tape bedding	Yes	ERA Report 3051-85	The gland was made off to test the reliability of alternate methods at that time and not current practice. The first 7 tests did not test for flame transmission but resulted in progressive deterioration under the gland. 8th test was for flame transmission. Severe thermal deterioration of the filler material (PVC string) and the tape bedding beyond the cable gland seal.
9	4 x 185	PVC/SWA/PVC tape bedding	No (assumed)	500	300		60	Propane 4.6% and Ethylene 6.5%		5+5	Inner heat shrink moulding applied to the branching point of the cores and tape bedding	No	ERA Report 3051-85	No significant deterioration of the core insulation, heat shrink moulding or the tape bedding
10	3.5 x 96	PVC/SWA/PVC	No (assumed)	500	300		60	Propane 4.6%		6	The first 3 tests with the end of the cable capped	No	ERA Report 3051-85	Cable with hollow PVC tube fillers. Evidence of flame penetration down the interstices of the cable.
11	3.5 x 96	PVC/SWA/PVC	No (assumed)	500	300		60	Hydrogen 27.5%		3		Not tested	ERA Report 3051-85	Cable with hollow PVC tube fillers. No significant damage to the cable.

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
12	3.5 x 96	PVC/SWA/PVC	No (assumed)	500	300		60	Ethylene 6.5% and Hydrogen 27.5%		2+1		Yes	ERA Report 3051-85	Cable with hollow PVC tube fillers. Flame propagation believed to be through the cable and not via the cable gland seal.
13	4 x 2.5	PVC/SWA/PVC	Yes (assumed)	500	300		60	Propane 4.6%		3		No	ERA Report 3051-85	No significant damage to the cable.
14	3 x 50	PVC/SWA/PVC	No (assumed)	500	300		60	Propane 4.6% and Hydrogen 27.5%		3+3		No	ERA Report 3051-85	Propane: No damage to inner bedding. Hydrogen: Significant damage to inner bedding under seal, axial slit and melt holes through bedding.
15	4 x 185	PVC/SWA/PVC	No (assumed)	500	300		60	Ethylene 6.5%		5+4	The first 5 tests were with the cable end uncapped followed by 4 tests with the end of the cable capped.	No	ERA Report 3051-85	Considerable leakage of combustion products through the cable with some thermal deterioration but no ignition. No further damage once the cable end was capped.
16	VariousPower cables	PVC/SWA/PVC	unknown	500	300		60	Propane 4.6% and Hydrogen 27.5%		3+3	Cable configurations for 10 cables are not listed in the report	No	ERA Report 3051-85	
17	3 x 50	PVC/SWA/PVC	No (assumed)	500	300		60	Ethylene 6.5%		5		Not tested	ERA Report 3051-85	Cable core temperature 70°C. Inner bedding severely damaged above the gland seal, smoke emitted through the gland beyond the seal.

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
18	3 x 50	PVC/SWA/PVC	No (assumed)	500	300		60	Ethylene 6.5%		10		Not tested	ERA Report 3051-85	Cable core temperature 50°C Inner bedding collapsed into the core interstices. Any further tests would have possibly resulted in complete failure of the bedding and an increased possibility of flame transmission was assumed.
19	3 x 50	PVC/SWA/PVC	No (assumed)	500	300		60	Ethylene 6.5%		9		Not tested	ERA Report 3051-85	Cable core temperature 9°C (Ambient) Inner bedding severely damaged above the cable gland seal. Smoke emitted through the cable gland beyond the seal.
20	3 x 50	PVC/SWA/PVC	No (assumed)	500	300		60	Ethylene 6.5%		10		Not tested	ERA Report 3051-85	Cable core temperature 70°C. However, during the heating period (i.e. before the flame sensitivity tests), the temperature was raised to 85°C for 5 minutes. Bedding severely 'necked' forcing bedding material into the cable interstices effectively sealing between the cores. Very little smoke
21	Various Control cables	PVC/SWA/PVC	No (assumed)	500	300		60	Ethylene 6.5%		3	Cable details are not recorded but it was noted that the cable bedding was only 50% of the thickness of the power cables tested.	Not tested	ERA Report 3051-85	37 core multi-core cables had the bedding seriously disrupted with core insulation damaged to the extent that the cores became short-circuited.

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
22	37	PVC/SWA/PVC	No (assumed)	1000	300		30	Ethylene 6.5%		7		Not tested	ERA Report 3051-85	Smoke emitted through the cable gland. Bedding severely damaged beyond the gland seal. Core insulation damaged such that cable was considered to have failed completely
23	37	PVC/SWA/PVC	No (assumed)	500	300		2	Ethylene 6.5%		10		Not tested	ERA Report 3051-85	No discernible thermal deterioration of the cable.
24	Various Power cables	EPR/SWA/EPR	unknown	500	300		60	Ethylene 6.5%		10	Cable configurations are not listed in the report	Not tested	ERA Report 3051-85	The test with a 3-core 70mm² caused smoke to issue from the free end of the cable. The bedding became 'necked' with some erosion of the core insulation due to hot gas penetration.
25	Various Control cables	EPR/SWA/EPR	unknown	500	300		60	Ethylene 6.5%		10		Not tested	ERA Report 3051-85	
Manufacturer A 2000														
26	16 x 0.56	PVC/PVC	No (assumed)	175	50	Unknown	0.85	Hydrogen 37%	1.4	10		No	Manufacturer A	
27	16 x 0.56	PVC/PVC	No (assumed)	100	50		0.85	Hydrogen 37%	1.4	10		No	Manufacturer A	
PTB 2004														
28	5 x 2.5	PVC/PVC	Yes (assumed)	300	30	Not stripped. Cable cut square		Hydrogen 28% and Acteylene 7.5%	1.5	6+2		No	2004/00317.1.0/1952	Cable replaced after test 8
29	3 x 1	PVC/PVC	Yes (assumed)	300	30				1.5	6+3		No	2004/00317.1.0/1952	
30	3 x 1	PVC/PVC	Yes (assumed)	300	30				1.5	6+3		No	2004/00317.1.0/1952	
31	3 x 2.5	PVC/PVC	Yes (assumed)	300	30				1.5	6+2		No	2004/00317.1.0/1952	Cable replaced after test 8

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
32	2 x 1	PVC/PVC	Yes (assumed)	300	30				1.5	6+3		No	2004/00317.1.0/1952	Suspected failure on the Acetylene tests after 5 Hydrogen ignitions but the failure could not be verified
33	2 x 1	PVC/PVC	Yes (assumed)	300	30				1.5	6+3		No	2004/00317.1.0/1952	
34	9 x 0.25	PVC/PVC	No (assumed)	300	30				1.5	6+3		No	2004/00317.1.0/1952	
35	25 x 0.25	PVC/PVC	No(assumed)	300	30				1.5	6+2		Yes	2004/00317.1.0/1952	Failed on the Acetylene tests after 5 Hydrogen ignitionsCable replaced after test 8
36	3 x 0.5	PVC/PVC	Yes (assumed)	300	30				1.5	6+3		No	2004/00317.1.0/1952	
37	3 x 0.75	PVC/PVC	Yes (assumed)	300	30				1.5	6+3		No	2004/00317.1.0/1952	
38	2 x 1.5	Thermocouple	Yes (assumed)	300	30				1.5	6+2		No	2004/00317.1.0/1952	Cable replaced after test 8
Testsafe (Aust) 2006 - 2012														
39	6	Fibre optic cable	Yes (assumed)	100	5	Cut flush to cable gland	4	Methane(58 %) and Hydrogen(42%) mixture @ 12.5% H_2	1	5	Group I test. Enclosure size only noted as over 2L	No	TR 27379	
40	6	Fibre optic cable	Yes (assumed)	100	5							No	TR 27379	
41	1	Twinaxial communication	Yes (assumed)	100	5							No	TR 27379	
42	2pr x 0.5	PVC/TCB/PVC	Yes (assumed)	100	5							No	TR 27379	
43	2pr x 0.5	PVC/TCB/PVC	Yes (assumed)	100	5							No	TR 27379	

Cable Details							Test Details						
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
44	5 x 1	SIL/SIL/TCB/SIL	Yes (assumed)	100	5	Cut flush to cable gland	4	Hydrogen 55%	1	10	No and size of cable cores based on application description as the cable configuration was not provided	No	TI2295	
45	24 x 1	PVC/TCB/PVC	No (assumed)	100	5	Cut flush to cable gland	4		1	5	Enclosure size only noted as over 2L	No	TR31556	
46	3pr x 0.5	PE/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	4		1	5		No	TR31556	
47	1	Coax comms	Yes (assumed)	100	5	Cut flush to cable gland	4		1	5		No	TR31556	
48	14 x 1	PVC/INDTCB/ PVC	No (assumed)	100	5	Cut flush to cable gland	4	Methane(58 %) and Hydrogen(42%) mixture @ 12.5% H2	1	5	Group I test. Enclosure size only noted as over 2L	No	32290	
49	7pr x 0.5	PVC/INDTCB/ PVC	No (assumed)	100	5	Cut flush to cable gland	4		1	5		No	32290	
50	2pr x 0.5	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	5		1	5+5	Different cables of the same style	No	32684	
51	2pr x 0.5	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	5		1	5+5		No	32684	
52	2pr x 0.5	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	5		1	5+5		No	32684	
53	2pr x 0.5	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	5		1	5+5		No	32684	
54	2 x 2.5	SIL/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	10	Group I test	No	33873	
55	4 x 2.5	SIL/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	10		No	33873	
56	6 x 0.5	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	10		No	33830	

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
57	4 x 0.75	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	10		No	33830	
58	4pr x 0.13	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20	Group I test - different cable brands	No	33849	
59	4pr x 0.13	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
60	4pr x 0.13	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
61	4pr x 0.13	PVC/PVC	Yes(assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
62	2 x 1	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20	Group I test	No	33849	
63	3 trple x 1.5	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
64	1pr x 0.2	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
65	3pr x 0.32	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
66	5 x 0.75	PVC/PVC	No (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
67	12 x 0.75	PVC/PVC	No (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
68	34 x 1.5	PVC/PVC	No (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
69	4 x 10	PVC/PVC	No (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
70	2 x 0.5	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
71	1	Coax comms	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
72	24 x 1.5	PVC/TCB/PVC	No (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
73	6	Fibre optic cable	Yes (assumed)	100	5	Cut flush to cable gland	33		1	20		No	33849	
74	7 x 0.5	PVC/PVC	Yes (assumed)	100	5	Cut flush to cable gland	7		1	5		No	33655	
75	12 x 0.75	PVC/PVC	No (assumed)	100	5	Cut flush to cable gland	7		1	5		No	33655	
76	2 x 0.75	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	7		1	5		No	TR33570	
77	3 x 0.75	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	7		1	5		No	TR33570	
78	2 x 1	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	7		1	5		No	TR33570	
79	12 x 0.5	PVC/TCB/PVC	No (assumed)	100	5	Cut flush to cable gland	7		1	5		No	TR33570	
80	6 x 0.75	PVC/TCB/PVC	Yes (assumed)	100	5	Cut flush to cable gland	7		1	5		No	TR33570	
81	25 x 0.5	PVC/TCB/PVC	No (assumed)	100	5	Cut flush to cable gland	7		1	5		No	TR33570	
TUV (Aust) 2014														
82	2 to 6 core	PVC/PVC and PVC/braid/PVC Larger cables have fillers to provide a well sealed cable	Yes (assumed)	100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 1 details to be confirmed	No	19500039.001	
83				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 2 details to be confirmed	No	19500039.001	
84				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 3 details to be confirmed	No	19500039.001	
85				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 4 details to be confirmed	No	19500039.001	
86				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 5 details to be confirmed	No	19500039.001	

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
87				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 6 details to be confirmed	No	19500039.001	
88				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 7 details to be confirmed	No	19500039.001	
89				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 8 details to be confirmed	No	19500039.001	
90				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 9 details to be confirmed	No	19500039.001	
91				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 10 details to be confirmed	No	19500039.001	
92				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 11 details to be confirmed	No	19500039.001	
93				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 12 details to be confirmed	No	19500039.001	
94				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 13 details to be confirmed	No	19500039.001	
95				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 14 details to be confirmed	No	19500039.001	
96	2 to 6 core	PVC/PVC Larger cables have fillers to provide a well sealed cable	Yes (assumed)	100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 1 details to be confirmed	No	19500094.001	
97				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 2 details to be confirmed	No	19500094.001	
98				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 3 details to be confirmed	No	19500094.001	
99				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 4 details to be confirmed	No	19500094.001	
100				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 5 details to be confirmed	No	19500094.001	

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
101				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 6 details to be confirmed	No	19500094.001	
102				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 7 details to be confirmed	No	19500094.001	
103				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 8 details to be confirmed	No	19500094.001	
104				100	5	Cut flush to cable gland	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Cable 9 details to be confirmed	No	19500094.001	
105	24 x 1	PVC/PVC	No (assumed)	30	100	Not stripped	10	Hydrogen 55% + Oxygen 9.5% mix	1	5	Replacement gland test onto the same cable. Cable details to be confirmed. Custom gland used.	No	19500097.001	
106	24 x 1	PVC/PVC	No (assumed)	30	100	Not stripped	10	Hydrogen 55% + Oxygen 9.5% mix	1	5		No	19500097.001	
107	24 x 1	PVC/PVC	No (assumed)	30	100	Not stripped	10	Hydrogen 55% + Oxygen 9.5% mix	1	5		No	19500097.001	
Intertek (EEMUA) 2015														
108	4 x 2.5	XLPE/PVC/SWA/PVC	No (confirmed in 2017 re-testing by Intertek)	3000	50	stripped back close to gland	12	Propane 4.6%	Unknown	3	Cable restricted breathing result is based on issue 2 of the Intertek-EEMUA report.Internal length is estimated based on photos of the test setup.	No	EEMUA ref 102027658CHE-001	No significant damage to the cable bedding.
109	3 x 50	XLPE/PVC/ SWA/PVC		3000	50	stripped back close to gland	12	Propane 4.6% and Hydrogen 28%	Unknown	3+3		No	EEMUA ref 102027658CHE-001	No significant damage to the cable bedding.
110	20pr x 0.75	PVC/SWA/PVC		1000	100	stripped back close to gland	12	Ethylene 6.5%	Unknown	10		Not tested	EEMUA ref 102027658CHE-001	Severe damage to core insulation is reported after many ignitions Not tested for flame transmission.
111	20pr x 0.75	PVC/SWA/PVC		1000	100	stripped back close to gland	3	Ethylene 6.5%	Unknown	10		Not tested	EEMUA ref 102027658CHE-001	Damage to core insulation. Not tested for flame transmission

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
112	20pr x 0.75	PVC/SWA/PVC		500	100	stripped back close to gland	2	Ethylene 6.5%	Unknown	10		Not tested	EEMUA ref 102027658CHE-001	Damage to core insulation. Not tested for flame transmission
113	3 x 50	XLPE/PVC/ SWA/PVC		3000	100	stripped back close to gland	12	Ethylene 6.5%	Unknown	10		Not tested	EEMUA ref 102027658CHE-001	20mm long split observed to bedding but this may have been caused while fitting off the gland. Not tested for flame transmission.
114	3 x 50	XLPE/PVC/ SWA/PVC		3000	100	stripped back close to gland	12	Ethylene 6.5%	Unknown	10		Not tested	EEMUA ref 102027658CHE-001	Re-test of previous test. Bedding split in 3 places, one of which went under the cable gland seal back to the cable armour. Not tested for flame transmission
115	3 x 50	XLPE/PVC/ SWA/PVC		3000	100	stripped back close to gland	2	Ethylene 6.5%	Unknown	10		Not tested	EEMUA ref 102027658CHE-001	Minor damage observed to core insulation via binder tape. Not tested for flame transmission.
116	3 x 50	XLPE/PVC/ SWA/PVC		1000	100	stripped back close to gland	2	Ethylene 6.5%	Unknown	10		Not tested	EEMUA ref 102027658CHE-001	Minor damage observed to core insulation via binder tape. Not tested for flame transmission.
Dekra 2016														
117	34 x 1	PVC/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
118	40 x 0.5	PVC/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
119	4 x 2.5	EPR/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
120	12 x 0.5	PVC/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
121	2 x 1	EPR/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
122	3 x 1.5	EPR/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
123	3 x 2.5	Si/Si	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
124	7 x 0.5	PVC/Scn/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
125	7 x 0.5	PVC/SWA/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
126	7 x 0.75	PVC/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
127	2+E x 1.5	PVC/Scn/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5%	1.5	5+5		No		
128	34 x 1	PVC/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		Yes		Subsequent tests in 2017 with longer cable lengths of 1.5m were successful (i.e. no flame transmission) - see later Dekra 2017 details, entry 139
129	40 x 0.5	PVC/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		Yes		Subsequent tests in 2017 with longer cable lengths of 1.5m were successful (i.e. no flame transmission) - see later Dekra 2017 details, entry 140

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
130	4 x 2.5	EPR/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
131	12 x 0.5	PVC/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		Yes		Subsequent tests in 2017 with longer cable lengths of 1.5m were successful (i.e. no flame transmission) - see later Dekra 2017 details, entry 141
132	2 x 1	EPR/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
133	3 x 1.5	EPR/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		Yes		Subsequent tests in 2017 with longer cable lengths of 1.5m were successful (i.e. no flame transmission) - see later Dekra 2017 details, entry 142
134	3 x 2.5	Si/Si	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
135	7 x 0.5	PVC/Scn/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
136	7 x 0.5	PVC/SWA/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
137	7 x 0.75	PVC/PUR	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
138	2+E x 1.5	PVC/Scn/PVC	Yes	450	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
Dekra 2017 - Further testing of those samples from previous tests in 2016 (entries 128, 129, 130, 131) that failed but with longer cables														
139	34 x 1	PVC/PVC	Yes	1500	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
140	40 x 0.5	PVC/PVC	Yes	1500	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
141	12 x 0.5	PVC/PVC	Yes	1500	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		
142	3 x 1.5	EPR/PUR	Yes	1500	50	Not stripped	40	Hydrogen 28% and Acteylene 7.5% and Propane 4.3%	1.5	5+5+5		No		

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
Intertek (EEMUA) 2017 - Further testing of one cable from 2015 tests														
143	3 x 50	XLPE/PVC/ SWA/PVC	No	3000	100	Stripped back close to gland and conductor s splayed out	2	Propane 4.6% and Hydrogen 28% and Acetylene 7.5%	Unknown	5+5+ 5		Yes	EEMUA ref 102027658CHE-001 - issue 2	Flame passed at 5th Hydrogen ignition and first subsequent Acetylene ignition. No damage to bedding. Ignition thought to be because the cable end was too close to the external bag.
144	3 x 50	XLPE/PVC/ SWA/PVC	No	3000	100	Stripped back close to gland and conductor s splayed out	40	Propane 4.6% and Hydrogen 28% and Acetylene 7.5%	Unknown	5+5+ 5		Yes	EEMUA ref 102027658CHE-001 - issue 2	Flame passed at 3rd Hydrogen ignition and 3 subsequent Acetylene ignitions. Cable bedding split to beyond the gland seal.
145	3 x 50	XLPE/PVC/ SWA/PVC	No	3000	100	Stripped back close to gland and conductor s splayed out	2	Ethylene 6.5%	Unknown	10		No	EEMUA ref 102027658CHE-001 - issue 2	Minor damage to cable bedding
146	3 x 50	XLPE/PVC/ SWA/PVC	No	3000	100	Stripped back close to gland and conductor s splayed out	40	Ethylene 6.5%	Unknown	10		No	EEMUA ref 102027658CHE-001 - issue 2	Damage to cable bedding
147	3 x 50	XLPE/PVC/ SWA/PVC	No	3000	100	Stripped back close to gland and conductor s splayed out	2	Propane 4.6% and Hydrogen 28% and Acetylene 7.5%	Unknown	5+5+ 5		Yes	EEMUA ref 102027658CHE-001 - issue 2	Flame transmission at all Hydrogen ignitons but not subsequent Acetylene ignitions. No damage to the bedding. Video evidence appears to show that transmissions occurred in vicinity of the gland and not from the end of the cable. The gland seal was slightly deformed – which suggests that the seal failed to prevent transmission.

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
KIWA 2017														
148	1 x 10	PVC	Yes (assumed)	2500	100	Not stripped	4.5	Hydrogen 27.5%	1	5	Ambient temperature 21C	No	170200556 issue 1	
149	4 x 0.5	TPE/TPE	Yes (assumed)	1360	100	stripped back close to the gland	4.5	Hydrogen 27.5%	1	5		No	170200556 issue 1	
150	12 x 1.5	PVC/PVC	No (assumed)	840	100	stripped back close to the gland	4.5	Hydrogen 27.5%	1	5		No	170200556 issue 1	
151	16 x 0.5	PVC/PVC	No (assumed)	2740	100	stripped back close to the gland	4.5	Hydrogen 27.5%	1	5		No	170200556 issue 1	
152	1 x 50	EPR	Yes (assumed)	2400	100	Not stripped	4.5	Hydrogen 27.5%	1	5		No	170200556 issue 1	
153	1 x 50	EPR	Yes (assumed)	1300	100	Not stripped	4.5	Hydrogen 27.5%	1	5		No	170200556 issue 1	
154	1 x 70	EPR	Yes (assumed)	3730	100	Not stripped	4.5	Hydrogen 27.5%	1	5		No	170200556 issue 1	
Manufacturer B 2018														
155	3 x 1.5	PVC/PVC	Yes (assumed)	100	25	stripped back to gland	70	Hydrogen 37%	Unknown	5	Approx 12mm cable ODs. Approximate cable details - based on photos of the test arrangement as details are not available	No	Report 7697	Barrier gland was used
156	3 x 1.5	PVC/PVC	Yes (assumed)	100	25	stripped back to gland	70	Hydrogen 37%	Unknown	5		No	Report 7697	Barrier gland was used
157	3 x 1.5	PVC/SCN/PVC	Yes (assumed)	100	25	stripped back to gland	70	Hydrogen 37%	Unknown	5		No	Report 7697	Barrier gland was used
158	no data	PVC/SCN/PVC	Yes (assumed)	100	100	Not stripped	70	Hydrogen 37%	Unknown	5		No	Report 7697	
159	no data	PVC/SCN/PVC	Yes (assumed)	100	100	Not stripped	70	Hydrogen 37%	Unknown	5		No	Report 7697	
160	no data	PVC/SCN/PVC	Yes (assumed)	100	100	Not stripped	70	Hydrogen 37%	Unknown	5		No	Report 7697	
161	no data	PVC/SCN/PVC	Yes (assumed)	100	5	Not stripped	70	Hydrogen 37%	Unknown	5		No	Report 7697	

Cable Details							Test Details							
Line ref.	Conductors (No. X mm²)	Cable type	Pass restricted breathing test	External cable length (mm)	Internal cable length (mm)	Internal cable fit off	Enclosure size (L)	Test gas or gas mixture	Test gas pressure (Bar)	No. of tests	Test procedure comments	Flame transmission	Reference Doc	Test result notes
162	no data	PVC/SCN/PVC	Yes (assumed)	100	5	Not stripped	70	Hydrogen 37%	Unknown	5		No	Report 7697	
163	no data	PVC/SCN/PVC	Yes (assumed)	100	5	Not stripped	70	Hydrogen 37%	Unknown	5		No	Report 7697	
Cable Gland Manufacturer/Presafe 2018														
164	25 samples	(NEK 606)	Yes	200	?	?	10 (approx)	Acteylene 8%		5	Approx 8 to 12mm cable ODs. Approximate cable details - based on photos of the test arrangement as details are not available	No	Presafe report D0003317 May 2018	
165	25 samples	(NEK 606)	Yes	200	?	?	10 (approx)	Hydrogen 27.5%		5		Yes	Presafe report D0003317May 2018	Flame transmission occurred on the first test
166	25 samples	(NEK 606)	Yes	500	?	?	10 (approx)	Acteylene 8%		5		No		
167	25 samples	(NEK 606)	Yes	500	?	?	10 (approx)	Hydrogen 27.5%		5		Yes		