Circular economy ecosystem to Recover, Recycle and Re-use F-gases contributing to the depletion of greenhouse gases -LIFE 3R

Deliverable: Methodology & Good Practice Guidelines

Action C1

Responsible for Deliverable: NATIONAL TECHNICAL UNIVERSITY of ATHENS (NTUA)

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Abstract

This deliverable focuses on the establishment of a sustainable **methodology** able to provide an effective F-gas recovery/recycling process in real-time and on-site. To this end, a series of instructions in the form of an operating manual are considered to be more than essential so that (field) installers can access all the basic knowledge as well as the practical skills required for sampling, analysis and characterization of recovered F-gas. Meanwhile, some practical recommendations and tips will be briefly presented on how to undertake leak checking, installation, servicing and maintenance of stationary refrigeration, air conditioning and heat pump equipment containing refrigerants (**Good Practice Guidelines - GPG**). It is supposed that the appropriate implementation of both the proposed methodology and GPG will lead to a coherent and robust Self-certification scheme, acting the latter, as an accurate database with a wide range of valid information on the F-gas quantity and quality.

Contents

*__Disclaimer__: All videos (hyperlinks) contained in the "Good Practice Guidelines (GPG)" section has an educational character and are in no way binding. In addition, they may be protected by third-party copyright.

1 Proposed methodology for F-gas recovery

1.1 Diagnostic tools, Key auxiliary equipment

As long as the Life3R project is in progress, a prototype is under development to meet all well-defined F-gas recovery and recycling requirements. The innovation element in this concept is supposed to be the combination of a classic refrigerant composition analyser with the Daikin's R-Cycle unit. The latter one is a portable refrigerant recovery device which applies an additional functionality by supporting a unique electrostatic separation method capable not only removing oil and contamination as a large distillation apparatus but also moisture and acid by a large filter dryer.

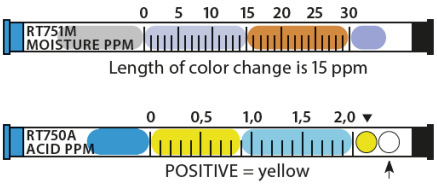
Hence, the ongoing prototypes are expected to enable the on-site composition determination of a refrigerant, its categorization as well as the removal of oil and moisture from it. This will have a very positive impact on field installers as the relevant procedure will be significantly upgraded and simplified in relation to the current practice. In this direction, the final version of the prototype units will incorporate IOT capabilities as extra in order to ensure the easy and direct data transfer from the unit to the Self-certification platform.

Overall, the proposed F-gas recovery process will include six (6) different diagnostic tools:

1. Portable Moisture and Acidity Checkers
2. Recovery Bottles
3. Portable Composition Analyzer
4. Vacuum Pump
5. Drier Filters
6. Recovery Machine

A summary of the key characteristics and operating principles of each of them is depicted in **Table 1** that follows:

Table 1: Key Characteristics & Operating Principles of diagnostic tools.

Diagnostic tools	***Key Characteristics & Operating Principles***	
Portable Moisture & Acidity Checkers	➢ Colour comparing sticks, refrigerant is injected through the stick. ➢ The sticks have an expiration date. Be aware to use it before the expiration date.	
Recovery Bottles	➢ Should equip both liquid and vapor valves (Recycling equips liquid valve, oil removal equips vapor valve in upside-down position, vacuuming equips vapor valve).	
Portable Composition Analyzer	➢ Relies on Non-Dispersive Infrared Technology. ➢ Liquid and vapor sampling possible. ➢ Blended refrigerants should be liquid sampled.	
Vacuum Pump	➢ Quality of vacuum has a very high correlation with moisture and non-condensables level of the output.	
Drier Filters	➢ Removal of moisture relies on the differentiation of evaporation temperatures for water and the refrigerants. ➢ Moisture is also extracted with oil. ➢ For better output results drier filters on suction line and on discharge line is necessary. ➢ Drier filters should be replaced every x kg of reclaim (x is stated in the info sheet of the drier filter). ➢ Quality of Drier Filter has a big impact on moisture levels.	
Recovery Machine	➢ R-Cycle is easy to use. ➢ Can be connected directly to the installed HVAC-R equipment. ➢ After connecting the refrigerant recovery bottle, the recovery and recycling process is automatic.	

1.2 Process flow

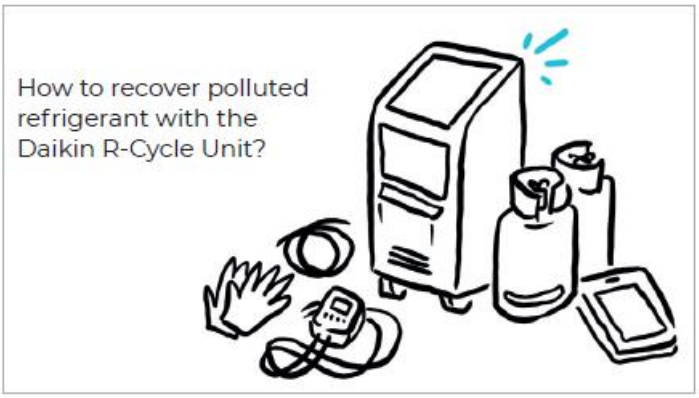


Figure 1: The basic tool components of the applied F-gas recovery process.

As a first step, the field installer has to confirm that a clean and vacuumized cylinder is readily available. This will then be placed on a scale to avoid any possibility to be filled up more than its rated volume (**Figure 2**).

Figure 2: Place a clean and vacuumized cylinder on a scale. **(Step 1)**

As a second step, both filter dryer and side glass must be connected to the Daikin's R-Cycle unit (**Figure 3**). Moreover, the release of nitrogen as well as the insertion of a molecular sieve are also required when using the unit for the first time. The sieve should be replaced every 20 hours of operation when recovering R-410A/R-32 and all 40 hours when recovering R-134a. The elapsed time can be checked through the timer integrated in the R-Cycle unit (**Figure 4**).

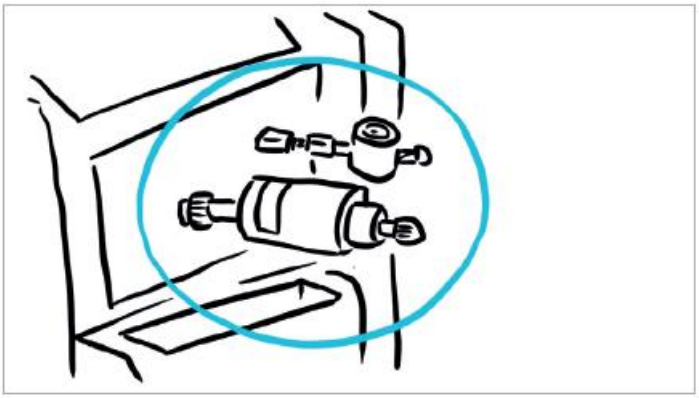


Figure 3: Connect the filter dryer and the side glass to the unit. **(Step 2)**

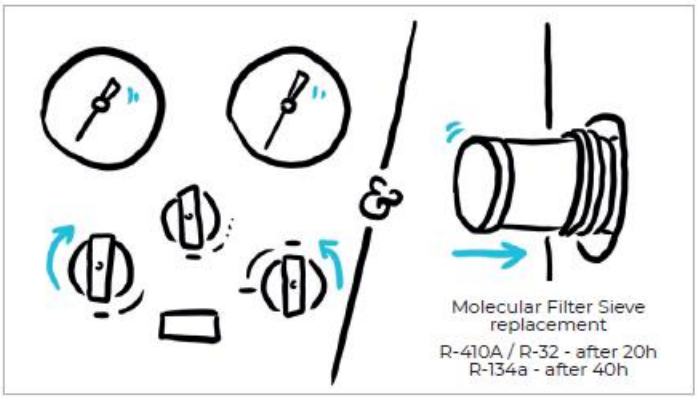


Figure 4: When using the unit for the first time, release the nitrogen from the unit and insert the molecular filter sieve. **(Necessary action before the first use of the unit)**

As a third step, the manifold will be connected to the cylinders and the unit under the condition that the cylinder valves are kept shut. Among others, the discharge hose should be connected to the manifold as well. At this point, the field installer needs to make sure to use the hose with the ball valves. Since all the above-mentioned actions have taken place, the vacuum pump can now be connected to the manifold, too. This implies the opening of all valves on the manifold and the starting of the pump. Once the vacuum is reached, the manifold and the pump will be closed and turned off, respectively (**Figure 5**).

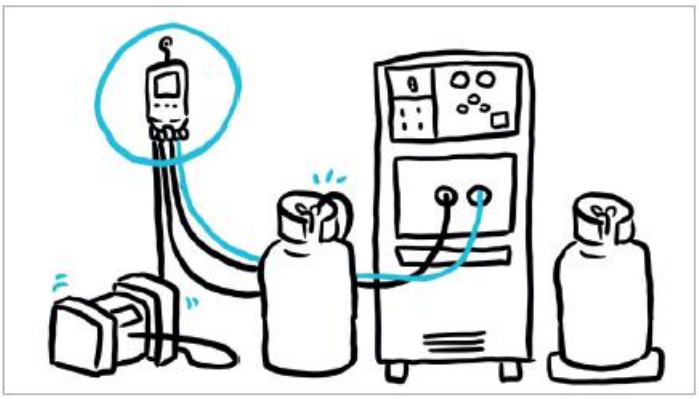


Figure 5: Connect the manifold to the cylinders, the unit and the vacuum pump, and start the pump until vacuum is reached. **(Step 3)**

As a fourth step, the ball valves of the discharge hose must be closed so that the connection of it to the empty cylinder can be feasible. Subsequently, the ball valves of the discharge hose and the liquid part of both cylinders are all to be opened. Furthermore, the field installer should slowly open the ports between the used refrigerant and the unit. Now, the unit will be adjusted to auto shut-off and then start with a push on the start button. During the extraction of the used refrigerant, the monitoring of the scale will contribute to the prevention from overfilling. The unit stops when the recovery cycle is complete. Likewise, the valves and the unit should be closed and turned off, respectively (**Figure 6**).

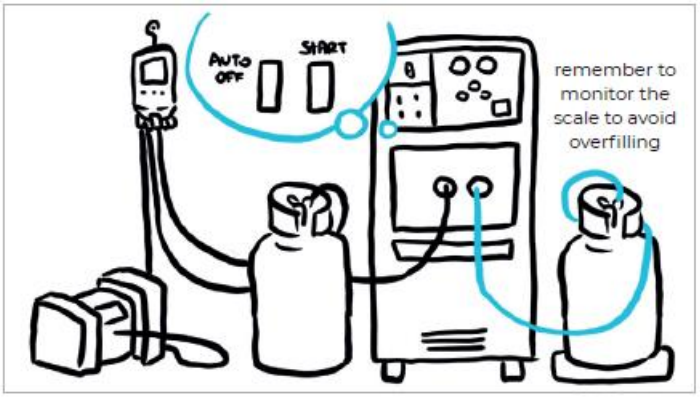


Figure 6: Extract the used refrigerant by adjusting the unit to auto shut-off and starting it with one push on the start button. The unit stops when the recovery cycle is complete. **(Step 4)**

As a final step, the purge of the remaining refrigerant from the unit will take place (**Figure 7**). For this purpose, the switch must be turned in purge while the unit is off. After that, the field installer has to run three back-to-back actions:

- Open the discharge port.
- Slowly turn the section port to purge, thus keeping the pressure below 2 bar.
- Start the unit with the start button.

When the unit stops, all valves will be closed.

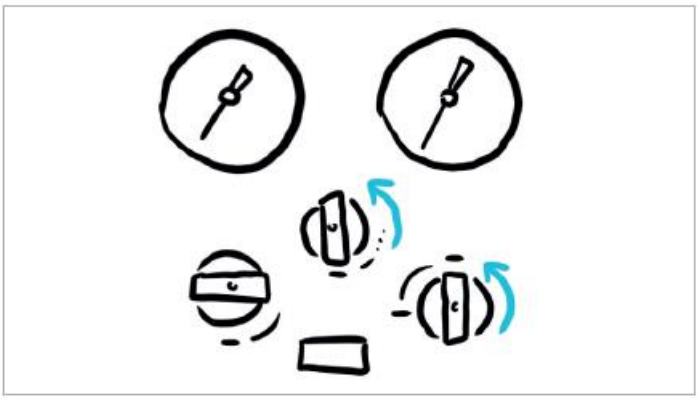


Figure 7: While the unit is off, turn the switch to purge in order to purge the remaining refrigerant from the unit. When the unit stops, close all valves. **(Step 5)**

The recovery cycle is now complete (**Figure 8**). Two equally representative videos with the methodology applied for the entire process can be found at the following YouTube links: https://www.youtube.com/watch?v=_oxrO6VHxrE and https://youtu.be/M5AntRqubrU.

Figure 8: The recovery cycle is now complete.

2 Good Practice Guidelines (GPG)

2.1 Recovery Machine

Regarding the **Recovery Machine**, a comprehensive video on how to properly recover refrigerant from an installed HVAC-R application, is available at the following link: https://youtu.be/p4tS_TcrY0c. Based on the use instructions attached in this video, a corresponding set of Good Practice Guidelines (GPG) has been established, like this in **Table 2**:

Table 2: Good Practice Guidelines (GPG) for Recovery Machine.

Step by Step	***Recovery Machine – Good Practice Guidelines (GPG)***
GPG 1	*Make sure the drier filter is connected to the suction portion of the recovery machine. Connect the recovery bottle to the discharge portion on the recovery machine and verify that it is in the closed position. Then start the recovery on the liquid side.*
GPG 2	*Reconnect your gauges to the condensing unit.*
GPG 3	*Connect the yellow hose to the filter drier that connects to the inlet on the recovery machine.* *Make sure it is set to liquid.*
GPG 4	*Open the valve and plug the recovery machine.*
GPG 5	*Nozzles must be set to recover and turn on the machine. Open the outlet suction.*
GPG 6	*Now we're going to open the liquid gauge.*
GPG 7	*After a few minutes, you may check the gauge and the recovery machine level of refrigerant.*
GPG 8	*Once you hit 0, close the right gauge, inlet, and outlet suctions. Turn off the recovery button and the system. Close the valves.*
GPG 9	*Take the gauge and transfer it to the vapor side. Open the valve. Set the inlet button to vapor. Switch on the recover, the outlet button and press start.*
GPG 10	*Open the low side gauge and we wait until we are below zero.*
GPG 11	*Close the low side, close the vapor valve on the recovery tank. Closet the inlet suction, the recovery button and shut down the pump.*

As already stated, the R-Cycle Unit also incorporates recycling functions other than refrigerant recovery. Therefore, this type of device equips distillation technique and make use of the distinction between evaporation points for the refrigerant and oil, water (moisture). That is why it is only applicable to azeotropic and near-azeotropic type blends. Nevertheless, it should be emphasized that non-condensables and acidity extraction is not possible.

In conclusion, two additional Good Practice Guidelines (GPG) are proposed for this case:

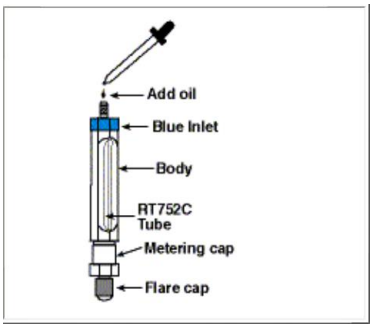
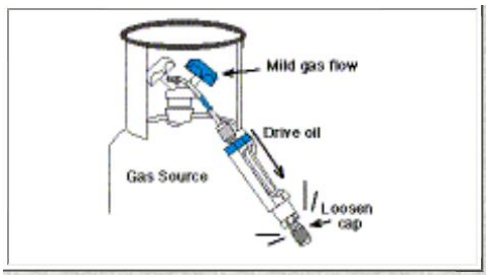
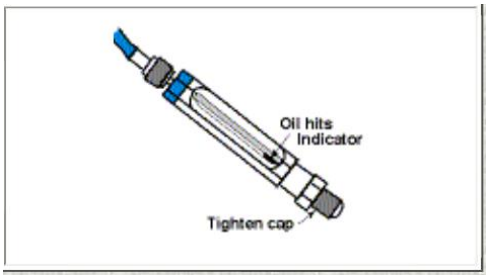
- **GPG 12**: Measure initial and final samples in terms of composition, moisture, non-condensables and acidity content.
- **GPG 13:** Equipping new bottle every time, or cleaning the bottles will eliminate the risk of cross-contamination through consecutive use.

2.2 Portable Moisture & Acidity Checkers

Except for the Portable Moisture & Acidity Checkers, the "Easy Oil Test" is considered to be the third basic detector tube under the Checkmate Method, the industry's only valid field test for measuring Acid and Moisture levels in both the compressor oil and in any F-gas. A comprehensive video with the entire contamination detector kit is available at the following link: https://www.youtube.com/watch?v=ueR7QYR8HYE&t=108s. Based on the use instructions attached in this video, a corresponding set of Good Practice Guidelines (GPG) has been established for both the Easy Oil Test and Moisture/Acid Detector Tubes.

Regarding the **Easy Oil Test** (RT 752 C), the relevant Good Practice Guidelines (GPG) on how to either pre-test stock Oil before addition to a System or test Oil that can be directly drained from a Compressor, are summarized in **Table 3**. Especially for this case, a complementary video is provided as a kind of more specific knowledge: https://youtu.be/-tcEHIC9uMk

Table 3: Good Practice Guidelines (GPG) for the Easy Oil Test.

Step by Step	Testing Oil "Outside" a System – Good Practice Guidelines (GPG)	
GPG 1	*Add about two (2) drops of Oil to the Blue inlet of a fully assembled unit with Detector Tube in place.*	
GPG 2	*Open gas valve to pressurize the assembly.*	
GPG 3	*Loosen flare cap for a mild bleed.*	
GPG 4	*Gas pressure will quickly drive the Oil through the Transfer Agent and deposit a stain on the Indicator.*	
GPG 5	*Stop flow by tightening the flare cap and close the gas valve.*	
GPG 6	*Disconnect entire assembly at extension hose relieving any remaining back pressure.*	
GPG 7	*Remove Detector Tube and match the Indicator to the Colour Chart.*	

It is the Colour Chart that shows six (6) possible levels of contamination with the description of what each colour change means. This means that the results can be interpreted by colour like below:

- Positive test results are:

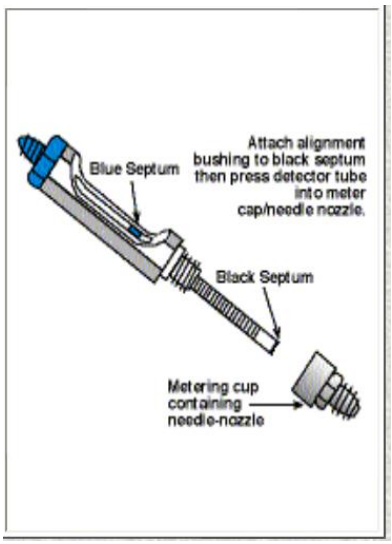
  1. **Yellow:** the level oil is so low, it is considered "dry".
  2. **Brown / orange:** the moisture level is low.
  3. **Pink:** the level of moisture/acid is acceptable.

- Negative test results are:

  4. **Red:** the moisture level is too high.
  5. **Violet:** acid hydrolysis.
  6. **Dark blue:** severe hydrolysis.

Regarding the **Moisture (RT 751 M) & Acid (RT 750 A) Detector Tubes**, the relevant Good Practice Guidelines (GPG) on how to take the F-gas testing to properly determine the moisture/ acid content of any used refrigerant (CFC, HCFC or HFC), are summarized in **Table 4**:

Table 4: Good Practice Guidelines (GPG) for Moisture & Acid Detector Tubes.

Step by Step	***Moisture & Acid Detector Tubes – Good Practice Guidelines (GPG)***	
GPG 1	*Arrange hose gauge manifold (as pictured above) with 8-10 ft. of 1/4 inch ID hose. Optimum is 9 feet.*	
GPG 2	*Connect Blue extension hose and Checkmate Body to gas source.*	
GPG 3	*Purge extension hose and body with the test gas.*	
GPG 4	*Stop purge. Slide and press Detector Tube into body Blue end first.*	
GPG 5	*Screw down metering cap.*	
GPG 6	*Connect to hose gauge arrangement.*	
GPG 7	*Start Refrigerant flow. Stop gas flow when low side gauge reaches the correct Termination Pressure for the Refrigerant being tested. Refer to Chart on back cover.*	
GPG 8	*Remove Detector Tube and note the length of colour change. Refer to chart on inside back cover.*	

2.3 Drier Filter

Regarding the **Drier Filter**, a comprehensive video on how to properly install it to an HVAC-R application is available at the following link: https://youtu.be/yhr88nTdaK4. Based on the use instructions attached in this video, a corresponding set of Good Practice Guidelines (GPG) has been established, like this in **Table 5**:

Table 5: Good Practice Guidelines (GPG) for Drier Filters.

Step by Step	***Drier Filter – Good Practice Guidelines (GPG)***
GPG 1	*Cut the pipe, clean it, install the drier filter.*
GPG 2	*Cut the pipe.*
GPG 3	*Clean both ends.*
GPG 4	*Remove the plastic inserts on both ends and dry fit your pipe into your filter drier.*
GPG 5	*Straighten the connections with a torch and let it cool off afterwards.*
GPG 6	*Install the valves into the condensing unit and pull the vacuum in to remove any contaminant.*

2.4 Portable Composition Analyzer

Regarding the **Portable Composition Analyzer**, a comprehensive video on how to use it to properly determine the composition of the recovered refrigerant on-site, is available at the following link: https://youtu.be/fok1xr7Lo7c. Based on the use instructions attached in this video, a corresponding set of Good Practice Guidelines (GPG) has been established, like this in **Table 6**:

Table 6: Good Practice Guidelines (GPG) for Portable Composition Analyzer.

Step by Step	***Portable Composition Analyzer – Good Practice Guidelines (GPG)***
GPG 1	*Press the left button on the analyzer.*
GPG 2	*Allow it to power on and then connect your supplied sample hose to the device.*
GPG 3	*Once the warm up process is complete, an air calibration will be required.*
GPG 4	*Press the right key button to begin. Air Calibration takes 130 seconds.*

3 Future work

Overall, it is estimated that both the proposed methodology and the guidelines of good practice (GPG) will make field installers capable of carrying out a composition analysis, in real-time and on-site, for any used F-gas contained in HVAC-R equipment as well as also proceeding to the recovery and recycling/reclamation of it, thanks to the Daikin's R-Cycle Unit. However, a **future update** will be evaluated if any characteristics and requirements of the current F-gas market as well as the considerations of stakeholders need to be integrated.

Finally, the upcoming **training campaign** should be designed in such a way as to be directly related to the methodology and Good Practice Guidelines (GPG). In other words, the training courses should aim at making the corresponding theoretical material fully understood and practically applied by the installers and the other stakeholders involved in the F-gas sampling, analysing and characterisation procedures. Besides, the latter are considered to be the main participants in the various training events.