Manuscript ID: 148
DOI: 10.18462/iir.icr.2019.148

Evaluation of Refrigerants Leakage Ratios based on Electronic Logging and Reporting System

Peter Tomlein[(a)], Michal TOMLEIN[(a)], Matúš TOMLEIN[(b)]

[(a,b,c)] Slovak Association for Cooling and AC Technology
Šamorín, 931 01, Slovak Republic, szchkt@szchkt.org

ABSTRACT

Success of international F gas agreements depends on effective measures taken responsibly. This paper describes monitoring of leakages based on data recorded using electronic logbooks according to EN 378 and Regulation (EC) No 1516/2007. Advantages of electronic data logging and reporting are shown on the possibilities of automatic analysis, fault detection and comparison, fast access to the full history of leak checks and various forms of output.
Using the implemented system, service engineers can get a quick survey of their customers, cooling circuits, details of all maintenance work and repairs, refrigerants in store, refrigerants added, recovered, reclaimed, and disposed of. This is possible directly at customer sites using tablet and smartphone applications, which also enable the service engineers to create electronic logs of inspections in the field. Experience from reporting of HFC refrigerant emissions shows that the data required by the IPCC methodology divided into several categories of use is difficult to obtain from companies in practice. The concept underlying this work is to take advantage of electronic data logging and reporting, the possibilities of automatic analysis, fast access to the full history and various forms of output.
Electronic data records from refrigerant handling on stock enable summarizing, reporting and analyzing important data in a chosen period. The Slovak data reporting system was launched into operation in the year 2009. We started dividing the data based on field of application in 2012. Weighted mean leakage for all applications, specifically for commercial refrigeration, air conditioning, transport refrigeration, heat pumps, industrial refrigeration, and domestic refrigeration, is calculated automatically. The historical development of the weighted mean leakage is analyzed according to the aforementioned fields of application. Data from the reporting system of monitored cooling circuits are compared with total leakages on national and international level.
This paper is based on the activities of the Slovak Association for Cooling and Air-Conditioning Technology started in the year 2003 supported by the Ministry of Environment. The electronically led documentation was developed from the previous paper form. The evaluated data were collected from service organizations.
Keywords: Accuracy, Computer, Leak, Logging, Refrigerant, Reporting, Statistic.

1. INTRODUCTION

Leakage reporting by category of usage (commercial, industry refrigeration, air conditioning, …) is implemented using a program for logging data about the usage of refrigerants called Leaklog. The function was added to Leaklog in response to the need to compare amounts of leakages according to the aims of the Kyoto Protocol and the methodology of IPCC from 2006 and also the EU Regulation about F gases.
The reporting function includes leakage monitoring by refrigerants and category of usage. An overall scheme of refrigeration reporting is shown in Fig. 1, where data about leakages on equipment from customers is input using Leaklog to the information system of SZ CHKT (Slovak Association for Cooling and AC Technology) and is, subsequently, automatically processed.
Reported data consists of only aggregate values of leakages and amounts of refrigerants in equipment by category of usage. Leaklog does not report any sensitive information about customers. A similar system is operated in Germany by the VDKF organization (Zaremski, 2016), which has published their results and so mutual comparison is possible. Leakage evaluation by VDKF was done in 2011 and 2016 from 260 enterprises and 111 thousand equipment from approximately 15 thousand customers with the total charge of 1790 thousand tons of refrigerants and an average

charge of 16.7 kg of refrigerant per equipment. Web information systems for data collection are operated also in Hungary, Estonia, but their results are not published. Similar web-based information systems are already in development in many other countries.

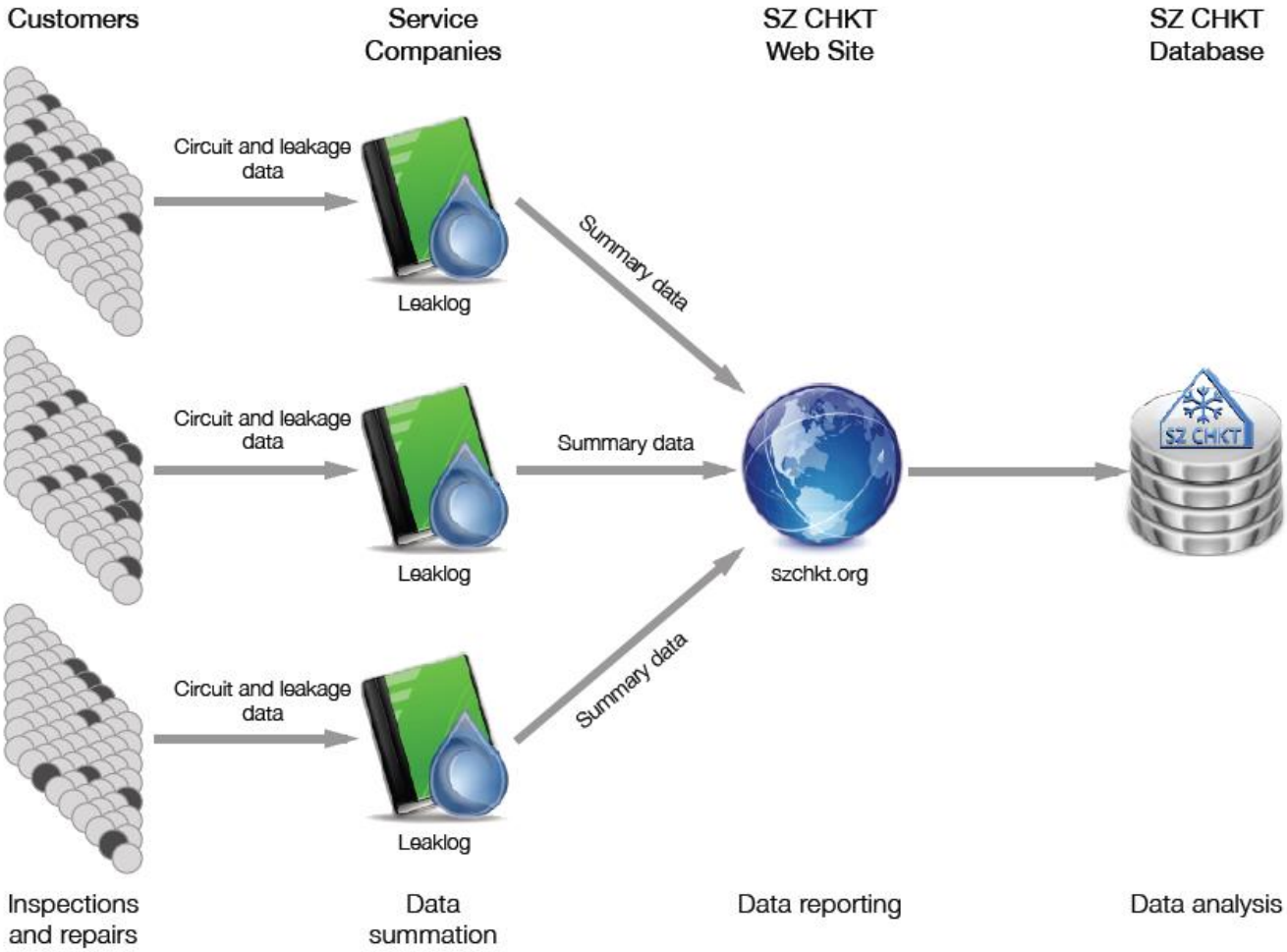


Figure 1: Data flow from customers using Leaklog to the information system of SZ CHKT at www.szchkt.org, where the data is automatically processed

As input to the information system at szchkt.org, two approaches for reporting data are supported:

1. yearly reporting by organizations using Leaklog, and
2. yearly reporting by organizations without Leaklog.

The first approach enables aggregation of precise data from companies, which are logging data about refrigerant movement directly in Leaklog. Using such data, it is possible to calculate average weighted percentage of refrigerant leakage per refrigerant charges in equipment and added amounts of refrigerants. The data is possible to summarize by refrigerant and category of usage (e.g., commercial, industrial cooling, AC and heat pumps).
The second approach enables aggregation of less precise data from all certified companies that may not be using Leaklog. Such summarized data shows trends in purchase development and consumption of refrigerants added to circuits as new charge or due to leakage.
The first approach is more precise as it enables calculation of average weighted percentage of refrigerant leakage by refrigerant and category of usage.

2. LEAKAGES BY CATEGORY OF USAGE

Reporting of leakages by category of usage (commercial, industrial cooling, AC, heat pumps, …) is implemented using the Leaklog software. Summarized amounts of refrigerants by year and category of usage are shown in Fig. 2. Fig. 2 shows added amounts, amounts of refrigerants in equipment, percentage of leakage by individual years for all refrigerants and for selected categories of usage.

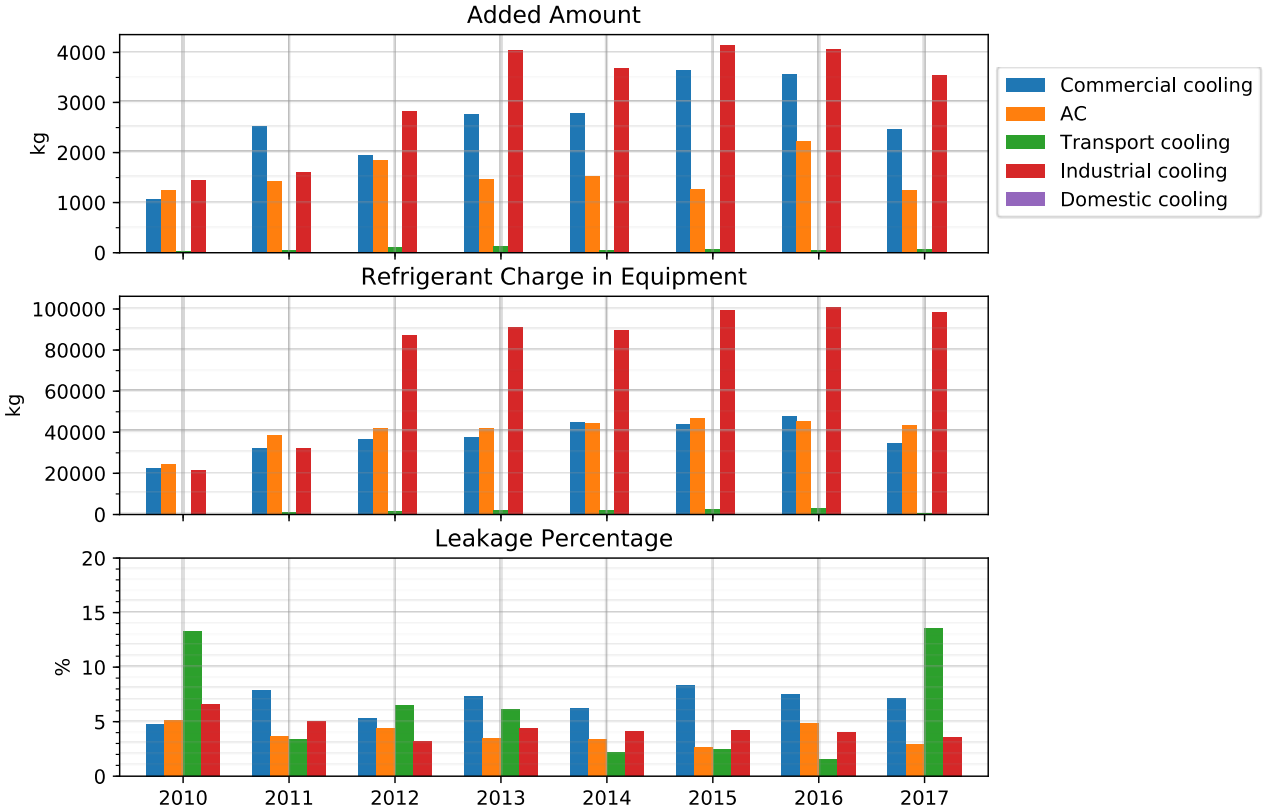


Figure 2: Added amount, refrigerant charge in equipment, and leakage percentage by year and usage for all refrigerants

2.1. Survey conditions

In Table 1, SZ CHKT has evaluated leakages from a total of nearly 8 thousand cooling circuits with different categories of usage with a total charge of nearly 200 tons with average leakage of all refrigerants at 4.2 % in the year 2017.
More than 55 refrigeration companies have taken part in the survey from the over 250 companies using the Leaklog software in Slovakia. In total, they reported 181 tons of refrigerants in equipment, which is approximately 20 % of the total charge of refrigerant in equipment in the Slovak Republic. The average charge was at 22.6 kg of refrigerant per circuit.

Table 1. Ratio of refrigerant amount in different categories of usage to total charge

Refrigerant	Category of usage – ratio of refrigerant amount on total refrigerants charges									
	All refrigerants		Commercial cooling		Air Conditioning		Heat pumps		Industr. cooling	
	kg	%	kg	%	kg	%	kg	%	kg	%
All	181252	100	34793	19.2	43313	23.9	4030	2.2	98654	54.4
R134a	29217	100	9619	32.9	4018	13.8	960	3.3	10190	34.9
R404A	26029	100	8213	31.6		0.0		0.0	13794	53.0
R407C	86953	100	10198	11.7	12805	14.7	360	0.4	63292	72.8
R410A	38957	100	5492	14.1	24842	63.8	2348	6.0	6228	16.0

2.1.1. Ratios of refrigerant amount to total refrigerant charges

The ratios of refrigerant amount to total refrigerant charges (181 252 kg) were as follows: R404A (14.3%), R407C (47.9%), R134a (16.12 %), R410A (21.4 %), others (0.28 %).
The ratios of single categories were the following: Commercial (19.2 %), Stationary AC (23.9 %), Industrial (54.4 %), Heat pumps (2.2 %).

From these ratios, we conclude that the most relevant results can be expected in Industrial cooling and Stationary AC, and for refrigerants R134a, R407C and R404A.

2.2. Total charges and leakages

The highest leakages according to Table 2 are found in commercial equipment (7.1 %), then industrial cooling (3.6 %), and AC (2.5 %). Heat pumps were exempted from the evaluation due to comparatively small amounts of refrigerants in included equipment.
Refrigerant R134a, which works with the lowest working pressures, has the lowest leakages in all categories. Similarly, refrigerant R407C shows lower leaks.
Higher leaks were found with refrigerants R404A and surprisingly also R410A. While R410A works with the highest pressures, in most categories as in AC, the expected leaks are lower, as indicated by the lowest average weighted leakage of 2.5 % in Table 2.

Table 2. Refrigerant amounts in equipment by category of usage with average weighted leakages until 1/1/2018

Refrigerant	Category of usage – average weighted leakage									
	All refrigerants		Commercial cooling		Air Conditioning		Heat pumps		Industrial cooling	
	kg	%	kg	%	kg	%	kg	%	kg	%
All	181252	4.2	34793	7.1	43313	2.5	4030	7.7	98654	3.6
R134a	29217	3	9619	3.5	4018	0.4	960	3.1	10190	3.5
R404A	26029	11.5	8213	11.5					13794	11.5
R407C	86953	2.5	10198	8.6	12805	3.1			63292	1.2
R410A	38957	4.3	5492	5.7	24842	3.3	2348	4.7	6228	7

2.3. Comparison of SZCHKT and VDKF results

The introduced results are compared with the results of VDKF (Zaremski, 2016). SZ CHKT has results from a lower number of circuits and lower amounts of refrigerant included in the assessment in relation to VDKF. The weighted average leakages published by VDKF are nearly 50 % lower in total, as well as in the assessed categories of usage of refrigerants. Absolute differences in Table 3 are up to 5 %.
Table 4 shows that by comparing the intensity of leakage by refrigerant, the differences between VDKF and SZ CHKT are higher – up to 5 %. This can partially be explained by the substantially lower amounts of refrigerant in equipment entering into the evaluation.
The highest and most surprising difference is with refrigerant R410A, which is mostly, but not only, charged into AC systems, where leakages are mostly low.
SZ CHKT data has shown 39 % higher total leakages than VDKF in Table 3. These higher differences are probably due to different numbers of reported data and should be lowered in the near future.

Table 3. Comparison of leakage amounts by kind of refrigerant between VDKF and SZ CHKT in the year 2015. Average leakages are compared for all refrigerants by category of usage

Refrigerant	Category of usage– Average weighted leakage in the year 2015									
	All refrigerants		Commercial cooling		AC		Heat pump		Industrial cooling	
	kg	%	kg	%	kg	%	kg	%	kg	%
All SZCHKT	198545	4.7	44012	8,3	47123	2.7	4030	4.4	99306	4.2
All VDKF	1740000	2.9	786000	3.14	149000	1.42	81000	0.79	403000	1.88

Table 4. Leakages by refrigerant in the year 2015. SZ CHKT data shows higher leakages at about 45 up to 84 % than VDKF.

Categories of usage	R134a			R404A			R407C			R410A		
	SZ CHKT	VDKF	Δ%	SZ CHKT	VDKF	Δ%	SZ CHKT	VDKF	Δ%	SZ CHKT	VDKF	Δ%
All categories	5.3 %	2.9 %	45	8.6 %	3.64%	58	4.2 %	1.89%	55	4 %	0.67%	84

2.4. Summary from leakage assessment by refrigerant

Fig. 2 shows by category of usage that leakages of refrigerants R134a, R407C, R410A and R404A are in the range from 2.2 up to 9.5 % including accidents. By refrigerant, the amount of leakage is the lowest for refrigerant R134a, then R407C, and the highest leakages are with refrigerants R410A and R404A.

The assessment shows that using most important refrigerants R134a, R404A, R407C, R410A, the average leakage during the assessed period in monitored categories of usage is under 10 %. The other refrigerants, such as R417A, R422A, R424A, and R507, were found to have higher leakage rates. They were excluded from the assessment due to the lower amounts of these refrigerants used in equipment. The resulting percentage of leakage was seen as not statistically significant enough.

Figs. 4–7 show the development of leakage by refrigerant. Figs. 8–11 show the development of leakage by category of usage in the years 2009–2017.

2.4.1. Price development

Price development of refrigerants in the Slovak Republic copies the price development in the EU. A rapid increase has started only at the beginning of the year 2017. The trend indicates that refrigerants with a GWP of over 2500 are becoming more expensive, and there will be a shortage on the market after the year 2020. The influence of increasing refrigerant prices has not become evident on leakage development (Figs. 3–11), due to the start only during the year 2017.

2.4.2. Leakage trends by refrigerant reported through Leaklog

Leakage trend of all refrigerants in percentage is decreasing as expected, which is reached with high probability due to precautions coming out from EU regulations.

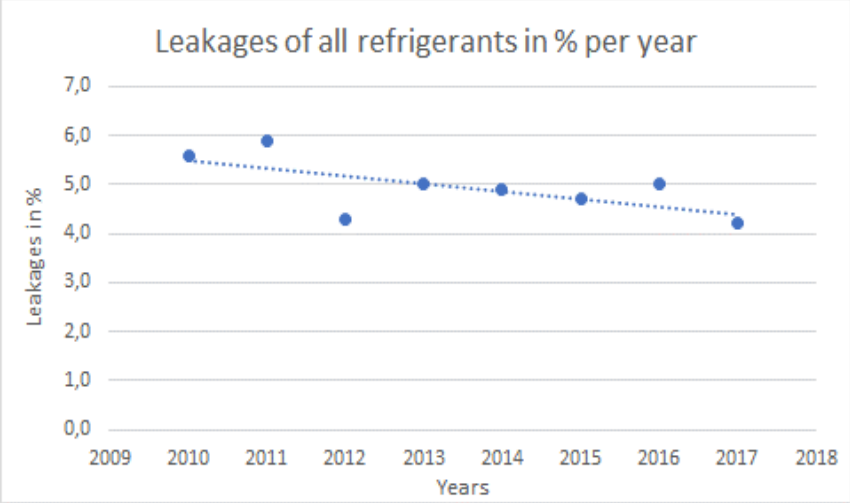
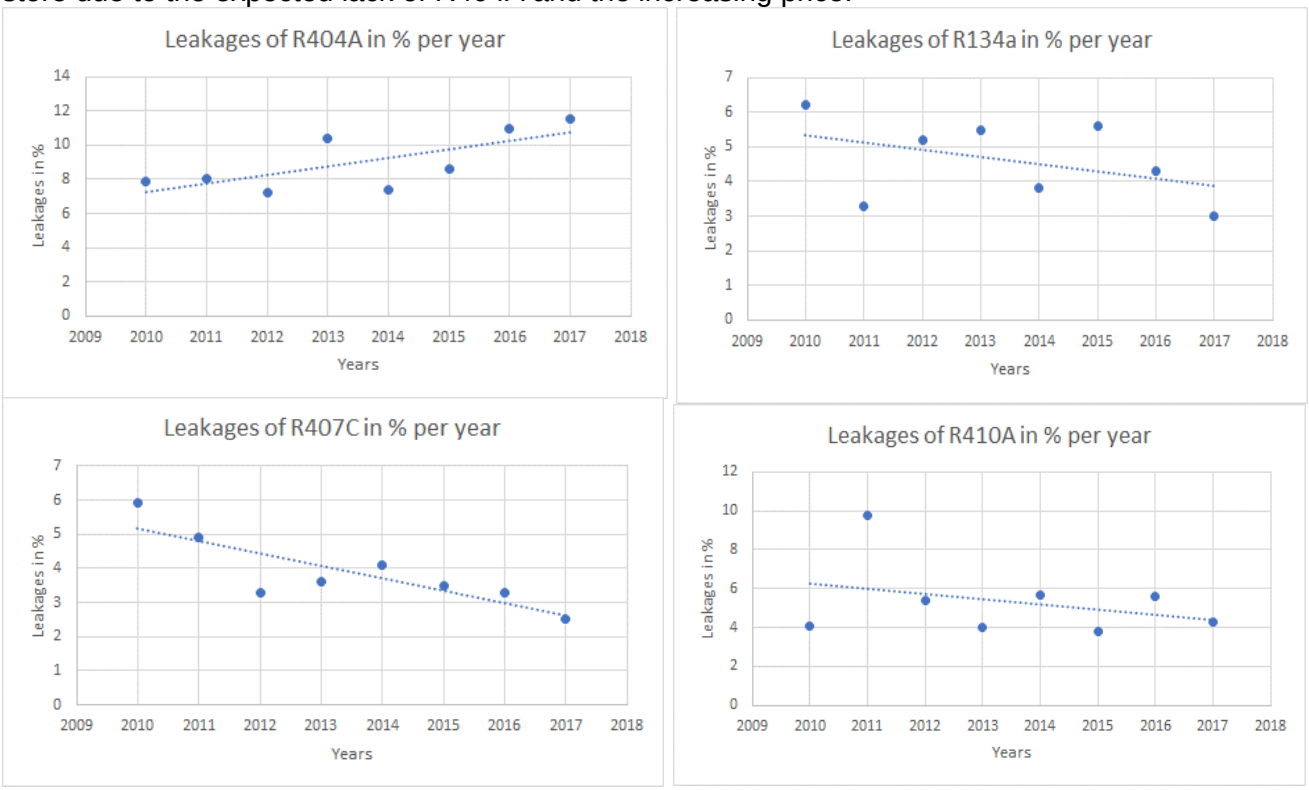


Figure 3: The decreasing leakage trend of all refrigerants in percentage

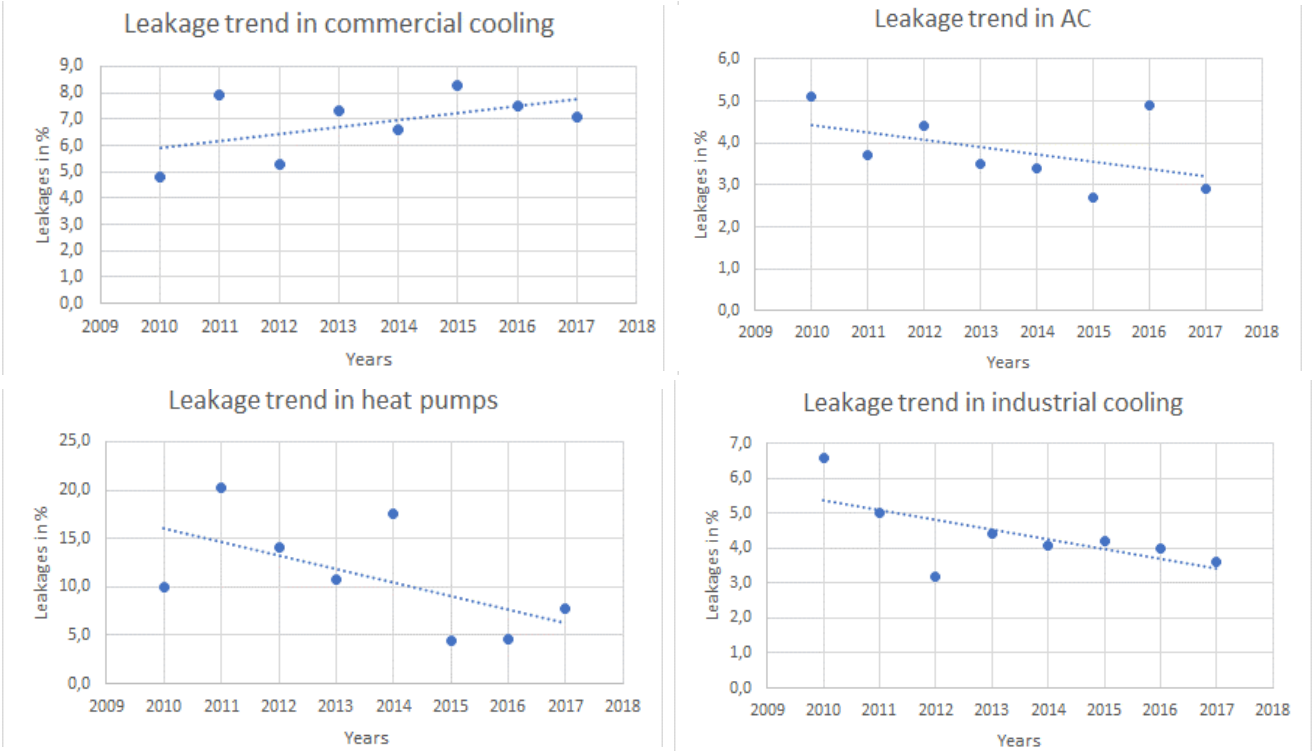
Leakage rates in Figs. 4–7 have an expected decreasing trend, except for refrigerant R404A. It is not easy to explain this development, but it is known that commercial cooling, where R404A is mostly implemented, has the highest leakages. This could be an effort of customers to have a reserve in store due to the expected lack of R404A and the increasing price.



Figs. 4-7: Leakage rates by refrigerant

2.4.3. Leakage trends by category of usage reported through Leaklog

Leakage rates by category of usage, shown in Figs. 8–11, have an expected decreasing trend, except for commercial cooling in Fig. 8, where mostly refrigerant R404A is used, probably due to reserves in customers store.



Figs. 8–11: Leakage rates by category of usage

2.4.4. Purchase trends of refrigerants reported by all certified companies

Fig. 12 shows total reported data both with and without Leaklog for refrigerants purchased and added to circuits as new charges and due to leakages. Refrigerants R410A and R407C show a stable trend and R404A has started decreasing trend in 2015.
This is not the case for the purchased amount of R134a, which fluctuates due to mainly changes in commercial cooling and car industry.

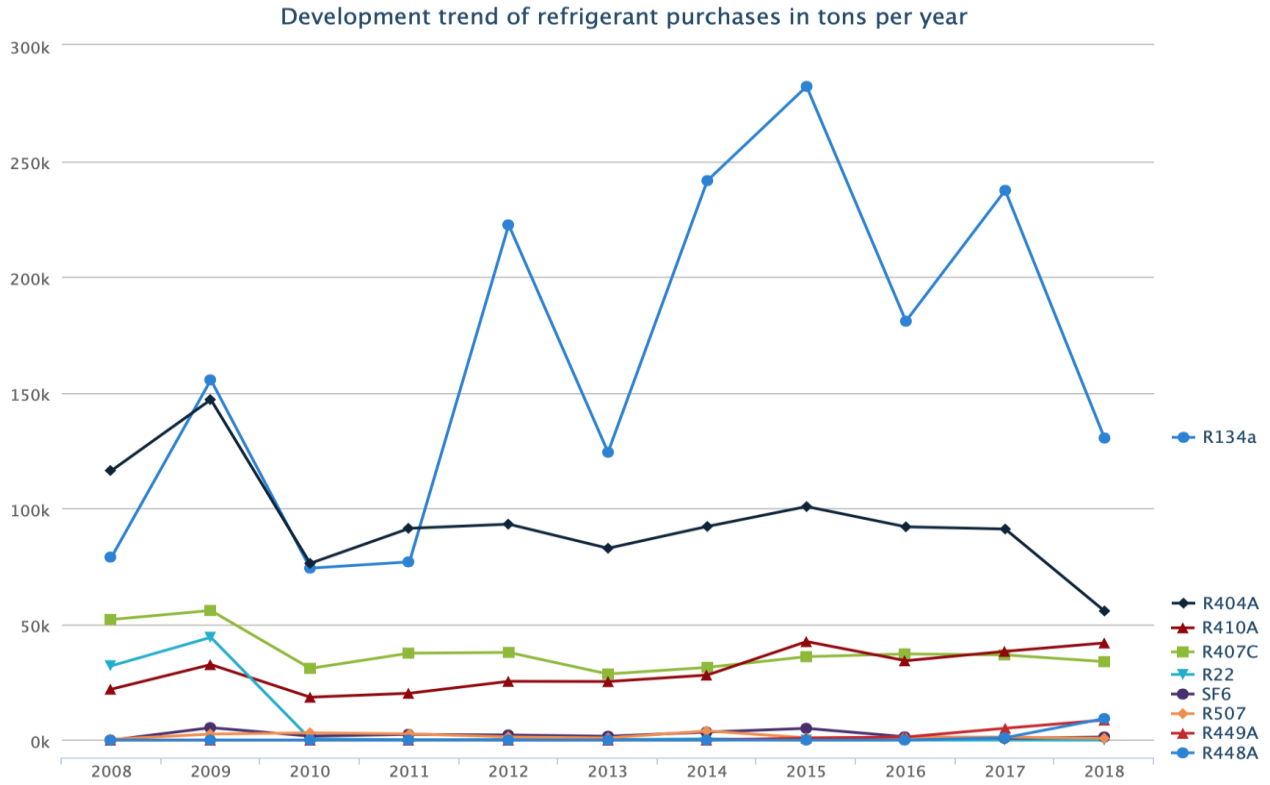


Figure 12: Development trend of refrigerant purchases in tons per year. The trend is mostly stable except for the fluctuating purchases of R134a influenced by the car industry. R404A has started decreasing trend in 2015

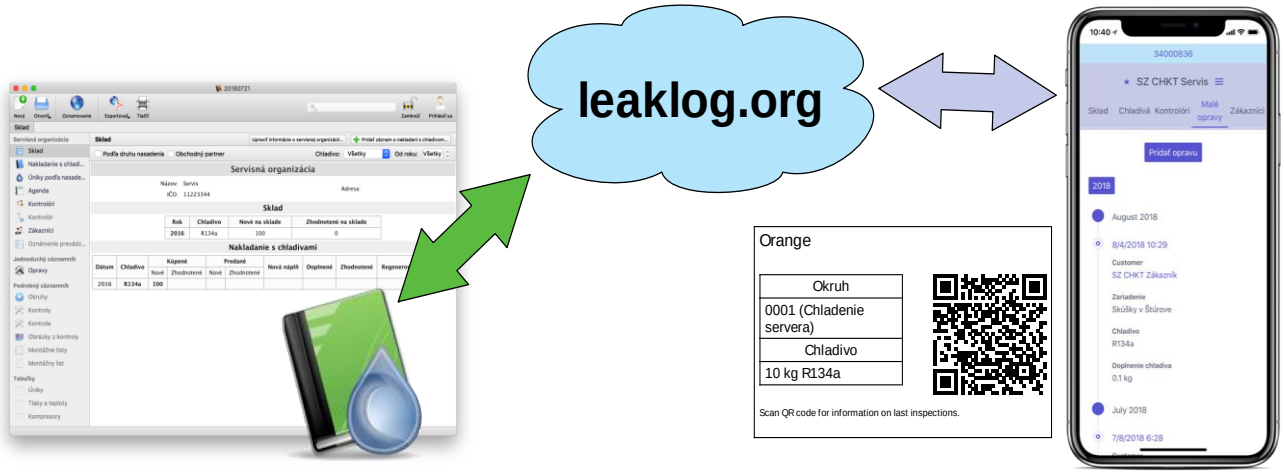


Figure 13: SZ CHKT introduced a new service named Leaklog.org that enables service companies and operators to share information about inspections of cooling equipment. Labels with QR codes placed on equipment link to logbooks with up-to-date information

2.5. Extension of Leaklog for equipment owners and operators

In response to upcoming regulations, SZ CHKT launched an extension of the Leaklog software built for equipment owners and operators intended to enable collaboration and data sharing with service companies. This new web-based solution integrates with existing Leaklog databases managed by service companies and provides an electronic logbook of circuits and inspections for owners and operators.
As shown in Fig. 13, the system offers fast access to circuit data for authorized persons via QR code labels attached to the equipment. The solution aims to replace the existing paper-based workflow and encourage companies to maintain detailed and high-quality data.

3. CONCLUSIONS

Decreasing trend of leakages was confirmed according to data reported through the program Leaklog, which, in the evaluated years, was not influenced by the increasing price of refrigerants or by the lack of refrigerants. Similarly, a decreasing trend was confirmed in the analysis of purchased refrigerants and amounts of refrigerants added to circuits in place of leaked refrigerants.
Comparison of the leakage size according to IPCC methodology from the year 2006 and also EU regulations on F gases has shown, that implemented precautions enabled a decrease in refrigerant consumption and also a decrease of refrigerants consumption added in place of leaked refrigerants. Leaklog enables logging and aggregation of not only summarized amounts of leakages, but also refrigerant usage per cooling circuits and by category of usage. Latest extensions of Leaklog enable service companies to easily share information from inspections with operators and/or owners of cooling circuits.

ACKNOWLEDGEMENTS

This paper is based on the activities of the Slovak Association for Cooling and Air-Conditioning Technology started in the year 2003 supported by the Ministry of Environment. The electronic documentation has been developed from the previous paper-based form. Electronic documentation is running since the year 2009.

NOMENCLATURE

AC	Air Conditioning	*HP*	Heat pumps
CC	Commercial cooling	*IC*	Industrial cooling
SZ CHKT	Slovak Association for RAC	*VDKF*	German Association for RAC

REFERENCES

Barrault, S., 2013. Refrigerant emissions and inventories platform. Proceedings of the IIR Conference on Compressors. Papiernicka, Slovak Republic, 71-71.

Tomlein, P., 2011. Inventory of F gases based on company certification. Proceedings of the IIR Congress, Prague.

Tomlein, P., 2013. Inventory of refrigerants. Proceedings of the IIR Conference on Compressors, Papiernicka, Slovak Republic, 68-68.

Zaremski, W., 2016. Aktualisierter statusbericht über leckgeraten. VDKF-Branchensoftware LEC. VDKF – Branchenbuch.

Regulation of EP and C (EC) č. 842/2006 (Ú. v. EÚ L 161, 14.6.2006) version 517/2014/EÚ

Act of Slovak National Parliament from 19. June 2009, No. 286/2009 Z.z, 348/2015 Z.z. and amendments No. 314/2009 Z.z., 382/2016 Z.z.