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Legal text for Annex [64]

Safety measures for flammable refrigerants

1. Background

Global warming is a major threat to society, and all measures must be taken to decrease the emissions of gases contributing to this threat. The use of fossil fuels must therefore be abandoned as agreed in the Paris agreement. As a consequence, heating of buildings and heating within industry must be based on renewable energy, harvested in the form of electricity. This means that the use of heat pumps will increase tremendously in the coming decades, in line with predictions, scenarios and plans from many different authorities and organizations worldwide, including the IEA and the EU. The refrigerants used until recently have global warming potentials (GWP) one to four thousand times higher than carbon dioxide. Large efforts have been spent on identifying new fluids with low GWP which can be used as refrigerants in vapour compression systems. The conclusions from these studies, in particular screenings done by NIST, is that we cannot expect to find new fluids which have low GWP and at the same time are non-flammable. The only notable exception for ordinary temperature levels is carbon dioxide, which is already successfully used in e.g. supermarket refrigeration, but which may be difficult to use with high efficiency for some other applications. The alternative mainly being promoted by the chemical industries is the use of Hydro Fluoro Carbon (HFC) refrigerants with double bonds, often called Hydro Fluoro Olefins (HFO), or blends of HFOs. These fluids/blends have lower GWP than most HFCs traditionally used, because of the shorter atmospheric lifetime. However, these fluids/blends also suffer from the tradeoff between low GWP and low flammability and it is difficult to find non-flammable refrigerants with GWP less than 500. In addition, HFOs like HFCs are synthetic substances not existing in the atmosphere, on land or in freshwater. Therefore, these fluids or their decomposition products may have unexpected effects on the environment in the long term. Already, there is a concern about the formation of TriFluoroAcetic acid (TFA) from the decomposition of some HFOs (and HFCs). TFA is an extremely stable compound which may accumulate in the natural environment for hundreds of years. It should also be mentioned that many HFCs and HFOs are by definition belonging to the group of substances called PFAS. Members of this group are known to cause decreased fertility, certain types of cancer, hormone disorders, just to mention a few[1]. At this moment, European authorities are working on a suggestion to ban all PFAS. This may affect the use of HFC and HFO refrigerants in the near future. Already, a new F-gas regulation is under way in Europe. According to the new regulation, the phase-out of F-gases is speeded up. With the predicted sharp increase in the sales of heat pumps, there will not be enough synthetic refrigerants available. Heat pump manufacturers are therefore developing products for hydrocarbon refrigerants, which are highly flammable. It is therefore highly likely that we in the near future will see a market dominated by flammable synthetic refrigerants and flammable hydrocarbons.

Since many years there has been an interest in using hydrocarbons as refrigerants. Isobutane is the standard solution for domestic refrigerators and propane is already used in some AC systems and heat pumps. The amount of refrigerant in such systems has been limited by regulations (in Europe EN378) and product safety standards (such IEC 60335–2–40 and IEC +60335–2–89, and their local adopted versions such as EN

[1] https://www.atsdr.cdc.gov/pfas/health-effects/index.html

60335–2–40 or UL 60335–2–40 and EN 60335–2–89 or UL 60335–2–89) due to the risks related to flammability and the risks have hampered the development of systems with larger capacity. Better understanding of the risks and novel ideas to limit the risks is necessary to allow modifications of the regulations and allowing safe use of flammable refrigerants for larger capacity systems.
Research has been funded by ASHRAE and AHRI related to flammability of refrigerants. This work has focused on assessing the risks of new synthetic refrigerants, both pure and blends. Less work seem to have been focused on reducing the risks with flammable fluids. Work is also currently underway in CEN, IEC and ISO. The work within this Annex will be based on all existing previous work.
The EU has supported a project called Life Front with the aim to remove “barriers posed by standards” for flammable refrigerants in refrigeration, air conditioning and heat pump applications. In this project, leak analysis, improved product safety design and risk assessment has been important parts. The project goals and work content has much in common with the now suggested Annex. Life Front is now completed, but the research and development in the area needs to continue.
The International Institute of Refrigeration (IIR) has a working party (WP) on refrigerant safety. This work is focusing on collecting information about accidents and incidents related to working fluids. This work is not considered to be overlapping the activities in this Annex. However, the OA will maintain close contacts with the IIR WP.
The proposed Annex is well connected to several previous IEA HPT Annexes. The following ones should be mentioned in particular, even though some of them are old:

- Annex 20 - Working Fluid Safety
- Annex 22 - Compression Systems with Natural Working Fluids
- Annex 54 – Heat Pump Systems with low Global Warming Potential (GWP) refrigerants

But also the following Annexes are partly related to safety with flammable refrigerants:

- Annex 23 - Heat Pump Systems for Single-Room Applications
- Annex 33 - Compact Heat Exchangers in Heat Pumping Equipment
- Annex 46 - Heat Pumps for Domestic Hot Water
- Annex 47 - Heat Pumps in District Heating and Cooling Systems
- Annex 50 - HPs in MF building

The only Annex directly focusing on working fluid safety, Annex 20, was finalized 29 years ago, but already at that time flammability was considered a concern when searching for alternatives to CFC and HCFC refrigerants. The proposed Annex will of course benefit from the experiences from previous Annexes.
The Annex is well in line with the Strategic Work Plan 2023 – 2028 for HPT TCP, where “Safety measures for operating with low GWP refrigerants” is mentioned as one of the high level tasks.

2. Description of technical sector; definitions

Ever since the vapour compression cycle was introduced, there has been a search for the ideal refrigerant. A hundred years ago, most fluids used (ammonia, sulphur dioxide, methyl chloride, hydrocarbons) were flammable, poisonous or both. As the compressors at the time were not hermetic, leakages must have been a constant problem. A special industial effort was done in the 1920s to develop a refrigerant which would be “safe” to use in people’s kitchens. As a result, the CFCs were re-invented by Thomas Midgley and Albert Henne. More than 40 years later, in 1974, the effect of CFCs and HCFCs on the ozone layer was understood, and the search for alternatives was initiated. Some years later, the high global warming impact of the HFCs, introduced as substitutes for CFCs, was realized, and the search continued. Since then, large efforts have been put into screening possible alternatives which should, ideally, be without environmental impact, non-flammable, non-toxic and give good system performance at the desired temperatures while maintaining reasonable pressure levels. One such study, performed by McLinden et

al.[2] included about 56000 fluids but after filtering for the desired properties, ended up with a short list of fluids, most of which were already used as refrigerants. In a later study, McLinden et al.[3] started the screening with >60 million chemical structures, but at the end of the screening process only 27 low-GWP substances remained, out of which most were well-known fluids already given an R-number. In the list are nine HFOs, as well as NH3, CO2, propane, propene and ethane. Only six novel molecules were identified in the screening. All of them were flammable and potentially hazardous in other ways. In conclusion the authors state that "Fluids with good COP and low toxicity are available, but all are at least slightly flammable". This study, and other similar ones, strongly indicate that it will not be possible to find new, low-GWP, non-flammable refrigerants for typical heat pump or AC-applications.

3. Objectives and scope

The ultimate goal of the Annex is to contribute to a broader safe use of flammable refrigerants. To reach this goal, the aim of the Annex is to increase the understanding of the risks related to the use of flammable refrigerants, and to develop methods and system designs to maintain the risks at acceptable levels also for systems with larger capacity than what is available on the market today. The objective is that the findings generated in the Annex will be used as background information when regulations regarding the use of flammable refrigerants are updated. It is expected that one outcome of the Annex is a set of recommendations for updates of the regulations. We have seen the important work done within Lifefront[4] and continued research in international cooperation can further support the safe use of flammable refrigerants.

The Annex will include investigations of a selected set of measures to limit the risks associated with using flammable refrigerants in heat pumps, AC-systems, refrigeration systems or similar based on the vapour compression cycle. The main focus will be on systems for heating/cooling or hot water production in single family buildings or for use in multifamily houses (up to 50 kW). The main focus will be on heat pumps placed indoors. It will also include risk assessments related to such use. The fluids considered could be hydrocarbons and synthetics. Safety issues during servicing and at the systems´ end of life will also be considered.

Large industrial heat pumps, heat pumps for district heating, heat pumps/AC systems for automotive and heat pumps built into home appliances like dishwashers, tumble dryers etc. will not be included.

As the number of participating countries, or their contributions, is not known beforehand, the extent of the work cannot be foreseen in advance.

4. Means

The Participants shall share the coordinated work necessary to carry out the work required for this Annex. The objectives shall be achieved by the following task-sharing activities:

Task 1: Technical solutions for limiting risks

Risks are related to possible concentrations of flammable fluids, total amounts of such fluids and presence of ignition sources. The risks can be alleviated by different technical solutions. Technical solutions to be investigated could be, but is not limited to, methods of limiting the amount of refrigerant released, e.g. through sectionalizing the system with

[2] Mark O. McLinden, et al. A thermodynamic analysis of refrigerants: Possibilities and tradeoffs for low-GWP refrigerants, Int. J. Refrigeration, vol. 38, (2014), pp. 80 – 92.
[3] McLinden et al. 2017, Limited options for low-global-warming-potential refrigerants, Nature communications, vol. 8, article no. 14476 (2017)
[4] Lifefront.eu

valves, rapid ventilation of gas to the ambient in case of leakage, use of enclosures with inert gases, diffusion/dilution of released refrigerant, ensuring sources of ignition are not present where leakages may occur. The solutions investigated will be determined by the Annex members based on literature reviews and discussions within the group. The expected outputs are recommendations for different technical solutions to increase safety.

Task 2: Investigation of leakage scenarios
The possible concentrations of flammable refrigerants under different scenarios can be investigated both through CFD simulations and through experimental studies. Such work has been done in previous projects, e.g. in Life Front and in studies sponsored by AHRI[5] and ASHRAE[6], but additional studies are required to build a solid framework for safe design of systems and installations. In the Annex we foresee CFD simulations, supported by experimental studies.
Scenarios could be defined by type of refrigerant, leakage rate and location, volume and shape of space, air velocities in the room etc.

Task 3: Leakage detection
Early identification of leakages increases the chances of alleviating the risks through countermeasures. Reliable systems for leakage detection are indispensable for safe use of flammable fluids in larger system but may also be applied to small systems. Within this task, available types of sensors and systems for leakage detection will be investigated and compared regarding accuracy, reliability and cost. Also, the location of sensors will be investigated.

Task 4: Charge reduction
Traditionally, system designers have not primarily been concerned about the charge of refrigerant. However, by designing systems so that the required charge of flammable refrigerant is minimized, the possible capacity per unit charge will increase. Already, heat pump systems have been demonstrated having propane charge of about 10 g/kW heat. Designing such systems, while maintaining high system efficiency, requires special care in the design and selection of each component. In this Task, designs of components and systems for minimum charge will be in focus. Charge reduction is one specific method to reduce risks and is therefore related to Task 1. As it concerns the complete design of the system, it is given a separate Task number.

Task 5: Risk assessment
In this Task, risk assessments will be performed for different technical solutions suggested in Tasks no 1 and 4. The risk assessments will be used as a means to evaluate the suggested solutions. The methodology used for the assessment will be dependent on the expertise of the participating partners.

Task 6: Communication and dissemination
For the Annex to have an impact, dissemination of the results is extremely important. In this Task, we foresee publications in both scientific journals and technical magazines. We also foresee seminars open for non-participants in connection with scientific conferences etc. See also Deliverables below.

In the initial phase of the Annex, the contributions of each participant will be discussed and defined, together with the methodologies used and the milestones of each partner as well as of the Annex as a whole.

[5] AHRI 9007, AHRI 8009, AHRI 8016, AHRI 8028
[6] ASHRAE 1806

5. Target audience and Benefits

As stated under Objectives, the ultimate goal of the Annex is to contribute to a broader safe use of flammable refrigerants. This is beneficial for all society as this would lead to decreased emissions of synthetic refrigerants with possible negative effect on the global environment, e.g. through spreading of high GWP fluids and of long-life fluids or decomposition products containing fluorine, including substances classified as PFAS. The target audience is primarily the scientific community, through which standardization committees and organizations will be reached. Ultimately, the target audience is the decision makers at national and international levels deciding about the regulations governing the use of refrigerants, both flammable and non-flammable.

6. Deliverables

The compulsory deliverables of the Annex are:

- Final report of the Annex according to template
- A public Annex Website as a subsite to the HPC website
- Progress reports to ExCo meetings according to template, once a year oral (focusing on results, achievements and/or success stories) and twice a year management reports
- Short status report to the HPC two - four times annually for publication in the Newsletter/Magazine, focusing on results, achievements and/or success stories
- One article per year, topical or non-topical, to the HPC Newsletter/Magazine
- Report to the HPT Annual report
- Text and pictures to a 2-page popular scientific summary of Annex results to be freely disseminated

Further deliverables of the Annex are:

- Seminars/Workshops: The Annex will arrange annually at least one seminar/workshop where participants in the Annex will have the possibility to present their work. These seminars, which will be open to non-members of the Annex, will be arranged in conjunction with scientific conferences on topics closely related to the theme of the Annex. Reports from these workshops will be compiled and made publicly available.
- Webinars: The Annex will arrange at least one webinar each year where findings of the work will be presented.
- It is the ambition that the work within the Annex will also result in articles published in scientific journals and/or presented at scientific conferences. Such articles will be the responsibility of the participants, but will be promoted and supported by the Operating Agent.
- Direct contact with standards committees such as IEC/EN 60335-2-40, EN 378, ISO 5149, ASHRAE SSPC 15 will be taken in order to ensure that the work of the Annex is relevant, and well-known by these committees.

7. Funding

(a) Working Meetings. The working meetings shall be hosted in turn by the several Participants. The costs of organizing and hosting meetings shall be borne by the host Participant.

(b) Publications: The cost of publishing the Final Report and summary assessments described in paragraph 6 above shall be equally shared by all the Participants.

(c) Individual Financial Obligations. Each Participant shall bear all the costs incurring in carrying out the Task activities, including reporting and travel expenses. Additionally, each Participant shall make a direct financial contribution to the Operating Agent to cover co-ordination and report preparation expenses and other Annex-related (e.g. Workshop) costs.

The table below shows the fees per participating country, based upon varying numbers of participating countries. Each Participant's fee shall be paid in 1 annual instalment.

No of participants	Participants' fees, €		
	2023	2024	2025
2	8000	8000	8000
3	6500	6500	6500
4	5000	5000	5000
5	4000	4000	4000
6	3500	3500	3500
7	3000	3000	3000
8	2700	2700	2700
9	2400	2400	2400
10	2200	2200	2200

8. Time schedule

It is proposed that this Annex be conducted over a period of 36 months to begin Jan 2023. The following is a tentative work schedule for the different tasks.

Start Date	End Date	Activity
230101	251231	Task 1: Technical solutions for limiting risks
230101	251231	Task 2: Investigation of leakage scenarios
230101	251231	Task 3: Leakage detection
230101	251231	Task 4: Charge reduction
230101	251231	Task 5: Risk assessment
230601	251231	Task 6: Communication and dissemination

The tasks can be considered as independent and results from one task is not directly required for any other task. For this reason, the tentative time schedule is also indicating parallel activities in all tasks throughout the project. The only exception is the Dissemination which cannot start until some results are reached.

9. Specific obligations and responsibilities of the participants

(a) Each Participant shall nominate a representative to participate in the work under this Annex.

(b) Each Participant shall carry out the equivalent of total 2 to 6 person months of task-sharing work during the programme period unless otherwise agreed by the Participants.

(c) Each Participant shall contribute to the working meetings and to a workshop on the results achieved through the activities conducted under this Annex, including the identification of speakers and participants.

(d) Each Participant shall make a direct financial contribution to the Operating Agent to cover co-ordination and report preparation expenses and other Annex related (e.g. Workshop) costs.

10. Specific obligations and responsibilities of the Operating Agent

The Operating Agent shall:

(a) Develop, in co-operation with the Participants, a detailed work programme, a framework for the Final Country Report and a budget for all the activities carried out under this Annex, including methodology and time schedule

(b) Provide the Executive Committee with periodic reports describing the progress of the work being accomplished under the Annex, once a year oral (focusing on results, achievements and/or success stories) and twice a year a management report.

(c) Deliver the results as described in Section 6.

(d) Provide to the Executive Committee, within six months after completion of all work under the Task, a Final Report for its approval and transmittal to the Agency.

(e) In co-ordination with the Participants, use its best efforts to avoid duplication with activities of other related programs and projects implemented by or under the auspices of the Agency or by other competent bodies.

(f) Provide the Participants with necessary guidelines for the work they carry out, assuring minimum duplication of effort.

(g) Co-ordinate the efforts of all Participants and ensure the flow of information within the Task.

(h) Co-ordinate the work to ensure the compulsory deliverables to the HPC Newsletter/Magazine and to the website

(i) Provide general administration

The IEA Heat Pump Centre will assist in the establishment of the Annex. Thereafter, the Heat Pump Centre will follow the Annex to check that the routines are followed, that the status and progress reports are delivered in due time and the quality of them. They will also assist the OA in the publication of the final reports and compilation of the summary in the end of the Annex. Therefore, it is the responsibility of the OA to follow the instructions of Heat Pump Centre.

11. Information and Intellectual property

(a) *Executive Committee's Powers.* The publication, distribution, handling, protection and ownership of information and intellectual property arising from this Annex shall be determined by the Executive Committee, acting by unanimity, in conformity with this Annex.

(b) *Right to Publish*. The Participants shall have the right to publish information provided to or arising from their Task, except for proprietary information, as defined in paragraph (c) below.

(c) *Proprietary Information.* For the purposes of this Annex, proprietary information shall mean information of a confidential nature such as trade secrets and know-how (for example, computer programmes, design procedures and techniques, chemical compositions of materials, or manufacturing methods, processes or treatments) which is appropriately marked provided that such information:

(1) Is not generally known or publicly available from other sources
(2) Has not previously been made available by its owner(s) to others without obligation concerning its confidentiality; and
(3) Is not already in the possession of the recipient Participant(s) without obligation concerning its confidentiality.

It shall be the responsibility of each Participant supplying proprietary information, and of the Operating Agent, to identify such information as proprietary and to ensure that it is appropriately marked.

The Participants and the Operating Agent shall take all necessary measures in accordance with this paragraph, the laws of their respective countries and international law to protect the proprietary information provided to or arising from this Task.

(d) *Production of Relevant Information by Governments.* The Operating Agent should encourage the governments of all Agency Participating Countries to make available or identify to the Operating Agent all published or otherwise freely available information known to them that is relevant to the Task.

(e) *Production of Relevant Information by Participants.* Each participant agrees to provide to the Operating Agent all previously existing information, and information developed independently of the Task, which can assist or is needed by the Operating Agent to carry out its functions in this Task, which is freely at the disposal of the Participants, and the transmission of which is not subject to any contractual and/or legal limitations, under the following conditions:

(1) The Participant will make such information available, at its own costs, provided that such costs are not substantial
(2) If substantial costs are necessary for the Participant to make such information available, the Operating Agent and all Participants will determine the charge of the costs for each participant, upon approval of the Executive Committee.

(f) *Use of Confidential Information.* If a Participant has access to confidential information which would be useful to the Operating Agent in carrying out the studies, assessments, analysis or evaluations described in this Annex, such information may be communicated to the Operating Agent but shall not become part of any report or other form of documentation issued as part of this Task, nor shall it be communicated to the other Participants, except as may be agreed between the Operating Agent and the Participant who supplies such information. This information has to be marked clearly as “confidential”.

(g) *Acquisition of Information for the Task*. Each Participant shall inform the Operating Agent of the existence of information that can be of value to the Task, but which is not freely available, and each Participant shall endeavour to make such information available to the Task under reasonable conditions, in which event the Executive Committee may, acting unanimity, decide to acquire each information.

(h) Reports on Work Performed under the Task. The Operating Agent shall prepare reports on all work performed under the Task and the result thereof, including studies, assessments, analysis, evaluations and other documentation, but excluding proprietary information, in accordance with paragraph 11(c) above.

(i) *Copyright.* The Operating Agent, or each Participant for its own results, may take appropriate measures necessary to protect copyrightable material generated under this Task. Copyright obtained shall be the property of the Operating Agent, for the benefit of the Participants provided, however, that Participants may reproduce and distribute such material, but shall not publish it with a view to profit, except as otherwise provided by the Executive Committee.

The Contracting Parties understand and agree that the name, acronym and emblem of the IEA has been notified to the World Intellectual Property Organisation (WIPO) Secretariat according to Article 6 of the Paris Convention for the Protection of Industrial Property, as amended on 28 September 1979. The Contracting Parties further understand and agree that the OECD/IEA shall retain the copyright to all IEA deliverables, materials or publications published or to be published by the IEA or jointly by the IEA and a third party to this Annex. Should the Contracting Parties use any such deliverables, materials or publications they shall give full acknowledgement to the OECD/IEA as being the source of the material with a copyright notice in the following form: © OECD/IEA, (year of publication).

(j) Authors. Each Participant shall, without prejudice to any rights of authors under its national laws, take necessary steps to provide the co-operation from its authors required to carry out the provisions in this paragraph. Each Participant shall assume the responsibility to pay awards or compensation required to be paid to its employees according to the laws of its country.

12. Operating Agent
The KTH Royal Institute of Technology, is designated as Operating Agent.

Contact information for the Operating Agent:

Name	Björn Palm
Affiliation	KTH Royal Institute of Technology,
Postal address	Department of Energy technology SE 100 44 Stockholm, Sweden
Telephone number	+46 8 7907453
E-mail address	bpalm@energy.kth.se

13. Participants in this Annex
The Contracting Parties which are Participants in this Task are the following:
Organizations/countries not participating will be deleted when participants have been confirmed.

Organisation	**Country**
The Federal Ministry of Transport, Innovation and Technology *Bundesministerium für Verkehr, Innovation und Technologie (bmvit)*	Austria
	Belgien
Natural Resources Canada	Canada
Danish Technological Institute	Denmark

TEKES	Finland
Forschungszentrum Jülich GmbH – confirmed by Letter of Participation 2022-12-15	Germany
Italian National Research Council	Italy
New Energy and Industrial Technology Development Organization	Japan
The Ministry of Knowledge Economy (MKE)	South Korea
NL Agency	Netherlands
ENOVA SF	Norway
The Swedish Energy Agency	Sweden
The Swiss Federal Office of Energy	Switzerland
The Department for Business, Energy and Industrial Strategy (BEIS)	United Kingdom
Department of Energy	USA

14. Research organisations participating in this Annex

The list below contains names and contact information to persons/organizations who have shown interest in participating in the Annex. However, their participation is not confirmed.

Organisation, Name, adress and website	Contact person, phone and e-mail	Country	Annex NT leader (Y/N)
Re-phridge LTD, www.re-phridge.co.uk	Daniel Colbourne, dc@re-phridge.co.uk	UK	N
NIBE, www.nibe.eu	Martin Forsén, martin.forsen@nibe.se	SE	N
RISE, www.ri.se	Metkel Yebiyo, metke.yebiyo@ri.se	SE	N
ERC Daikin Europe, www.daikin.eu	Martin Dieryckx, dieryckx.m@daikineurope.com Frank Vancoppenolle, vancoppenolle.f@daikineurope.com	BE	N
RWTH Aachen University	Christian Vering, cvering@eonerc.rwth-aachen.de	DE	N
AIT, www.ait.ac.at (to be confirmed)	Veronika Wilk, veronika.wilk@ait.ac.at	AT	N
Oilon Technology Oy, www.oilon.com	Juha Aaltola, juha.aaltola@oilon.com	FI	N
Fraunhofer ISE, www.ise.fraunhofer.de	Thore Oltersdorf - *confirmed* Thore.oltersdorf@ise.fraunhofer.de Lena Schnabel, lena.schnabel@ise.fraunhofer.de Peter Schossig, peter.schossig@ise.fraunhofer.de	DE	N
SINTEF, www.sintef.no	Christian Schlemminger, christian.schlemminger@sintef.no	NO	N
Rheem Manufacturing Company, www.rheem.com	Harshad Inamdar, harshad.inamddar@rheem.com	US	N
Enertech, www.enertech.se	Kent Karlsson, kent.karlsson@enerech.se	SE	N

Participation is open for 6 months after this legal text is approved.