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Moisture problems and building defects in basement

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Abstract
This work studies moisture problems in the basement. What possible outside and inside factors create having moisture in the basement. Furthermore, possible solutions of how it is possible to lower moisture in the basement. The study is carried out on an existing building in Kuopio, Finland. The existing building has moisture problems in the basement, to decrease moisture problems fan was installed to take drier air from the outside and bring it inside to dehumidify the basement.

In order to study this situation, calculations are carried out. Data of relative humidity and temperature is collected from the eleven months. The graphs are carried out in order to understand the better situation. Moisture content calculations are carried out to find out real situation in the basement.

The main conclusions of this work are to find out the fan operating principle and does it runs correctly. During this work findings, show that fan operating principle is incorrect. Possible solutions are carried out in order to lower moisture problem in the basement.

Subject headings, (keywords)
Moisture in basement, moisture problems, basement, building defects

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1 INTRODUCTION

General overview

According to World Health Organization, the definition of moisture is "any visible, measurable, or perceived outcome caused by excess moisture indication indoor climate or problems of durability in building assemblies caused by various leaks of water". Furthermore, it also said that "moisture can be transported in both liquid and vapor phases by capillary suction, wind pressure, diffusion, convection and gravity (water pressure)". /1/.

Moisture problems are common in buildings. According to the studies, 76 percent of the buildings have moisture problems. Due to building envelopes defects, moisture problems are more common. Around 75-80 percent of studied houses, had moisture problems due to building defects/1/.

A lot of money is used to fix this issue. A study was carried out in Finland in 450 buildings which were built in different decades. They had the same moisture problem. In 80% of studied houses leakage problem was noticed. Surveyors admitted that one part of water leakage was due to flaws in the construction and another half was due to the aging of the materials. Furthermore, certain defects were characteristic for houses build in a certain decade. Especially it was seen on the construction side/2/.

Water in the building is also one of the reasons that can lead to the sick building syndrome. Moisture in the building is the main source of poor indoor quality, mold growth and a symptom of the unhealthy building. /3./There are many ways for moisture to enter the building like rainwater that can enter through windows, walls, doors, and roof. It is possible for groundwater entering through the basement. /1/.The investigation of these defects in building structure and moisture problems will be carried out in this thesis.

The first part of this bachelor thesis is theoretical. In this part, moisture problems and building defects are investigated in the buildings that could be caused by rainwater, condensation, and groundwater. While explaining the existing problems also, possible solutions are carried out to solve these problems.

In the second part of this thesis, an existing building is examined. The building has moisture problems in the basement. The fan was installed in order to minimize moisture content in the basement. In order to find out if the fan is working properly, moisture content calculations were made. The results are shown in the graphical and numerical form.

Aims

The aim of this work is to investigate the fan operating principle during the whole year. The fan was installed in order to use outside more dry air and take it to the inside of the basement and in that way dry the basement.

1.1 Methods

The evaluation of existing building is carried out. The location of the building is in Kuopio, Finland. The building is for elderly people and it is built next to the lake. Due to that, the building had excess moisture in the basement. A supervising company "Schneider" has installed the fan. The fan operating principle is simple. It takes dryer air from the outside and brings it into the basement in order to dehumidify. The fan works by the principle of relative humidity difference. If the relative humidity is lower outside, then it starts to run at full capacity, if not then it only runs with 30 percent of its full capacity. The investigation is done by the fan, does it works properly. The data is gathered from 0.1.12.2014 till 18.10.2015. The data is recorded every ten minutes. In the basements, there are three data lockers for temperature measurements on one for humidity measurements. Outside of the building one temperature and one humidity sensors is installed. The average value of humidity and temperature value is calculated per hour. The graphs are carried out for easier understanding of existing situation. Then moisture calculations are carried out.

2 CAUSES OF MOISTURE PROBLEMS

World Health Organization (WHO) in 2009 have defined that there are ten common moisture problems in the buildings; plumbing leaks and spill (1), groundwater or rain-water leaking through building envelopes (2), condensation (3), water licking by capillary suction through porous materials in the foundation (4) poorly vented or unvented swimming pools (5), insufficient dehumidification by ventilation systems (6), usage of wet materials during constructions (7), infiltration of warm or moisturized outside air (8), poorly compensated drainage due to air conditioning, heating and ventilation system deficiency (9), and exfiltration of moist or warm indoor air through holes and cracks in the enclosure during cold weather (10)/1/.

The leakage causes the biggest moisture problem in buildings. Water leaking through the building envelopes such as roof, windows, doors and ceiling causes a lot of moisture issues. A study carried out by Chew. M.Y.L. in his paper "Defect Analysis in Wet Areas of Buildings. Construction &building materials" he identifies major defects in the walls and also floors such as; water leakage through joints, water leakage through cracks. 53 percent of all moisture problems are caused by a lot of defects on walls and floors /4/.

Moisture and, of course, vapor penetrates through the walls (external to the internal wall). The World Health Organization has identified that moisture can go through the cracks and holes creating condensation on the walls and ceiling. /1./ Nevertheless, Environmental Protection Agency (EPA) has created recommendations for moisture control. First, to control condensation, and controlling water entering the premises and second, wet areas should be dried and dehumidified when it is necessary. It is very important that all the materials during construction are dry, and in the case they are not dry, they need to be dried immediately to avoid dampness or any other symptoms that wetness of the materials can cause /5/.

Moisture problems occur in the buildings especially in the basements due to improper design, the environment, poor handiwork and ventilation factors /1/.

Improper design

For moisture appearance design factor has a huge impact. Architects should avoid and minimize irregular forms in the building construction because they might collect moisture like water and dust. One of the wrong decisions is a bad choice of the materials. The conducted study by Chew M.Y.L stated that the most important thing to have a sustainable and durable building is the selection of the materials which could prevent and help to control defects occurrence in the building /4/.

Environment

The environment has the biggest impact on the building. Changes in climate during the year affect the building the most. The wind, rainwater and temperature changes during the year cause moisture problems in the buildings. In the northern countries, the weather conditions are systematically humid and wet during spring and autumn. During winter, humidity is very high outside due to heavy snowfalls. Absolute humidity is the highest during summertime in July and August. This has the biggest influence on the building structure, mostly on the façade of the building because of the contraction stress and expansion /6/. The envelope of the building is designed to protect the inside of the building from weather impact on the building sustainability. The defects in the roof that can allow leaks in the building cause huge damage to the structure of the building. Not only the structure is damaged but also interior which could lead to the sick building syndrome and it could cause serious impact on indoor air quality/3/. /18/.

Poor handiwork

One of the main factors that lead to the building defects is the poor workmanship /6./ A study was carried out by the division of environmental health, National health Institute in Kuopio, Finland (1998) in 450 buildings which were built in different decades and were checked for signs of water leakage in the structures. The results were shocking. Leakage problem was noticed in 80 percent of the studied buildings. Surveyors admitted that the one part of the water leakage were due to flaws in the construction and the other half were due to the aging of the materials. More than 55 percent of all inspected buildings needed to be refurbished. Furthermore, certain defects were determined and were characteristic of the certain decade of the building. Especially it was seen on the constructional side method used in different decade's /2/.

Ventilation

Ventilation is also one of the sources that help moisture to enter the building. There are three categories of ventilation in the buildings they are (1) mechanical ventilation for supply and exhaust air in the building (2) natural ventilation which depends on the openings of envelopes such as windows etc. and air movement in the premises and (3) hybrid or in other words mixed ventilation which is seen in figure 1. It uses natural or fan with low energy consumption which is combined with an independent mechanical ventilation system. /5/.

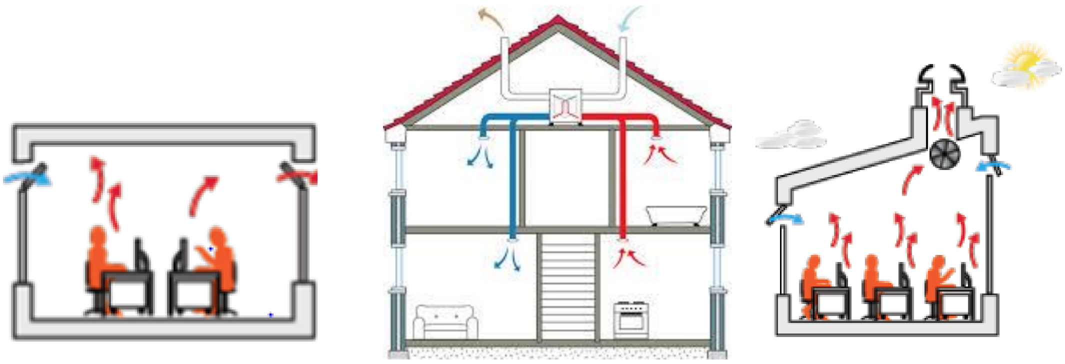

FIGURE 1. Examples of Natural, Mechanical and Hybrid ventilation /7/ /8/ /9/

One of the main functions of the ventilation system is to control the humidity level in the premises. Mechanical ventilation, for example, should have a very good dehumidification capacity in order to remove moisture from the premises and control the dew point. Basements or crawl spaces could increase the same amount of humidity level in the building during the day as all combined premises in the building /5/.

2.1 Condensation problems during seasons

Condensation problems during cold weather

In cold weather conditions, condensation occurs on the inside of the external walls or on the roof assemblies. The temperature will be near the outdoor temperature on the cladding and sheeting on the outer layer of insulation. The surface temperature of the windows is often much colder than the temperature of the walls and condensation will occur on the windows most likely first. If the temperature of the indoor wall is lower than the dew point of the surroundings, it means that most likely condensation may occur in the air gap between insulation layers of the wall. In case, there is a hole in the wall and the building is under negative pressure the infiltration of cold air can pass through the insulation and may lower the temperature of indoor wall surface to the temperature below the dew point /5/.

Often condensation occurs within the assembly. As an example could be shown the joint of the steel tie that is located inside the wall and goes to the external wall which is colder than an internal wall of the building. Since the tie conducts, heat from the inside faster than the insulation more humid indoor air will go through that joint and due to that condensation will occur on the tie /10/.

Most of the times the issues within roof and walls assemblies are hidden and could be accepted as the rainwater problems. A swimming pool hall can be taken for an example where the air is much more humid and warmer. For this air, it is easier to leak through the ceiling and insulation to the attic during the cold season. This moisture of air can freeze and accumulate in the attic. It could stay up there till the warm season. During this period, it would start melting and go back to through the ceiling. If it is found during the rainy day it could be misleading to the surveyors and they would think that it occurred due to rainwater. /5/.

Condensation problems during hot weather

During hot weather season, there is the possibility of having condensation. Mostly it happens in the buildings equipped with air conditioning systems. These systems are usually very big and it is hard to control them properly. Air conditioning (AC) systems can provide of having condensation inside the building. There are six possible ways how condensation can occur on the premises. Air conditioning system cools down all surfaces indoors, some more than the others (1) when system is not being used for de-humidification for a long time, air conditioning system removes air without removing moisture, it increases the dew point of the air and there is a bigger chance for condensation to occur (2) air in the room is warmer than the supplied air in ducts, refrigerant or in diffusers (3) when exhausted air from the building is higher than the makeup air it leads to outdoor air to come through holes and cracks in the building envelope and that air will condensate on the chilled surface of the AC system (4) when sun is shining on the wet surfaces of masonry wood or stucco it raises the temperature of the material, when temperature is high enough the evaporation of the water will occur forcing at the same time forcing fluid to enter the assembly if that happens it could reach the cold surface of indoor wall (5) during cooling conditions condensation on the inside surfaces of exterior walls might be caused by intentional or accidental vapor barrier (6). For example, when from the ground vapor is going to the basement it might condensate when it touches the vapor barrier on inside of basement wall /5/.

3 CONSEQUENCES OF MOISTURE

Mold and bacteria

Ishak stated in his Journal of building appraisal that poor ventilation in the building could lead to the growth of mold. The high amount of water in the air can encourage mold and bacteria growth Figure 2 shows what kind of problems and what kind of bacteria grow with a certain point of relative humidity. If the relative humidity is lower than 40% it is the best environment for bacteria, viruses, respiratory infections etc. to grow. On the other hand, if the humidity is too high then it is a good environment for bacteria, viruses, fungi and mites etc. to grow. In order to have a clean indoor air, the humidity should be between 40-60 percent./11/., /12/.

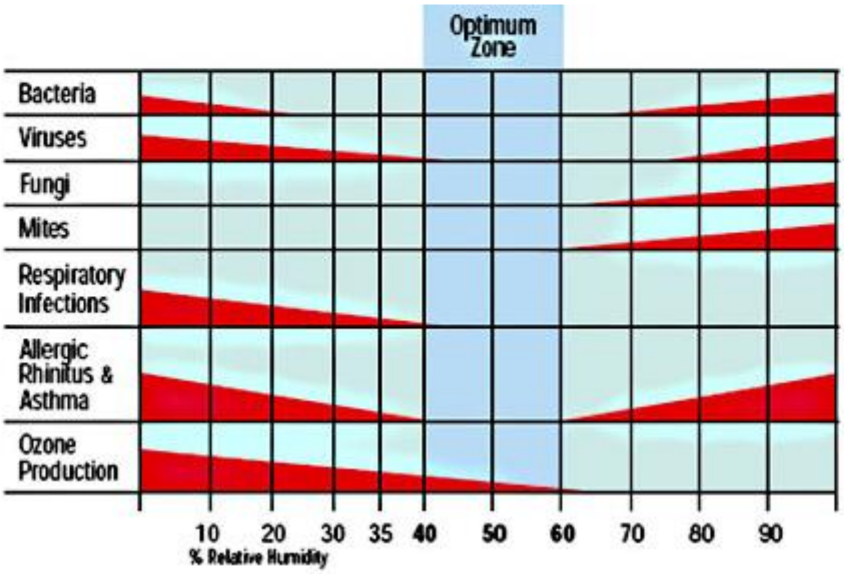

FIGURE 2. Indirect health effects of relative humidity in indoor environments /14/

Increasing or reducing humidity to avoid dampness or condensation problems are not always good solutions because the water vapor content in the air is not changing alt-hough if the temperature is changing. Condensation will occur on the windows and walls most likely first. So that water wouldn't condensate on the cold surface of the wall, the dew point of the air has to be above the temperature of the surface of the wall. /5/., /12/., /14/.

Micro-organisms in ventilation system

All ventilation systems and air conditioning systems should be planned, manufactured and maintained in such a way to avoid growth of hazardous micro-organisms. With high values of relative humidity or high amounts of water content provides a nutrient sub-strate for growth of microorganisms. In ventilation system, all materials should be "closed pored" which means the material should not absorb any humidity or release odors to the premises. Furthermore, it has to provide an unpleasant environment for the growth of microorganisms. The best environment for the microorganism to grow is in water or in humid surfaces such as on the humidifiers or on cold surfaces with conden-sate liquid. These are the best environments for legionella, algae, and molds to grow. /12/., /14/.

4 MOISTURE IN BASEMENT

Moisture and water problems are well known to everyone who has a basement in his house or in any other building. This problem is well known but very frequently not well understood and properly treated. When the basement is rarely used and is separated from the living area, it may not cause any problem at all. However, if the basement is used quite often moisture problems can become rather annoying and uncomfortable. They could even lead to health problems. In figure no. 3 we can see a properly built house. In this case, rainwater cannot enter the house/13/.

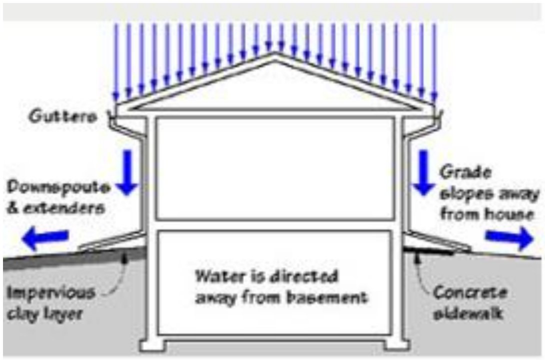

FIGURE 3. Properly build house to avoid moisture inside the house /13/

However, rainwater is not the only problem that leads to having moisture in the basement. Figure 4 shows that there is also a possibility for groundwater to enter the basement and ruin it.

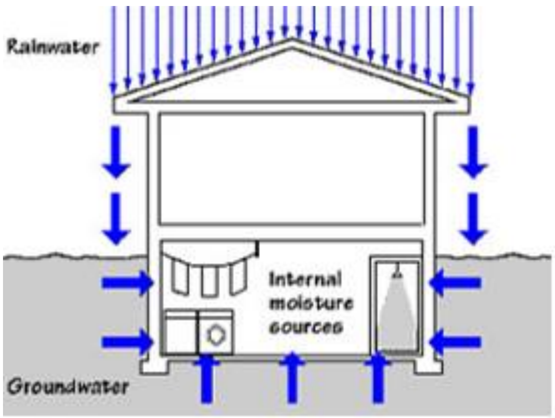

FIGURE 4. Other sources of moisture in basement /13/

Having moisture in the basement is the perfect environment for mildew and mold to grow humid carpets and beneath coverings of the wall. Finishing basement without fixing the moisture problem in it may result in mold and mildew occurrence and also making health conditions even worse. It is possible to solve the water problem in the basement. However, it is very expensive to do it right /13/.

To fix moisture problems in the basement, it is very important to understand where the water source is. What causes water to enter in the basement in the first place? There are three main sources of moisture appearance in the basement. The first source is, of course, the water from the rain and ground water that enters the basement because it is located at the lowest point in the building. The second source of moisture problems in the basement it could occur from humidifiers, bathrooms, unvented clothes dryers as well as the moisture in the concrete after construction. The third source is the exterior dump that enters the basement and condensates on the cold surfaces/13/.

There are four mechanisms that transfer moisture from the outside to inside liquid water flow, air movement, vapor diffusion and capillary suction. Occasionally due to poor construction having cracks in foundation may lead to moisture getting through into the building and causing more damage. In most of the cases, nevertheless, basements and the house itself structurally can be well built but are not well build to be able to handle water drainage system. It is very common that the failure occurs on the slope of the ground surface away from the foundation from the walls or there is not enough of good spout drainage system. Relatively frequently the lack or non-functioning subsurface drainage systems can lead to water entering the building. All of these problems can be fixed if it is done step by step /13/.

4.1 Symptoms

The basement needs to be refurbished if there are any of the following symptoms: 1) water dripping from the walls, 2) waters standing on floor, 3) very humid and damp air, 4) during summer there is condensation on the cold walls and floor, mildew, 5) mold and unpleasant odors, 6) deterioration of wood or any carpets or furniture, 7) staining and blistering of wall coverings /5/.

4.2 Sources of moisture in basement

Rain and groundwater

In 1 cm of rainwater, there are 1863 liters of the water which fall down on the roof top of 20 square meter house. Without the proper installation of downspout, grading and gutter some of this water may enter the basement. The groundwater may also rise due to flooding, longer rainy days or seasonal site conditions. That's why to drain tile system is needed around the basement walls no matter if the soil is sandy or it is gravel /5/.

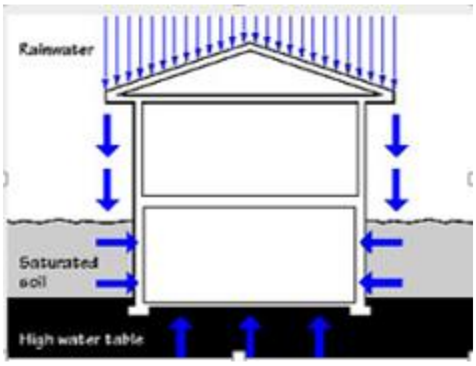

FIGURE 5. Water entries to the building /13/

The figure above represents how the water can enter the building. There are possibilities that it might enter the ground in cases of flooding, or through the rooftop during the rain.

Ventilation with outside air

During summertime, the windows in the basements are often opened for fresh air to enter the premises as shown in figure 6. The outside air is warmer and more humid during summertime it makes condensation on the cold surfaces of the walls and floors in the basement /5/.

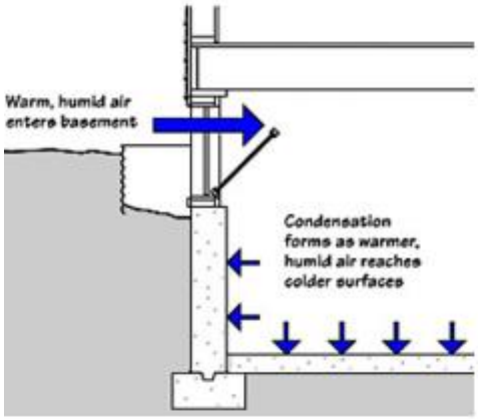

FIGURE 6. Ventilation with outside humid air /5/

People who own basement will notice the moisture on the walls and will consider the fact that they have water leakage through the walls. However, the real reason for moisture occurrence on the walls is condensation on the cold surface of the wall.

4.3 Moisture movement mechanisms

Capillary suction

The definition of capillary suction explains moisture movement through porous materials. Waters is drawn up through pores in the concrete footing and slab and through the walls. Due to this, it creates dampness which is seen on the basement walls. Most of the time it is seen on the metal cold joints which are connected to the concrete. Due to that water rises by capillary draw significantly /11/.

Figure 7 represents how moisture due to capillary suction enters the building base floor. These pores even if they are small are more dangerous than the big cracks in the walls. This is due to capillary suction ability. The smaller the pores are the more power they have to draw the liquid inside. The example could be given for the blood test. When you are donating the blood, the nurse sticks the needle to your vain and the glass tube fills very fast although the diameter of the needle is very small /11/.

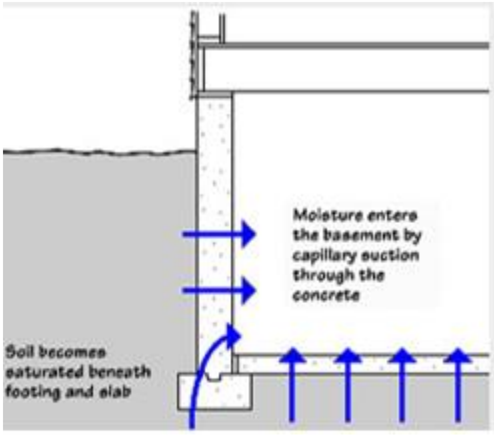

FIGURE 7. Capillary suction of porous materials /13/

The same process occurs with capillary suction in the concrete walls, where the liquid travels through the pores. The smaller they are more liquid they can absorb, which leads having moisture on the walls.

Air leakage

Stack effect is the movement of air entering and leaving the building. Figure 8 represents how the air movement is created due to stack effect.

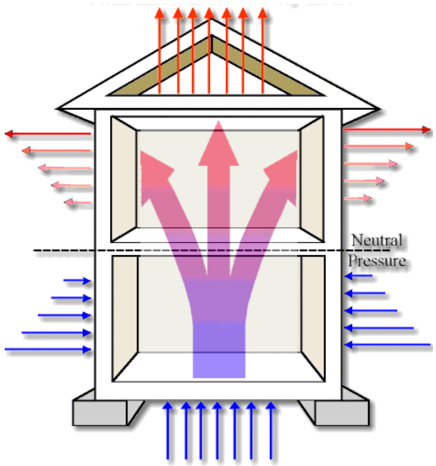

FIGURE 8. Stack effect in two story house /15/

Air is leaving the building through the chimneys, through stacks or any other containers resulting from the bouncy of the air. Buoyancy in the building occurs due to density difference in the air, temperature difference and the difference in water vapor content in the air /16/.

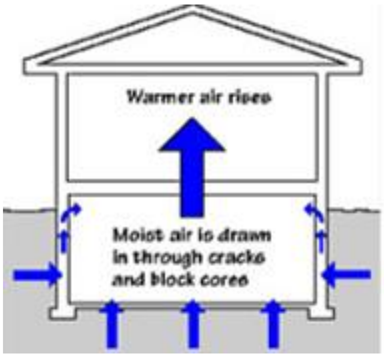

FIGURE 9. Air leakage through walls and floor /16/

Stack effect is created due to warm air rising upward almost in all houses. This makes negative pressure in the basement and draws moist air through the cracks, openings which are in the foundation. Due to that sumps have to have an airtight covering. If the block cores are left open it makes moist air be drawn through concrete block foundation/5/.

Vapor diffusion

Vapor diffusion could be defined as the movement of water vapor through the building material. It shows the conductivity of the building material and the difference of driving vapor force difference /17/.

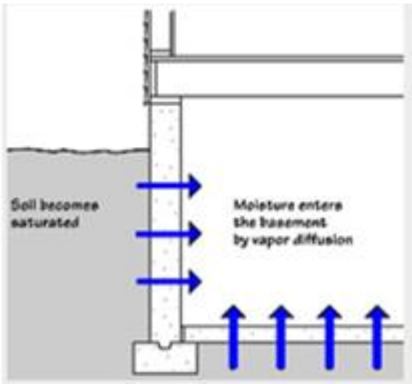

FIGURE 10. Vapor diffusion through foundation /17/

Very often in basements water can diffuse from the ground through the concrete walls and floors because it could be wet due to flooding and underground water. Due to that water will travel to drier place in the basement, which means the dampness will go up.

To slow down this process all kind of insulation needs to be used, for example, water-proof insulation or polyethylene insulation layer stops water from coming from the ground to dry basement premises /17/.

4.4 Moisture problems causes and solutions in basement

Insufficient grading

If the ground next to the building is in level with the building or the ground has the slope towards the house this causes that all the water is directed directly to the basement as shown in figure 11. This could happen when the soil next to the house is not backfilled without proper compaction. This causes that ground settles after some time and it could shrink in some places next to the building, which leads to water to come easier to the basement/13/.

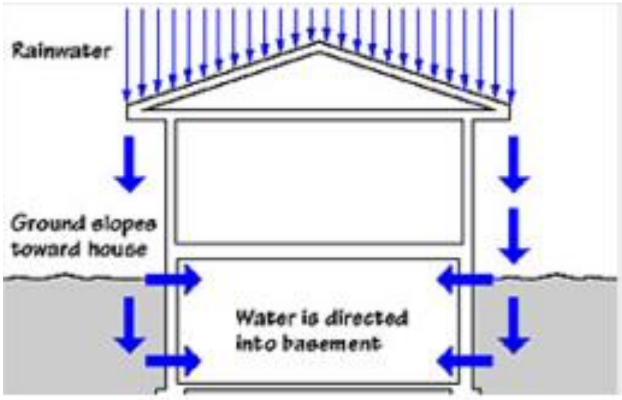

FIGURE 11. Insufficient grading /13/

This mostly happens under the foundation where water is collected next to the wall of the basement. The solution for this kind of problem would be to place earth next to the foundation that it would have an inclination of at least 3 cm per one meter of length. Due to that, this situation of water leakage into the basement could be avoided/13/.

Imperfect or no gutters and downspouts

If the gutters and downspouts are missing this it causes that rainwater can reach the foundation of the building much easier as is it shown in figure 12.

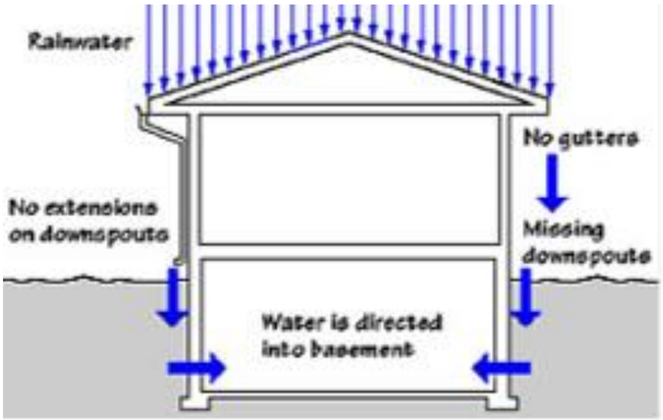

FIGURE 12. No gutters and downspouts /6/

The downspout with no splash block is even worse than no gutters or downspout at all. This is because it is making a huge volume of the water from the roof to fall on one particular concentrated area near the basement. The best solution for this situation would be to place every 15 meters downspout. The extensions should be placed and the length of them should be at least one meter. Sidewalk with a slope next to the foundation of the building is very efficient. They help to prevent water leakage into the basement during rainfall /6/.

Improperly designed windows

Window openings in the basement can cause the same problem as drains next to the wall when they are installed improperly. As it is shown in figure 13 windows are installed below the ground level. Very often when they are improperly built water has

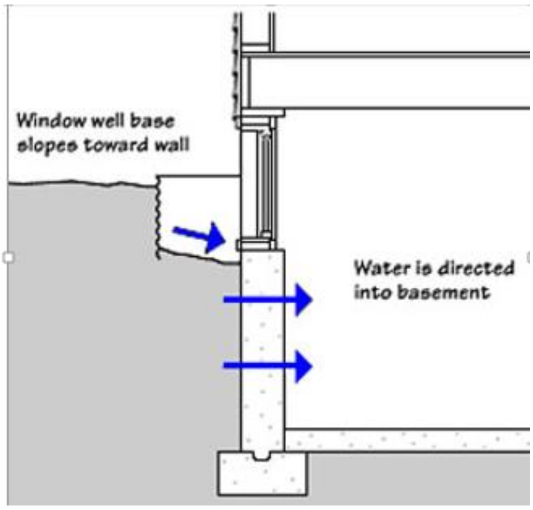

FIGURE 13. Improperly designed windows /5/

direct flow into the basement. It is more likely that water will enter through the windows rather than from the foundation. To solve a problem like this, the extra drain should be installed with an extension from the foundation. It will help that water wouldn't be able to come directly to the window opening/5/.

Cracks in structure

Blocks of concrete and concrete itself during the year of exploitation usually develop cracks. These cracks could be very serious for example one of the reasons could be if the joints are nor properly connected to the foundation. If it happens it makes a wall to be unstable and to move. This movement and makes the cracks. They also can occur due to soil movement, when the soil after construction is settling down. As it is shown in figure 14. Most of the time drainage system prevent water entering to the basement through the cracks, but refurbishment is needed /5/.

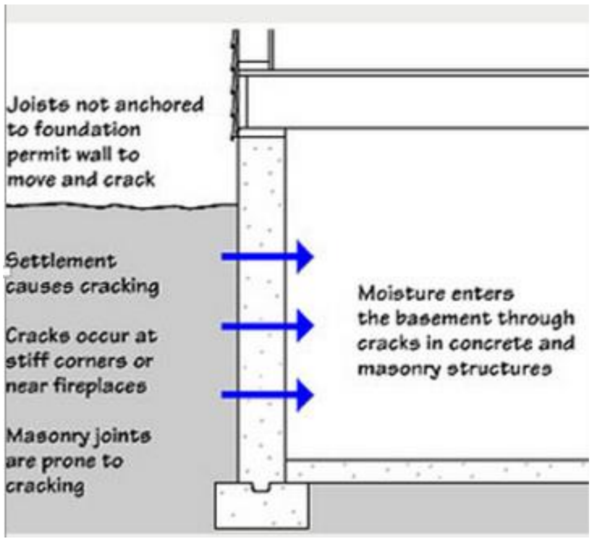

FIGURE 14. Structural cracks /5/

Most common solution to this kind of issue would be proper design and proper connection between foundation and structure which are above.

4.5 Solutions for moisture problems in basement

The best solution to any kind of problem in the building is to repair the things that are easy and have low cost. Then logical order should be approached. It should be solved with the most positive result and of course as small as possible expenses. Having moisture problems, the best way would be to remove or to control the moisture source/5/.

Condensation on the wall can occur in the summer too. If it does occur it is not allowed to ventilate basement with warm humid outside air. It is recommended to ventilate with air conditioning system, with a heat exchanger and dehumidifier /13/.

Dehumidification also could be one of the options to remove moisture and odors in the basement, but it doesn’t solve the problem and it’s not a complete solution for this kind of issue. Actually, if the dehumidifier is used in this kind of basement it could make even more damage than it was before. Drying the basement air, moisture can get to the basement faster causing efflorescence and spalling of concrete/5/.

One of the less expensive solutions for moisture problems in the basement would be to use membrane or coating inside of the walls in the basement. The water remains there but this kind of coating forces water to move to another direction/4/.

Another solution is to evaluate and check the gutters, downspouts and the surface around the building. It has to be fixed in the first place. If the moisture problem remains the same then the drainage (interior and exterior) system should be checked /4/.

Proper installation of downspouts and gutters

Most of the basement problems can be solved simply just directing rainwater to another direction using gutters and downspouts. It is a simple solution to carry out the water from the foundation. Figure 15 represents how rain water is carried away from the foundation by installing proper gutters and downspouts.

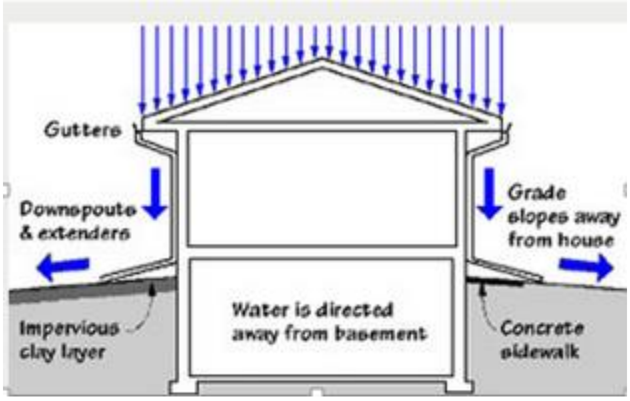

FIGURE 15. Properly installed gutters and downspouts /5/

Soil next to the house should have slopes to make water flow to another direction. The soil should also be covered either by sidewalk or by a clay layer. These solutions may solve the problem of water entering into the basement. Even is drainage system needs to be installed, it is very important to remove as much as possible water at the source/5/.

External drainage system

One of the most expensive but most effective water control in the basement is installing an external drainage system. It is done by digging the area around the foundation of the existing building and reconstructing it, the same way as building a new one/13/.

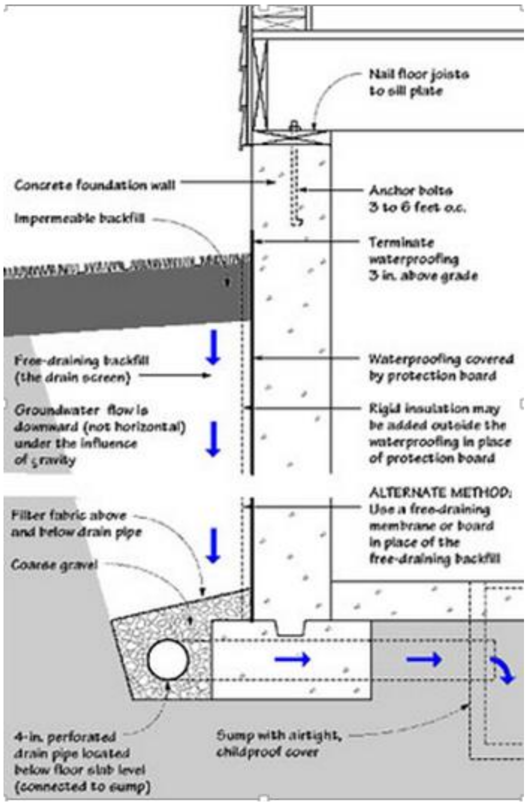

FIGURE 16. External drainage system /13/

Sometimes it is necessary that foundation should be repaired too. Most of the time the external drainage system uses sand. It is necessary to install leveled drain pipe at the foundation level. Drain tile would be recommended to put beside or on the top of the footing. A minimum 30 centimeters of caroused aggregate should be put next to the drain tile. Figure 16 represents how this situation would look like in real life. Using cross section, we can see there drain pipe should be placed and how the water would travel using this method.

Drainage channel above concrete slab

Most of the time when moisture and water are found in basement internal drainage system are installed. One of the simplest and not expensive method is used. The drainage channel is put on the foundation wall and the base floor slab. Water is collected and then through drainage system is drained into the sump. On the top of the slab, there is used another channel. Thanks to this channel water travel to the sump basin. The cover of the sump has to be airtight and childproof/4/. The more detail view is seen in figure 18.

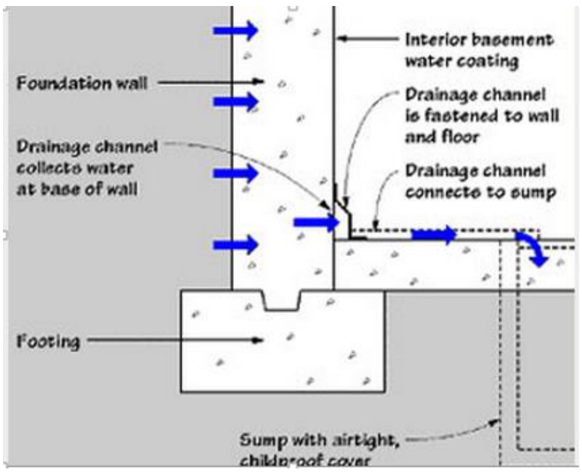

FIGURE 17. Internal drainage channel/12/

This solution would suit the best a concrete with a lot of cracks. It would not solve the problem in very big masonry walls because water would stay in it. Using this method water is not removed completely. As the result in the basement, there could be still problems with mold, mildew, humidity. It also doesn’t solve groundwater problems /12/.

Drainage channel within slab edge

There is also the possibility to place a drainage on the top of the footing at the base of the wall. The concrete next to the slab edge has to be removed. Drainage channels have to be connected to the drain pipe which will end at the sump. As in the previous case, it has to have a cover that is air tight and childproof /5/. The more detailed picture is shown in figure 18.

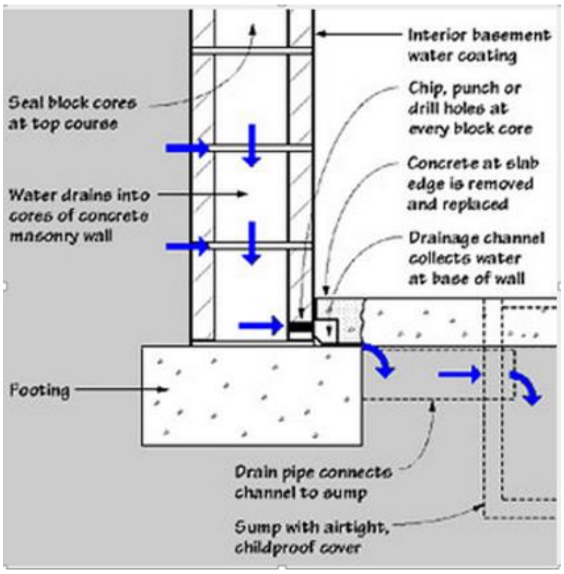

FIGURE 18. drainage channel with slab edge/5/

It is very good solution for a building with masonry walls and water problem because it helps to drain the block cores. Holes are drilled in order to permit water staying in one place. It is also required to remove some concrete from the foundation as shown in figure 18 to fit the drill in. The cost of this kind of system depends on the manufacturer which was selected. Moisture is allowed to penetrate through concrete, it is important to cap the tops and put vapor moderator coating on the walls /5/.

Drainage system beneath the slab

Drainage system which is installed at the perimeter of the footing is one of the most effective systems of the internal drainage systems. To have this kind of drainage system, it is necessary to remove and replace concrete at the slab edge. The pipe is put beneath the slab. Due to this pipe, it drains all moisture to the area below. It is very similar to an external system which at the end is connected to the sump. As in previous cases is has to have waterproof and airtight cover/13/. The more detailed picture of this kind of situation is represented in figure 19.

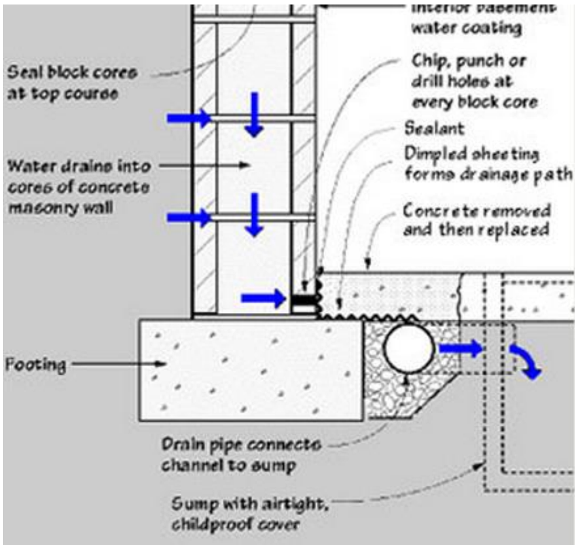

FIGURE 19. Drainage system beneath the slab /12/

The dimpled sheeting is used in this approach. It is placed on the base of the wall and beneath the edge of the slab. This method is less expensive than other specialized systems /12/.

Studied case

The case studied building is using outside dry air and brings it to the basements and in this way it dries out the humid inside air in it. This situation is shown in figure 20.

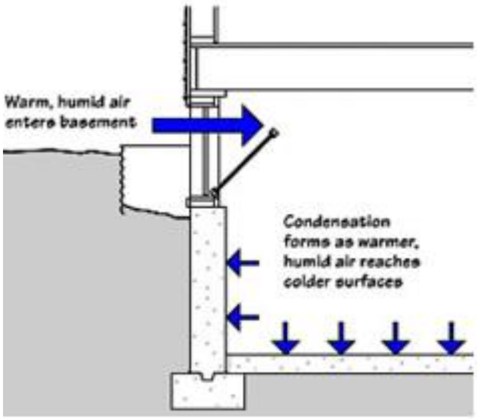

FIGURE 20. Drying basement with dry outside air

As it was mentioned before the supervision company installed the fan in order to take the dry air from the outside and to dehumidify more moist air indoors. The more about this solution is told in the following paragraph.

5 MEASUREMENTS AND CALCULATIONS

Building Description

The case building location is in Kuopio, Finland. It is four-storey building for elderly people. This building has moisture problems in the basement. This is because the ground water level is high in this area and nearby there is a small lake. The building area of this building is 2811.5 m^2. Figure 21 and 22 contains a picture of the exterior completed house and the cross section of it. The more detailed plan is shown in Appendix 1.

FIGURE 21. Elderly house in Kuopio

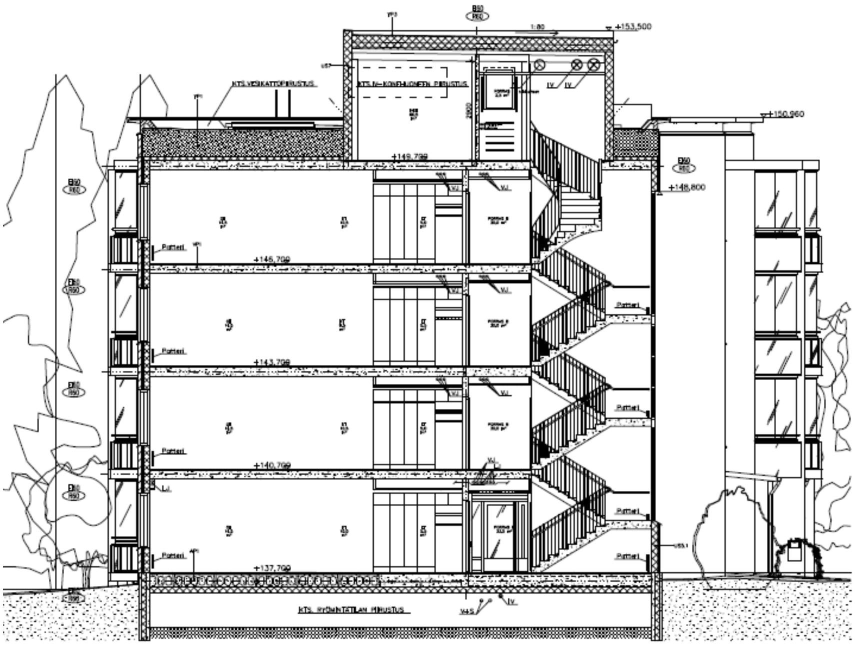

FIGURE 22. Cross section of the building

To avoid condensation in the basement, an exhaust air fan was installed. The idea of this fan installation is to dry basement space air with drier outside air which is taken from small openings in the basement wall and then removed with the fan. The fan can work in two ways either with full speed or 30 percent of a full speed.

In the basement, there are three sensors measuring the temperature inside and one humidity sensor inside there are also sensors for temperature and humidity monitoring outside the building. The fan is controlled by the humidity level in the basement. It starts to run when humidity level outside is lower than inside. The difference between outside relative humidity and inside relative humidity is about 15%. The data is stored every ten minutes.

The fan was installed in 2014. After half a year supervising company “Schneider” noticed that after fan installation the conditions in the basement didn’t change. Having data for from December 2014 till October 2015 the graphics and calculations were carried out.

5.1 Measurements

After receiving data from “Schneider” company, the received data was analyzed. The data was simplified. Since data was collected every ten minutes. It was simplified and an average of the hour was extracted. The following results were obtained. Table 1 represents a short example how the data was simplified to an average per hour.

TABLE 1. Simplified data

<table>
<tr><td></td><td></td><td rowspan="6">Aver-age pre hour</td></tr>
<tr><td>M.PL2/PF3.1-TE1</td><td></td></tr>
<tr><td>ALAPOHJA LÄMPÖTILA</td><td></td></tr>
<tr><td>(Basement tempera-ture)</td><td></td></tr>
<tr><td>Aika</td><td>Arvo °C</td></tr>
<tr><td>(Time)</td><td>(Value °C)</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>1.12.2014 0:00:00</td><td>13.6</td><td rowspan="4">13.6</td></tr>
<tr><td>1.12.2014 0:10:00</td><td>13.6</td></tr>
<tr><td>1.12.2014 0:20:00</td><td>13.6</td></tr>
<tr><td>1.12.2014 0:30:00</td><td>13.6</td></tr>
</table>

1.12.2014 0:40:00	13.6	
1.12.2014 0:50:00	13.6	
1.12.2014 1:00:00	13.6	13.6
1.12.2014 1:10:00	13.6	
1.12.2014 1:20:00	13.6	
1.12.2014 1:30:00	13.6	
1.12.2014 1:40:00	13.6	
1.12.2014 1:50:00	13.6	
1.12.2014 2:00:00	13.6	13.6
1.12.2014 2:10:00	13.6	
1.12.2014 2:20:00	13.6	
1.12.2014 2:30:00	13.6	
1.12.2014 2:40:00	13.6	
1.12.2014 2:50:00	13.6	

Figure 23 and 24 show graphs of temperature and humidity variation. In graph 25 the fan speed is shown during June because in summer (2015 year) the fan is running not only 30 percent of its full speed as in winter, but it is boosting the air in the basement, it works with full capacity (100 percent). More graphs of temperature and humidity values can be found in appendix 2.

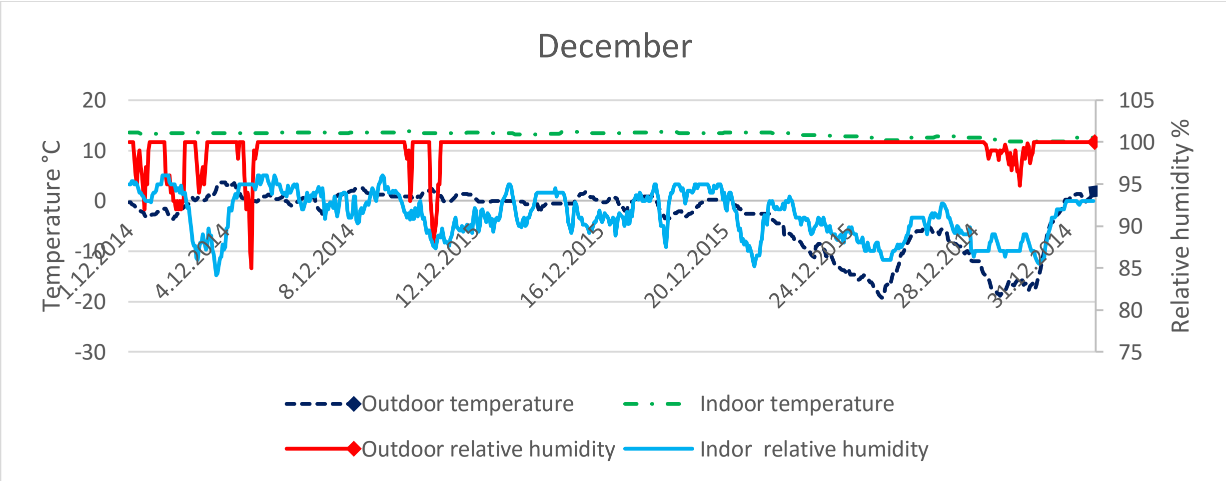

FIGURE 23. December outdoor and indoor humidity and temperature in basement

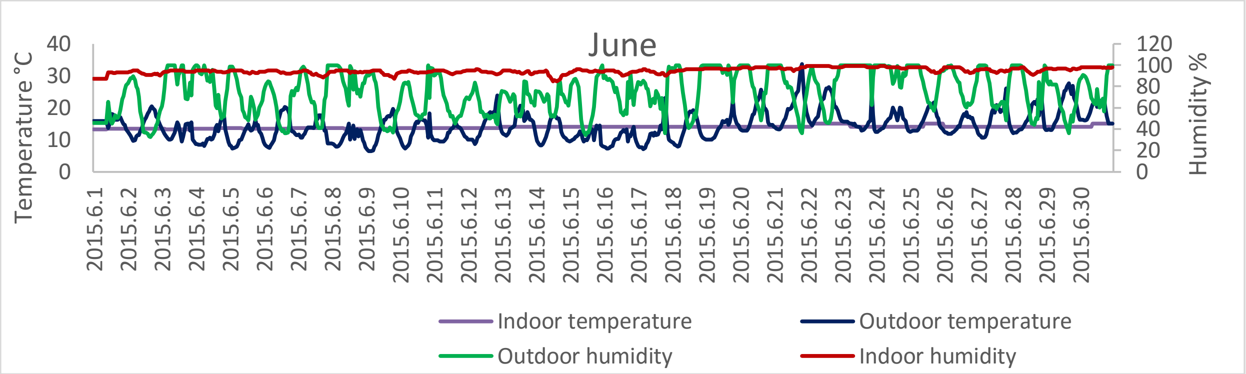

FIGURE 24. June outdoor and indoor humidity and temperature in basement

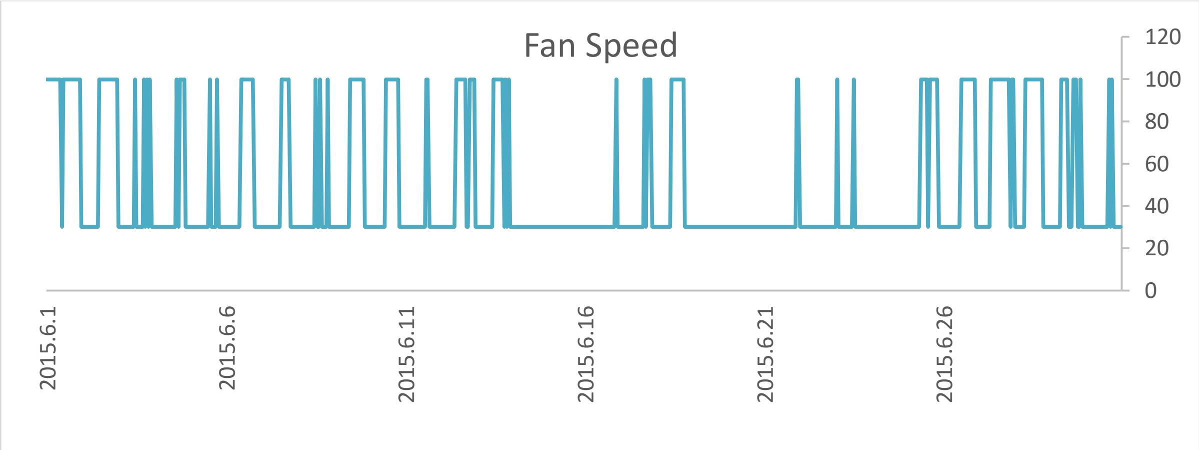

FIGURE 25. Fan speed during June

When we are looking at these figures and fan operation principle it seems that the fan works properly, and it has to take moisture from the basement. However, moisture is still remaining in the basement, and the fan doesn't help. Calculations were carried out in order to find out real situation what is happening in the basement. All the calculations are shown in the next chapter.

5.2 Calculations

To find out why there is moisture in the basement, the moisture content in the basement is calculated. In order to calculate moisture content, the following formulas were used. The examples are shown for the calculations of December and June months.

In order to find out moisture content in the air, first of all, the pressure of saturated water vapor is found. Approximation of it is found in formula (1).

$$p' = \frac{\exp\left(77.345+0.0057T-\frac{7235}{T}\right)}{T^{8.2}} \quad (1)$$

Where:

$T -\ outdoor/indoor\ temperature, K$

After this, the partial pressure has to be calculated. It could be calculated using formula 2:

$$p_h = p' \cdot \varphi \quad (2)$$

Where:

$p' - pressure\ of\ saturated\ water\ vapor$

$\varphi -\ outdoor/indoor\ relative\ humidity$

Moisture content in the air can be calculated using formula 3:

$$x = 0.622 \cdot p_h/(p_0 - p_h)\ \text{, g/kg} \quad (3)$$

Moisture removed from the indoor air is calculated by the formula 5:

$$x' = \frac{q_m(x_{ind}-x_{out})}{1000}, g/s \quad (4)$$

Example:

The example is given for December and for the June, to show the difference in moisture content during summer and winter period.

December:

Temperature outside and insides in °C into Kelvins:

T_{out}= -0.3 °C → T_{out} =273+ (-0.3) = 272.7 K

T_{ins}=13.6 °C → T_{ins} = 273+ 13.6 = 286.6 K

Using 1 equation we are calculating pressure of saturated water vapor:

$$p'_{out} = \frac{\exp\left(77.345+0.0057\cdot 272.7-\frac{7235}{272.7}\right)}{272.7^{8.2}} = 589$$

$$p'_{ins} = \frac{\exp\left(77.345+0.0057\cdot 286.6-\frac{7235}{286.6}\right)}{286.6^{8.2}} = 1537.73$$

The partial pressure of water vapor:

$p_{h\ out} = 589 \cdot 1 = 589$

$p_{h\ ins} = 1537.73 \cdot 0.95 = 1460.8$

Outdoor and indoor moisture content is calculated x:

$$x_{out} = 0.622 \cdot \frac{589}{101325-2.14} \cdot 1000 = 3.64\ g/kg$$

$$x_{ind} = 0.622 \cdot \frac{1460.8}{101325-1460.84} \cdot 1000 = 9.1\ g/kg$$

For a better understanding how moisture is removed from the basement figure 26 is made below.

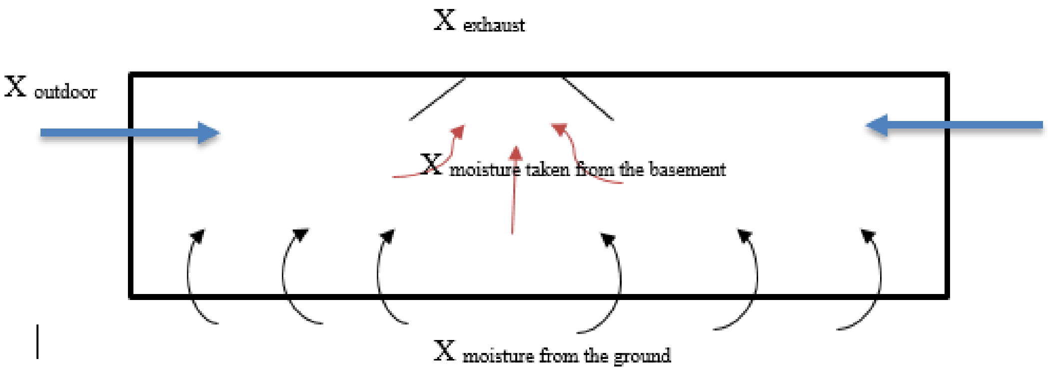

FIGURE 26. Moisture from the ground removing principle

When the fan is running full speed the exhaust system takes 135 l/s from the basement. During December fan, is running with 30percent of its full capacity, since that it takes 40.5 l/s →0.0405 m^3/s. Mass flow rate, in this case, is $q_m = 1.2 \cdot 0.0405$ =0.0486 kg/s →48.6 g/s. Moisture taken from the basement is:

$$x' = \frac{48.6\cdot(9.1-3.6)}{1000} = 0.27\ , g/s$$

$$x' = 0.27 \cdot 3600 = 954.8\ g/h$$

TABLE 2: Example of one-day calculations in December

Date	Hour	Outdoor temperature	Indoor temperature	Outdoor relative humidity	Indor relative humidity	m^3/s outdoor	outdoor tem K	Indoor tem K	phs(T)	phs(T)	2) Partial pressure of water vapour OUT	2) Partial pressure of water vapour IND	Outdoor moisture content g/kg	Indoor moisture content g/kg	kg/s	g/s	moisture taken by fan from ground g/s	moisture taken by fan from ground g/h
1.12.2014	0	-0.3	13.6	1.00	0.95	0.0405	272.7	286.6	589.8	1537.7	589.8	1460.8	3.6417	9.1	0.0486	48.6	0.3	954.8
	1	-0.3	13.6	1.00	0.95	0.0405	272.7	286.6	589.8	1537.7	589.8	1460.8	3.6417	9.1	0.0486	48.6	0.3	954.8
	2	-0.6	13.6	1.00	0.95	0.0405	272.4	286.6	575.6	1537.7	575.6	1466.0	3.5536	9.1	0.0486	48.6	0.3	975.9
	3	-0.8	13.6	1.00	0.95	0.0405	272.2	286.6	568.6	1537.7	568.6	1466.0	3.5103	9.1	0.0486	48.6	0.3	983.4
	4	-1.0	13.6	0.98	0.95	0.0405	272.0	286.6	561.7	1537.7	550.5	1460.8	3.3977	9.1	0.0486	48.6	0.3	997.5
	5	-1.3	13.6	0.96	0.95	0.0405	271.7	286.6	548.1	1537.7	526.2	1463.4	3.2471	9.1	0.0486	48.6	0.3	1026.6
	6	-1.3	13.6	0.95	0.95	0.0405	271.7	286.6	548.1	1537.7	520.7	1460.8	3.2131	9.1	0.0486	48.6	0.3	1029.8
	7	-1.7	13.6	0.98	0.95	0.0405	271.3	286.6	531.6	1537.7	520.9	1453.2	3.2144	9.1	0.0486	48.6	0.3	1021.0
	8	-1.8	13.4	0.99	0.94	0.0405	271.3	286.4	530.3	1517.8	525.0	1426.7	3.2394	8.9	0.0486	48.6	0.3	987.5
	9	-2.1	13.3	0.97	0.94	0.0405	270.9	286.3	516.1	1507.9	500.6	1417.4	3.0883	8.8	0.0486	48.6	0.3	1003.6
	10	-2.2	13.3	0.96	0.94	0.0405	270.8	286.3	512.9	1507.9	492.4	1412.4	3.0374	8.8	0.0486	48.6	0.3	1007.0
	11	-2.2	13.3	0.94	0.94	0.0405	270.8	286.3	512.9	1507.9	482.1	1409.9	2.9738	8.8	0.0486	48.6	0.3	1015.3
	12	-2.8	13.3	0.92	0.93	0.0405	270.2	286.3	491.2	1507.9	451.9	1404.9	2.7863	8.7	0.0486	48.6	0.3	1042.6
	13	-3.2	13.3	0.97	0.93	0.0405	269.8	286.3	476.1	1507.9	461.9	1402.4	2.8482	8.7	0.0486	48.6	0.3	1029.0
	14	-3.2	13.3	0.95	0.93	0.0405	269.8	286.3	476.1	1507.9	452.3	1402.4	2.7892	8.7	0.0486	48.6	0.3	1039.3
	15	-3.2	13.3	0.99	0.93	0.0405	269.8	286.3	476.1	1507.9	471.4	1402.4	2.9072	8.7	0.0486	48.6	0.3	1018.7
	16	-3.2	13.3	1.00	0.93	0.0405	269.8	286.3	476.1	1507.9	476.1	1402.4	2.9367	8.7	0.0486	48.6	0.3	1013.5
	17	-2.9	13.3	1.00	0.93	0.0405	270.1	286.3	488.1	1507.9	488.1	1399.9	3.0110	8.7	0.0486	48.6	0.3	997.7
	18	-2.7	13.3	1.00	0.94	0.0405	270.3	286.3	494.2	1507.9	494.2	1412.4	3.0487	8.8	0.0486	48.6	0.3	1005.0
	19	-2.7	13.3	1.00	0.94	0.0405	270.3	286.3	494.2	1507.9	494.2	1417.4	3.0487	8.8	0.0486	48.6	0.3	1010.6
	20	-2.7	13.3	1.00	0.94	0.0405	270.3	286.3	494.2	1507.9	494.2	1417.4	3.0487	8.8	0.0486	48.6	0.3	1010.6
	21	-2.5	13.3	1.00	0.94	0.0405	270.5	286.3	500.4	1507.9	500.4	1420.0	3.0869	8.8	0.0486	48.6	0.3	1006.6
	22	-2.2	13.3	1.00	0.95	0.0405	270.8	286.3	512.9	1507.9	512.9	1432.5	3.1646	8.9	0.0486	48.6	0.3	1006.9
	23	-2.2	13.3	1.00	0.95	0.0405	270.8	286.3	512.9	1507.9	512.9	1432.5	3.1646	8.9	0.0486	48.6	0.3	1006.9

June:

Temperature outside and insides in °C into Kelvins:

T_{out}= 14.1 °C → T_{out} =273+14.1 = 287.1 K

T_{ins}=14 °C → T_{ins} = 273+ 14 = 287K

Using 1 equation we are calculating pressure of saturated water vapor:

$$p'_{out} = \frac{\exp\left(77.345+0.0057\cdot 287.1-\frac{7235}{287.1}\right)}{287.1^{8.2}} = 1588.56$$

$$p'_{ins} = \frac{\exp\left(77.345+0.0057\cdot 287-\frac{7235}{287}\right)}{287^{8.2}} = 1578.27$$

Partial pressure of water vapor is calculated using 2 equation:

$$p_{h_{out}} = 1588.56\cdot 1 = 1588.56$$

$$p_{h_{ind}} = 1578.27\cdot 0.97 = 1530.92$$

Outdoor and indoor moisture content is calculated x:

$$x_{out} = 0.622 \cdot \frac{1588.56}{101325-1588.56} \cdot 1000 = 9.9\ g/kg$$

$$x_{ind} = 0.622 \cdot \frac{1530.92}{101325-1530.92} 1000 = 9.5\ g/kg$$

During summer fan is running at full capacity 100 percent. When it is running with the full speed it takes 135 l/s →0.135 m^3/s. The mass flow rate, in this case, is:

$q_m = 1.2 \cdot 0.135$ =0.162 kg/s→162 g/s,

When the fan is running with 30percent of its full capacity as in the previous case in winter in December it takes 40.5 l/s →0.0405 m^3/s. Mass flow rate in this case is:

$q_m = 1.2 \cdot 0.0405$ =0.0486 kg/s →48.6 g/s,

Moisture taken from the basement is calculated in the following steps:

$$x' = \frac{48.6 \cdot (9.5-9.9)}{1000} = -0.01774\ , g/s$$

$$x' = -0.01774 \cdot 3600 = -63.85\ g/h$$

The examples of one-day calculations in June are shown in Table3.

TABLE 3: Example of one-day calculations in June

		Outdoor temperature	Indoor temperature	Outdoor humidity		Indoor humidity		Fan Speed	m^3/s outdoor	outdoor tem K	Indoor tem K	phs(T)	phs(T)	2) Partial pressure of water vapour OUT	2) Partial pressure of water vapour IND	Outdoor moisture content g/kg	Indoor moisture content g/kg	kg/s outdoors	g/s	**moisture taken by fan from ground g/s**	**moisture taken by fan from ground g/h**
2015.6.21	0	14.1	14	1	100	0.97	97	30	0.0405	287.1	287	1588.556	1578.273	1588.556	1530.925	9.9069	9.5420	0.0486	48.6	-0.01774	-63.8471
	1	13.85	14	1	100	0.97	97	30	0.0405	286.85	287	1562.959	1578.273	1562.959	1530.925	9.7448	9.5420	0.0486	48.6	-0.00986	-35.4803
	2	13.45	14	1	100	0.97	97	30	0.0405	286.45	287	1522.758	1578.273	1522.758	1530.925	9.4903	9.5420	0.0486	48.6	0.002512	9.042427
	3	13.3	14	1	100	0.972	97.17	30	0.0405	286.3	287	1507.918	1578.273	1507.918	1533.555	9.3964	9.5586	0.0486	48.6	0.007884	28.38061
	4	13.3	14	1	100	0.978	97.83	30	0.0405	286.3	287	1507.918	1578.273	1507.918	1544.077	9.3964	9.6252	0.0486	48.6	0.01112	40.03248
	5	13.63	14	1	100	0.97	97	30	0.0405	286.6333	287	1541.069	1578.273	1541.069	1530.925	9.6062	9.5420	0.0486	48.6	-0.00312	-11.2328
	6	14.72	14	0.96	96	0.97	97	30	0.0405	287.7167	287	1653.275	1578.273	1587.144	1530.925	9.8980	9.5420	0.0486	48.6	-0.0173	-62.2825
	7	16.13	14	0.863	86.33	0.963	96.33	30	0.0405	289.1333	287	1810.795	1578.273	1563.32	1520.403	9.7471	9.4754	0.0486	48.6	-0.0132	-47.5291
	8	16.63	14	0.828	82.83	0.963	96.33	30	0.0405	289.6333	287	1869.453	1578.273	1548.53	1520.403	9.6534	9.4754	0.0486	48.6	-0.00865	-31.1454
	9	18.05	14	0.842	84.17	0.97	97	30	0.0405	291.05	287	2044.797	1578.273	1721.037	1530.925	10.7474	9.5420	0.0486	48.6	-0.05858	-210.899
	10	19.55	14	0.79	79	0.97	97	30	0.0405	292.55	287	2246.004	1578.273	1774.343	1530.925	11.0862	9.5420	0.0486	48.6	-0.07505	-270.178
	11	19.47	14	0.802	80.17	0.97	97	30	0.0405	292.4667	287	2234.387	1578.273	1791.234	1530.925	11.1937	9.5420	0.0486	48.6	-0.08027	-288.975
	12	19.88	14	0.788	78.83	0.97	97	30	0.0405	292.8833	287	2293	1578.273	1807.649	1530.925	11.2981	9.5420	0.0486	48.6	-0.08535	-307.248
	13	20.88	14	0.738	73.83	0.957	95.67	30	0.0405	293.8833	287	2439.193	1578.273	1800.938	1509.881	11.2554	9.4089	0.0486	48.6	-0.08974	-323.071
	14	21.55	14	0.69	69	0.945	94.5	30	0.0405	294.55	287	2541.126	1578.273	1753.377	1491.468	10.9529	9.2924	0.0486	48.6	-0.0807	-290.525
	15	23.47	14	0.625	62.5	0.955	95.5	30	0.0405	296.4667	287	2855.214	1578.273	1784.509	1507.251	11.1509	9.3922	0.0486	48.6	-0.08547	-307.696
	16	24.55	14	0.575	57.5	0.96	96	30	0.0405	297.55	287	3047.324	1578.273	1752.211	1515.142	10.9455	9.4421	0.0486	48.6	-0.07306	-263.031
	17	25.22	14	0.507	50.67	0.96	96	30	0.0405	298.2167	287	3171.07	1578.273	1606.676	1515.142	10.0218	9.4421	0.0486	48.6	-0.02817	-101.409
	18	28.8	14	0.415	41.5	0.968	96.83	30	0.0405	301.8	287	3914.18	1578.273	1624.385	1528.295	10.1340	9.5254	0.0486	48.6	-0.02958	-106.49
	19	32.23	14	0.378	37.83	0.98	98	30	0.0405	305.2333	287	4763.913	1578.273	1802.347	1546.708	11.2644	9.6419	0.0486	48.6	-0.07885	-283.867
	20	33.65	14	0.358	35.83	0.98	98	30	0.0405	306.65	287	5158.668	1578.273	1848.523	1546.708	11.5583	9.6419	0.0486	48.6	-0.09314	-335.298
	21	24.58	14	0.538	53.83	0.98	98	30	0.0405	297.5833	287	3053.41	1578.273	1643.752	1546.708	10.2568	9.6419	0.0486	48.6	-0.02989	-107.589
	22	21.27	14	0.662	66.17	0.98	98	100	0.135	294.2667	287	2497.358	1578.273	1652.419	1546.708	10.3118	9.6419	0.162	162	-0.10853	-390.691
	23	18.73	14	0.725	72.5	0.99	99	100	0.135	291.7333	287	2134.409	1578.273	1547.447	1562.49	9.6466	9.7418	0.162	162	0.015431	55.54984

5.3 Analysis of results

After analyzing the results, the moisture from the basement is taken away during winter, spring and autumn seasons. During summer time, moisture is brought into the basement, during summer time fan is running at full capacity. Even though the relative humidity is low during summer but moisture content is the highest during summer. It can be explained using Moeller chart in figure 27.

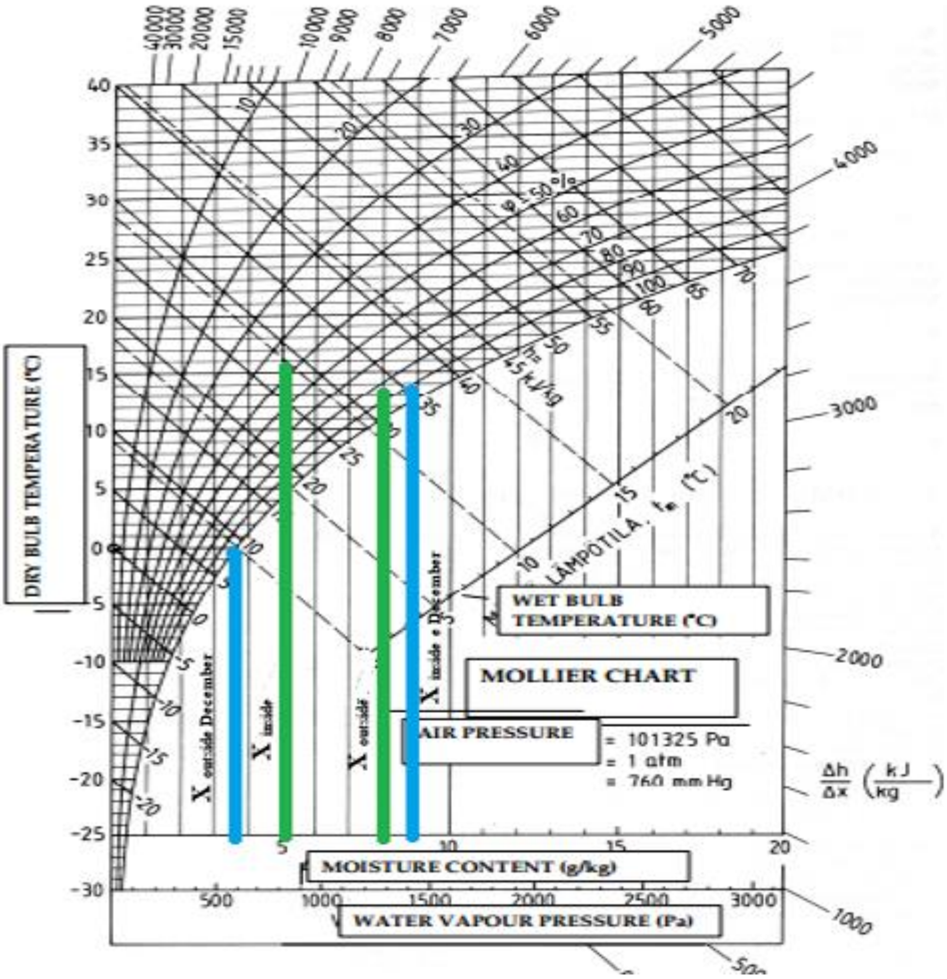

FIGURE 27.Moeller Chart

Blue lines represent moisture content during December. As we can see the humidity level outside is high 100 percent, but moisture content is low 3.64 g/kg and inside relative humidity is 95% and moisture content is 9.1 g/kg. During winter time, it is recommended to ventilate basement with outside air because it is drier. However, during summertime, the outdoor relative humidity is lower 80 percent and moisture content is 9.9 g/kg indoor relative humidity is 56 % and moisture content is 5.2 g/kg. During summertime, moisture is brought inside from the outdoor air. During that time fan is running 100 percent so it is boosting the moisture to the inside of the basement. Due to that, it is not recommended to use a fan with full capacity during summertime because it is bringing moisture to the basement. The fan should be boosted during winter time autumn and spring seasons when the moisture contents in the air are lower. Only then basement could be dried from the moisture in outside air.

Conclusions

As a result, of this work the investigation on the fan working principle was done. Based on the monthly graphs conclusions can be done. Humidity level is changing in the basement according to the temperature and the humidity of the outside air. The fan runs at full capacity only during the summer time, during others seasons, it remains working with constant speed, 30 percent. After investigating this situation, the conclusions were made that fan works according to the relative humidity level. If the outdoor relative humidity is lower by 10-15 percent than the inside relative humidity then the fan starts to boost the air in the basement and starts to run at full capacity. This situation occurs during summertime. However, even after boosting the fan, the basement still remains “wet”.

The calculations were carried out and the moisture content of the air was calculated. The results were made for winter and summer period. During winter season even though the humidity level was high the moisture content in the air remains very low. However, summer time situation is totally different. The relative humidity level is quite small, but moisture content is very high. Furthermore, the fan is working at full capacity. This means that the fan is bringing the moisture to the basement during summertime, and during the winter, it only ventilates with 30 percent of its full speed.

The recommendation for this situation would be simple. In order to ventilate basement with outside air, it should be done during winter, spring and autumn seasons because the moisture content outdoors is the smallest. It actually can help to remove moisture from the basement. During summer time, it is not recommended to ventilate basement with outside air because moisture ratio is very high. The fan has to run with minimum power 30 percent of its full capacity. During other seasons, the fan can be boosted in order to dry the basement.

The air handling unit with heat recovery and dehumidifiers could be installed too. The solution is more expensive but very effective. Not only energy would be recovered but also, it would be dehumidified and the basement would be dry.

One of the less expensive solutions for moisture problems in the basement would be to use membrane or coating inside of the walls in the basement. The water remains there but this kind of coating forces water to move to another direction.

Another solution is to evaluate and check the gutters, downspouts and the surface around the building. If the moisture problem remains the same then the drainage (interior and exterior) system should be checked. The main idea of checking the ground is that it would have a slope in other word inclinations from the building. These slopes help to direct the water from the building.

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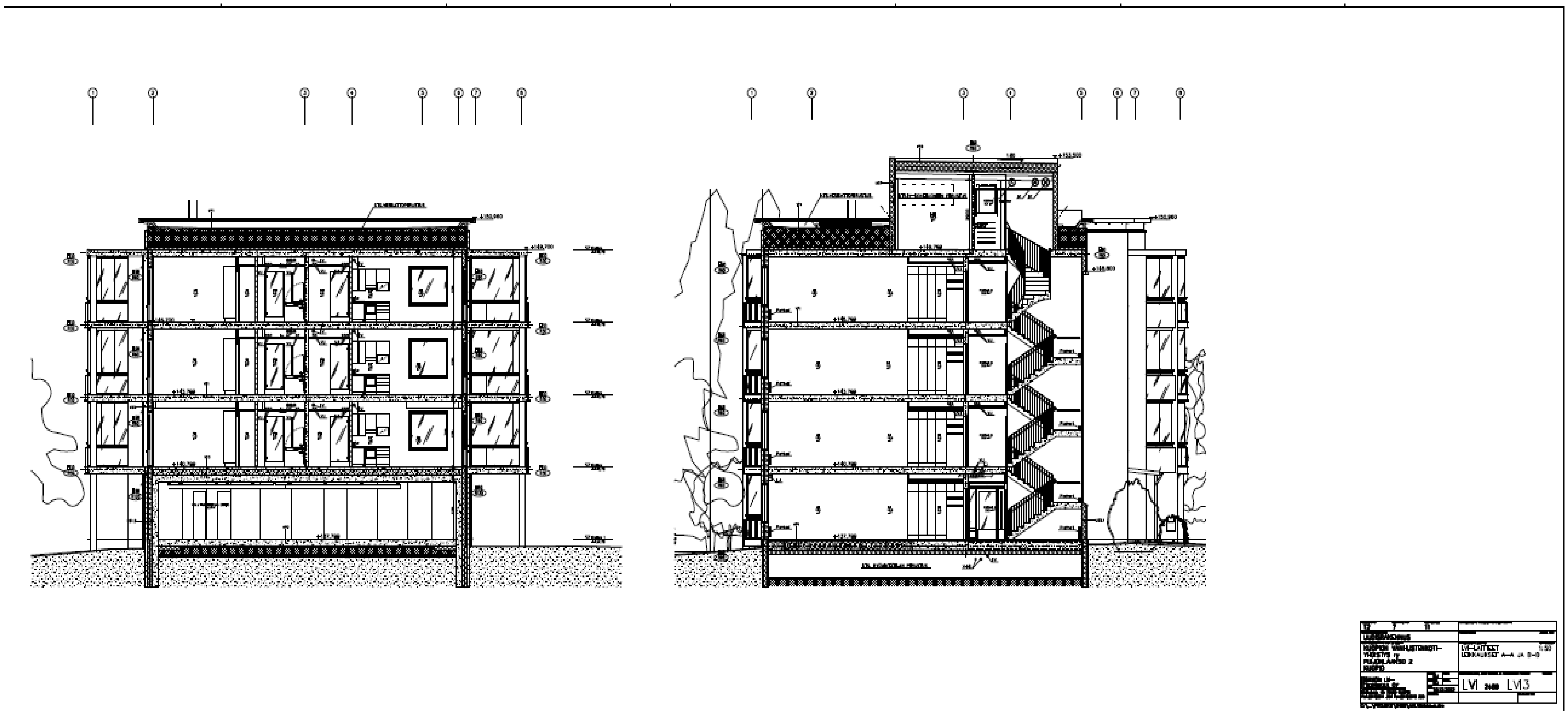
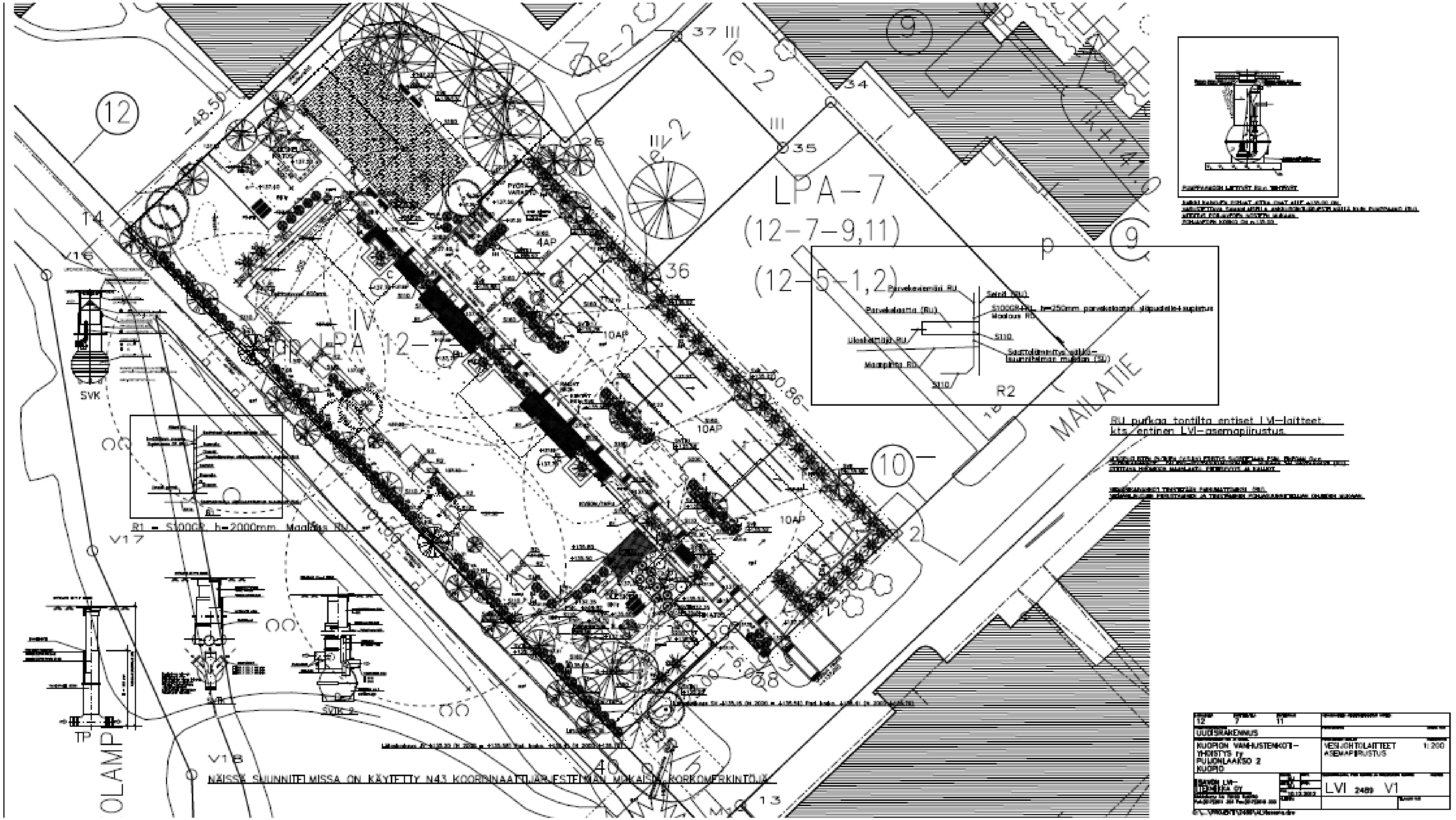
APPENDIX 1.

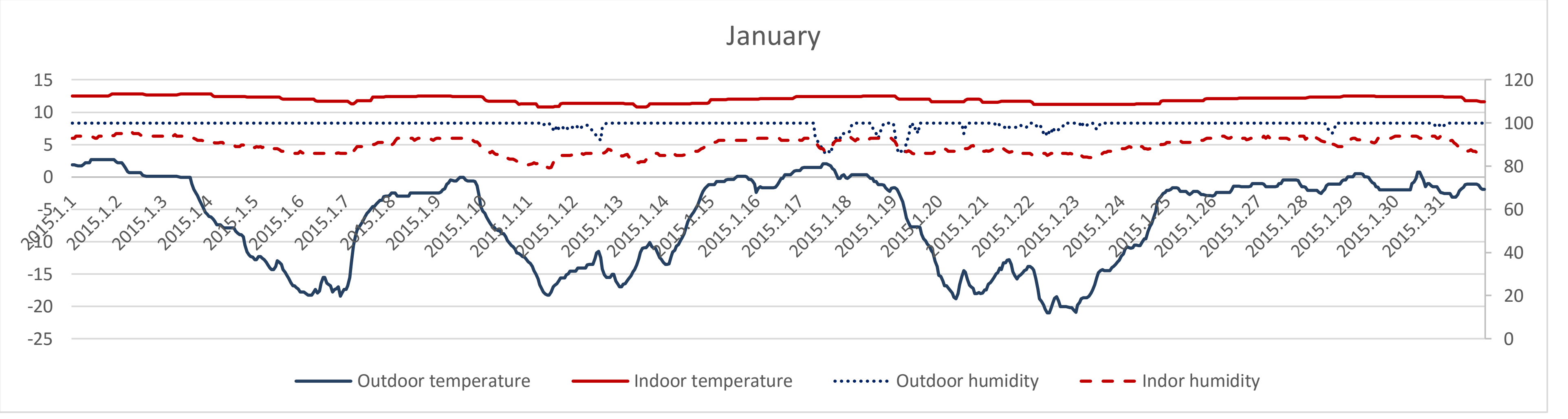


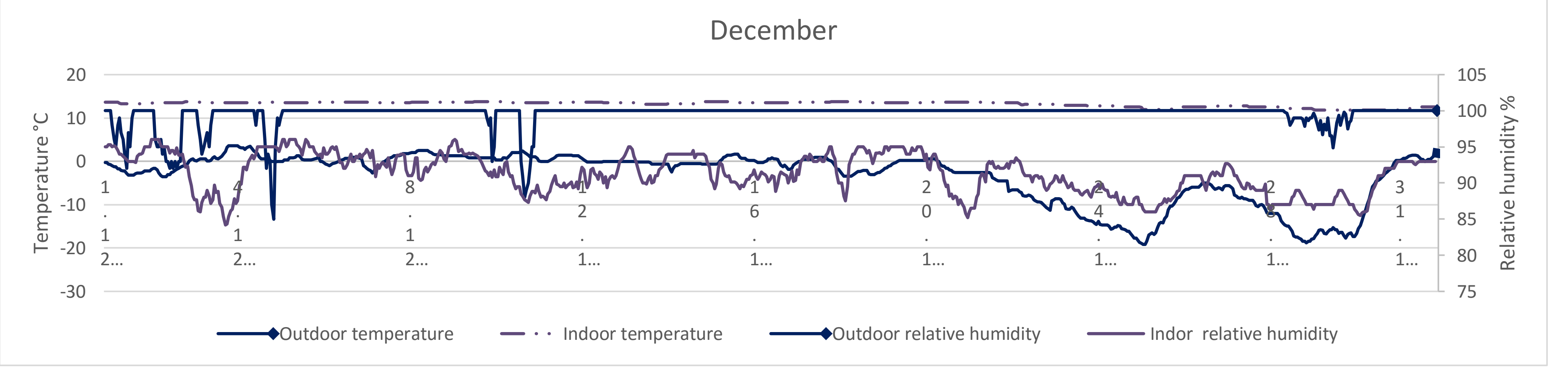
APPENDIX 1.


LPA-7
(12-7-9,11)
(12-5-1,2)
MAILATIE
10AP
4AP
SVK
TP
R1 = S100GR, h=2000mm. Maalaus RU
R2
S110
RU purkaa tontilta entiset LVI-laitteet.
kts. entinen LVI-asemapiirustus.
NÄISSÄ SUUNNITELMISSA ON KÄYTETTY N43 KOORDINAATTIJÄRJESTELMÄN MUKAISIA KORKOMERKINTÖJÄ
UUDISRAKENNUS
KUOPION VANHUSTENKOTI-YHDISTYS ry
PUIJONLAAKSO 2
KUOPIO
VESIJOHTOLAITTEET
ASEMAPIIRUSTUS
1:200
LVI 2489 V1

APPENDIX 2

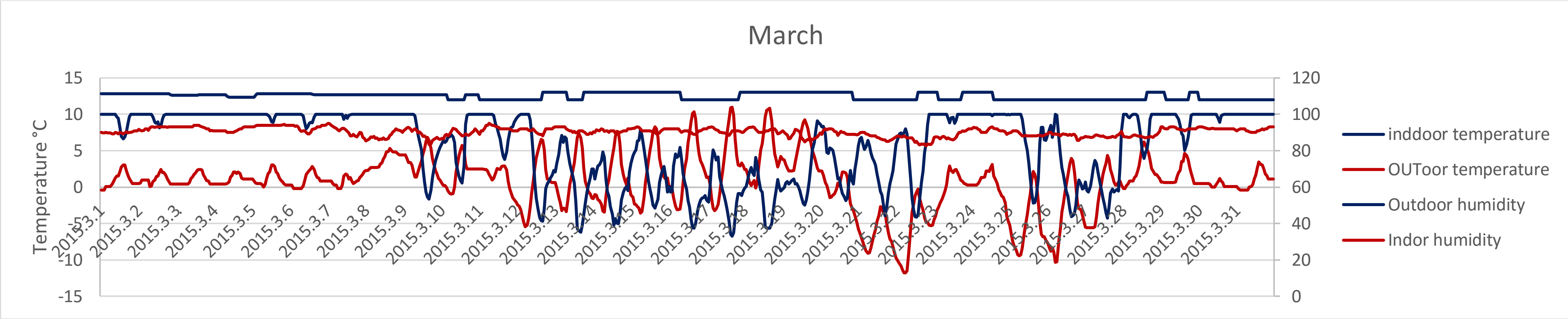
(1).

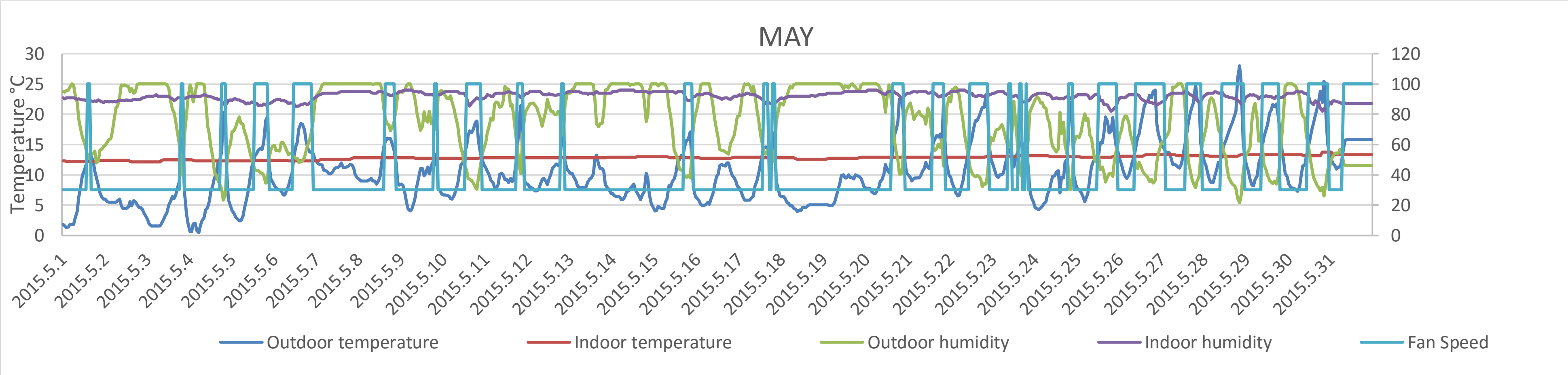

January
15
10
5
0
-5
-10
-15
-20
-25
120
100
80
60
40
20
0
2015.1.1
2015.1.2
2015.1.3
2015.1.4
2015.1.5
2015.1.6
2015.1.7
2015.1.8
2015.1.9
2015.1.10
2015.1.11
2015.1.12
2015.1.13
2015.1.14
2015.1.15
2015.1.16
2015.1.17
2015.1.18
2015.1.19
2015.1.20
2015.1.21
2015.1.22
2015.1.23
2015.1.24
2015.1.25
2015.1.26
2015.1.27
2015.1.28
2015.1.29
2015.1.30
2015.1.31
Outdoor temperature
Indoor temperature
Outdoor humidity
Indor humidity


December
Temperature °C
20
10
0
-10
-20
-30
Relative humidity %
105
100
95
90
85
80
75
Outdoor temperature
Indoor temperature
Outdoor relative humidity
Indor relative humidity

APPENDIX 2

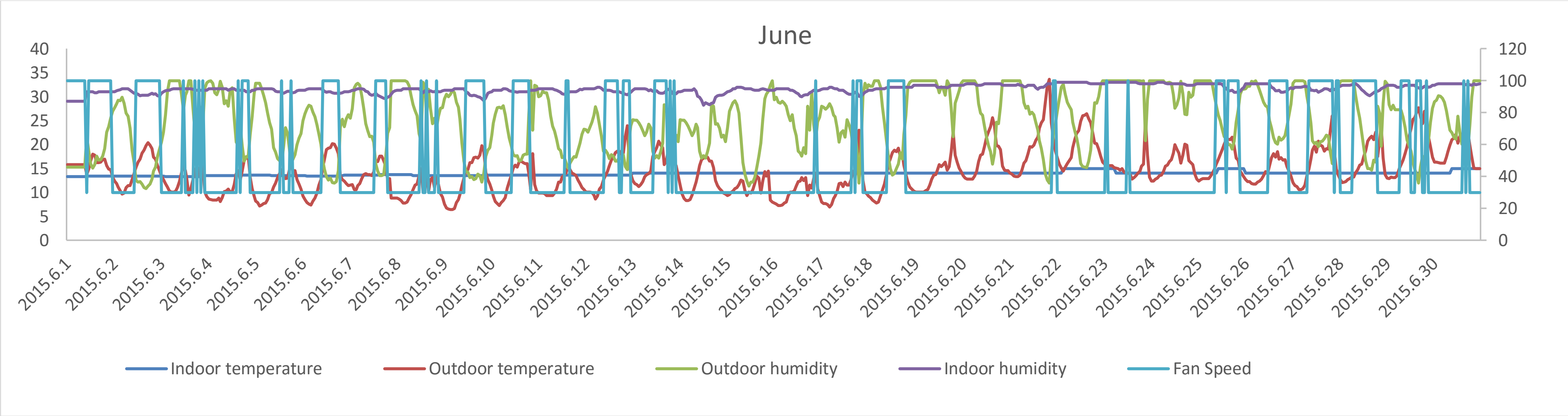
(2).


March
Temperature °C
15
10
5
0
-5
-10
-15
120
100
80
60
40
20
0
inddoor temperature
OUToor temperature
Outdoor humidity
Indor humidity


MAY
Temperature °C
30
25
20
15
10
5
0
120
100
80
60
40
20
0
2015.5.1
2015.5.31
Outdoor temperature
Indoor temperature
Outdoor humidity
Indoor humidity
Fan Speed

APPENDIX 2

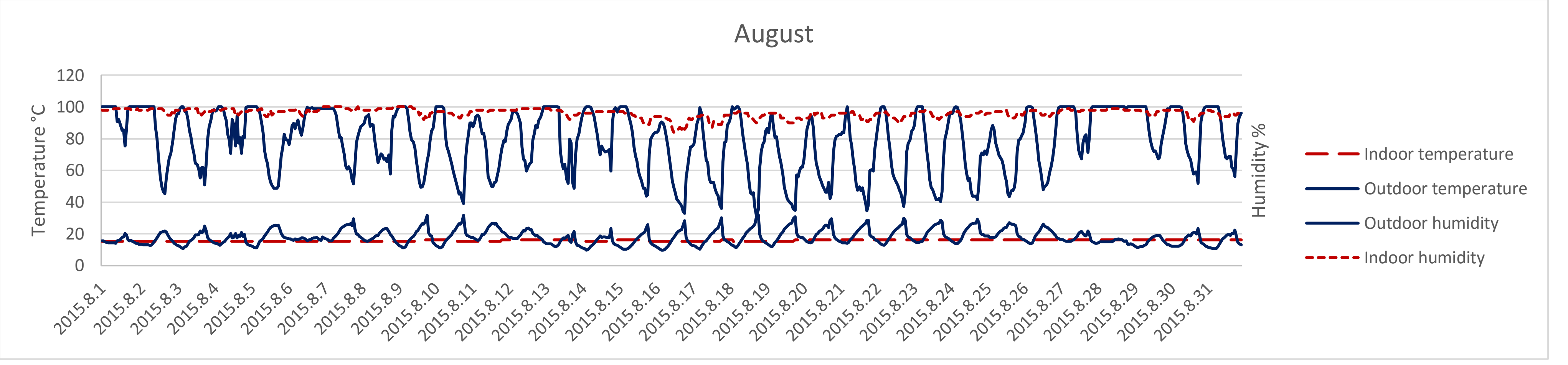
(3).



June
40
35
30
25
20
15
10
5
0
120
100
80
60
40
20
0
2015.6.1
2015.6.2
2015.6.3
2015.6.4
2015.6.5
2015.6.6
2015.6.7
2015.6.8
2015.6.9
2015.6.10
2015.6.11
2015.6.12
2015.6.13
2015.6.14
2015.6.15
2015.6.16
2015.6.17
2015.6.18
2015.6.19
2015.6.20
2015.6.21
2015.6.22
2015.6.23
2015.6.24
2015.6.25
2015.6.26
2015.6.27
2015.6.28
2015.6.29
2015.6.30
Indoor temperature
Outdoor temperature
Outdoor humidity
Indoor humidity
Fan Speed

APPENDIX 2

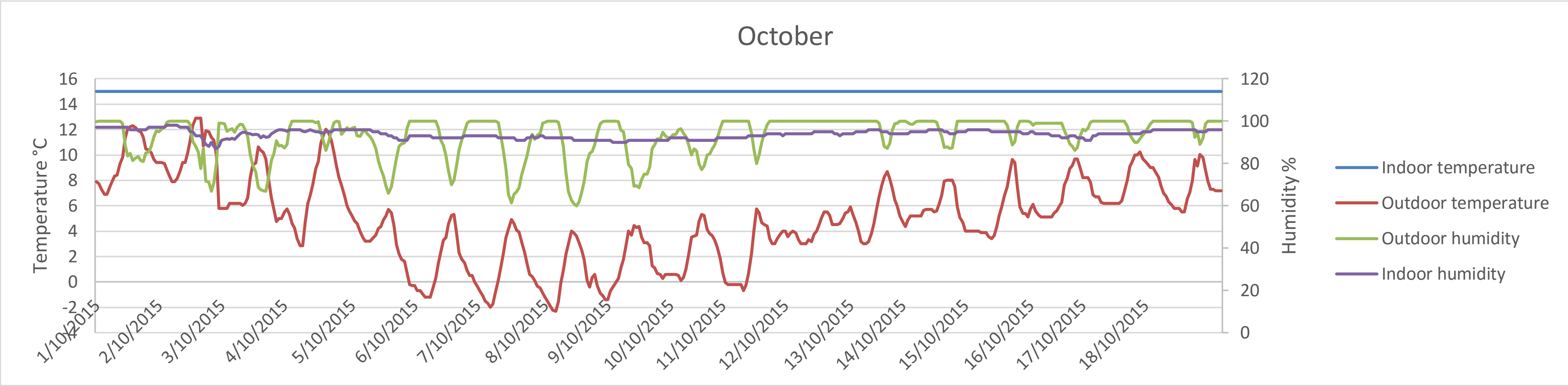
(4).



August
120
100
80
60
40
20
0
Temperature °C
Humidity %
2015.8.1
2015.8.2
2015.8.3
2015.8.4
2015.8.5
2015.8.6
2015.8.7
2015.8.8
2015.8.9
2015.8.10
2015.8.11
2015.8.12
2015.8.13
2015.8.14
2015.8.15
2015.8.16
2015.8.17
2015.8.18
2015.8.19
2015.8.20
2015.8.21
2015.8.22
2015.8.23
2015.8.24
2015.8.25
2015.8.26
2015.8.27
2015.8.28
2015.8.29
2015.8.30
2015.8.31
Indoor temperature
Outdoor temperature
Outdoor humidity
Indoor humidity

APPENDIX 2

(5).



October
Temperature °C
Humidity %
16
14
12
10
8
6
4
2
0
-2
-4
120
100
80
60
40
20
0
1/10/2015
2/10/2015
3/10/2015
4/10/2015
5/10/2015
6/10/2015
7/10/2015
8/10/2015
9/10/2015
10/10/2015
11/10/2015
12/10/2015
13/10/2015
14/10/2015
15/10/2015
16/10/2015
17/10/2015
18/10/2015
Indoor temperature
Outdoor temperature
Outdoor humidity
Indoor humidity

APPENDIX 3

(1).

		Outdoor temperature	Indoor temperature	Outdoor relative humidity	Indor relative humidity	m^3/s outdoor	outdoor tem K	Indoor tem K	phs(T)	phs(T)	2) Partial pressure of water vapour OUT	2) Partial pressure of water vapour IND	Outdoor moisture content g/kg	Indoor moisture content g/kg	kg/s	g/s	**moisture taken by fan from ground g/s**	**moisture taken by fan from ground g/h**
1.12.2014	0	-0.3	13.6	1.00	0.95	0.0405	272.7	286.6	589.8	1537.7	589.8	1460.8	3.6417	9.1	0.0486	48.6	0.27	954.8
	1	-0.3	13.6	1.00	0.95	0.0405	272.7	286.6	589.8	1537.7	589.8	1460.8	3.6417	9.1	0.0486	48.6	0.27	954.8
	2	-0.6	13.6	1.00	0.95	0.0405	272.4	286.6	575.6	1537.7	575.6	1466.0	3.5536	9.1	0.0486	48.6	0.27	975.9
	3	-0.8	13.6	1.00	0.95	0.0405	272.2	286.6	568.6	1537.7	568.6	1466.0	3.5103	9.1	0.0486	48.6	0.27	983.4
	4	-1.0	13.6	0.98	0.95	0.0405	272.0	286.6	561.7	1537.7	550.5	1460.8	3.3977	9.1	0.0486	48.6	0.28	997.5
	5	-1.3	13.6	0.96	0.95	0.0405	271.7	286.6	548.1	1537.7	526.2	1463.4	3.2471	9.1	0.0486	48.6	0.29	1026.6
	6	-1.3	13.6	0.95	0.95	0.0405	271.7	286.6	548.1	1537.7	520.7	1460.8	3.2131	9.1	0.0486	48.6	0.29	1029.8
	7	-1.7	13.6	0.98	0.95	0.0405	271.3	286.6	531.6	1537.7	520.9	1453.2	3.2144	9.1	0.0486	48.6	0.28	1021.0
	8	-1.8	13.4	0.99	0.94	0.0405	271.3	286.4	530.3	1517.8	525.0	1426.7	3.2394	8.9	0.0486	48.6	0.27	987.5
	9	-2.1	13.3	0.97	0.94	0.0405	270.9	286.3	516.1	1507.9	500.6	1417.4	3.0883	8.8	0.0486	48.6	0.28	1003.6
	10	-2.2	13.3	0.96	0.94	0.0405	270.8	286.3	512.9	1507.9	492.4	1412.4	3.0374	8.8	0.0486	48.6	0.28	1007.0
	11	-2.2	13.3	0.94	0.94	0.0405	270.8	286.3	512.9	1507.9	482.1	1409.9	2.9738	8.8	0.0486	48.6	0.28	1015.3
	12	-2.8	13.3	0.92	0.93	0.0405	270.2	286.3	491.2	1507.9	451.9	1404.9	2.7863	8.7	0.0486	48.6	0.29	1042.6
	13	-3.2	13.3	0.97	0.93	0.0405	269.8	286.3	476.1	1507.9	461.9	1402.4	2.8482	8.7	0.0486	48.6	0.29	1029.0
	14	-3.2	13.3	0.95	0.93	0.0405	269.8	286.3	476.1	1507.9	452.3	1402.4	2.7892	8.7	0.0486	48.6	0.29	1039.3
	15	-3.2	13.3	0.99	0.93	0.0405	269.8	286.3	476.1	1507.9	471.4	1402.4	2.9072	8.7	0.0486	48.6	0.28	1018.7
	16	-3.2	13.3	1.00	0.93	0.0405	269.8	286.3	476.1	1507.9	476.1	1402.4	2.9367	8.7	0.0486	48.6	0.28	1013.5
	17	-2.9	13.3	1.00	0.93	0.0405	270.1	286.3	488.1	1507.9	488.1	1399.9	3.0110	8.7	0.0486	48.6	0.28	997.7
	18	-2.7	13.3	1.00	0.94	0.0405	270.3	286.3	494.2	1507.9	494.2	1412.4	3.0487	8.8	0.0486	48.6	0.28	1005.0
	19	-2.7	13.3	1.00	0.94	0.0405	270.3	286.3	494.2	1507.9	494.2	1417.4	3.0487	8.8	0.0486	48.6	0.28	1010.6
	20	-2.7	13.3	1.00	0.94	0.0405	270.3	286.3	494.2	1507.9	494.2	1417.4	3.0487	8.8	0.0486	48.6	0.28	1010.6
	21	-2.5	13.3	1.00	0.94	0.0405	270.5	286.3	500.4	1507.9	500.4	1420.0	3.0869	8.8	0.0486	48.6	0.28	1006.6
	22	-2.2	13.3	1.00	0.95	0.0405	270.8	286.3	512.9	1507.9	512.9	1432.5	3.1646	8.9	0.0486	48.6	0.28	1006.9
	23	-2.2	13.3	1.00	0.95	0.0405	270.8	286.3	512.9	1507.9	512.9	1432.5	3.1646	8.9	0.0486	48.6	0.28	1006.9

APPENDIX 3

(2).

2015.1.10	0	-5.3	12.3	1	**100**	**0.88**	87.8	0.041	267.7	285.3	406.4491	1412.195	406.4491	1239.907	2.5051	7.7057	0.0486	0.0405	48.6	0.252747	909.8908
	1	-5.6	11.9	1	**100**	**0.87**	87.333	0.041	267.4	284.9	397.2723	1375.429	397.2723	1201.208	2.4483	7.4623	0.0486	0.0405	48.6	0.243678	877.2419
	2	-6.2	11.8	1	**100**	**0.87**	87	0.041	266.8	284.77	379.4696	1363.362	379.4696	1186.125	2.3382	7.3675	0.0486	0.0405	48.6	0.244423	879.9218
	3	-6.717	11.7	1	**100**	**0.87**	86.833	0.041	266.28333	284.7	364.7121	1357.364	364.7121	1178.644	2.2469	7.3205	0.0486	0.0405	48.6	0.246573	887.6632
	4	-7.133	11.7	1	**100**	**0.86**	86.167	0.041	265.86667	284.7	353.1853	1357.364	353.1853	1169.595	2.1757	7.2636	0.0486	0.0405	48.6	0.247273	890.1833
	5	-7.633	11.7	1	**100**	**0.87**	86.833	0.041	265.36667	284.7	339.7821	1357.364	339.7821	1178.644	2.0928	7.3205	0.0486	0.0405	48.6	0.254063	914.6257
	6	-7.8	11.7	1	**100**	**0.86**	85.833	0.041	265.2	284.7	335.4161	1357.364	335.4161	1165.071	2.0658	7.2352	0.0486	0.0405	48.6	0.251229	904.4247
	7	-8.133	11.7	1	**100**	**0.86**	85.5	0.041	264.86667	284.7	326.8338	1357.364	326.8338	1160.546	2.0128	7.2067	0.0486	0.0405	48.6	0.252425	908.7299
	8	-8.3	11.7	1	**100**	**0.86**	85.5	0.041	264.7	284.7	322.6164	1357.364	322.6164	1160.546	1.9868	7.2067	0.0486	0.0405	48.6	0.253691	913.2886
	9	-8.383	11.7	1	**100**	**0.85**	85.167	0.041	264.61667	284.7	320.526	1357.364	320.526	1156.021	1.9738	7.1783	0.0486	0.0405	48.6	0.252938	910.5756
	10	-8.8	11.7	1	**100**	**0.85**	85.333	0.041	264.2	284.7	310.2537	1357.364	310.2537	1158.284	1.9104	7.1925	0.0486	0.0405	48.6	0.256712	924.1635
	11	-8.8	11.7	1	**100**	**0.84**	84.167	0.041	264.2	284.7	310.2537	1357.364	310.2537	1142.448	1.9104	7.0931	0.0486	0.0405	48.6	0.251878	906.7625
	12	-9.217	11.7	1	**100**	**0.84**	83.833	0.041	263.78333	284.7	300.2759	1357.364	300.2759	1137.923	1.8488	7.0647	0.0486	0.0405	48.6	0.253493	912.5731
	13	-9.8	11.7	1	**100**	**0.84**	83.833	0.041	263.2	284.7	286.7876	1357.364	286.7876	1137.923	1.7655	7.0647	0.0486	0.0405	48.6	0.25754	927.1441
	14	-10.22	11.7	1	**100**	**0.83**	83.167	0.041	262.78333	284.7	277.4866	1357.364	277.4866	1128.874	1.7081	7.0079	0.0486	0.0405	48.6	0.257569	927.2494
	15	-10.63	11.7	1	**100**	**0.83**	83.167	0.041	262.36667	284.7	268.4556	1357.364	268.4556	1128.874	1.6523	7.0079	0.0486	0.0405	48.6	0.260278	937.0013
	16	-10.8	11.7	1	**100**	**0.83**	83.333	0.041	262.2	284.7	264.9173	1357.364	264.9173	1131.136	1.6305	7.0221	0.0486	0.0405	48.6	0.26203	943.3064
	17	-11.22	11.7	1	**100**	**0.83**	82.667	0.041	261.78333	284.7	256.2529	1357.364	256.2529	1122.087	1.5770	6.9653	0.0486	0.0405	48.6	0.261867	942.7215
	18	-11.72	11.5	1	**100**	**0.82**	82.333	0.041	261.28333	284.53	246.1901	1342.469	246.1901	1105.3	1.5150	6.8599	0.0486	0.0405	48.6	0.259764	935.1496
	19	-11.8	11.2	1	**100**	**0.82**	82	0.041	261.2	284.2	244.5477	1313.111	244.5477	1076.751	1.5048	6.6808	0.0486	0.0405	48.6	0.251553	905.5891
	20	-12.05	11.3	1	**100**	**0.82**	81.833	0.041	260.95	284.27	239.6791	1318.937	239.6791	1079.33	1.4748	6.6970	0.0486	0.0405	48.6	0.253798	913.6731
	21	-12.3	11.3	1	**100**	**0.81**	81.333	0.041	260.7	284.3	234.8972	1321.858	234.8972	1075.112	1.4453	6.6705	0.0486	0.0405	48.6	0.253946	914.2045
	22	-12.38	11.3	1	**100**	**0.81**	81	0.041	260.61667	284.3	233.3222	1321.858	233.3222	1070.705	1.4356	6.6429	0.0486	0.0405	48.6	0.253075	911.0696
	23	-12.8	11.3	1	**100**	**0.81**	81	0.041	260.2	284.3	225.5882	1321.858	225.5882	1070.705	1.3879	6.6429	0.0486	0.0405	48.6	0.255393	919.4139

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(3).

2015.3.17	0	1.3	12	0.528	52.8	0.92	92	0.0405	274.3	285	662.2585	1384.541	349.6725	1273.778	2.1540	7.9188	0.0486	0.0405	48.6	0.280173	1008.624
	1	1.367	12	0.517	51.667	0.9267	92.667	0.0405	274.3667	285	665.4425	1384.541	343.812	1283.008	2.1177	7.9770	0.0486	0.0405	48.6	0.284758	1025.13
	2	0.367	12	0.605	60.5	0.9267	92.667	0.0405	273.3667	285	619.0776	1384.541	374.542	1283.008	2.3077	7.9770	0.0486	0.0405	48.6	0.275525	991.8905
	3	-1.55	12	0.728	72.833	0.93	93	0.0405	271.45	285	2.048831	1384.541	1.492232	1287.623	0.0092	8.0060	0.0486	0.0405	48.6	0.388647	1399.131
	4	-2.88	12	0.803	80.333	0.9267	92.667	0.0405	270.1167	285	1.951948	1384.541	1.568065	1283.008	0.0096	7.9770	0.0486	0.0405	48.6	0.387212	1393.965
	5	-3.22	12	0.782	78.167	0.92	92	0.0405	269.7833	285	1.928307	1384.541	1.507294	1273.778	0.0093	7.9188	0.0486	0.0405	48.6	0.384406	1383.861
	6	-3.05	12	0.748	74.833	0.915	91.5	0.0405	269.95	285	1.940099	1384.541	1.451841	1266.855	0.0089	7.8753	0.0486	0.0405	48.6	0.382304	1376.296
	7	-2.38	12	0.765	76.5	0.9117	91.167	0.0405	270.6167	285	1.987841	1384.541	1.520699	1262.24	0.0093	7.8462	0.0486	0.0405	48.6	0.380872	1371.139
	8	-1.05	12	0.657	65.667	0.9017	90.167	0.0405	271.95	285	2.086133	1384.541	1.369894	1248.394	0.0084	7.7591	0.0486	0.0405	48.6	0.376682	1356.055
	9	0.7	12	0.618	61.833	0.9	90	0.0405	273.7	285	634.204	1384.541	392.1495	1246.087	2.4166	7.7445	0.0486	0.0405	48.6	0.258937	932.1732
	10	2.117	12	0.58	58	0.8983	89.833	0.0405	275.1167	285	702.2081	1384.541	407.2807	1243.779	2.5102	7.7300	0.0486	0.0405	48.6	0.253681	913.2526
	11	3.867	12	0.553	55.333	0.8983	89.833	0.0405	276.8667	285	795.0718	1384.541	439.9397	1243.779	2.7124	7.7300	0.0486	0.0405	48.6	0.243856	877.8809
	12	5.7	12	0.518	51.833	0.895	89.5	0.0405	278.7	285	903.8486	1384.541	468.4949	1239.164	2.8893	7.7010	0.0486	0.0405	48.6	0.233849	841.8548
	13	7.45	12	0.477	47.667	0.895	89.5	0.0405	280.45	285	1019.734	1384.541	486.0733	1239.164	2.9982	7.7010	0.0486	0.0405	48.6	0.228554	822.7961
	14	9.367	12	0.41	41	0.885	88.5	0.0405	282.3667	285	1161.519	1384.541	476.2229	1225.319	2.9372	7.6139	0.0486	0.0405	48.6	0.227288	818.2381
	15	10.87	12	0.342	34.167	0.895	89.5	0.0405	283.8667	285	1284.319	1384.541	438.809	1239.164	2.7054	7.7010	0.0486	0.0405	48.6	0.242785	874.0255
	16	10.95	12	0.33	33	0.9083	90.833	0.0405	283.95	285	1291.464	1384.541	426.1832	1257.625	2.6272	7.8172	0.0486	0.0405	48.6	0.25223	908.027
	17	9.867	12	0.35	35	0.91	91	0.0405	282.8667	285	1201.25	1384.541	420.4376	1259.932	2.5917	7.8317	0.0486	0.0405	48.6	0.254664	916.791
	18	6.617	12	0.433	43.333	0.91	91	0.0405	279.6167	285	963.0109	1384.541	417.3047	1259.932	2.5723	7.8317	0.0486	0.0405	48.6	0.255607	920.1838
	19	4.367	12	0.518	51.833	0.91	91	0.0405	277.3667	285	823.5251	1384.541	426.8605	1259.932	2.6314	7.8317	0.0486	0.0405	48.6	0.252732	909.8346
	20	3.05	12	0.565	56.5	0.91	91	0.0405	276.05	285	750.4646	1384.541	424.0125	1259.932	2.6138	7.8317	0.0486	0.0405	48.6	0.253589	912.9193
	21	2.9	13	0.565	56.5	0.905	90.5	0.0405	275.9	286	742.5165	1478.62	419.5218	1338.151	2.5860	8.3244	0.0486	0.0405	48.6	0.278885	1003.988
	22	3.317	13	0.553	55.333	0.9	90	0.0405	276.3167	286	764.7804	1478.62	423.1785	1330.758	2.6086	8.2778	0.0486	0.0405	48.6	0.27552	991.8737
	23	2.983	13	0.578	57.833	0.9	90	0.0405	275.9833	286	746.9229	1478.62	431.9704	1330.758	2.6631	8.2778	0.0486	0.0405	48.6	0.272875	982.3508

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(4).

2015.5.29	0	11.6	13.3	0.534	53.4	0.9	91	30	0.0405	284.6	286.3	1348.41	1507.918	720.0508	1378.237	4.4518	8.5772	0.0486	48.6	0.200495	721.7828
	1	10.58333	13.3	0.557	55.7	0.9	92	30	0.0405	283.583	286.3	1260.284	1507.918	701.5584	1392.311	4.3367	8.6660	0.0486	48.6	0.210406	757.4632
	2	9.333333	13.3	0.578	57.8	0.9	93	30	0.0405	282.333	286.3	1158.912	1507.918	670.2376	1402.364	4.1418	8.7295	0.0486	48.6	0.222962	802.6634
	3	8.333333	13.3	0.762	76.2	0.9	93	30	0.0405	281.333	286.3	1083.06	1507.918	824.9307	1394.824	5.1055	8.6819	0.0486	48.6	0.17381	625.7148
	4	8.25	13.3	0.84	84	0.9	93	30	0.0405	281.25	286.3	1076.941	1507.918	904.6307	1402.364	5.6032	8.7295	0.0486	48.6	0.151934	546.9613
	5	9.25	13.3	0.872	87.2	0.9	92	30	0.0405	282.25	286.3	1152.417	1507.918	1004.524	1389.798	6.2282	8.6501	0.0486	48.6	0.117708	423.7479
	6	9.833333	13.3	0.768	76.8	0.9	92	30	0.0405	282.833	286.3	1198.565	1507.918	920.8972	1387.285	5.7049	8.6343	0.0486	48.6	0.142367	512.521
	7	11.91667	13.3	0.622	62.2	0.9	90	30	0.0405	284.917	286.3	1376.944	1507.918	856.0002	1362.153	5.2995	8.4757	0.0486	48.6	0.154367	555.7204
	8	13	13.3	0.633	63.3	0.9	92	30	0.0405	286	286.3	1478.62	1507.918	936.4592	1382.258	5.8022	8.6026	0.0486	48.6	0.136096	489.9474
	9	14.75	13.3	0.59	59	0.9	91	100	0.135	287.75	286.3	1656.839	1507.918	977.5348	1374.719	6.0592	8.5550	0.162	162	0.404318	1455.545
	10	16.25	13.3	0.468	46.8	0.9	92	100	0.135	289.25	286.3	1824.336	1507.918	854.3972	1382.258	5.2895	8.6026	0.162	162	0.536724	1932.208
	11	17.41667	13.3	0.435	43.5	0.9	92	100	0.135	290.417	286.3	1964.703	1507.918	854.6457	1389.798	5.2910	8.6501	0.162	162	0.54418	1959.049
	12	18.26667	13.3	0.398	39.8	0.9	92	100	0.135	291.267	286.3	2072.846	1507.918	825.6839	1387.285	5.1102	8.6343	0.162	162	0.570896	2055.226
	13	20.26667	13.3	0.363	36.3	0.9	92	100	0.135	293.267	286.3	2348.108	1507.918	853.146	1379.745	5.2816	8.5867	0.162	162	0.535421	1927.516
	14	20.66667	13.3	0.353	35.3	0.9	92	100	0.135	293.667	286.3	2406.845	1507.918	850.4184	1384.771	5.2646	8.6184	0.162	162	0.543318	1955.943
	15	21.56667	13.3	0.343	34.3	0.9	91	100	0.135	294.567	286.3	2543.721	1507.918	873.3443	1369.692	5.4078	8.5233	0.162	162	0.504714	1816.97
	16	21.23333	13.3	0.36	36	0.9	91	100	0.135	294.233	286.3	2492.253	1507.918	897.211	1367.179	5.5569	8.5074	0.162	162	0.477991	1720.767
	17	21.73333	13.3	0.338	33.8	0.9	92	100	0.135	294.733	286.3	2569.802	1507.918	869.4497	1387.285	5.3835	8.6343	0.162	162	0.526635	1895.887
	18	19.48333	13.3	0.395	39.5	0.9	92	100	0.135	292.483	286.3	2236.707	1507.918	883.4991	1387.285	5.4712	8.6343	0.162	162	0.512419	1844.708
	19	17.23333	13.3	0.503	50.3	0.9	91	30	0.0405	290.233	286.3	1942.037	1507.918	977.492	1374.719	6.0589	8.5550	0.0486	48.6	0.121308	436.7104
	20	14.05	13.3	0.678	67.8	0.9	91	30	0.0405	287.05	286.3	1583.407	1507.918	1074.078	1372.205	6.6640	8.5391	0.0486	48.6	0.09113	328.0685
	21	12.3	13.3	0.813	81.3	0.9	92	30	0.0405	285.3	286.3	1412.195	1507.918	1148.586	1387.285	7.1316	8.6343	0.0486	48.6	0.07303	262.9066
	22	10.3	13.3	0.983	98.3	0.9	93	30	0.0405	283.3	286.3	1236.647	1507.918	1216.036	1397.337	7.5555	8.6977	0.0486	48.6	0.055512	199.8426
	23	9.633333	13.3	1	100	0.9	94	30	0.0405	282.633	286.3	1182.563	1507.918	1182.563	1414.93	7.3451	8.8088	0.0486	48.6	0.071136	256.0903

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(5).

2015.6.21	0	14.1	14	1	100	0.97	97	30	0.0405	287.1	287	1588.556	1578.273	1588.556	1530.925	9.9069	9.5420	0.0486	48.6	-0.01774	-63.8471
	1	13.85	14	1	100	0.97	97	30	0.0405	286.85	287	1562.959	1578.273	1562.959	1530.925	9.7448	9.5420	0.0486	48.6	-0.00986	-35.4803
	2	13.45	14	1	100	0.97	97	30	0.0405	286.45	287	1522.758	1578.273	1522.758	1530.925	9.4903	9.5420	0.0486	48.6	0.002512	9.042427
	3	13.3	14	1	100	0.971667	97.16667	30	0.0405	286.3	287	1507.918	1578.273	1507.918	1533.555	9.3964	9.5586	0.0486	48.6	0.007884	28.38061
	4	13.3	14	1	100	0.978333	97.83333	30	0.0405	286.3	287	1507.918	1578.273	1507.918	1544.077	9.3964	9.6252	0.0486	48.6	0.01112	40.03248
	5	13.633	14	1	100	0.97	97	30	0.0405	286.6333	287	1541.069	1578.273	1541.069	1530.925	9.6062	9.5420	0.0486	48.6	-0.00312	-11.2328
	6	14.717	14	0.96	96	0.97	97	30	0.0405	287.7167	287	1653.275	1578.273	1587.144	1530.925	9.8980	9.5420	0.0486	48.6	-0.0173	-62.2825
	7	16.133	14	0.8633	86.33333	0.963333	96.33333	30	0.0405	289.1333	287	1810.795	1578.273	1563.32	1520.403	9.7471	9.4754	0.0486	48.6	-0.0132	-47.5291
	8	16.633	14	0.8283	82.83333	0.963333	96.33333	30	0.0405	289.6333	287	1869.453	1578.273	1548.53	1520.403	9.6534	9.4754	0.0486	48.6	-0.00865	-31.1454
	9	18.05	14	0.8417	84.16667	0.97	97	30	0.0405	291.05	287	2044.797	1578.273	1721.037	1530.925	10.7474	9.5420	0.0486	48.6	-0.05858	-210.899
	10	19.55	14	0.79	79	0.97	97	30	0.0405	292.55	287	2246.004	1578.273	1774.343	1530.925	11.0862	9.5420	0.0486	48.6	-0.07505	-270.178
	11	19.467	14	0.8017	80.16667	0.97	97	30	0.0405	292.4667	287	2234.387	1578.273	1791.234	1530.925	11.1937	9.5420	0.0486	48.6	-0.08027	-288.975
	12	19.883	14	0.7883	78.83333	0.97	97	30	0.0405	292.8833	287	2293	1578.273	1807.649	1530.925	11.2981	9.5420	0.0486	48.6	-0.08535	-307.248
	13	20.883	14	0.7383	73.83333	0.956667	95.66667	30	0.0405	293.8833	287	2439.193	1578.273	1800.938	1509.881	11.2554	9.4089	0.0486	48.6	-0.08974	-323.071
	14	21.55	14	0.69	69	0.945	94.5	30	0.0405	294.55	287	2541.126	1578.273	1753.377	1491.468	10.9529	9.2924	0.0486	48.6	-0.0807	-290.525
	15	23.467	14	0.625	62.5	0.955	95.5	30	0.0405	296.4667	287	2855.214	1578.273	1784.509	1507.251	11.1509	9.3922	0.0486	48.6	-0.08547	-307.696
	16	24.55	14	0.575	57.5	0.96	96	30	0.0405	297.55	287	3047.324	1578.273	1752.211	1515.142	10.9455	9.4421	0.0486	48.6	-0.07306	-263.031
	17	25.217	14	0.5067	50.66667	0.96	96	30	0.0405	298.2167	287	3171.07	1578.273	1606.676	1515.142	10.0218	9.4421	0.0486	48.6	-0.02817	-101.409
	18	28.8	14	0.415	41.5	0.968333	96.83333	30	0.0405	301.8	287	3914.18	1578.273	1624.385	1528.295	10.1340	9.5254	0.0486	48.6	-0.02958	-106.49
	19	32.233	14	0.3783	37.83333	0.98	98	30	0.0405	305.2333	287	4763.913	1578.273	1802.347	1546.708	11.2644	9.6419	0.0486	48.6	-0.07885	-283.867
	20	33.65	14	0.3583	35.83333	0.98	98	30	0.0405	306.65	287	5158.668	1578.273	1848.523	1546.708	11.5583	9.6419	0.0486	48.6	-0.09314	-335.298
	21	24.583	14	0.5383	53.83333	0.98	98	30	0.0405	297.5833	287	3053.41	1578.273	1643.752	1546.708	10.2568	9.6419	0.0486	48.6	-0.02989	-107.589
	22	21.267	14	0.6617	66.16667	0.98	98	100	0.135	294.2667	287	2497.358	1578.273	1652.419	1546.708	10.3118	9.6419	0.162	162	-0.10853	-390.691
	23	18.733	14	0.725	72.5	0.99	99	100	0.135	291.7333	287	2134.409	1578.273	1547.447	1562.49	9.6466	9.7418	0.162	162	0.015431	55.54984

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(6).

2015.8.12	0	18.8	**16**	**0.85**	84.6	0.98	98	30	0.0405	291.8	289	2143.3332	1795.429	1813.26	1759.52	11.3715	10.9959	0.0486	48.6	-0.0183	-65.7133
	1	17.9	**16**	**0.89**	89	0.98	98	30	0.0405	290.85	289	2019.2002	1795.429	1797.088	1759.52	11.2560	10.9959	0.0486	48.6	-0.0126	-45.5045
	2	17.6	**16**	**0.91**	90.5	0.98	98	30	0.0405	290.6	289	1987.5999	1795.429	1798.778	1759.52	11.2630	10.9959	0.0486	48.6	-0.013	-46.7291
	3	17.6	**16**	**0.93**	92.5	0.98	98	30	0.0405	290.6	289	1987.5999	1795.429	1838.53	1759.52	11.5119	10.9959	0.0486	48.6	-0.0251	-90.2778
	4	17.2	**16**	**0.97**	97	0.98	98	30	0.0405	290.18	289	1935.8954	1795.429	1877.819	1759.52	11.7518	10.9959	0.0486	48.6	-0.0367	-132.249
	5	17.1	**16**	**0.97**	97.3	0.98	98	30	0.0405	290.1	289	1925.6972	1795.429	1874.345	1759.52	11.7289	10.9959	0.0486	48.6	-0.0356	-128.235
	6	17.1	**16**	**0.97**	96.8	0.98	98	30	0.0405	290.1	289	1925.6972	1795.429	1864.717	1759.52	11.6686	10.9959	0.0486	48.6	-0.0327	-117.694
	7	17.2	**16**	**0.96**	95.5	0.99	99	30	0.0405	290.18	289	1935.8954	1795.429	1848.78	1777.47	11.5701	11.1081	0.0486	48.6	-0.0225	-80.8222
	8	18.4	**16**	**0.93**	92.7	0.99	99	30	0.0405	291.35	289	2083.7243	1795.429	1930.918	1777.47	12.1021	11.1081	0.0486	48.6	-0.0483	-173.908
	9	19.2	**16**	**0.9**	89.5	0.99	99	30	0.0405	292.18	289	2195.2838	1795.429	1964.779	1777.47	12.3282	11.1081	0.0486	48.6	-0.0593	-213.463
	10	20.7	**16**	**0.75**	74.8	0.99	99	30	0.0405	293.68	289	2409.3195	1795.429	1802.974	1777.47	11.3374	11.1081	0.0486	48.6	-0.0111	-40.1159
	11	22.1	**16**	**0.67**	67	0.99	99	30	0.0405	295.1	289	2628.0044	1795.429	1760.763	1777.47	11.0965	11.1081	0.0486	48.6	0.00056	2.03177
	12	21.9	**16**	**0.66**	66.2	0.99	99	30	0.0405	294.85	289	2588.1976	1795.429	1712.524	1777.47	10.7882	11.1081	0.0486	48.6	0.01555	55.9821
	13	23.2	**16**	**0.6**	59.5	0.99	99	30	0.0405	296.18	289	2806.7493	1795.429	1670.016	1777.47	10.5437	11.1081	0.0486	48.6	0.02743	98.7503
	14	23.5	**16**	**0.63**	62.5	0.99	99	30	0.0405	296.52	289	2863.842	1795.429	1789.901	1777.47	11.3072	11.1081	0.0486	48.6	-0.0097	-34.8239
	15	22.8	**16**	**0.64**	64.3	0.99	99	30	0.0405	295.77	289	2736.783	1795.429	1760.664	1777.47	11.1082	11.1081	0.0486	48.6	-2E-07	-0.00087
	16	22.5	**16**	**0.65**	65.2	0.99	99	30	0.0405	295.52	289	2695.5387	1795.429	1756.593	1777.47	11.0778	11.1081	0.0486	48.6	0.00147	5.30369
	17	20.1	**16**	**0.79**	79.2	0.99	99	30	0.0405	293.1	289	2324.0076	1795.429	1839.839	1777.47	11.5593	11.1081	0.0486	48.6	-0.0219	-78.9301
	18	19.5	**16**	**0.83**	83.2	0.99	99	30	0.0405	292.52	289	2241.351	1795.429	1864.057	1777.47	11.7017	11.1081	0.0486	48.6	-0.0288	-103.842
	19	18.7	**16**	**0.88**	88.3	0.99	99	30	0.0405	291.68	289	2127.7374	1795.429	1879.501	1777.47	11.7851	11.1081	0.0486	48.6	-0.0329	-118.44
	20	18.9	**16**	**0.87**	86.8	0.99	99	30	0.0405	291.85	289	2150.0477	1795.429	1866.958	1777.47	11.7091	11.1081	0.0486	48.6	-0.0292	-105.14
	21	17.9	**16**	**0.92**	91.5	0.99	99	30	0.0405	290.85	289	2019.2002	1795.429	1847.568	1777.47	11.5722	11.1081	0.0486	48.6	-0.0226	-81.1923
	22	16.9	**16**	**0.94**	93.7	0.99	99	30	0.0405	289.93	289	1905.442	1795.429	1784.764	1777.47	11.1660	11.1081	0.0486	48.6	-0.0028	-10.1299
	23	16.6	**16**	**0.97**	96.7	0.99	99	30	0.0405	289.6	289	1865.4914	1795.429	1803.308	1777.47	11.2775	11.1081	0.0486	48.6	-0.0082	-29.6357

APPENDIX 3

(7).

1/10/2015	0	7.9	15	0.998	99.8	0.97	97	30	0.0405	280.9	288	1051.574	1683.78	1049.47	1633.3	6.5098	10.1903	0.0486	48.6	0.178875	643.9501
	1	7.73333	15	1	100	0.97	97	30	0.0405	280.7333	288	1039.681	1683.78	1039.68	1633.3	6.4484	10.1903	0.0486	48.6	0.181857	654.6852
	2	7.31667	15	1	100	0.97	97	30	0.0405	280.3167	288	1010.465	1683.78	1010.47	1633.3	6.2654	10.1903	0.0486	48.6	0.190752	686.708
	3	6.9	15	1	100	0.97	97	30	0.0405	279.9	288	981.9762	1683.78	981.976	1633.3	6.0870	10.1903	0.0486	48.6	0.199421	717.9164
	4	6.9	15	1	100	0.97	97	30	0.0405	279.9	288	981.9762	1683.78	981.976	1633.3	6.0870	10.1903	0.0486	48.6	0.199421	717.9164
	5	7.4	15	1	100	0.97	97	30	0.0405	280.4	288	1016.25	1683.78	1016.25	1633.3	6.3016	10.1903	0.0486	48.6	0.188991	680.3692
	6	7.9	15	1	100	0.97	97	30	0.0405	280.9	288	1051.574	1683.78	1051.57	1633.3	6.5230	10.1903	0.0486	48.6	0.178234	641.6437
	7	8.31667	15	1	100	0.97	97	30	0.0405	281.3167	288	1081.834	1683.78	1081.83	1633.3	6.7127	10.1903	0.0486	48.6	0.169014	608.4489
	8	8.4	15	1	100	0.97	97	30	0.0405	281.4	288	1087.977	1683.78	1087.98	1633.3	6.7512	10.1903	0.0486	48.6	0.167141	601.7073
	9	9.31667	15	1	100	0.97	97	30	0.0405	282.3167	288	1157.611	1683.78	1157.61	1633.3	7.1883	10.1903	0.0486	48.6	0.145898	525.2339
	10	9.81667	15	0.98667	98.6667	0.97	97	30	0.0405	282.8167	288	1197.224	1683.78	1181.26	1633.3	7.3369	10.1903	0.0486	48.6	0.138677	499.2365
	11	11.3167	15	0.88833	88.8333	0.97	97	30	0.0405	284.3167	288	1323.321	1683.78	1175.55	1633.3	7.3010	10.1903	0.0486	48.6	0.140421	505.5148
	12	12.0667	15	0.835	83.5	0.97	97	30	0.0405	285.0667	288	1390.645	1683.78	1161.19	1633.3	7.2108	10.1903	0.0486	48.6	0.144806	521.302
	13	12.2333	15	0.84667	84.6667	0.96	96	30	0.0405	285.2333	288	1406.008	1683.78	1190.42	1616.4	7.3945	10.0836	0.0486	48.6	0.130691	470.4863
	14	12.3167	15	0.81333	81.3333	0.96	96	30	0.0405	285.3167	288	1413.746	1683.78	1149.85	1616.4	7.1395	10.0836	0.0486	48.6	0.14308	515.0875
	15	12.15	15	0.82667	82.6667	0.96	96	30	0.0405	285.15	288	1398.308	1683.78	1155.93	1616.4	7.1778	10.0836	0.0486	48.6	0.141222	508.3976
	16	11.9	15	0.83333	83.3333	0.96	96	30	0.0405	284.9	288	1375.429	1683.78	1146.19	1616.4	7.1166	10.0836	0.0486	48.6	0.144196	519.1043
	17	11.8167	15	0.81333	81.3333	0.96	96	30	0.0405	284.8167	288	1367.876	1683.78	1112.54	1616.4	6.9053	10.0836	0.0486	48.6	0.154463	556.0661
	18	11.4	15	0.80833	80.8333	0.96	96	30	0.0405	284.4	288	1330.657	1683.78	1075.61	1616.4	6.6737	10.0836	0.0486	48.6	0.165721	596.5946
	19	10.4833	15	0.85	85	0.96	96	30	0.0405	283.4833	288	1251.897	1683.78	1064.11	1616.4	6.6016	10.0836	0.0486	48.6	0.169226	609.2134
	20	10.4	15	0.855	85.5	0.97	97	30	0.0405	283.4	288	1244.945	1683.78	1064.43	1633.3	6.6035	10.1903	0.0486	48.6	0.174318	627.5459
	21	10.15	15	0.88333	88.3333	0.97	97	30	0.0405	283.15	288	1224.292	1683.78	1081.46	1633.3	6.7103	10.1903	0.0486	48.6	0.169128	608.8618
	22	9.65	15	0.92667	92.6667	0.97	97	30	0.0405	282.65	288	1183.889	1683.78	1097.07	1633.3	6.8083	10.1903	0.0486	48.6	0.164369	591.7269
	23	9.4	15	0.95333	95.3333	0.97	97	30	0.0405	282.4	288	1164.132	1683.78	1109.81	1633.3	6.8882	10.1903	0.0486	48.6	0.160485	577.7463