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FLAMMABLE REFRIGERANTS IN SERVICE

Service equipment and R290

Suitable service equipment is required to ensure safe handling of flammable refrigerants during maintenance and service of refrigeration systems and heat pumps. The use as well as possible misuse must be considered for a risk assessment. Risks may arise when A2L refrigerants and especially R290 are handled incorrectly.

Picture: CPS

Scales, type CPS CC220

Within the scope of the investigation presented here, tests were carried out on service equipment in a flammable atmosphere (R290/air) at a highly ignitable concentration. The service devices tested were an extraction station, vacuum pump, filling scale and a fitter's aid from the manufacturer CPS. The aim of the investigation was to determine whether a hazard, and in particular an ignition effect, can be ruled out through the operation of the service equipment in the event of misuse. Misuse is understood to mean the creation or presence of an incorrectly induced flammable atmosphere.

The tests, which were carried out with an operating robot specially programmed for this purpose by ref-tech company in a special test chamber at the German National Metrology Institute (PTB), have shown that the service equipment examined does not represent an effective ignition source during incorrect handling of R290.

Introduction to the factual situation

Safe handling during servicing

The intended use of the service equipment considered here includes only the handling of approved refrigerants and avoidance of refrigerant release. Deliberate release of fluorinated refrigerant is not permitted under current legislation and would, therefore, be classified as gross negligence. Furthermore, avoidance of refrigerant release can be expected as a professionally recognised procedure during servicing. This typical professional procedure is also expected to be applied to handling flammable refrigerants and is even more important due to the chemical property of flammability. Therefore, a flammable atmosphere does not arise from the handling of the refrigerant when service equipment is used as intended, neither in the vicinity of the equipment nor in a supply line. Consequently, the first result of a risk assessment for intended use is that no reduction of the risk is necessary, provided that equipment such as vacuum pumps or suction devices are leak-proof.

However, special attention must be paid to the proper installation and arrangement of the exhaust hose. The vacuum pump extracts a significant amount of gas, for example R290 from a refrigeration system, which can lead to accumulation and formation of a flammable atmosphere in closed and poorly ventilated rooms. This process would correspond to the misuse already described above.

Risk assessment according to the EU Machinery Directive

According to the principles of the EU Machinery Directive, which applies, for example, to vacuum pumps and extraction devices, a risk assessment of a machine "includes its intended use and any reasonably foreseeable misuse". The risk assessment required by the Machinery Directive can be carried out according to EN ISO 12100:2010, which is designated as a harmonised standard for the Machinery Directive.

A foreseeable misuse to be considered is the release of the refrigerant due to incorrect behaviour of the service professional during handling and also a possible creation of flammable atmosphere.

In principle, this risk (human error) should be minimised through behavioural change measures because this can effectively prevent the creation of flammable atmospheres. However, it should also be noted that the

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frequency of human errors can be reduced, but not completely eliminated. As a "technical protective measure", forced ventilation of the working environment (mobile fan) can be used to prevent the formation of a flammable atmosphere. Both measures, apart from warnings and the provision of appropriate "user information", are not within immediate influence of the manufacturer of service equipment.

However, the design of the service equipment must be seen as being within immediate influence of the manufacturer, and in particular the checking of the ignition effectiveness and, if necessary, the corresponding adjustment of the design.

Examples of misuse and the risks

- incorrect connection of hoses,
- use of damaged hoses,
- incorrect installation of the vacuum pump or incorrect routing of the exhaust hose,
- suction of air-refrigerant mixtures from a refrigeration system into which air has penetrated after a leakage,
- unsuitable working environment,
- use of unsuitable or faulty ventilation equipment.

These malpractices may result from a lack of knowledge on the part of the service person, a lack of care in carrying out the service work or in maintaining the service equipment. Malpractice with respect to hoses or a vacuum pump may lead to an accumulation of refrigerant in closed and poorly ventilated rooms. If a concentration above the lower explosion limit (LEL of R290:38 g/m³) is reached, an ignition can be triggered by an existing effective ignition source (such as a service device) with various consequences.

Investigation objective

Based on the previous explanations and conclusions, it is, therefore, reasonable and justified to carry out an investigation of the ignition effectiveness of service equipment in a flammable atmosphere. The objective of the tests carried out was to determine for selected service equipment whether this equipment or its components can be ignitable in a flammable R290/air atmosphere during typical switching operations and operating processes performed by the service technician during normal intended operation in accordance with the operating instructions and, in addition, during unintended operation involving mishandling and malpractice. A highly ignitable mixture with a concentration of 5.2 vol.% of R290 in air was to serve as the flammable atmosphere.

Picture: CPS

Fitter's aid, type CPS MD100WVHE

Picture: CPS

Vacuum pump,type CPS VPS6DEV (model with solenoid valve (1) at the inlet; (2) on-off switch)

Description of the tests, set-up and operation

All investigated devices were provided for the tests by the CPS company. Some of the devices were approved for use with R290 at that time, but none was approved for operation in a potentially explosive atmosphere. The devices investigated were a scale, a fitter's aid, a vacuum pump and an extraction station. For each of the devices, a typical operating procedure was determined and described on the basis of the operating instructions, which was to be carried out in the tests. These operating procedures contained all operating steps that would occur during regular use in the intended normal operation. All the units investigated have different operating procedures

A total of seven tests were carried out.

- Test 1: Scales CPS CC220, fitter's aid CPS MD100W VHE and other small devices
- Test 2: Vacuum pump CPS VPS6DEV, without suction (inlet closed with a cap)
- Test 3: Vacuum pump CPS VPS6DEV, suction of ignitable mixture (inlet open)
- Test 4: Extraction station CPS TRS21E (external ignition sources), operating procedure
- Test 5: Extraction station (internal ignition sources), delivery of ignitable mixture (5.2 vol.%)
- Test 6: Extraction station (internal ignition sources), delivery of ignitable mixture (10 vol.%)
- Test 7: Repeat test with scales CPS CC220 and other scales

Picture: CPS

Operating robot, positioned here on the floor of the test chamber

Robot control

The service devices in the selected test chamber were operated by a desktop robot. When selecting the robot, care was taken to ensure that it did not itself represent an effective source of ignition and this was also checked and confirmed in advance of the actual tests with the service devices in the test chamber in an atmosphere with 5.2 vol.% of propane in air. In preparation for the tests, ref-tech equipped the robot with suitable operating attachments and combined them with the respective service devices to be investigated to form a reproducible experimental set-up. Then all the intended operating procedures of the service devices were programmed by ref-tech and then tested extensively. It was necessary to extensively test and try out the operating robot in advance in order to be able to reliably start up all test procedures in the test chamber later on. The programming, testing and trial phase was carried out in an internal laboratory of ref-tech and the test set-up was then delivered to the test field and the test chamber of the National Metrology Institute and reassembled there.

Test set-up and equipment

The test set-ups with the devices to be investigated and the operating robot were set up in a test chamber of the National Metrology Institute that allowed the intended operating procedures to be carried out in an explosive air/propane atmosphere. The procedures for operating and filling the test chamber were ensured by the National Metrology Institute. The devices were connected in the chamber with all necessary supply lines (power supply, hoses) and the operating robot with supply and control lines. After completion of the set-up, a test run of the operating procedures was carried out to check and ensure that the intended operation in the test was implemented as planned by the robot control. The control was carried out via a computer that was placed outside the chamber.

After successful testing of the operating procedures, the chamber was sealed for each test and filled with the intended mixture containing 5.2 vol.% of propane in air. The accuracy of the determination of the propane content was ±0.3 vol.%.

Test execution and operating procedure

In the closed test chamber filled with the propane/air mixture, the intended operating procedure of one device or several devices were started one after the other. Each operating procedure was carried out 10 times per service device at a constant atmosphere in the chamber (test cycle). As an example, we provide the description of the operating procedure for the extraction station that was carried out as part of the investigation of possible external ignition sources of the device. The extraction station sucked in air from the outside environment of the chamber (hall) via a hose that was led out of the chamber and conveyed it into a second hose that was also led out of the chamber. This hose had a shut-off valve with which the hose could be closed and opened manually outside the chamber to trigger and release the high-pressure shut-off. With the shut-off valve closed, the robot switched on the extraction station in the closed chamber filled with the ignitable mixture and then let it run until the internal pressure switch of the extraction station switched off. Then the valve was opened manually and the pressure switch was reset by the robot. After a further run time of five seconds, the robot switched off the extraction station and the valve was closed again

Picture: CPS

Extraction station, type CPS TRS21E: Operating controls on the control box

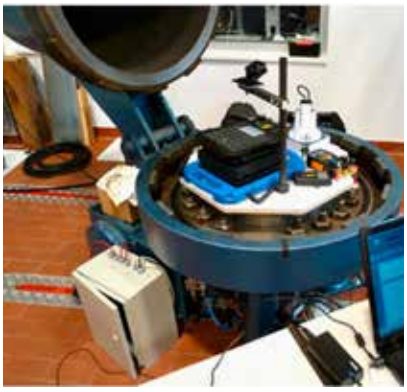
manually. One operating procedure lasted about 36 seconds and was performed ten times in the test cycle. The movements of the operating robot were tracked by means of live images from a high-speed camera installed in the chamber for accurate documentation of a possible ignition event. The execution of the test was also randomly observed through viewing glasses of the test chamber. The operation of the vacuum pump and the extraction station could be heard acoustically outside of the test chamber. Video recordings were made in the test chamber to document the execution of the operating procedures in the test according to the plan.

Video documentation

During all tests, a video recording was made inside the test chamber to document the successful execution of the operating procedures in the test according to the plan. These recordings were also used to create an overall video, which gives a complete idea of the investigation with explanations of the background and objectives of the tests, the recordings of the various test executions in the test chamber and the presentation of the results.

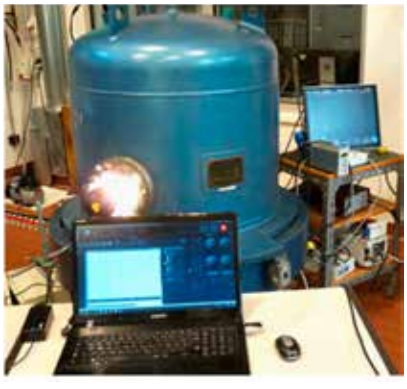
Results and discussion

All tests carried out were without an ignition event. The scales and the fitter's aid showed no ignition behaviour in the R290/air mixture in the test cycle with 10 operating procedures. The vacuum pump showed no ignition behaviour in two test cycles, neither with a closed inlet nor with an open inlet and extraction of the most ignitable mixture - i.e. also no internal ignition. The examined extraction station showed no ignition behaviour in the test cycle with normal switching operations (including overpressure cut-off). In addition, it was found in further tests that no internal ignition (or external ignition) occurred even during extraction of ignitable mixture. These tests were carried out with extraction of a mixture with 5.2 vol.% and 10 vol.% of propane for a period of approx. 13 min and approx. 20 min respectively. The test results prove that in the event of a faulty release of flammable refrigerant and the formation of an explosive atmosphere in a service situation or faulty delivery of an explosive mixture, no ignitability is to be expected from the devices tested. This conclusion refers to the devices in the examined proper condition. The conclusion does not apply to poorly maintained, damaged or incorrectly repaired equipment. Furthermore, it should not be inferred from the investigation that operation of the service devices in an explosive atmosphere would be permissible. The results should also not lead to careless actions when servicing refrigeration systems with flammable refrigerant. The avoidance of releases and thus the prevention of the formation of explosive atmospheres is the most important measure to prevent accidents, especially since the presence of other effective sources of ignition cannot be ruled out.



Picture: CPS

Test set-up at the National Metrology Institute: The closed test chamber



Picture: CPS

Test set-up at the National Metrology Institute: opened with service devices and the operating robot mounted on the floor

Summary

No ignition events could be detected or observed with any of the tested devices. Even when the most ignitable mixture was extracted by the extraction station or conveyed by the vacuum pump, no internal or external ignition could be detected. A video documentation of all tests was made with the presentation of set-ups, executions and results.

This investigation has determined that the CPS devices exceed the necessary safety requirement, which is also documented in the operating instructions, because the intended use in a flammable atmosphere is excluded. The results are apt to show that, even if a flammable atmosphere occurs due to faulty operation or incorrect behaviour by the operator, no ignition is to be expected from the operation of the CPS devices. Faulty operation also includes incorrectly routed or screwed hose connections and, for example, incorrect routing of the exhaust hose. The vacuum pump VPS6DEV from CPS has been replaced by the new series of vacuum pumps named VPB4D, VPB6D and VPB12D. A comparison of the electrical components between the previous and the new series showed that it can be assumed that the ignition characteristics of the new series are the same. Therefore, it can also be concluded that no ignition events are to be expected in case of misuse of the current devices.

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