Building and Environment 111 (2017) 238–248

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Indoor relative humidity as a fire risk indicator

Torgrim Log

Western Norway University of Applied Sciences, Haugesund, Norway

ARTICLE INFO

Article history:
Received 10 September 2016
Received in revised form
28 October 2016
Accepted 2 November 2016
Available online 3 November 2016

Keywords:
Weather stations
Relative humidity
Dry wood
Fire risk

ABSTRACT

A low cost weather station has been tested for monitoring relative humidity (RH) in sitting rooms as a dry wood fast fire development risk indicator. Ten Norwegian wooden homes/flats, built between 1843 and 2012, were selected for testing during the winter 2015/2016. Linear calibration curves for each in- and outdoor sensor, based on saturated inorganic salt solution controlled air, were needed to ensure ±3% RH accuracy. Recorded average moisture supply to the indoor air during the winter varied from 0.30 to 2.64 g/m^3, with mean 1.29 ± 0.75 g/m^3. The oldest buildings and the modern balanced ventilation buildings were generally driest. A near step change to drier weather in January resulted in a 6–7 days decay period for recorded indoor RH of the older buildings with wood panel wall linings. This was within reasonable proximity (30%) of theoretically expected step change diffusion controlled wood panel drying. The decay period was shorter for a modern building with plasterboard wall linings. A similarly long decay period was not observed for subsequent rising RH values two weeks later. This discrepancy may be explained by wood desorption adsorption hysteresis. The calibrated weather stations gave reliable results throughout the winter season. They served, and may very well also in the future serve, as detectors for warning local fire brigades about emerging dry wood fire risk situations. Due to hysteresis, more research is, however, needed to know when to call off a dry indoor climate high fire risk condition as the conditions gets less dry.

1. Introduction

Relative humidity is for several reasons recorded in buildings. One main reason is connected to the humidity as a potential deterioration problem to the wooden constructions [17,27]. Another reason is the potential of energy optimization [29,40]. Much work is also related to relative air humidity as an indoor air quality parameter [19,39]. Research has also been done regarding indoor relative humidity as a possible cause of higher death rates during winter months in northern climates [5]. A major study of ventilation systems and building fabric on the stability of indoor temperature and humidity in detached houses was done in Finland [16]. Based on continuous temperature and humidity recordings in bedrooms and living rooms, it was concluded that the ventilation had a greater effect on the indoor climate than the properties of the building fabric and types of buildings. The recorded dampening effect of hygroscopic materials was significantly lower than in simulations studies. Influence of furniture and textiles was recognized as a factor probably playing a significant role in indoor humidity dampening, together with air change rates, window airing, etc.

Norway has a rich tradition with respect to wooden constructions. This is partly due to the abundant forests covering major parts of the lowlands also north of the Arctic Circe. Some of the most well-known traditional wooden objects are the 28 remaining 800–900 years old Viking Stave Churches as well as Viking ships preserved in sea mud or at burial sites. Most wooden constructions were, however lost due to the humid climate and associated wood deterioration processes. Others were lost in the fires raging through the centuries [23].

It is general knowledge in Norway that the fire frequency is highest during winter time. This is usually explained by increased use of open flame, such as open fire places and candle lights during the dark Nordic winter as well as Advent, Christmas and New Year celebrations. During the winter time, temperatures decrease well below zero in the inland. In west coast areas windy weather is the norm during parts of the winter season, either fairly humid air from the Atlantic Ocean or adiabatically heated (still subzero) dry air descending from central Norwegian mountains. Excessive heating by electricity, i.e. the normal mode of heating, may trigger fires originating from the electrical wiring systems. Chimney fires due to

E-mail address: torgrim.log@hsh.no.

http://dx.doi.org/10.1016/j.buildenv.2016.11.002
0360-1323/

increased use of wood burners also add to the picture of increased winter time fire frequency (www.dsb.no). December and January are therefore the months of highest, and fairly equal, fire frequency in Norway, as seen in Fig. 1, though the open flame fire cause is not that obvious in January. Generally lower outdoor temperatures in January, with lower dew point, may be a separate explanation, as explained by Pirsko and Fons [28] for selected areas of the USA. According to Babrauskas [2] this is probably valid also for modern buildings.

Major conflagrations have also been experienced in the winter time, like the one in the west coast town of Ålesund, January 23rd, 1904. Not much is known about the Ålesund fire, which came out of control in storm strength wind (22–30 m/s wind speed), destroyed 850 structures and resulted in 10.000–12.000 homeless people [21]. One may be lead to think that such fires are only a part of history and not of particularly interest in a modern society. During January 2014 it was, however very dry and windy in large parts of South-Western Norway. January 18th a fire started in a private home in Lærdalsøyri and raged through this West-Norwegian mountain region fjord community. The fire destroyed 40 structures, including 4 historic buildings and 15 private homes and threatened the whole village including the Old Lærdalsøyri cultural heritage site. It was the largest peace time fire in Norway since 1923 when 250 structures were lost in Hemnesberget [23]. The importance of the adiabatically heated low relative humidity sub-zero temperature air drying the structures in Lærdal was, together with strong wind, identified as an important cause of the severe fire development [21]. The fire spread mechanisms were identified as typical spotting ignition fire spread [35]. The cold dry weather continued and 10 days later a subzero wild fire in heather (*Calluna vulgaris*) dominated areas in Flatanger destroyed 59 structures [9,22]. In this period, a far more devastating cold climate fire took place at Résidence du Havre nursing home, L'Isle-Verte, Quebec, Canada, January 23, 2014, resulting in 32 fatalities and 15 injured [10]. In the official investigation reports of these three fires [9,10] the potential indoor drying of wooden materials during winter weather was not mentioned. However, already 60 years ago, Pirsko and Fons [28] showed that the frequency of urban building fires was correlated with relative air humidity in the summer and dew point temperature in the winter for selected areas studied in the USA. Though building materials and construction methods have changed since then, and the correlation may be somewhat weaker today, Babrauskas [2] reckoned that the findings from 1956 were probably still valid.

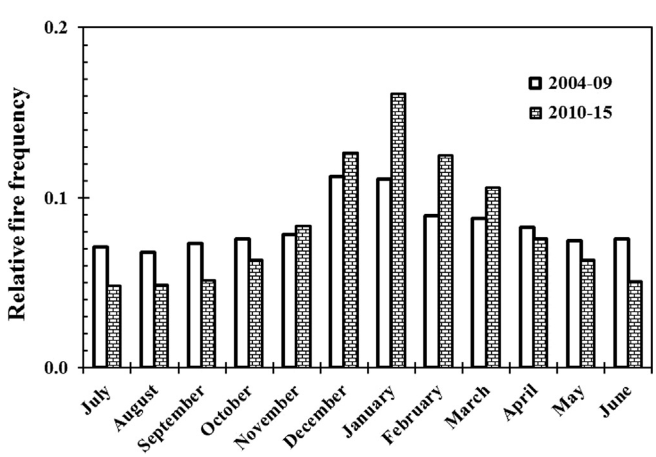

Fig. 1. Relative fire frequency in Norway during the 6 year periods 2004-09 (9,070 fires) and 2010-15 (17,417 fires, including chimney fires). Data from www.dsb.no.

The time needed for a 2.5 kW fire to develop to flashover in ¼ scale wooden pine test rooms of different Fuel Moisture Content (FMC) was documented by Kraaijeveld et al. [20]. The time to flashover was reduced from 8 min for wood at 9 wt% FMC to only 4 min at 4.5 wt% FMC. At room temperature, this respectively corresponds to about 20% RH and 50% RH [34]. Faster development of a fire in a detached home, with (in Norway) mandatory smoke alarm systems installed, may not represent a huge risk to the inhabitants as they most likely still have sufficient margins for evacuation. In a larger construction where evacuation takes more time, or where the inhabitants are not autonomous, a faster fire development may develop into a catastrophe [10]. If there is much wind, early flashover may result in very fast fire spread to neighbor structure, and over large distances making the situation very challenging for the firefighting efforts [18]. Indoor relative humidity of inhabited (heated) wooden structures may therefore represent an important indicator regarding the fast development and severity of a potential building fire. Such a telltale may be very valuable for contingency planning, resource allocations [26] and warning of the public about increased fire risk.

The present work describes testing of low cost consumer market equipment for recording indoor and outdoor temperatures and relative humidity in 10 buildings in South-West Norway. The system should be web based to allow for online recordings and storage of the recorded data in a format suitable for instant readings as well as for subsequent data analysis. The first purpose was to evaluate whether such equipment could produce data at a satisfactory precision during one winter, and if not, develop calibration procedures to increase the accuracy to sufficient levels and test it during a winter season. The second purpose was to inform the local fire brigades of any identified suddenly decreasing indoor relative humidity, i.e. a telltale of increasing fire risk. The third purpose was to try to calculate the humidity supply in the different buildings as that might be beneficial for potential future fire risk modelling. The article is organized in parts describing the theory of humidity and humidity transport, equipment and calibration procedures, equipment performance during a winter season and humidity supply in 10 selected homes/flats in South West Norway. The paper reports average water supply and elaborates parts of the recorded relative humidity time series of special interest for selected buildings. It finally concludes regarding the usefulness of the methods and equipment as a promising potential increased fire risk identification methodology.

2. Theory

2.1. Water vapor concentrations in air

The water saturation vapor pressure is a function of temperature and may be calculated by [37]:

$$P_{sat} = 610.78 \cdot e^{\left(\frac{17.2694 \cdot T_c}{T_c + 238.3}\right)} \ (\mathrm{Pa}) \tag{1}$$

where T_c is the temperature (°C). The water concentration may be calculated by:

$$C_{w,sat} = \frac{P_{sat} \cdot M_w}{R \cdot T} \ \left(\mathrm{kg/m^3}\right) \tag{2}$$

where M_w (0.01802 kg/mol) is the molecular mass of water, R (8.314 J/K mol) is the molar gas constant and T (K) is the absolute temperature, i.e. T_c + 273.15 K. The relative humidity (RH) is an expression for the actual concentration of water in the air to the saturation concentration, i.e. RH = $P_w/P_{w,sat}$ = $C_w/C_{w,sat}$. At low