

Women in the Refrigeration Industry

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ABSTRACT

The refrigeration industry plays a major and increasing role in today's global economy, with significant contributions made in food, health, energy and environmental domains which policy makers need to better understand and take into account. The need for engineering and technical staff is currently increasing due to the growing demand for refrigerating capacities, along with the unique skills required from refrigeration-related professions in the field of energy and environment. Women are still significantly and visibly under-represented in the refrigeration industry. The purpose of this paper is to demonstrate the current preliminary state-of-the-art of women in the refrigeration field collected from national refrigeration institutions and associations. Suggested incentive actions are the outcomes of the second meeting of the official IIR Women in Refrigeration sub-group.

INTRODUCTION

The International Institute of Refrigeration (IIR) estimates (2015^a) that the total number of refrigeration, airconditioning and heat pump systems in operation worldwide is roughly 3 billion. Global annual sales of such equipment amount to roughly 300 billion USD. Almost 12 million people are employed worldwide in the refrigeration sector which consumes about 17% of the overall electricity used worldwide. Statistical data presented in the IIR Informatory Note (2015^a) highlights the importance of the refrigeration sector which is expected to grow further in the coming years because of increasing cooling needs in numerous fields and global warming. A recent study from the University of Birmingham (2015) reveals that by the middle of this century, people all over the world will use more energy for cooling than heating. The refrigeration industry plays a major and increasing role in today's global economy, with significant contributions made in food, health, energy and environmental domains which policy makers need to better take into account.

The IIR (2015^a) estimates that almost 12 million people are employed worldwide in the refrigeration sector, which means that almost 4 workers out of 1000 have a job linked to the manufacturing, installation, maintenance and servicing of refrigeration equipment. This ratio is even higher in countries, such as Australia, where around 173,000 people (1.5% of the workforce) are employed in over 20,000 businesses operating in the refrigeration sector (Australian Government, 2015). In the US, employment of mechanics and installers in heating, refrigeration and air conditioning is expected to grow by 21% from 2012 to 2022, much faster than the average for all occupations (11%) (US Bureau of Labor Statistics, 2015). In this field, the need for engineering and technical staff (e.g. installers and mechanics) increases due to the growing demand for refrigerating capacities, along with the unique skills required from refrigeration-related professions in the field of energy and environment (IIR, 2015^a). Women are still

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significantly and visibly under-represented in the refrigeration industry. For instance, women represent 10% of the IIR commission members (41 women versus 369 men) and less than 10% of participants of the IIR Congress held in August 2015 in Yokohama (Japan) were female (IIR, 2015^b). Global Cold Chain Alliance (2015) stated that women represent only approximately 12% of their members. The purpose of this paper is to demonstrate the current state-of-the-art of women in the refrigeration field from the national refrigeration institutions and associations. Suggested incentive actions are the outcomes of the second meeting of the official IIR Women in Refrigeration sub-group that took place at the 12th IIR Gustav Lorentzen Conference on Natural Refrigerants (GL2016) in Edinburgh (UK).

WOMEN IN SCIENCE AND ENGINEERING

Governments and industry across the industrialized countries support efforts to improve the representation of women professionals in the field of science and engineering by recognizing the scale of the untapped pool of qualified women in this area. Although these efforts have had a positive impact, engineering remains a largely male-dominated profession in most countries.

A United Nations Educational, Scientific and Cultural Organization (UNESCO) report on Women in Science (2012) shows national breakdowns of female researchers in science worldwide. At regional levels, this report stated the averages of 45.2% for Latin America and the Caribbean; 34.0% for Europe; 34.5% for Africa; 18.9% for Asia; 39.2% for Oceania; and unfortunately, there is no regional average available for North America due to a lack of data. These figures include women working in life sciences which involve the scientific study of living organisms (such as microorganisms, plants, animals, and human beings). Women are highly represented in life sciences (NSF, 1996).

Table 1. Percentage of Women in Engineering per Country (Colombo *et al.*, 2016)

Country	Women %	References	Country	Women %	References
Australia	9.8	Engineers Australia, 2012	Netherlands	5.5	Eurostat, 2014
Brazil	14.2	Maria Rosa Lombardi, 2005	New Zealand	13	IPENZ, 2013
Canada	22.3	Status of Women Canada, 2012	Norway	6.2	Eurostat, 2014
China	~ 40	In STEM; Engineer Live, 2013	Romania	5.5	Eurostat, 2014
Denmark	18	Eurostat, 2012	Russia	40.9	ParisTech Review, 2010
Estonia	68	The Globe and Mail, 2013	South Africa	10	IGU/UNESCO, 2013
France	23	Eurostat, 2012	South Korea	< 15	Sci Dev Net, 2014
Germany	13	Eurostat, 2012	Spain	5.4	Eurostat, 2014
India	12	IGU/UNESCO, 2013	Sweden	26	IGU/UNESCO, 2013
Italy	14	Eurostat, 2012	Switzerland	5.7	IGU/UNESCO, 2013
Japan	< 15%	Sci Dev Net, 2014	Turkey	1,8	Eurostat, 2014
Kenya	8	IGU/UNESCO, 2013	United Kingdom	8,7	IGU/UNESCO, 2013
Malaysia	10,6	Unesco 2015	United States	15	CareerBuilder, 2014

Despite these needs of engineers due to shortage (UNESCO, 2010), records show that women were significantly under-represented in the fields of engineering, constituting an average of 10-20% of engineering workers International Gas Union (IGU)/UNESCO report (2013). Table 1 summarizes published data of the percentage of women in engineering per country. According to the IGU/UNESCO report (2013), in the US and Europe, women now constitute 30% of university engineering students, and that number rises to 35% in India, 15% in South Africa, and up to 60% in the Gulf countries (including Kuwait). However, even in countries where the number of women studying in STEM has increased, this trend has not necessarily translated into increased hiring of women engineers. Indeed, a large number of graduate students do not exercise the engineering profession, which is due to several factors such as cultural and religious orientations.

WOMEN IN REFRIGERATION

There are no official records of the number and/or percentage of women in the refrigeration industry and few incentives have been put in place to encourage women to consider a career in the industry. Established in 2004, Women in HVACR (Heating, Ventilation, Air Conditioning and Refrigeration) (Women in HVACR, 2015) is based in the USA with the objectives to improve the lives of members by providing professional avenues to connect with other women growing their careers in the HVACR industry. Women in HVACR empowers women to succeed through networking opportunities, mentoring and education. The Cryogenic Society of America had a cover story on women in cryogenics and superconductivity (2015) where several women who are excelling in this field discussed their experiences. A report from the US Department of Labor (2014) stated that women represent 1.2% of the heating, air conditioning, and refrigeration mechanics and installers for non-traditional (male-dominated) detailed occupations. According to the North American Industry Classification System (NAICS, 2011) in Canada, the percentage of women represents about 1.7% of the refrigeration and air conditioning mechanics (includes office staff, etc.) of the maintenance and equipment operation trades. Women in ACR series of the UK ACR Journal (2015) interviewed several women working in the HVACR industry on their career path, development and prospective.

At the latest IIR International Congress of Refrigeration (ICR2015) in Japan, the IIR organized the first Women in Refrigeration network session (IIR, 2015^b) where the twenty attendees (75% female, 25% male) were present to discuss some key aspects of women in refrigeration drawing both on their own experiences and those of others to reflect on what helped and hindered women from joining the profession. A preliminary state-of-the-art of women in refrigeration industry was presented (Colombo *et al.*, 2016).

Survey

Obtaining some records of the number or/and the percentage of women working in the refrigeration industry excluding office and support staff was a difficult task according to the different national refrigeration associations/organizations approached. Therefore, it was decided that the number or/and the percentage of women registered as private members of national associations could be appropriate figures of women representation in the industry. 25 worldwide national refrigeration associations have been contacted for this purpose.

Results

Eighteen of the listed associations replied to the IIR request for the percentage of female members registered as private members in the year 2014-2015 and are shown in Table 3. Women registered under corporate memberships were excluded as they could be office and/or support staff with no knowledge and practice of refrigeration. Some associations were kindly requested to provide additional figures on the evolution of their women memberships since the previous decade. Some associations were unable to provide information.

The IIR Brazilian correspondent provided figures from the Brazilian Society for Contamination Control which was not related to the HVAC industry. Canada quoted the figures from the North American Industry Classification System (NAICS, 2011). Additional information included the IIR Chinese correspondent who stated that women have played a very important role in the Chinese HVAC&R industry and for the last 10 years the female membership had remained stable. The Japanese contact stated that the female membership had significantly increased by 68% from 2005 to 2015. The Jordanian correspondent replied that Jordan does not have any national refrigeration association and that the JNC is part of the mechanical engineering branch of the University of Jordan (UJ). However, they stated that the numbers of women students in the UJ who take classes in refrigeration is around 8% of the total students attending these courses and the same percentage of women join design activities in areas of refrigeration and air conditioning practices. The Russian contact tried unsuccessfully to obtain national figures from the Russian Government and therefore provided an estimation of 3% highlighting that after studies a certain percentage of married girls probably leave the profession, but in general they try to work in the refrigeration industry. The South

African president also added that the women membership has increased by 35% since 2005. The Swiss correspondent replied that statistics about the gender of the employees of their company members was unavailable and that all their company members were male. It should also be noted that the Swiss association also has individual memberships. ASHRAE provided figures of 3.92% for 2008, 3.20% for 2011 and 4.33% (2015) demonstrating an increase of 10% in female memberships over this period.

The Romanian figures are quite high compared to the other associations and include women managers, professors, experts, technicians, assistants. The Romanian correspondent added that at the time of Ceausescu, women in engineering were representing more than 30%. For instance in 1983 in the Building System Faculty of the Technical University of Civil Engineering of Bucharest, women were about 50% graduated women as building services (BS) diplomat engineers and on the total graduated women as BS diplomat engineers 30% were involved in refrigeration and air conditioning.

Table 2. Percentage of Women Membership (Colombo et al., 2016)

Country	%
Australia	3.1
Brazil	6.25 (Not reliable)
Canada	1.7
China	19.5
Congo	0.1
France	7
Germany	5.3
Italy	8.8
Japan	2.3
Jordan	8 (Not reliable)
New-Zealand	1
Norway	2.2
Russia	3 (Not reliable)
Switzerland	0
USA	4.33
United Kingdom	2
Romania	33
South Africa	2.8

Figure 1 compares per country the data obtained from the UNESCO report on women in Science (2012), women in Engineering in Table 1 and women in Refrigeration in Table 3.

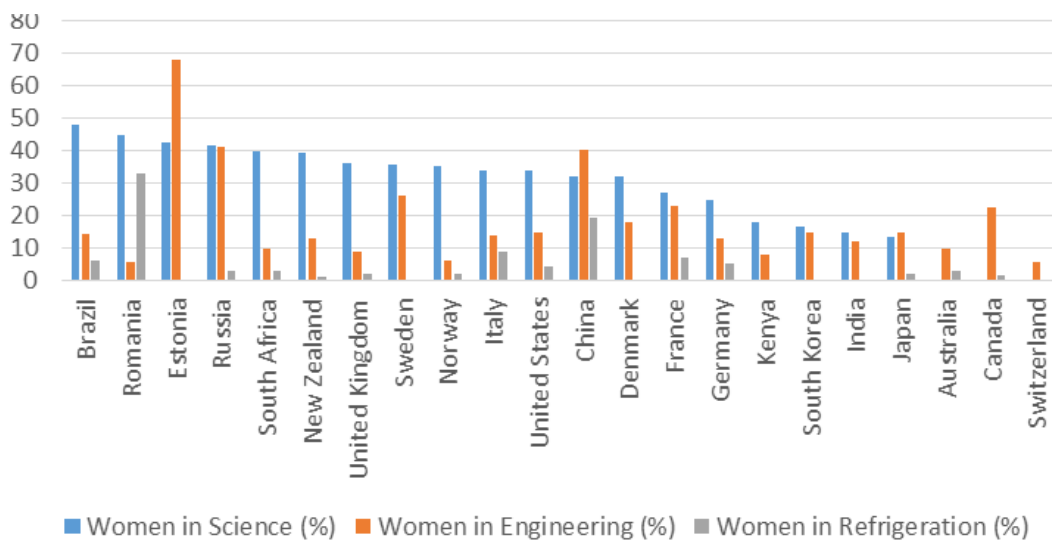


Figure 1 Women in STEM (Colombo *et al.*, 2016)

The gap between women in Science and women in Engineering/Refrigeration is significant and highlights the fact that women are less attracted by engineering and technical careers. It is noticed that communist and ex-communist countries are more likely to have high number of women working in STEM such as Romania, Estonia, China and Russia.

OUTCOMES OF 2ND DISCUSSION GROUP

Since the IIR first Women in Refrigeration network session in Japan, the “Woman in Refrigeration” sub-working group part of the IIR “Career in Refrigeration” working group has been officially launched and approved by the IIR Science and Technology Council (STC). A second meeting has been organised during the 12th IIR Gustav Lorentzen Conference on Natural Refrigerants (GL2016) in Edinburgh (UK).

The overall discussion topic for the meeting was how the sub-working potentially could attract young people into the industry and increase both the cultural diversity and numbers of women in refrigeration. The conversation highlighted some key areas. These are outlined below along with some specific quotes from meeting attendees.

1. Issues around attracting more young people into refrigeration:

- Lack of specific degrees in refrigeration: Refrigeration crosses over with other engineering degrees, which have higher profiles. “I discovered refrigeration during my chemical engineering degree”; “In Australia people fall into refrigeration”.
- Recognising the need for young people at all levels: The refrigeration industry needs multifaceted, ‘jack of all trades’ people, to undertake the varied work. “We need technicians too and that is a different educational route”.
- Remuneration and status of refrigeration: “Refrigeration is hidden/invisible in the UK”
- Are there specific barriers for women?: Consider using different language “‘Mechanical’ can be off-putting for some women but they are attracted to ‘energy’ and ‘environmental’”; Design, as well as

site work is available and this is important for some women to know, who may prefer not to go on site. “We need women not just as engineers but also in design, finance and marketing”; “The challenge is we need to show they are needed”.

- What problem are we trying to solve?: Recruitment into engineering or into refrigeration? “Maybe both?. In the UK alone 1.2m new people in engineering of all types are currently needed.
- Research needed: PhD in Women in Engineering; Family connections “In Germany – a high % of women engineers have engineer Fathers”; “Promotional ideas should be proposed”.
- Make increasing use of social media: Video stories of ‘how I got into refrigeration’ – put on YouTube (ref. engineer’s dance); Facebook stories about real people “The humans of HVAC & R”; Twitter – use #GL2016 and similar to send out positive messages for young people and women. #CARE is already set up?; Linked-in groups (some of these already exist, are they cross-linked?).
- Use stories about helping people/solving problems: Start in early school (this was successfully used in US where women engineers are close to 30%). “In Hanover the Montreal Protocol was a driver for recruitment – ‘save the world’”.
- National/educational campaigns/ideas: eg UK Women in Engineering. Need to share what all countries are doing and what is working/not working. Early years work experience/ open weeks for women in the purpose to influence the influencers – parents, teachers, career advisers to recommend STEM careers and the industry sponsored talks such “Cool science” and the planned 2018 exposition on Refrigeration at the Cité des sciences (La Villette, Paris). Could this more widely/be replicated elsewhere? Links through Ashrae committee/global alliance.
- Rebrand the industry: HVAC &R → ‘Climate Control’ or ‘Sustainable cooling & heating.’

2. Target audiences

- What targets does the working group have? How can it harness more support from the industry to help achieve them?: The target audience will be the main discussion of the 3rd meeting that will place during one of the 2017 IIR conferences.

CONCLUSION

This paper describes the outcomes of dedicated group discussions that took place at the first and second IIR Woman in Refrigeration meetings. The refrigeration industry plays a major and increasing role in today’s global economy, with significant contributions made in food, health, energy and environmental domains which policy makers need to better take into account. Estimates have shown that almost 4 workers out of 1000 have a job linked to the manufacturing, installation, maintenance and servicing of refrigeration equipment. Records show that women are significantly under-represented in the fields of engineering (only 10-20% of the work force), and especially in the refrigeration industry women are significantly and visibly under-represented. Unfortunately, there are no official records on the number and/or percentage of women in the refrigeration and few incentives to encourage them into the industry have been put in place. The preliminary evaluation demonstrated that 6.13% (average of Table 3) of women are members of national refrigeration associations/organizations/institutions. This figure could potentially be extrapolated to represent women in the whole refrigeration industry. However, it is important to highlight that there has been a significant increase in women membership in some countries such as South Africa and Japan which should

be encouraged and duplicated in other countries.

The progresses of the initial objectives (Colombo et al., 2016) of the first meeting were focused on the different social, environmental and economic aspects by:

- Setting up a “Woman in Refrigeration” IIR sub-working group as part of a “Career in Refrigeration” working group which has been launched in February 2016 by the IIR STC (IIR Working Group, 2016).
- Having more women represented on each IIR working group and commission. In 2016, Prof Judith Evans and Dr Catarina Marques have been respectively appointed as the new president of the IIR Commission C2 on food science (IIR, 2016^a) and engineering and the chairman of the “Career in Refrigeration” IIR working group (IIR, 2016^b).
- Increase visibility by promoting refrigeration to the young generation including other minority groups. The IIR is part of the Management Committee of the Exposition on Refrigeration at the La cité des sciences et de l'industrie (in Paris, France) planned 2018 which has the main objective to promote refrigeration to kids from primary, secondary and high schools.

REFERENCES

- Australian Government, Department of Environment, 2015. Cold hard facts 2: A study of the refrigeration and air conditioning industry in Australia, 2013. Available from: www.environment.gov.au/atmosphere/ozone/publications/cold-hard-facts-2.html
- ACR Journal UK, 2015. Women in ACR articles. Available at: <http://www.acrjournal.uk/apps/search?q=women+in+acr>
- BLS Reports, 2014. Women in the Labor Force: A Databook. U.S. bureau of labor statistics. Available at: <http://www.bls.gov/opub/reports/cps/women-in-the-labor-force-a-databook-2014.pdf>
- CareerBuilder, 2014. Just 15% of Workers In Engineering Occupations are Women. Available at: <http://thehiringsite.careerbuilder.com/2014/11/17/15-workers-engineering-occupations-women>
- Colombo, I., Marques, C., C., Evans, J., Kauffeld, M., Fournier, S., Tarlea, G., 2016. Women in the cold chain industry. Proceedings of the 4th IIR International Conference on Sustainability and the Cold Chain. Auckland, New Zealand, April 7-9, 2016. <http://dx.doi.org/10.18462/iir.iccc.2016.0003>
- Cryogenic Society of America, 2015. Featuring Women in Cryogenics and Superconductivity. Available at: http://www.cryogenicsociety.org/csa_highlights/featuring_women_in_cryogenics_and_superconductivity/
- Engineers Australia, 2012. Women in engineering, a statistical update. Policy Analyst, International and National Policy, Australia. Available at: https://www.engineersaustralia.org.au/sites/default/files/shado/Representation/Information_Papers/women_in_engineering_2012.pdf
- Engineer Live, 2013. How to increase the global ranks of women engineers. Available at: <http://www.engineerlive.com/content/how-increase-global-ranks-women-engineers>
- Eurostat, 2012. EU Labour Force Survey. Percentage of engineering professionals who are female.
- Eurostat, 2014, Percentage of active population of Human Resources in Science and Technology (HRST), women scientists and engineers , 2011 data.
- Global Cold Chain Alliance, 2015. GCCA Establishes Online Community for Women in The Cold Chain. Available at: <http://www.gcca.org/coldcon/2015/08/24/gcca-establishes-online-community-for-women-in-the-cold-chain>
- International Institute of Refrigeration (IIR), 2015^a. The Role of Refrigeration in the Global Economy. IIR 28th Informatory Note on Refrigeration Technologies, September 2015.
- International Institute of Refrigeration (IIR), 2015^b. The IIR brings women in refrigeration to the forefront. Available at: <http://www.iifir.org/clientBookline/recherche/NoticesDetailles.asp?VIEWALL=TRUE&ToutVisualiser=1&INSTANCE=EXPLOITATION&iNotice=13&ldebut=>
- International Institute of Refrigeration (IIR), 2016^a. New president of IIR Commission C2 on food science and engineering. http://www.iifir.org/clientBookline/service/reference.asp?INSTANCE=EXPLOITATION&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0018525&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN

- International Institute of Refrigeration (IIR), 2016^b. New IIR Working Group on Careers in Refrigeration “CaRe”. http://www.iifir.org/clientBookline/service/reference.asp?INSTANCE=EXPLOITATION&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0018580&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN
- IIR Working Group, 2016. Terms Of Reference of the Careers in Refrigeration “CaRe”. www.iifir.org/userfiles/file/about_iir/working_parties/WG_CaRe_ToR.pdf
- International Gas Union/United Nations Educational, Scientific and Cultural Organization (IGU/UNESCO), 2013. Forum UNESCO/UIG pour les femmes ingénieures: Note Conceptuelle. Available at: GU/UNESCO Roundtable on Women in Engineering.
- Lombardi. M., 2005. Cahiers du Genre : Le genre et ses frontières. Les femmes ingénieures dans le Brésil d'aujourd'hui. Available at: http://www.cairn.info/zen.php?ID_ARTICLE=CDGE_042_0159.
- National Science Foundation (NSF), 1996. Women, Minorities, and Persons with Disabilities in Science and Engineering: 1996. Available at: <http://www.nsf.gov/statistics/women/>
- ParisTech Review, 2010. Why aren't there more women engineers? Available at: <http://www.paristechreview.com/2010/09/29/why-more-women-engineers/>
- Professional Engineers New Zealand (IPENZ), 2013. Women in Engineering: An update on progress in 2013. Available at: <https://www.ipenz.nz/home/news-and-publications/news-article/women-in-engineering-an-update-on-progress-in-2013>.
- Sci Dev Net, 2014. More Asian women find success in science. Available at: <http://www.scidev.net/asia-pacific/gender/feature/more-asian-women-find-success-in-science.html>
- Status of Women Canada, 2012. Women in Canada: a Gender-based Statistical Report, 6th edition, Statistics Canada. Available at: <http://www.statcan.gc.ca/pub/89-503-x/89-503-x2010001-eng.htm>
- Statistics Canada, 2011. 2011 National Household Survey: Data tables. Available at: <https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/dt-td/Rp-eng.cfm?LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=0&GK=0&GRP=0&PID=106738&PRID=0&PTYPE=105277&S=0&SHOWALL=0&SUB=0&Temporal=2013&THEME=98&VID=0&VNAMEE=&VNAMEF=>
- The Globe and Mail, 2013. Gender geography: Where's the best place in the world to be a woman. Available at: <http://www.theglobeandmail.com/news/national/gender-geography-wheres-the-best-place-in-the-world-to-be-a-woman/article9488293>
- United States Department of Labor, Bureau of Labor Statistics, Occupational Outlook Handbook, 2014-15 Edition, Heating, Air Conditioning, and Refrigeration Mechanics and Installers. Available at: <http://www.bls.gov/ooh/installation-maintenance-and-repair/heating-air-conditioning-and-refrigeration-mechanics-and-installers.htm>
- University of Birmingham, 2015. University of Birmingham, 'Birmingham Energy Institute policy commission requests evidence for important new report on need to rethink cooling'. Available at: <http://www.dearman.co.uk/#!/University-of-Birmingham-Birmingham-Energy-Institute-policy-commission-requests-evidence-for-important-new-report-on-need-to-rethink-cooling/ccrp/558149310cf201107e2d9d1b>
- United Nations Educational, Scientific and Cultural Organization (UNESCO), 2012. Women In Science. Available at: <http://www.uis.unesco.org/FactSheets/Documents/sti-women-in-science-en.pdf>
- United Nations Educational, Scientific and Cultural Organization (UNESCO), 2010. Engineering: issues challenges and opportunities for development. ISBN 978-92-3-104156-3.
- United Nations Educational, Scientific and Cultural Organization (UNESCO), 2015. Girls and Women in Science, Technology, Engineering and Mathematics in Asia. UNESCO Bangkok Office.
- US department of labor, 2014. Nontraditional Occupations. Available at: <https://www.dol.gov/wb/stats/Nontraditional%20Occupations.pdf>.
- Women in HVACR, 2015. Available at: <http://www.womeninhvacr.org/webapp/p/19/focus>.