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ISSUE 2

VERSION 1.0



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VOLUME 19 ISSUE 2 (VER. 1.0)

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GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: J  
GENERAL ENGINEERING  
Volume 19 Issue 2 Version 1.0 Year 2019  
Type: Double Blind Peer Reviewed International Research Journal  
Publisher: Global Journals  
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

## Urban Heat Island Effect on Building Electricity use

By Menglin S. Jin & Rebecca Huff

*University of Maryland*

*Abstract-* The campus-wide electricity use in University of Maryland, College Park (UMCP) is highly correlated with the outdoor 2-meter surface air temperature, at hourly, daily, and monthly scales, with the correlation coefficients normally  $> 0.70$  in 2014 and 2015. Nevertheless, 2-meter surface air temperature has evident spatial heterogeneity, determined by underlying surface types and surrounding vegetation fraction, with up-to 6 °F difference between a roof on campus and a vegetation-covered airport for the clear days on July 2014 and 2015. Such urban heat island effect (UHI) signal suggests that urban local surface air temperatures, instead of those in an nearby airport, may be needed in order to accurately forecast the electricity use for a given urban community. In addition to outdoor weather conditions, campus electricity use amount is also affected by other factors such as human behavioral pattern, for example, weekdays vs weekends. Therefore, interdisciplinary effort from weather system, society, and mechanical engineering is needed to fully understand and thus forecast electricity use.

*GJRE-J Classification: FOR Code: 580799*



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# Urban Heat Island Effect on Building Electricity use

Menglin S. Jin <sup>α</sup> & Rebecca Huff <sup>σ</sup>

**Abstract-** The campus-wide electricity use in University of Maryland, College Park (UMCP) is highly correlated with the outdoor 2-meter surface air temperature, at hourly, daily, and monthly scales, with the correlation coefficients normally > 0.70 in 2014 and 2015. Nevertheless, 2-meter surface air temperature has evident spatial heterogeneity, determined by underlying surface types and surrounding vegetation fraction, with up-to 6 °F difference between a roof on campus and a vegetation-covered airport for the clear days on Julys 2014 and 2015. Such urban heat island effect (UHI) signal suggests that urban local surface air temperatures, instead of those in an nearby airport, may be needed in order to accurately forecast the electricity use for a given urban community. In addition to outdoor weather conditions, campus electricity use amount is also affected by other factors such as human behavioral pattern, for example, weekdays vs weekends. Therefore, interdisciplinary effort from weather system, society, and mechanical engineering is needed to fully understand and thus forecast electricity use.

## 1. INTRODUCTION

Electricity is needed to power heating, ventilation and air conditioning (HVAC). An average of 41% of the consumed electricity in the U.S. is used by HVAC systems [Goetzler *et al.* 2014], which is widely implemented on buildings to maintain human comfortable level. In addition, lightings and lab equipment such as computers also need electricity. Accurately forecasting electricity need for a building, a community, or a city is critical for the facility management to plan the resources in advance for sustainable development and electricity savings. Various natural weather factors, in particular, the ambient air temperature and humidity, affect the amount of electricity used in buildings [Jin 2018]. In addition, the configuration of the building structure such as the materials of the roof and exterior walls, the shape of the building, the slope of the roof and the number and size of the windows affect building energy use [DOE 2015, Wei *et al.*, 2016]. Various studies assess building contributions to the Urban heat island effect (UHI) and vice versa. For example, Shahmohamadi *et al.* [2011] showed that the lack of impervious surface materials in the city Tehran, Iran forced “an evaporation deficit in the

city which is caused intensity of urban heat island.” If the city continues to build structures using “waterproof and low albedo” materials, the surface air temperature there would further rise. UHI is mainly caused by reduced surface albedo [Jin *et al.* 2005], less vegetation coverage in the city, less soil moisture, and reduced heat capacity in urban surfaces [Table 1]. Specifically, for vegetation surface, the heat capacity is 1300J/g/K while the asphalt parking lot and roof are only 1000 J/g/K and 837 J/g/K, respectively. Therefore, with the same amount of solar radiation absorbed, vegetative covered airport would have less ground temperature increase than the parking lot and roof since part of the solar radiation absorbed in the airport is redistributed as latent heat flux. Furthermore, parking lot and roof surface albedo differs from vegetation- covered airport, as shown in Table 1, and results in UHI (Jin *et al.* 2005).

Via evapotranspiration, soil moisture affects atmospheric humidity, another parameter important for HVAC control on building environment. Urban regions have less soil moisture for evaporation, a natural physical process that cools down the surface [Zhao *et al.* 2013]. Dickinson [1992] concluded that “presence or absence of vegetation is significant”, which can be revealed through the diurnal temperature and humidity variations between urban and rural surfaces. Humidity affects electricity use similarly to how outdoor temperatures do. The specific heat capacity of water, as expressed by Perlman, is defined as “water has to absorb 4.184 Joules of heat for the temperature of one gram of water to increase 1 degree Celsius (°C).” Therefore, it takes electricity to make the air drier just as ground water needs absorption of solar radiation to evaporate. According to Byrd Heating and Air Conditioning, “air conditioners cool homes by removing heat and moisture from the air. When humidity levels are excessive, they need to work a lot harder.” As HVAC systems work through high humidity levels, more electricity is needed to power moisture off the room and cool a building. Nevertheless, due to the limited availability of humidity data, this study only studies the air temperature effect on building electricity use.

This study compares 2-meter surface air temperatures measured from various urban surfaces with that in a local airport, College Park, MD. Temperature heterogeneity throughout a small city like

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College Park, MD of 30,000 population, namely, apparently indicate the UHI<sup>1</sup>

signal, a well known phenomena that city surface is hotter than non-urban region. More importantly, the electricity use on the University of Maryland, College Park (UMCP) campus has high correlation coefficients with outdoor 2-meter air temperatures. In addition, the airport 2-meter surface air temperature, which is traditionally used in energy industry, is less related to UMCP building electricity use than other surfaces in a city environment. Airport 2 meter surface air temperature, in general, is lower than urban surfaces at night as well by 2-6 °F. The electricity use on UMCP campus showed a high-correlation relationship (coefficient ~0.81) with the 2-meter surface air temperature. Nevertheless, abrupt electricity use may occur for currently unclear reasons and forecasting such abrupt change is a key need in current energy industry. Correlation coefficient could be as low as 0.1-0.5 when abrupt electricity use appears. The section below discusses the data used in this work. Section 3 briefs the methodology of this study as well as uncertainty discussion, followed by the results analyses in Section 4. A final remark is given in Section 5.

## II. DATA

To study the urban heterogeneity and UHI signals, six surface types were analyzed, including a roof located on the top of the UMCP Atlantic Building (ATL) which is 50 feet tall red brick research and lab building (Figure 1b), two roofs in the National Aeronautics and Space Administration Goddard Space Flight Center (NASA GSFC) campus that is ~2.5 miles away in direct distance from the UMCP campus, an asphalt parking lot and a grass field at GSFC (Figure 1a), and College Park airport which is 1.5 miles away from UMCP. In UMCP, the 2-meter surface air temperatures was measured by Earth Networks SM(EN) weather station located 5 feet above the roof surface. This weather station records the temperature on a 24 hours/7 days a week basis with 15-minute interval in order to assess the diurnal, daily, monthly and seasonal variations. The ATL roof is comprised of a rough stone surface and has a tan coloration. Field experiment was conducted at NASA GSFC campus by the NASA Climate Adaption Science Investigation group (M. Carroll, personal communication,

<sup>1</sup> Urban heat island effect (UHI) originally is observed from 2-meter surface air temperature (Landsberg, 1975, Oke 1982). On this weather field, UHI is most evident at night and therefore is called as "nocturnal phenomenon". Nevertheless, UHI has also been identified from the satellite-based land surface skin temperature (Jin et al. 2005, Zhang et al. 2017). On skin temperature, UHI signal is apparent during both daytime and nighttime. Skin temperature and 2-meter surface air temperature have different physical meaning and thus magnitude, as discussed by Jin (2010, 2012). During daytime, mixing in boundary transfers heat from the surface to 2-meter air level, and thus reduces UHI signal during the day at 2-meter air level. Given the focus of this study, only 2-meter air temperature is analyzed.

2016). The temperature equipment used in GSFC field experiment was the "HOBO U23 Pro v2 External Temperature/Relative Humidity Data Logger-023-002" at 2 meters above each surface. During the time of collection in October 2013 - November 2015, the NASA Climate Adaption Science Investigation group programmed the loggers to record the temperature in 15-minute intervals beginning at the start of each hour and the data are sampled to hourly for use. The logger includes a radiation shield to minimize sunlight influence on the temperature. In addition, two-meter surface air temperatures recorded by an Automated Weather Observing System (AWOS) station at the College Park Airport located 1.5 mile away from the UMCP campus is also used. The temperature sensor is approximately 5 feet above the ground and also includes a radiation shield to minimize sunlight influence, as standard requirement by WMO.

The hourly, campus-wide electricity data used in this analysis was provided by UMCP facility management (Susan Curry, personal communication, 2016). The electricity use was measured in Kilowatt Hours (kWh) on six different accounts for the campus and these accounts have been summed to represent the entire campus electricity use.

## III. METHODOLOGY

The diurnal, seasonal, and inter-annual variations of the 2-meter surface air temperature measured at the five different urban surfaces, together with College Park airport weather station measurements, are compared with the electricity use on the UMCP campus, via correlation coefficient calculation, Box-and-Whisker Plot analysis, and regression analysis. Five urban surfaces (parking lot, one grass field, two roofs) located at the NASA GSFC are only approximately 2.5 miles away from the UMCP campus and normally have the same atmospheric and boundary-layer conditions. These GSFC sites are used to study the different urban surfaces impacts under the same solar insolation and wind conditions in 2014 and 2015.

### a) Uncertainty Analysis

Uncertainties of the results may exist on the *in-situ* 2-meter surface air temperature measurements. While other surfaces remained similar relative features in 2014 and 2015, ATL roof was colder than the airport during the daytime and warmer than the latter in 2015. Two possible reasons are for such a big difference: inter-annual weather variation in city or calibration error. The 2-meter surface air temperatures data from the ATL roof need to be further validated to understand this two-year variations. Unfortunately, without other UMCP sites to cross-validate, we cannot determine what is the reason for the difference. This is also the reason that GSFC observations are included to across-check the UHI and electricity use relations. Nevertheless, a 2.5 km

away might lead to different atmospheric conditions sometimes, which is another uncertainty source.

The field experiment of GSFC, although well documented and calibrated, covered only two years from late October 2013 through early November 2015. This limits the capability to understand the relationship between surface air temperatures and the electricity use. A statistical analysis with longer observation duration would be insightful.

Last, and most importantly, in order to reach a better understanding of the electricity use, in particular, extreme electricity use, individual building electricity usage data is needed. The electricity data used in this study is a sum of about 200 buildings on the UMCP campus. Each building, nevertheless, has unique requirement of energy use and people behavior pattern. This analysis only reveals an integrated sense of the relation between 2-meter air temperature and campus wide electricity use.

#### IV. RESULT DISCUSSION

UHI signal is evident on the monthly diurnal cycle of the 2-meter surface air temperatures measured at the College Park airport and UMCP Atlantic Building roof (ATL, Figure 2a), with the ATL roof temperature higher than the airport by 2-3 °F at night but less than 1 °F during the day for July 2015. The UHI is significant at night when more longwave radiation emitted from the building walls and campus roads heated up the 2-meter air than in CA airport. In addition, more water-proof surfaces in UMCP than in airport led to less soil moisture evaporation thus nighttime temperature. The CP airport is surrounded by grassy surfaces and therefore soil moisture underlying led to higher specific heat capacity and evaporation, which redistributed part of the absorbed radiative radiation into latent heat flux and thus slowed down the warming process. Specifically, the general patterns of the diurnal cycle for both surfaces were similar: temperatures decreased after sunset and the cooling continued until sunrise in the next morning. As daylight began, 2-meter air temperatures raised because of the absorption of solar radiation at the ground surfaces and then gradually warmed up the air above the ground. Maximum temperature was reached in the mid-afternoon hours (4 p.m. in summer time which is one hour after the real local time). Nevertheless, temperature peaked at different time for these two surfaces - ATL roof at 4:00 p.m. and the CP airport at 5:00 p.m. (summer time). After the peak, a decreasing continued when the sunlight gradually diminished.

During 10:00 a.m. to 7:00 p.m., ATL roof outdoor surface air temperature was close to CP airport with only 0-0.5 °F difference. Such a feature on monthly-average scale might be that the average process smoothed large day by day variation. Specifically, in July 2014 (Figure 2b), the box-and-whisker plot revealed that

larger day-by-day variations occurred in CA airport, in particular, at night and during the noon, than in campus roof. In addition, CA airport was hotter than ATL roof from 1-7 PM. Nevertheless, ATL roof was still warmer than the airport during the nighttime hours. The CP airport surface air temperature had a wider range of readings possibly due to the effects of soil moisture changes. Although both surfaces may receive approximately the same amount of solar radiation, the underlying surface albedo of the mastic asphalt roof material is 5-7% while the dry vegetation albedo varies from 1-25% (Table 1), therefore on dry July days the airport had larger variations at absorbing surface insolation, leading to the larger 2-meter air temperature variations than ATL roof did. On the other hand, at night, the observed large variation on 2-meter surface air temperature at the airport was probably due to clouds cover and soil moisture variations.

This inter-annual variations of July 2014 (Figure 2b) and 2015 (Figure 2a) proves a well-studied UHI phenomenon previously revealed by Oke (1982): UHI is most significant at night on 2-meter surface air temperature variable. During the daytime, the UHI signal could be well mixed by boundary-layer convection and thus had reduced magnitude or even no signal at all. Note that in July 2015, ATL roof temperature was close or higher than that in airport around noon to early afternoon (Figure 2a) while in July 2014, it was lower than the airport (Figure 2b). Such a big 2-year difference may be due to two reasons: inter-annual variations in weather conditions or measurement uncertainty. The ATL roof temperature records were not well validated since there were no other roof data at UMCP available. To gain more understanding, field experiment data conducted at 2.5 miles away in GSFC campus were analyzed in this study.

All six surfaces showed similar seasonal variations on the 2-meter surface air temperatures (Figure 3a-c). In April 2014, at nights (Figure 3a), cooling of each surface was a result of reduced longwave radiation emitted from the underlying ground. ATL roof was warmer than the airport between 12:00 a.m. and 7:00 a.m., a UHI signal of 1.5-2 °F. At night from 8:00 p.m. and 11:00 p.m. UHI signal gradually increased since heat absorbed by building walls and roads in daytime was re-emitted in form of longwave radiation to heat up surface-layer atmosphere. Furthermore, urban temperature heterogeneity is evident. In April 2014, UMCP ATL roof had the lowest diurnal range compared with NASA GSFC campus surfaces and CP airport. The roof 2 of NASA GSFC had the highest monthly-average surface air temperature (66 °F). ATL roof also had the lowest daytime peak among all these surfaces, with difference by as much as 4 °F from roof 2 at early afternoon. Such a large difference may be partly due to the relatively condensed urban building blocks on UMCP campus than on GSFC and partly due to

uncertainty of roof measurements. Nevertheless, different part of urban area having different temperature and thus different UHI magnitude is a well-known, physically sound feature in urban system. How such a feature can be used in electricity use forecast is an important question to be addressed.

A clear bell-curve was observed for UMCP campus-wide electricity use with the lowest value occurring at 3:00 a.m. and the maximum occurring at 2:00 p.m. This electricity use pattern followed the temperature diurnal cycle pattern. A 3:00 a.m. minimum was reasonable since people left campus and students rest after nighttime studies. At sunrise, the electricity use began to increase, resulting from heating each building before students and faculty arrival as well as turning on lab equipment, lighting, classroom tools, etc. for the day. Less heating was needed in the afternoon hours, followed the maximum at 2:00 p.m. due to warm ambient air temperatures outside the buildings.

In July 2014, electricity use pattern and 2-meter surface air temperatures had similar diurnal cycles as in April 2014 (Figure 3b). The monthly averaged minimum temperatures were observed around sunrise due to radiative cooling at night. Again, ATL roof had the highest 2-meter surface air temperature during the nighttime hours than other surfaces, suggesting the most significant UHI effect on the UMCP campus. Nevertheless, the electricity use amount differed from April. With fewer students and faculty on campus in July, the electricity use decreased from April, although still high during most of the daylight hours with the maximum occurring at 2:00 p.m. just before the average surface air temperature maximum. Specifically, the maximum in April was 20700 kWh and in July was only 16500 kWh, a 20% decrease even though the outdoor air temperature had a 21 °F increase (April maximum 66 °F while July maximum 87 °F). July is one of the hottest months of the year in Maryland and thus many buildings on campus use air conditioning to accommodate for the warm temperatures outdoors. Between 11:00 a.m. and 300 p.m. the electricity use amounts were very similar, showing almost constant high electricity use between 16,000 kWh and 16,500 kWh.

November 2014 was a cold month with the averaged 2-meter surface air temperature minimum below 40 °F and maximum around 52 °F (Figure 3c). Again, ATL roof continued to show strong nighttime UHI signal by comparing with the CP airport. The averaged 2-meter surface air temperatures at the NASA GSFC campus, on the other hand, were similar in July and the roof 2 topped out with the highest temperature at 4:00 p.m.. In addition, the averaged electricity use followed the surface air temperatures with the minimum occurring at 3:00 a.m. and the maximum occurring at 4:00 p.m., which is after the maximum temperature of 3 p.m. This 4:00 p.m. maximum may be not only due to needed heat for decreasing solar radiation in winter, but also to the

need of turning on lights in buildings. Further, the absolute amount of electricity use in November was less than in April and July because in winter a lot of buildings used steamed water to warm the building, a different mechanic approach instead of electricity-based AC and thus less electricity used.

To study inter-annual variations, April and July 2015 are analyzed (Figure 4). First, the diurnal cycle of 2-meter air temperatures were very similar in April 2015 (Figure 3a) and in April 2014 (Figure 4a) with the maxima both occurred at 4:00 p.m. Roof 2 of NASA GSFC campus was still the warmest among all 6 surfaces during daylight hours. Although the field data was missing for this month, comparisons were still meaningful. ATL roof continued to show UHI effect during the nighttime hours up until the sunrise at 7:00 a.m., with the maximum UHI at 12:00 a.m. and 6 a.m. of approximately 4 °F. However, the ATL Roof remained the coolest during the daylight hours in this month among the 6 surfaces.

Similar to 2014, the monthly averaged electricity use peaked before the maximum temperature in April 2015 while the minimum at 3:00 a.m. Having a minimum at 3 a.m. for each analyzed month may suggest that there could be a regulated amount of electricity use during the nighttime hours on the UMCP campus before a large jump in electricity need after sunrise. The electricity use quickly increased after sunrise due to the influx of students and faculty arrival on campus and thus needed both lightning and heat in the buildings. Therefore, human behavior pattern, together with air temperature condition, affects campus electricity use.

The maximum 2-meter surface air temperature in July 2015 occurred at 4:00 p.m. with the roof 2 surface being the warmest among the 6 surfaces (Note this is summer time, Figure 4b). However, UMCP ATL roof stayed warmer than CP Airport in both daytime as well as nighttime, which was different from that in July 2014, indicating a daytime and nighttime UHI. The GSFC field surface had the lowest averaged hourly 2-meter surface air temperature during the nighttime in July 2015. Furthermore, the electricity use showed the inter-annual similarities in July 2015 to July 2014. The maximum electricity use had a leveling period between the hours of 10:00 a.m. to 3:00 p.m. In addition, the actual kWh values were much greater in 2015 than in 2014 by 3,000 kWh, which was consistent with the daytime UHI occurring in July 2015 on campus.

High correlation coefficient (>0.75) between hourly electricity use and 2-meter surface air temperature for the week of August 1-5, 2015 occurred for all urban surfaces (Figure 5 a-c, other surfaces not shown). The maximum correlation was approximately 0.80 for the field of GSFC, with 0.75 for roof 2 and 0.77 for parking lot. In this week, in particular, the field seems to be a better index for electricity use than the parking lot or roof 2. On each day, the campus electricity use



had clear diurnal cycle, following the 2-meter surface air temperature. Since August was the month when many students and faculty were not on campus for summer break and thus few events scheduled on campus, the electricity use was likely only geared towards HVAC and lighting for buildings. Nevertheless, daily variations in electricity use were evident and, in particular, there was an abrupt decrease on August 5 morning. Reasons for this sudden decrease and then jump back were unidentified. From all the two-year data analyzed, such an abrupt change in electricity use occurred not rarely. Unfortunately, reasons for such abrupt change were unidentified due to the limited data availability. Such abrupt change could lead to power outage and a significant jump on electricity bills, but forecasting such an electricity abrupt change is challenge if reasons unknown. The only conclusion one can draw so far is that such an abrupt change in electricity use may not be induced by weather.

People behavioral pattern affected the electricity use. For example, the campus electricity use differed on weekday and weekend. During the weekdays, electricity was more predictable due to the daily electricity use routine on the UMCP campus, specifically, August 3, 4, and 5 except for its abrupt change for a short period of time in the morning. On the contrary, August 1st and 2nd, 2015 were Saturday and Sunday, respectively, and had significant decrease in electricity use due to a lower energy demand on the campus. This suggests that when forecasting electricity use, weekday and weekends should be separately simulated.

The correlation coefficients between UMCP campus electricity use and 2-meter surface air temperatures for parking lot, roofs, grass field and CA airport on each days of August 2015 showed heterogeneous surface impacts on electricity use (Figure 6). First, although August 10th was missing due to the lack of data, correlation coefficients were in general more than 0.75, indicating a possible relationship between surfaces and the electricity. Specifically, more than 1/3 days, the coefficients were above 0.90. Second, the lowest correlation occurred on August 28th, 2015 which was below 0.27 for all surfaces. August 28th was one of the first days when students moved into their dormitories on the UMCP campus, which may need for more electricity to meet the demand of students and their families coming onto campus. Since August 29th (a Saturday) correlation coefficients recovered, the university likely adjusted the electric load need to accommodate the influx of students. Third, differences in correlation were detectable, suggesting that different surface was related to electricity use differently. The field surface, again, had in general the largest coefficients in August 2015. The correlation for field on August 9th and August 14th were almost 1.0, indicating almost a 100% correlation between surface air temperatures and electricity used. On days such as August 17th, 21st and

27th much smaller correlations were shown for all surfaces, due to sudden change on electricity use field with unidentified reasons. The ATL roof data were not reliable to be included in this specific analysis.

Extreme electricity use, for example, August 5th 2015, is most needed to be forecasted since the facility management needs to foresee the needs so that they can arrange strategies in advance to save electricity bills. Energy price normally soars on extreme use hours and if too much electricity use might lead to blackout. Nevertheless, forecasting extreme electricity use is a challenge since it depends not only outdoor weather but also many known or unknown society factors and building facility configurations. In other worlds, simply use weather information cannot accurately forecast extreme electricity use since these two are not linearly related. For example, the maximum 2-meter surface air temperature for August 3rd, 4th, and 5th were 93 °F, 94 °F, and 90 °F, respectively, and the electricity use on these three days were 18000 kWh, 20000 kWh, and 23000 kWh, respectively (Figure 5). A 11% increase in electricity use for a 1 °F temperature increase, from August 3 to August 4. On August 5, however, although 2-meter surface air temperature decreased by 4 °F from August 4th, the electricity use in fact increased by 15%. The daily correlation coefficients for extreme day (August 5th) case was 0.92 between field and electricity use, which was higher than all the rest surfaces studied (Figure 5). Nevertheless, this high correlation coefficient does not lead much ways to forecast the extreme temperature use on that day. More research, combined both natural, societal, and mechanical data, are urgently needed.

A random day (July 30th, 2014) was selected to show the UHI signals for a specific summer day (Figure 7). This day was chosen only because it represented typical diurnal variations of UHI. First, UHI signals were evident at night from 9 PM to 8 AM, a well-known nocturnal phenomenon which was also shown in monthly mean (Figure 3b). The UHI signal could be ~6 °F between UMCP ATL roof and College Park airport, at 6 AM, and could be relatively small for Roof 1 and Roof 2, with about ~5 °F. During the daytime, the UHI signals for all three roofs were not evident, partly because of strong convection rapidly exchanging heat at the lowest surface-layer. Clear nighttime UHI might be important for HVAC control strategy, for example, most of building HVAC has free cooling operation, which uses the outside fresh air to replace building inside air at night when weather conditions are proper. This is an important way to save HVAC energy. Free cooling threshold is a function of outside air temperature. For example, in UMCP, when 2-meter air temperature is 60-70 °F, it is set to do free cooling (Curry, UMCP facility manager, personal communication, 2016). Currently, airport air temperature forecast is used in energy use industry. As shown from Figure 7, airport temperature

could be 5-6 °F lower than campus building outside temperature. If based on airport temperature, HVAC management may miss free cooling nights when airport cooler than 60 °F but UMCP temperature within 60-70 °F. Therefore, forecasting building outside air temperature could be helpful for HVAC control planning.

Regression equations were derived based on hourly 2-meter surface air temperature of UMCP ATL measurements and campus-wide electricity use data for June 2014. Again, weekday and weekends had apparently different values, as previously discussed in Figure 5. The regression equation for weekdays is:

$$Y = -17374 + 402.5 X,$$

where Y is hourly campus-wide electricity use amount and X is 2-meter building outside air temperature. Units of coefficient is 402.5kWh/°F and -17374kWh, respectively. For the weekends, the regression equation is:

$$Y = -3868.9 + 17885X,$$

Where the units of coefficients are -3868.9kWh and 17885 kWh/°F, respectively.

In addition to 2-meter air temperature, we also combined humidity information (dew point, relative humidity) and vegetation index from remote sensing to better interpret the spread of electricity use (results not shown). Nevertheless, neither humidity nor vegetation index can better explain why for the same outdoor air temperature, large differences on electricity use occur. Simple put, other factors in addition to weather conditions may be responsible for big increase in electricity use.

Most importantly, abnormal values of electricity use occurred for almost all surface air temperatures. For weekdays, for example, it could be 25000 kWh for air temperature of 80 °F. Even for weekends, when much fewer events and population, electricity use could be extreme at 18000 kWh at 70 °F. Understanding such extremes in electricity use is most critical, but challenge, in order to forecast it. Our research showed that big values seem to be partly due to human behavioral such as football games on campus, building HVAC configurations, and building structure. Nevertheless, we are far from being able to weight the key reasons to a level to forecast such extremes. Interdisciplinary collaborations among HVAC engineering, facility data record, and weather information are needed for future research.

## V. CONCLUSION

This study focused on addressing how different surface surfaces affect the electricity use on the UMCP campus. Analyses on the monthly averaged hourly surface air temperature for April, July and November 2014 as well as April and November 2015 show clear UHI signals for all urban surfaces (parking lot, ATL roof,

roof 1, roof 2 and field), with relatively different magnitudes due to thermal and dynamical differences. ATL roof, in particular, shows strong, consistent UHI signals up-to 6 °F during the night hours but much less in the daylight hours. In addition, the surfaces such as the roof surfaces on the NASA GSFC campus were warmer than airport by as much as 4 °F, mostly during the daytime hours.

The diurnal cycle of electricity use, in general, follows the outdoor air temperature well. The correlation coefficients between 2-meter surface air temperatures among surfaces on the NASA GSFC campus, CP airport and the UMCP electricity use all showed similar, high correlation (>0.75) for most of the days. Nevertheless, extreme electricity use and abrupt changes may occur, from time to time, with unidentified reasons. In addition, the field might be an adequate index to forecast electricity use since it had a correlation of above 0.80, while the other surfaces has correlation around 0.70-0.74 (Figure 6).

Outdoor air temperature is partly responsible for building electricity use. Therefore UHI has important use on electricity use management. Nevertheless, other factors, such as human behavior pattern, building mechanical configuration and thermal materials, also attribute to electricity use.

Weather system impact on the electricity use is an inter-disciplinary research. Observations and efforts from weather system, mechanical engineering, and society are essential in order to improve current knowledge to a level to forecast electricity use as functions of local weather, people behavior, and underlying land cover and economic factors.

## ACKNOWLEDGEMENTS

This work is funded by NASA Precipitation Program (award NNX16AD87G) and NSF I-Corps Program (award number 1639727). Thanks go to Mark Carroll of SSAI for providing us GSFC measurements. Study was part of the senior thesis of the co-author Huff.

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TABLES AND FIGURES

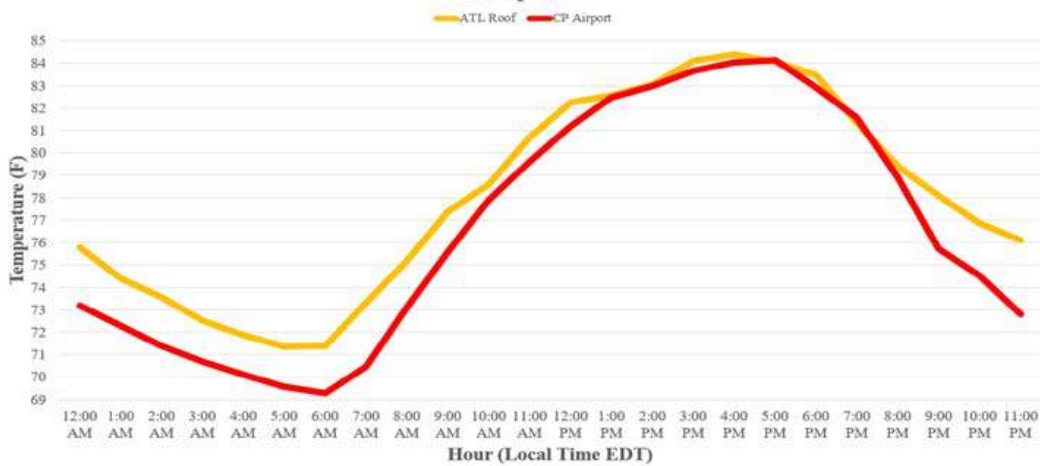
Table 1: Typical values for urban surfaces [Dobos 2005, Duan *et al.* 2012, IES, Ramirez *et al.* 2012,U.S. EPA 2008].

Surface Qualities	Dry Vegetation	Parking Lot (Asphalt)	Mastic Asphalt Roof Material	Bare Soil	Water
Albedo	1-25%	2-10%	5-7%	25-45%	10%
Emissivity	75-99%	90-98%	92-97%	55-75%	90%
Heat Capacity	1300 J/g K	1000 J/g K	837 J/g K	837 J/g K	4175 J/g K
Hydraulic Conductivity	2.03 W/m K	0.500 W/m K	1.150 W/m K	1.729 W/m K	N/A



Figure 1: Maps of the locations and surrounding land cover for (a) NASA GSFC campus field experiments 1 is parking lot, 2 is grass field, 3 and 4 are roof 1 and roof 2, respectively; and (b) UMCP Atlantic Building roof site from Earth Network. The weather station in College Park airport is not shown since it is a standard weather station locating above grass, as required by WMO standard

July 2015: Average Hourly Temperature for ATL Roof and CP Airport



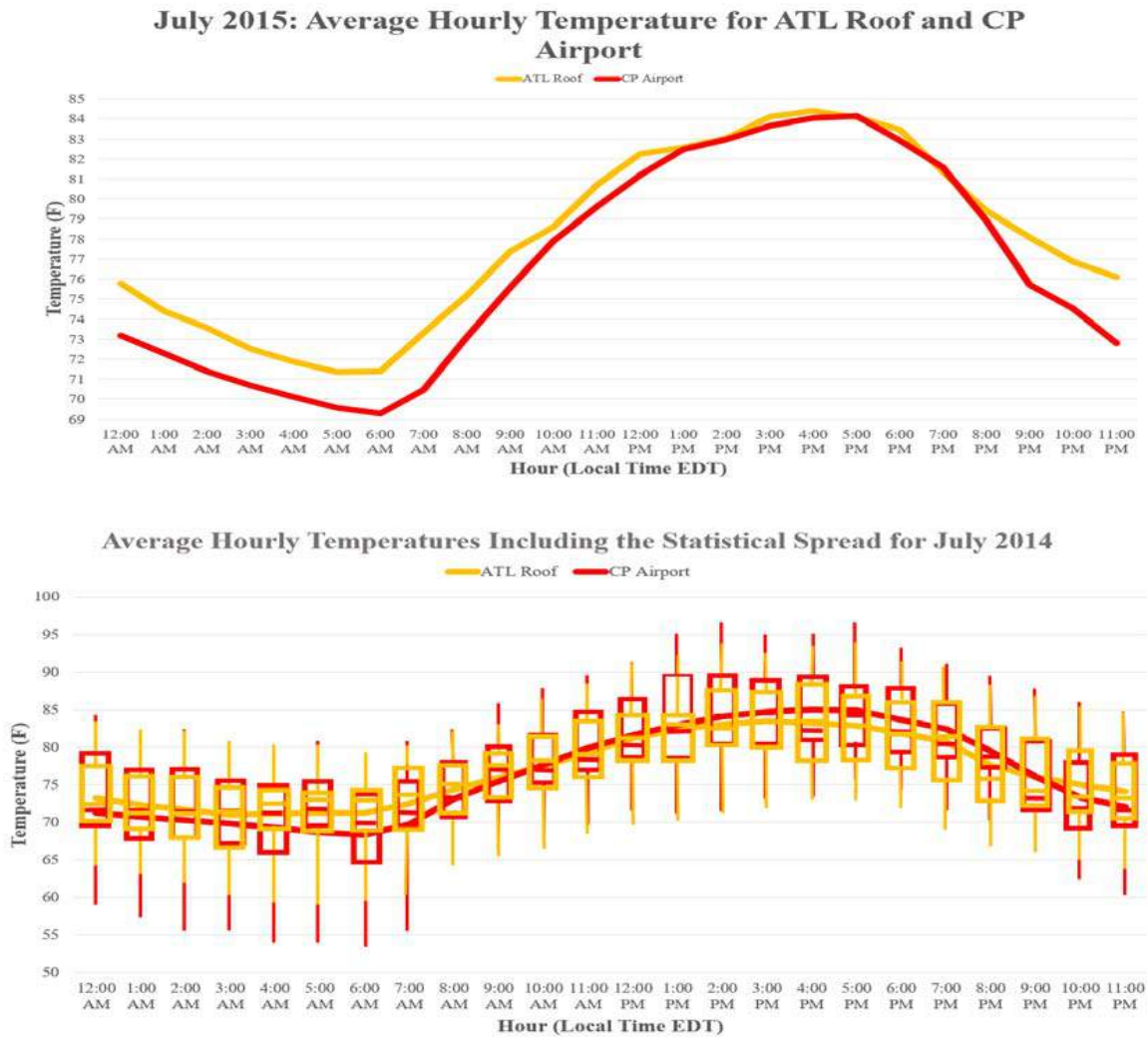
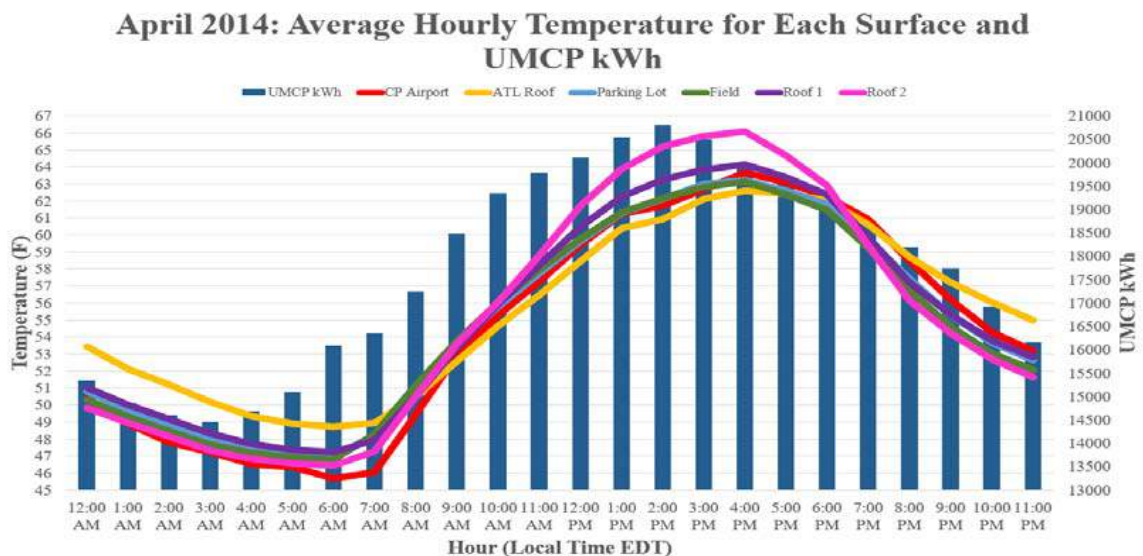
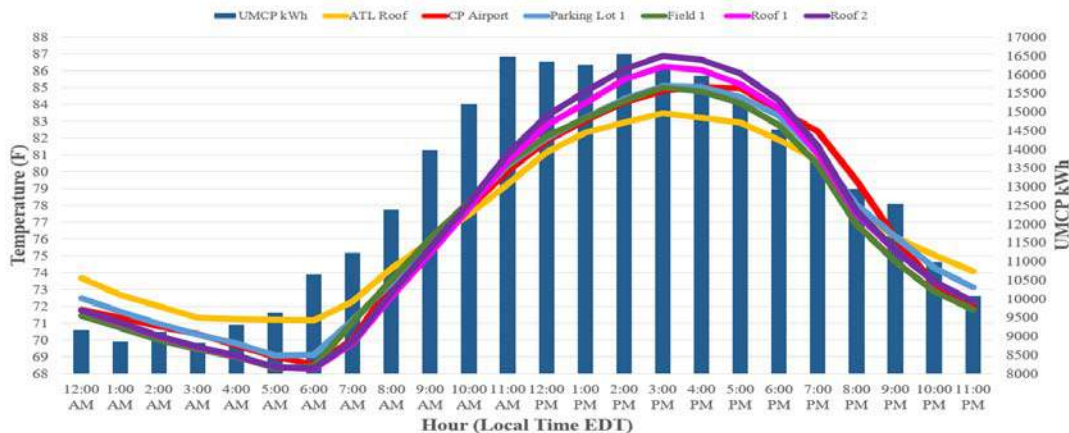


Figure 2: (a). Monthly averaged hourly 2-meter surface temperatures for University of Maryland College Park (UMCP) Atlantic Building roof (ATL Roof) and College Park airport (CP Airport) for July 2015. (b). Same as (a) except for July 2014 including a Box-and Whisker plot analysis showing the spread of temperatures for each hour.



**July 2014: Average Hourly Temperature for Each Surface and UMCP kWh**



**November 2014: Average Hourly Temperature for Each Surface and UMCP kWh**

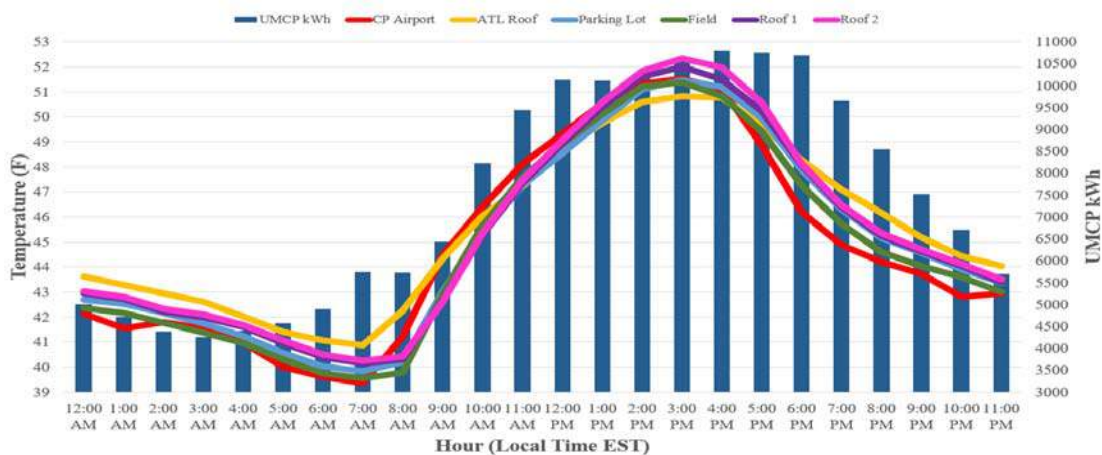
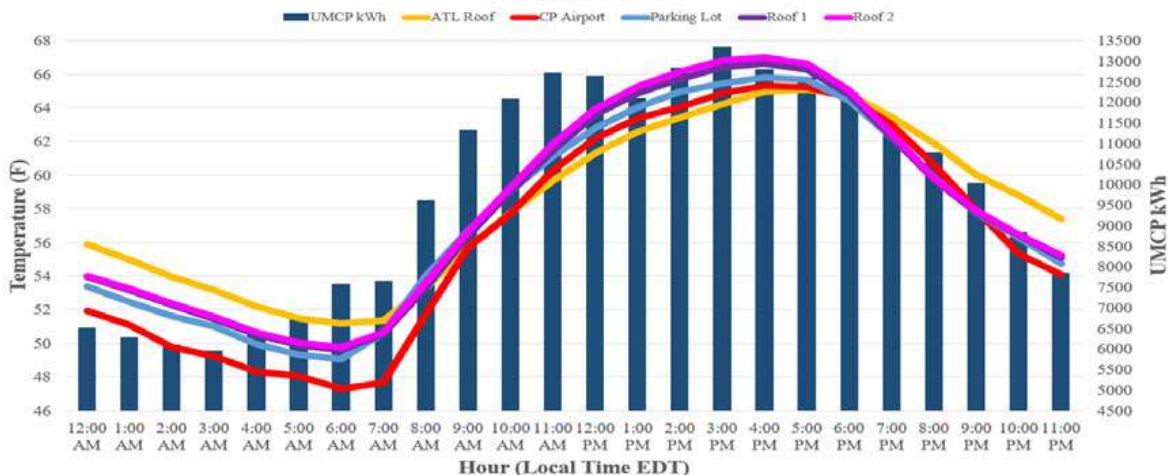


Figure 3: (a). The monthly averaged hourly 2-meter surface air temperature (unit: °F) in April 2014 for CP Airport, ATL Roof, Parking Lot, Field, Roof 1 and Roof 2 with the UMCP campus- wide average hourly electricity use (unit: kWh). (b). Same as (a) except for July 2014. (c). Same as (a) except for November, 2014

**April 2015: Average Hourly Temperature for Each Surface and UMCP kWh**



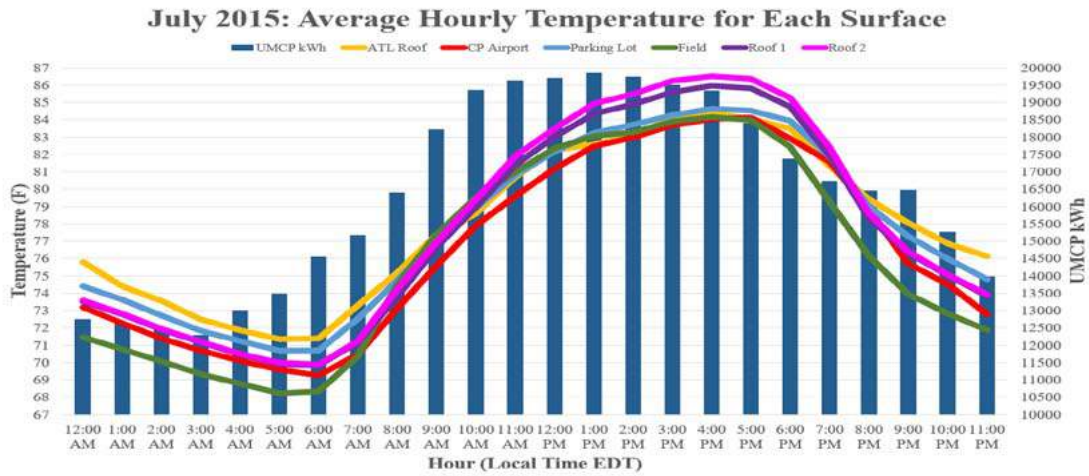


Figure 4: (a). Same as Figure 5 except for April, 2015. (b). Same as (a) except for July, 2015.

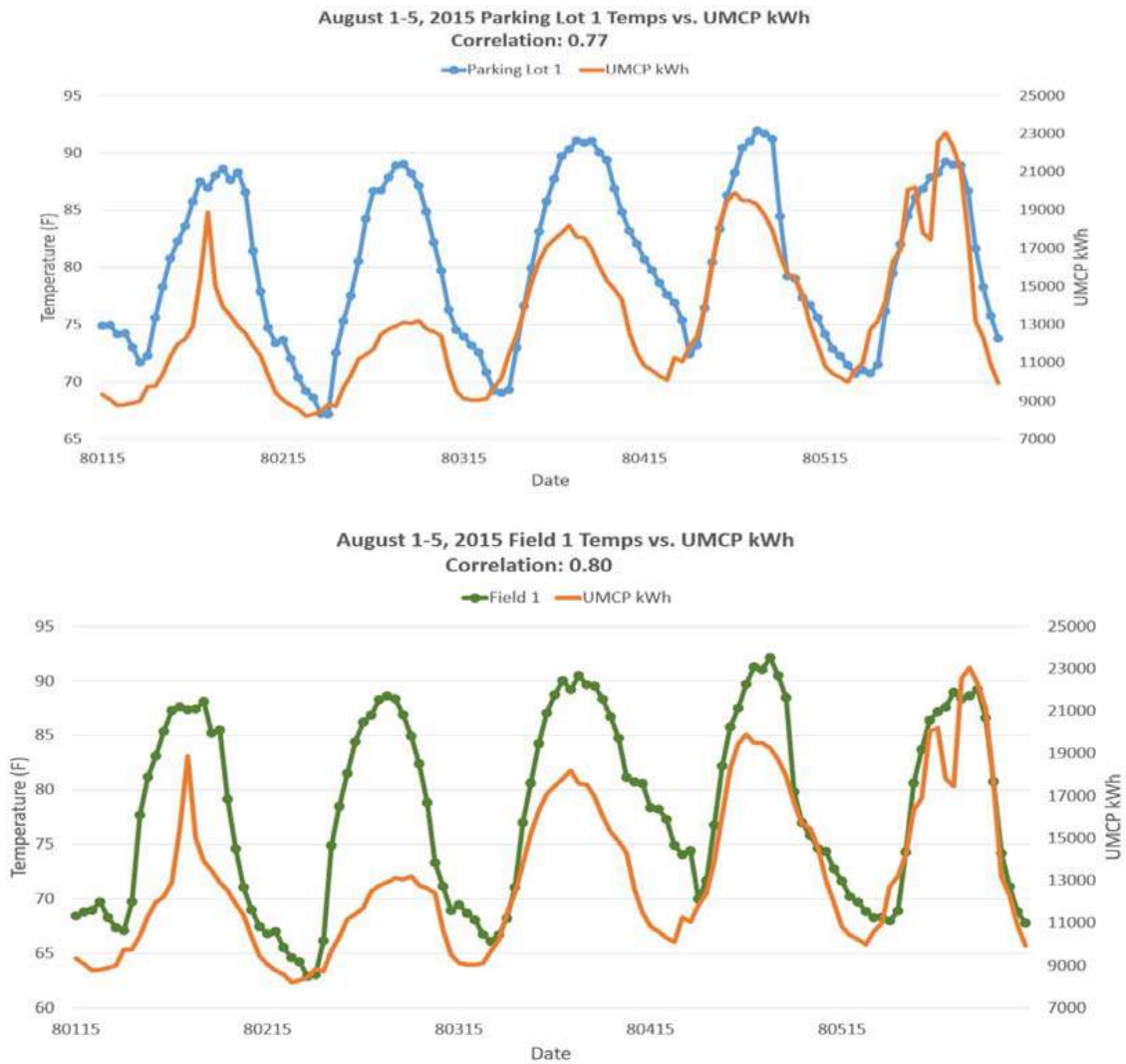


Figure 5: Weekly variations of UMCP campus electricity (unit: kWh) use with the 2-meter surface air temperature measured at (a) Parking Lot, (b) Field, and (c) Roof 2 August 1 – 5, 2015. Correlation coefficients between surface air temperature and electricity-use have been calculated.

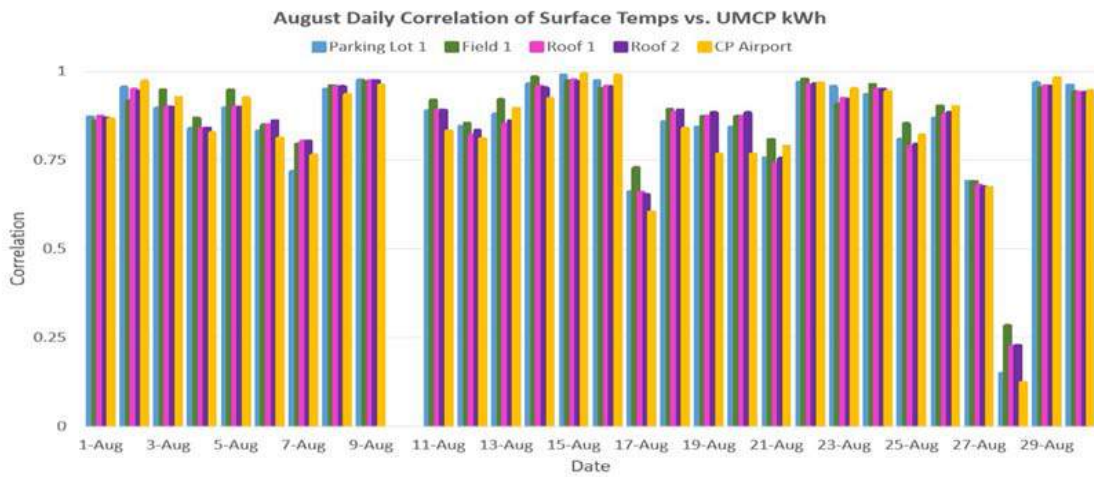


Figure 6: Daily correlation coefficients between surface air temperature and the UMCP campus electricity use in August 2015. August 10 is not included due to missing data.

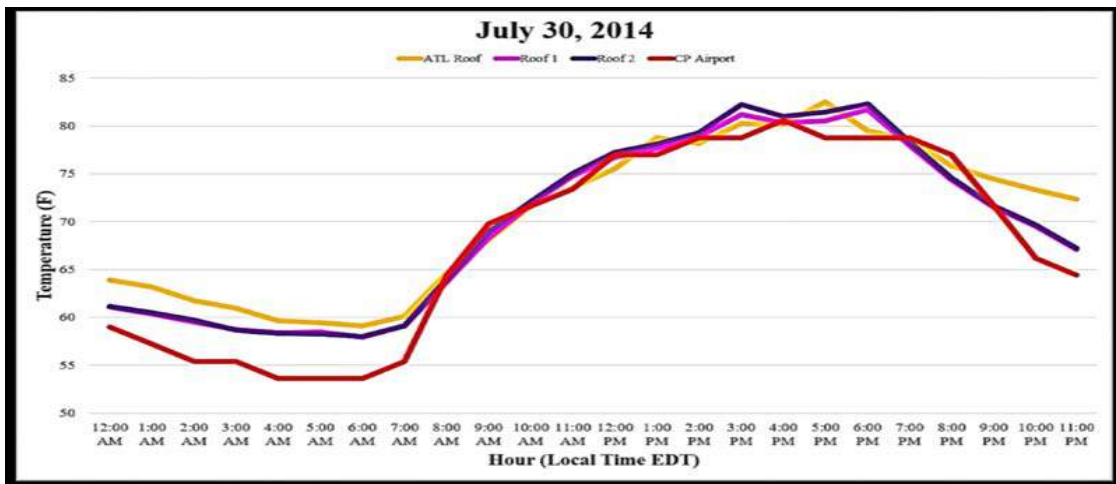


Figure 7: Daily diurnal cycle of 2-meter surface air temperature for the roofs in UMCP campus (ATL Roof), GSFC (Roof 1 and Roof 2) and Collage Park airport (CP Airport).

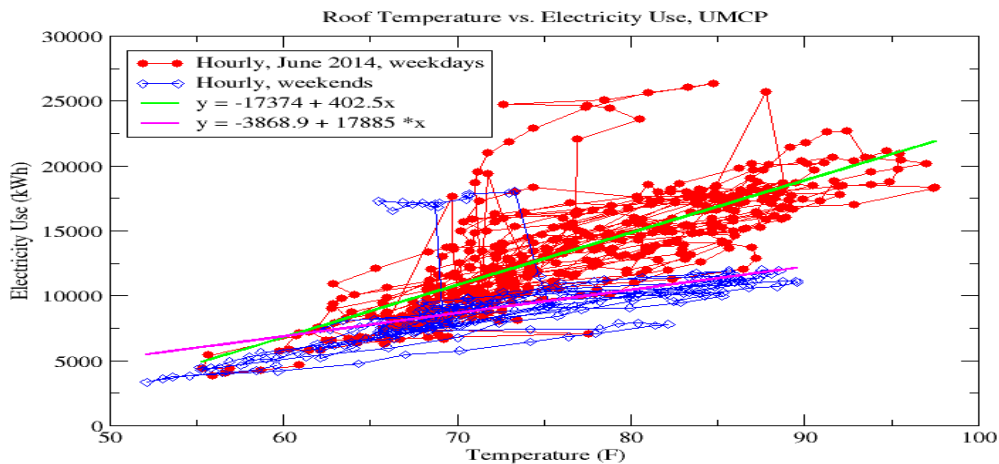


Figure 8: Regression model for UMCP campus wide electricity use based on hourly 2-meter surface air temperature measurements and electricity use data. Data is for June 2014. Weekday and weekends are analyzed differently.





GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: J  
GENERAL ENGINEERING  
Volume 19 Issue 2 Version 1.0 Year 2019  
Type: Double Blind Peer Reviewed International Research Journal  
Publisher: Global Journals  
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

## Cameras for the Drying of the Wood

By Fedor Mende

*Annotation-* In the book are examined different methods of the drying of wood, and also construction of drying chambers for their realization. The universal drying chamber, which ensures the high quality of drying with the minimum expenditures of energy, is in detail described. Camera is fully automated and in all time of drying does not require the interference of operator. In spite of high characteristics, camera is so simple that for its production it does not require special equipment and expensive completing.

*Keywords:* wood, drying, cameras, wood moisture, heat of evaporation.

*GJRE-J Classification:* FOR Code: 091599



*Strictly as per the compliance and regulations of:*



# Cameras for the Drying of the Wood

Fedor Mende

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## I. ESSENCE, PURPOSE AND THE VALUE OF THE DRYING OF THE WOOD

In the growing tree is contained a significant quantity of moisture. It is necessary for maintaining the vital activity of the cells of tree. Under the natural conditions of life of forest the moisture plays positive role also in each extinct tree. It contributes to development in the wood of microorganisms, therefore, to its timely biological destruction and to fertilizer of soil.

With the use of the felled and processed wood appears the need for averting of its biological destruction, giving to wood the resistance to rotting. Most simply this is achieved by removal from the wood of almost entire moisture. Thus from the unstable raw material wood is converted into the very valuable material, which is been preservable long time. However, moisture in an excess quantity frequently is used for the protection of wood from the rotting. It is known from the practice that the underwater part of the piles, the flooded logs and T. p. remain long time - ten and hundreds years. The method of the flood of wood raw material for its seasonal storage widely is used in the plywood production, and the artificial overhead irrigation of the piles of logs - in the saw-mill. In this case of the wood by moisture air (including oxygen), necessary for the vital activity of the wood-attacking fungi, is displaced. Especially rapidly (in 1-2 months) in the summer time spoils felled, but not dressed and, therefore, not dried up in a short time, the wood of beech, birch and aspen; rot the damp boards, packed in the dense piles. Therefore it is necessary the log of these wood species, and also maple, ash, alder-tree, linden and others to urgently saw and then boards immediately to dry with the maximum permissible intensity. Basic factors of rotting the wood: the moderate temperature (5-40° C), atmospheric oxygen and its significant (but not close to maximum) humidity. For

retaining the wood it is desirable so that as a result the dehydration in it would remain the less fifth part of the moisture with respect to the mass of wood itself, and in the case of storage the method of additional moistening the mass of moisture must be more than the mass of wood itself. The ratio of the mass of moisture to the mass of wood itself is called its humidity of. In the noted examples the wood moisture content is 0.2 (20%) and more (more than 100%). If wood will be found under operating conditions on open air, by atmospheric precipitations preliminary drying for the protection of wood from the rotting is useless in view of the inevitability of repeated moistening.

The most economical and extended method of the dehydration of wood - this is its drying, achieved due to the supply to the moist material of heat by heated air (or combustion products) and the removal of the evaporated moisture by the same, but by partially moistened and cooled air. For transforming one kilogram of water into the vaporous state with the atmospheric pressure be required to spend about 2300 kJ (540 kcal) of energy. The process of evaporating the moisture with the aid of air can occur without its artificial preheating, which is characteristic for the atmospheric drying, when the heat of the surrounding air heated by the sun is used. Since the volume of the separating from the material vapor at a usual temperature of drying (50-100° C) approximately in 1,2 - 1,7 thousand once is more than the volume of the evaporated water, vapor is fixed from the heated wood into the ambient air. Consequently, for the drying it is necessary with air to bring energy and to take away vaporous moisture, T. e. to accomplish air circulation using the material. The duration of the process of the drying of lumber in the special cameras is completely significant (1-60 days) depending on thickness and species of lumber. Since with the blowing lumber burst by dry air, the process of drying is carried out in the moist medium. For these purposes the moisture, which was evaporated from the wood, is used: left the pile moistened air repeatedly is preheated in the air stoves (or they add hot combustion products) and for a second time they direct into the same pile of material, the method of the recirculation of air uses.

A quantity of moisture, which is contained in the freshly-felled or floatable wood, decreases because of runoff of it in the liquid state (mechanical dehydration) or the transformation of liquid into the vapor, ie change in its state of aggregation. Is most tempting the removal of moisture from the wood precisely in the liquid state, without the heat expenditure for its vaporization. It is

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noted that in the very damp lumber of some wood species (beech, pine tree) with the vertical position in the summer time the part of the moisture inside the wood overflows it downward and even emerges outside. With heating of wood this effect grows.

By studies is established that with the steaming of beech lumber of the on Wednesday saturated vapor with the temperature near  $100^{\circ}\text{C}$  the substantial part of the moisture is moved away from the wood in the liquid phase during the horizontal addition of boards or billets, ie with the transverse current of moisture. Their humidity with the temperature near  $100^{\circ}\text{C}$ , the atmospheric pressure and the duration of steaming not less than 10 h is reduced from the initial 70- by 80% to 40%, but in the drier simultaneously steamed beech it rises almost to this value. The advance of moisture coincides in this case with the direction of heat flux in the wood, moisture is moved from the greater temperature to smaller.

If vaporization in the moist material occurs at a temperature of equal or higher than  $100^{\circ}\text{C}$ , the process of drying is called evaporation. If vaporization occurs at a temperature of moisture lower than  $100^{\circ}\text{C}$ , process is called evaporation. Since at a temperature lower than  $100^{\circ}\text{C}$  the pressure of vapor it is equal to the atmospheric pressure (0,1 MPa, 1 bar, 760 mmof mercury), under the atmospheric conditions of pairs intensively it can be removed from the material only together with air.

Evaporation from the medium dry material (when moisture is in hygroscopic state) occurs at a temperature of moisture and material higher than  $100^{\circ}\text{C}$ .

In the winter time wood partially gets dry in open air (method of sublimating), when moisture passes from solid state to vaporous.

Thus, by the term the dehydration of imply removal from the wood of moisture in any form of it and by any possible methods.

The wood, utilized in the form of boards and billets in building, machine building, which work woods, furniture and other productions, after the proper drying only acquires biological resistance to rotting, ability to preserve form and sizes of components in the articles, maximum mechanical strength with the smallest density, it is processed well, has minimum thermal conductivity, electrical conductivity and other The mechanical strength of wood sharply grows in proportion to the decrease of a quantity of moisture in the range lower than 30%, moreover it grows continuously to the removal of entire moisture; simultaneously wood becomes more easily. In a number of cases (for example, with the delivery of logs by alloy) the mass of the very moist wood as a result of drying decreases doubly. In proportion to the drying out of wood to a comparatively low humidity are improved its technological properties - cleanliness of sawing, planing, grinding, strength of gluing, fineness and others

Simultaneously rises its heat of combustion, which is substantial with the use of wood wastes as the fuel.

Depending on the conditions of using the wood the purpose of drying and requirement for the separate properties of the dried wood are different: with the mass drying of lumber at the saw-mill plants this averting of the subsequent biological destruction of wood and the decrease of transport loads with the delivery to user; for the building and the wood processing, furthermore, averting the subsequent deformation and premature wear of different devices and articles made of it, and also an improvement in its physicomechanical properties; in the furniture production, besides that indicated, giving a number of positive technological properties; in the special productions (plywood, match, wood boards) - giving to material additional properties in accordance with the requirements of the technological processes of these productions; in the musical industry, besides of entire enumerated, reaching quick aging (stabilization) of wood. In all cases the purpose of drying - transformation of wood from the natural raw material into the industrial material with radical improvement in this case in its biological, physicochemical, technological and consumer properties. As a result drying is obtained the refined material, more qualitative and more valuable, which corresponds to the varied high demands, presented to it under different production and living conditions. The economic value of the drying of wood is great. The drying of wood in enterprises usually is carried out to the assigned magnitude of its humidity in the special drying plants. An essential deficiency in the unseasoned wood -its subsequent second shrinking in the perpendicular direction to the fiber length, which leads to the appearance of clearances in the mating parts, their warping in different directions, splitting. Because of this article after production sharply in a short time reduces its quality indicators or it becomes unsuitable. Consequently, the increased moisture content in the wood during the production from it of production is inadmissible; production will be low-quality, with the small resource of service. For example, furniture (everyday, school, etc) that prepared from the insufficiently dried wood, becomes unsuitable in 2-4 years; the analogous furniture, prepared from the well dried material, serves 20-40 years and more, ie it is approximately 10 times longer.

The woodworking and furniture enterprises will work in the large measure ineffectively, if the drying of wood on them is unsatisfactory and the manufactured production under operating conditions rapidly becomes unsuitable. Doors, window boxes, flooring and overlaps, prepared from the insufficiently dried up wood, after a certain time crack, in them the slots appear; doors and door casings be distorted, the floor boards and the elements of overlap are warped, plastering is destroyed,

structural wooden elements are surprised by fungi. In the winter time this building, which lost airtightness, is blown through by wind. Soon it is necessary to overhaul after its construction. In this case the losses usually many times exceed the basic cost of wood. Almost all lumber should be dried on the spot their sawing, moreover immediately, and it is desirable in the common flow with the sawing. The process of their drying it is necessary to consider as the integral part of the technology of the production of boards and billets. To users must dispatch dry lumber, since with the transport of moist wood superfluously are expended means on the transportation of huge quantities of water, which is about half of the mass of wood itself. Furthermore, moist wood in the way frequently spoils. The incorrect process of drying leads also to the significant losses because of the appearance of stresses, warping and cracks in the material. Unsatisfactory drying and output of rejected product in the drying shop can remain for a long time unnoticed, since the results of the defective drying in the absence of proper control (after the nonuniformity of the humidity of the dried material or its incomplete drying) are shown after the significant time after the production of the production, when it is paid by user and is in operation itself. Drying bypasses inexpensively - of about 10% of the cost of the dried wood. Expenditures for the construction of drying plants in the time of their action (about 10 years) are equal to 1% of the cost of the wood dried in them.

## II. HUMID AIR AND ITS PROPERTY

In nature there is no dry air, in which there are no vapors of water. Such an air can be obtained only by special methods having, for example, passed the humid air through the coil, located in liquid nitrogen. With this procedure with the passage of air through the coil the vapors of water are condensed on the internal walls of coil, and dry air will be obtained at its output.

If is located the mixture of any gases, then each separate gas in this mixture is characterized by partial pressure. The partial pressure  $P_{\Pi}$  this the gas pressure, which it will render it the wall of vessel, if we from this vessel remove all the remaining gases. The sum of all partial pressures of gases, which compose the atmosphere, is equal to atmospheric pressure. Since the water vapors, which form part of the atmosphere are also gas, they have their partial pressure. At an assigned temperature the unit volume of dry air can dissolve in itself only specific quantity of water in the form pair. And the higher the temperature, the greater the quantity of water vapor will be in the obtained mixture. If, at an assigned temperature, they will reach the limit of this solubility, then such an air is called the saturated humid air. To such an air corresponds the

well defined quantity of water, which feels per unit volume of dry air and the well-defined partial pressure of vapors of water of  $P_H$ , which is called or saturation pressure of water vapor. The absolute and relative humidity of air is distinguished.

Absolute humidity this a quantity of moisture, which is contained in one cubic meter of air. Is calculated this humidity into  $g/m^3$ . Is used also this concept as the moisture content of humid air of  $d$ , which indicates the quantity of water, which is contained in one kilogram of dry air  $d = \frac{m}{M}$ , where  $m$  - mass of water in the grams, which is contained in one kilogram of dry air, and  $M$  - mass of one kilogram of dry air.

In connection with the fact that at a specific temperature of air in it can maximally be contained only specific quantity of moisture (with an increase in the temperature a maximally possible quantity of moisture it increases, with the decrease of the temperature of air it it decreases), it is introduced the concept of the relative humidity  $\varphi$ . which is measured in the percentages  $\varphi = \frac{P_{\Pi}}{P_H} 100\%$ , where  $P_{\Pi}$  and  $P_H$  - partial and pressure of water vapor at this temperature. The data about the moisture content of humid air depending on relative humidity are cited in the table1.

For determining the relative humidity of air are used the psychometric charts, in which by a difference in the indications between the dry and moist thermometers it is possible to determine the relative humidity of air.

Tables 1

T	Humidity air, $\varphi$ %											
	100	90	80	70	60	50	40	30	20	10	5	0
	d	d	d	d	d	d	d	d	d	d	d	d
0	3,8	3,5	3,1	2,7	2,3	2	1,5	1,1	0,8	0,4	0,2	0
10	7,8	7,0	6,2	5,4	4,6	3,9	3,1	2,3	1,5	0,8	0,4	0
20	15	13,5	12	10,4	9	7,4	5,9	4,4	3	1,5	0,7	0
30	28	25	22	19	16	14	11	8,1	5,4	2,7	1,3	0
40	50	45	39	34	29	24	19	14	9,4	4,7	2,3	0
50	88	78	69	59	50	41	33	24	16	7,8	3,9	0
60	156	137	119	102	85	69	54	40	26	13	6,3	0
70	268	246	210	176	145	116	90	65	42	20	10	0
80	571	471	387	314	251	196	148	104	66	31	15	0
90	1509	1097	818	616	463	344	248	169	103	48	23	0
100	-	5754	2559	1488	955	635	423	271	158	70	33	0

Tables 2

li icationd dry thermo- meter, °C	Difference in the indications of dry and moist thermometers, °C											
	0	1	2	3	4	5	6	7	8	9	0	
	Humidity air, $\varphi$ %											
12	100	89	78	68	57	48	38	29	20	11	-	
13	100	89	79	69	59	49	40	31	23	14	6	
14	100	89	79	70	60	51	42	34	25	17	9	
15	100	90	80	71	61	52	44	36	27	20	12	
16	100	90	81	71	62	54	46	37	30	22	15	
17	100	90	81	72	64	55	47	39	32	24	17	
18	100	91	82	73	65	56	49	41	34	27	20	
19	100	91	82	74	65	58	50	43	35	29	22	
20	100	91	83	74	66	59	51	44	37	30	24	
21	100	91	83	75	67	60	52	46	39	32	26	
22	100	92	83	76	68	61	54	47	40	34	28	
23	100	92	84	76	69	61	55	48	42	36	30	
24	100	92	84	77	69	62	56	49	43	37	31	
25	100	92	84	77	70	63	57	50	44	38	33	

T dry	Difference in the indications of dry and moist thermometers, °C														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Humidity air, $\varphi$ %														
30	93	87	79	73	66	60	55	50	44	39	34	30	25	20	16
32	94	87	80	73	67	62	57	52	46	41	36	32	28	23	19
34	94	87	81	74	68	63	58	54	48	43	38	34	30	26	22
36	94	88	81	75	69	64	59	55	50	45	40	36	32	28	25
38	94	88	82	76	70	65	60	56	51	46	42	38	34	30	27
40	94	88	82	76	71	66	61	57	53	48	44	40	36	32	29
42	94	89	83	77	72	67	62	58	54	49	46	42	38	34	31
44	94	89	83	77	73	68	63	59	55	50	47	43	40	36	33
46	94	89	84	78	74	69	64	60	56	51	48	44	41	38	34
48	95	90	84	79	74	70	65	61	57	52	49	46	42	39	36
50	95	90	84	79	75	70	66	62	58	54	50	47	44	41	37
52	95	90	84	79	75	71	67	63	59	55	51	48	45	42	38
54	95	90	84	80	75	72	68	64	60	56	52	49	46	43	39
56	95	90	85	80	76	72	68	64	60	57	53	50	47	44	41
58	95	90	85	81	77	73	69	65	61	58	54	51	48	45	42
60	95	90	86	81	77	73	69	65	61	58	55	52	49	46	43
62	95	91	86	81	78	74	70	66	62	59	56	53	50	47	44
64	95	91	86	82	78	74	70	67	63	60	57	54	51	48	45
66	95	91	86	82	78	75	71	67	63	60	57	54	51	49	46
68	95	91	87	82	78	75	72	68	64	61	58	55	52	49	47
70	96	91	87	83	79	76	72	68	64	61	58	55	53	50	47
72	96	91	87	83	79	76	72	69	65	62	59	56	53	50	48
74	96	92	87	84	80	76	73	69	65	63	60	56	54	51	49
76	96	92	87	84	80	77	73	70	66	64	61	57	55	52	50
78	96	92	88	84	80	77	73	70	66	64	61	58	55	53	51
80	96	92	88	84	80	77	74	70	66	65	61	59	56	53	51
82	96	92	88	84	80	77	74	71	67	65	62	59	56	54	52
84	96	92	88	84	80	77	74	71	68	66	62	59	56	54	52
86	96	92	88	84	80	78	75	72	69	66	63	60	57	55	52
88	96	92	89	85	81	78	75	72	69	66	63	60	57	55	53
T dry	Difference in the indications of dry and moist thermometers, °C														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Humidity air, $\varphi$ %														
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

32	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	14	15	-	-	-	-	-	-	-	-	-	-	-	-	-
56	38	35	33	30	28	25	23	21	19	17	15	-	-	-	-
58	39	36	34	31	29	27	25	22	20	18	17	15	-	-	-
60	40	37	35	32	30	28	26	24	22	20	18	16	14	-	-
62	41	38	36	33	32	28	27	25	23	21	19	17	16	-	-
64	42	39	37	34	33	30	28	26	24	22	20	18	17	16	-
66	43	40	38	35	34	31	29	27	25	23	22	20	18	17	15
68	44	41	39	36	35	32	30	28	26	24	23	21	19	17	16
70	45	41	39	37	36	33	31	29	27	25	24	22	20	18	17
72	46	42	40	38	37	34	32	30	28	26	25	23	21	19	18
74	47	43	41	39	38	35	33	31	29	27	26	24	22	20	19
76	48	44	42	40	38	36	34	32	30	28	27	25	23	21	20
78	49	45	42	40	39	37	35	33	31	29	27	25	24	22	21
80	49	45	43	41	40	38	36	34	32	30	28	26	25	23	22
82	49	46	44	42	40	38	36	34	32	30	29	27	26	24	23
84	49	46	44	42	41	39	37	35	33	31	30	28	26	25	23
86	50	47	45	43	42	40	38	36	34	32	30	28	27	26	24
88	50	48	46	44	42	40	38	36	34	33	31	29	28	27	25

In the Table 2 and Table3 are cited the data for the determination of the moisture content of air from a psychrometric difference in temperatures of the dry and moist thermometers over wide limits of a change in temperature and humidity of air.

Table 2 is used for determining the relative humidity of the atmosphere, while Table 3 is used for determining the parameters of the drying agent (air) in the drying chambers.

### III. HYGROSCOPICITY OF THE WOOD

The water to be found in the wood two basic structural elements: in the volume of cells - this the so-called free moisture and in the walls of cell walls. This moisture is called hygroscopic or connected.

The maximum quantity of connected moisture, which can be found in the wood, approximately equally for all wood species comprises at room temperature of about 30%.

Entire moisture of higher than 30% is free. The evaporation of the free moisture from the wood occurs with the same energy losses and from free surface water. Heat of vaporization of water with the atmospheric pressure is 2260 kJ/kg (540 kcal/kg). In order to evaporate one kilogram of water, it is necessary to consume 1.6 kWh of electric power.

The maximum value of wood moisture content, with which is possible the absorption (absorption) by it of moisture from that saturated the ferry boat of air, determines the limit of the hygroscopic state of wood and it can be the defined limit of the hygroscopicity of. Thus, the limit of hygroscopicity designates the boundary value of humidity between the located in the cells of wood at room temperature hygroscopic (to 30%) and free (higher than 30%) moisture.

With an increase in the temperature the limit of hygroscopicity is reduced. Thus, if at room temperature the limit of the hygroscopicity of the wood of all species in any part of the stem of about 30%, then with 60° C about 26%, and with 90° C are reduced approximately to 20%.

The evaporation of the connected moisture, which is located in the cell walls, is hindered, and for its absorption air must be drier, and the expenditure of heat increased. In this case the heat of vaporization of the connected moisture can increase to 3600 kJ/kg (860 kcal/kg)[1].

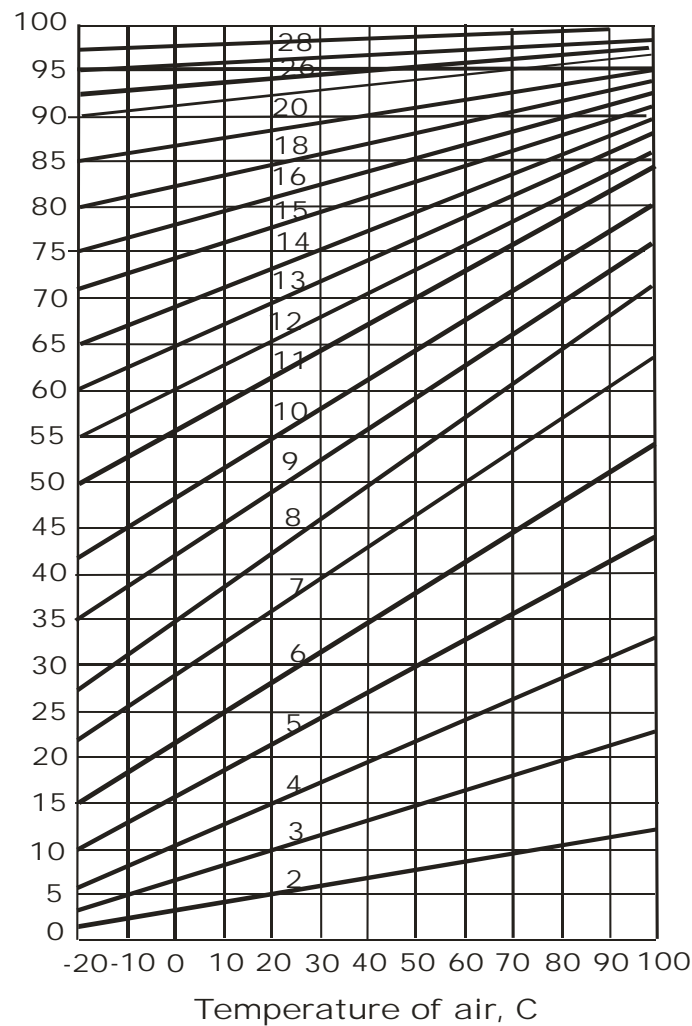


Fig. 1: Diagram of the equilibrium moisture (Н.Н.Чулицкий)[1].

Dry wood possesses large hygroscopicity, and it is, being placed into the moist atmosphere, it rapidly absorbs moisture. Equilibrium wood moisture content corresponds to each value of temperature and humidity of air. Equilibrium moisture this is that humidity, which in the course of time acquires the wood, being found in the humid air with the assigned temperature and the humidity. Thin lumber reach equilibrium moisture faster than thick. The process of absorption of moisture bears exponential nature, and lumber absorb a basic quantity of moisture or they return in the first day of a stay under the new conditions.

For determining the equilibrium moisture is useful to use diagram which is given in Fig. 1. Is here along the vertical axis plotted the relative humidity of air, and on the horizontal - its temperature.

As to use this diagram? For finding the relative humidity of the ambient atmosphere it follows to use the psychometric Table 2 and Table 3. Using these tables, on a difference in temperatures between the dry and moist thermometers the relative

humidity of the atmosphere finds. Moist thermometer is made, winding by its thin layer of cloth and then dipping into the water.

For the more rapid establishment of temperature both dry and wet-bulb thermometer is desirable to blow out with the aid of the fan or by other or what method. If the temperature of air and its humidity is known, then the equilibrium value of wood moisture content is located on the intersection of the lines of the assigned temperature and humidity of air. One should consider that, so that the preliminarily dried wood would reach equilibrium moisture with the ambient atmosphere, is required time and, the thicker the lumber, the greater the time for this is required. For the assortment with thickness about 50 mm to this be required near the 2nd day. But the surface layers of dry wood, as they collect, so also return moisture very rapidly. Even having fallen under the rain, which occurs during the transport of dry wood, the gotten wet lumber rapidly acquire equilibrium moisture with the atmosphere of that accommodation in which they are located. The



gotten wet lumber should be packed in the dry accommodation on the padding and after a certain time it is possible to release them into the production.

To before load lumber into their drying chamber is very desirable to dry up in fresh air. For this the lumber stack on the padding with the thickness 25-30 mm. For the purpose of the more intensive free convection of pile one ought not to make wider than the 2nd meters. With piling of boards it is desirable to plot them not close to each other, but to leave between them clearances (spaces) 3-5 cm. If piles are plotted not under the shed, then as the last layer should be used the rejected boards or slabs. To avoid the soakings of piles during their rain conceal by slate or by another roofing. To avoid the entries of solar rays on the edge of piles, them also guard.

In the summer time this preliminary drying must last approximately one month, in the winter time one-and-a-half two times longer. The measure indicated gives the possibility 2 times to approximately reduce power consumption.

#### IV. PROPERTIES OF MOIST AND DRY WOOD AND THE PROCESSES, PROCEEDING IN THE WOOD DURING THE DRYING BY

The wood, as natural polymer, possesses the elasto-compressible properties: in the heated moist state it easily is deformed as elasto-compressible body, while in the dry state in the larger measure - as elastic. The characteristic property of lumber during their desiccation-appearance in them of deformations and stresses. Deformations are manifested in the direction transverse to the fiber length. Deformations over the section of material appear without the application of external forces; therefore they can be named internal. Are distinguished the reversible elastic of the deformation of wood, which include with the prolonged drying the deformation of elastic after-effect (called sometimes resilient-elastic), and not reversed, residual of with their simultaneous flow in the time in the cross section of the dried assortment. The appearance of internal cracks and microscopic cracks is the most dangerous marriage with the drying of solid rocks. The manifestation of such properties of wood during the drying can be represented by the following experience, which clearly reflects laws governing entire drying process. If we cut off the small piece of damp board, to cleave it longitudinally to two layers (Fig. 1- A), having and then fastened in pairs their ends and heating wood, it is slow, into several stages, to unwedge in the middle (Fig. 1 - B), the layers as a result of application of force will be bent, ie in them will arise the deformations and the stresses, which outside stretch (sign +), which inside compress (sign -). The dried slightly stressed

layers will remain bent even after effort will be removed. In spite of bend, in the wood will not prove to be elastic deformations and, therefore, it will not be stresses. If we then both bent layers longitudinally cut into the plates and to even them from one end, plates will prove to be the different length: in the middle it is shorter, and on the edges are longer (Fig. 1- B) although their humidity will be identical. Is explained this by the fact that tensile elastic stresses acted outside the layers and deformation, after extending their external zone. In the inner zone were manifested the compressive elastic deformations, which also passed into those not reversed, residual, after reducing the size of wood (independent of shrinkage, additionally to it). Hence it follows that under the action of elastic deformations wood behaves as elasto-compressible body, it can permanently be extended or be compressed, especially in the moist and heated state. In this case the elastic deformation spontaneously passes into the residual, fixing new size. Is such the characteristic of the first stage of the drying, when the danger of appearance in the lumber of external cracks appears.

If we without cutting both bent layers into the plates, attempt ourselves to straighten them, in the outer zone will appear those compressing, but in the internal - stretching elastic deformations. In the case of the application of significant force, the stretching elastic deformations in the inner zone of layers can lead to the internal cracks. If wood was compressed having gradually, preliminarily moistened heating its, internal cracks will not appear and the dried layers stopped up in the flat state will gradually become straight lines. After cutting them to the plates, it is possible to establish that the length of all plates is identical as at the beginning of experience. This means that residual dilatational strain arose in the inner zone of layers, and in the external - compressions, ie occurred the phenomenon, opposite earlier to that observed. In this schematically consists the characteristic of the second stage of the drying, when there is a danger of appearance in the thick lumber of the internal cracks, which resemble shells in the metal-casting.

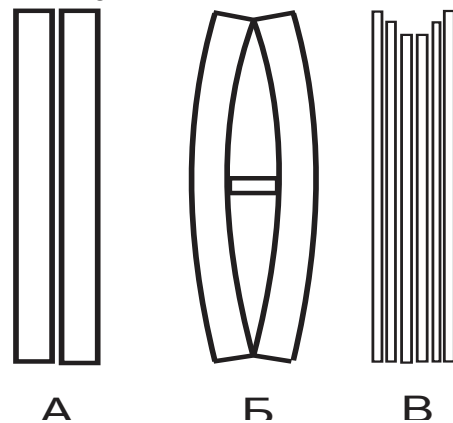


Fig. 2: Diagrams of the elasto-compressible deformations of wood during the drying.

But this is the only mechanism of the formation of internal cracks. It is experimentally known that with the slow drying the coefficient of shrinkage is greater than with the rapid. If the rate of drying is too high, then the outer layers of board dry more rapidly, while inner layers they remain still moist and they continue slowly to dry. In this situation in the board is formed the box of outer dry layers, whose coefficient of shrinkage is less than in those inner layers, which will dry more slowly. This leads to the fact that the longitudinal cracks and microscopic cracks begin to appear during the continuation of drying inside the board.

Of the property of wood as elastic body must be known because one of the basic defects of drying (internal cracks and shell) can be explained only by formation and accumulation of residual deformations in the heated moist wood. For this reason external cracks at lap-time frequently do not appear even with a large drop in the humidity on the thickness of assortment. Furthermore, as a result of the manifestation of residual deformations changes the value of shrinkage and warping the correctly packed (fixed between the padding) material is prevented. This important property of wood must be correctly used for purposes of its more qualitative drying.

With the decrease of the content in the wood of connected moisture, T. e. with the humidity it is lower than 30%, intracellular moisture begins to evaporate and wood dries. With the presence in wood of the free moisture, when its humidity exceeds 30%, the sizes of the cells of wood are kept constants. Thus, the limit of hygroscopicity (30%) -this simultaneously the limit of the shrinkage of wood. Shrinkage and reverse process - swelling - the inherent properties of natural wood.

in connection with the anisotropism of structure the shrinkage of wood is unequal in different directions: lengthwise fibers it smallest (of about 0,1% with the removal from the wood of entire moisture). Large longitudinal shrinkage is characteristic only of wood, which grew in the inclined state, (to 5%). The greatest shrinkage (to 8 12%) occurs in the direction of annual layers, ie in the tangential direction. Shrinkage along a radius of stem composes 4-8%, ie almost 2 times less than in the direction of annual layers. The wood of alburnum dries somewhat more than the wood of nucleus. Shrinkage on the end area and also by the volume of assortment, is approximately equal to the sum of shrinkages in the radial and tangential directions. For example, if shrinkage in tangential direction 10%, and on radial 6%, wood dries both in the cross section and by the volume approximately to 16%, independent of the form of pieces. The value of the shrinkage of wood by the volume approximately corresponds to the volume of the connected moisture evaporated from the wood. Since the wood of more compact rocks contains per unit of volume more than the connected moisture, it

more dries. Consequently, the wood of oak, maple, h<sup>o</sup>nbeam and as it is characterized by larger shrinkage than the wood of fir tree, poplar, alder-tree. Exception from this rule is the shrinkage of the wood of aspen and linden, which approximately corresponds to the shrinkage of oak. It is characteristic for the wood of linden, furthermore, the small difference in the value of radial and tangential shrinkages, in consequence of which this wood they prefer with the production of critical components, for example in the pattern production. On the contrary, in the wood of cedar and fir tree radial shrinkage is small in comparison with the tangential (1: 27).

In the practice of the calculation of drying plants use the not depending on the shrinkage conditional density of the wood of  $\rho_y$  (kg/m<sup>3</sup>), by which is implied the ratio of the mass of wood in the absolutely dry state of  $m$  to its volume of  $V$  with the humidity of higher than

$$30\%: \rho_y = \frac{m}{V}.$$

The values of conditional densities and humid characteristics of the wood of basic wood species are given in the table № 4.

Using a concept the conditional density of convenient to find a quantity  $M$  (kg/m<sup>3</sup>) of the moisture, moved away 1 m<sup>3</sup> of wood, in spite of a change in this case in its volume:  $M = \rho_y (w_h - w_k) / 100$ ,

where  $w_h$  - wood moisture content to the drying (%);  $w_k$  - wood moisture content after drying (%). The value of shrinkage, in reference to 1% of decrease of a quantity of connected moisture, is called the coefficient of shrinkage, and it is designated by the letter  $k$ .

The percentage of the shrinkage  $U$  according to this direction will be determined by the multiplication of the coefficient of shrinkage by the value of the decrease of humidity in the hygroscopic state (ie is below 30%)  $U = K(30 - w_k)$ . For example, the thin, slowly dried pine board with the width of 200 mm, tangential sawing, with the initial humidity is higher than 30% and by final 10%, with  $k=0,31$  will dry to the value in 0, 31 (30 - 10) =6,2%, ie its width in the dry state will be 187,6 mm. The lateral deformations of lumber, which are manifested with the drying, have great significance for the effective use of wood.

## V. DRYING REGIMES OF LUMBER

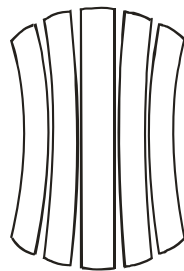
Drying regime is called the totality of the actions of the drying agent (air) on the material, which ensure the assigned quality and the speed of its drying. Drying regimes are represented in the form the timetable of the

temperature of air, its psychrometric difference and the state of material, which are changed in the Tables 4.

*Tables 4:* Process of drying. They provide for three stages of drying and they are represented in the table № 5. In the table are accepted the following designations.

Wood Species	Density			Coefficient of shrinkage in % to 1% of humidity			Wood moisture content on the root	
	Humid. 12%	Abs. dry	Humid. conditi	Radial	Tangen-tial	Volu-metric	Heart-wood	Sap-wood
Birch	630	600	500	0.28	0.34	0.64	78	78
Beech	650	620	530	0.18	0.35	0.55	64	64
Hornbeam	800	760	630	0.24	0.35	0.61	60	60
Oak	700	650	550	0.19	0.29	0.50	64	72
Spruce	450	420	360	0.17	0.31	0.50	40	118
Cedar	440	410	350	0.12	0.28	0.42	70	115
Maple	690	650	550	0.20	0.32	0.54	51	51
Linden	500	470	400	0.23	0.33	0.58	63	60
Larch	660	630	520	0.20	0.39	0.61	82	82
Alder	530	490	420	0.17	0.30	0.49	84	84
Aspen	500	480	400	0.15	0.30	0.47	82	82
Fir	380	350	30	0.12	0.31	0.44	101	101
Pine	500	470	400	0.18	0.31	0.51	33	112
Poplar	460	430	360	0.14	0.28	0.44	110	110
Ash	690	650	550	0.19	0.31	0.52	35	36

as a result of the larger shrinkage of wood in the tangential direction, than in the radial, the boards, sawn from the log, acquire after drying form shown in Fig. 2



*Fig. 3:* End form of boards after their drying.

T - the temperature of air in camera, t - difference in the temperature between the dry and wet-bulb thermometer,  $\varphi$  - humidity of air in the camera.

Table 5

	Humidity the wood	The number of regime and the humidity of air in the camera $\varphi$ %														
		1			2			3			4			5		
		T	t	$\varphi$	T	t	$\varphi$	T	t	$\varphi$	T	t	$\varphi$	T	t	$\varphi$
A	$\geq 30$	90	4	85	82	3	88	75	3	87	69	3	87	63	2	91
	30 – 20	95	7	76	87	6	78	80	6	77	73	6	76	67	5	78
	$\leq 20$	120	32	32	108	27	35	100	26	35	91	24	36	83	22	36
B	$\geq 30$	90	5	81	82	4	84	75	4	84	69	4	83	63	3	86
	30 – 20	95	9	70	87	8	72	80	8	70	73	7	72	67	6	75
	$\leq 20$	120	34	29	108	29	32	100	28	32	91	25	34	83	23	34
C	$\geq 30$	90	7	75	82	6	77	75	5	80	69	5	79	63	4	82
	30 – 20	95	11	65	87	11	66	80	9	66	73	8	69	67	7	71
	$\leq 20$	120	36	26	108	21	30	100	24	30	91	26	33	83	24	32
G	$\geq 30$	90	9	69	82	8	71	75	7	73	69	6	76	63	5	78
	30 – 20	95	13	60	87	12	60	80	11	61	73	10	63	67	9	64
	$\leq 20$	120	37	25	108	33	27	100	31	27	91	28	30	83	25	30
D	$\geq 30$	90	11	63	82	10	65	75	9	66	69	8	68	63	7	70
	30 – 20	95	15	54	87	14	55	80	13	55	73	12	56	67	11	58
	$\leq 20$	120	38	24	108	35	24	100	33	25	91	30	20	83	27	28

The disturbance of regime in these stages with the drying of solid rocks is separately dangerous. The upper layers of lumber begin to dry up with too intensive a drying, forming the rigid crust, which not only prevents the removal of moisture from the lumber, but it does not give to be compressed to the inner layers of the woods, which dry more slowly and therefore they have the larger coefficient of shrinkage. This regime leads to the appearance of internal microscopic cracks, and, therefore, to the marriage.

## VI. UNIVERSAL LUMBER-KILN CAMERA

The described methods of the drying of wood, which foresee its three stages, do not yield to automation and require a constant interference of operator. Moreover, any disturbance of regime, can lead to the irreparable consequences, whose price is very great, as wood, especially solid rocks, stands not cheaply. Now we will in detail describe the fully automated camera, which in entire cycle of work does not require the interference of operator. Moreover in the camera with the identical success can be dried both soft and solid rocks of wood. Such cameras are exploited by us and our customers of more than 10 years, and in them it was not serious breakdowns. In several cameras it was necessary to replace the malfunctioned engines, but these are not our fault, but the fault of the producers of engines.

With the construction of any complex article always is necessary to be encountered with the need for

fulfilling contradictory requirements and to find between them a compromise. It is known that any universal device, capable of carrying out several functions, always more complex and is less reliable than the device, intended for fulfilling one function. And rarely it succeeds to reach this compromise that this would be not thus. The described camera presents that rare case, when to make this it was possible.

Let us formulate the basic tasks, which were placed with the development of the camera indicated:

1. The first and main condition is this obtaining of the high-quality dry wood, which possesses the assigned humidity, the absence in it of the external and internal cracks in the absence of warping and the guide of assortment. These conditions correspond to the first category of drying.
2. Simplicity into operation and independence of regime from possible turning offs of electric power. This requirement is especially important with the operation of cameras in the rural locality, where such stoppages not rarity.
3. Ease of fabrication not requiring the specialized equipment and expensive completing.
4. Simplicity of assembling and dismantling, and portability in the dismantled state in the cargo machine.

5. Simplicity of replacement all completing, that malfunctioned in the process of operation, without the unloading from the camera of wood.
6. Correspondence to ecological requirements with respect to that locality, where the camera is used,
7. Camera must be flame-resistant and this one of the most important requirements.

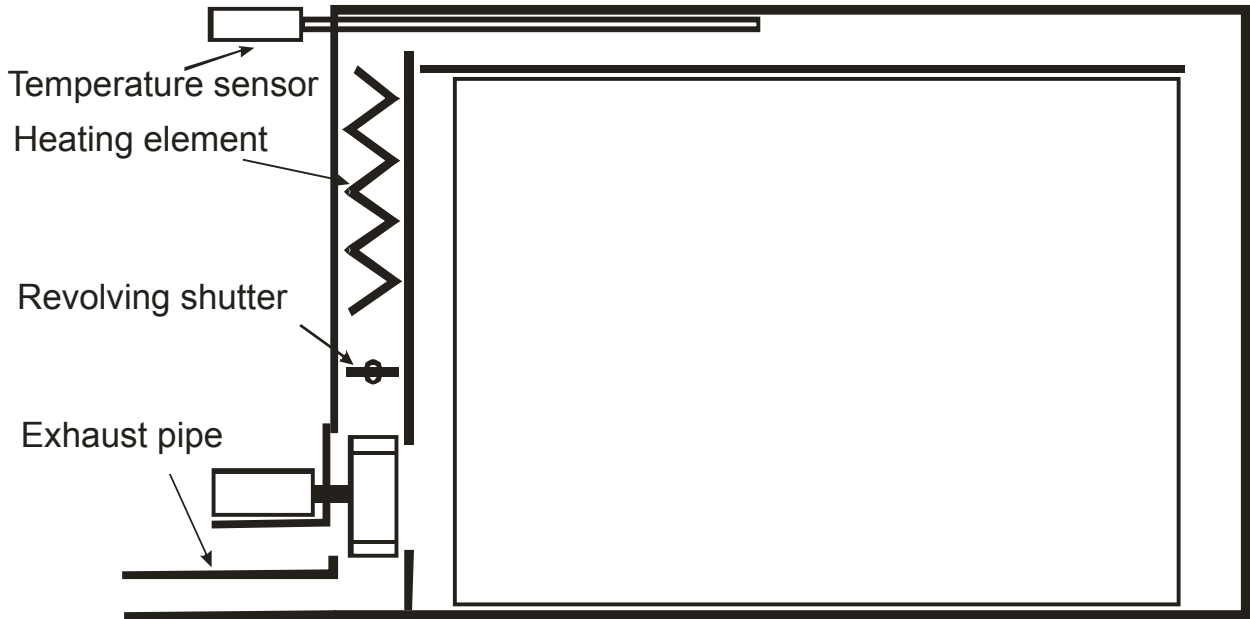


Fig. 4: Diagram of universal drying chamber

In the literature very box of camera accepted to call enclosures and subsequently we will use this terminology.

Let us at first draw the overall diagram of camera (Fig. 3), and let us then describe its separate units and methods of their production.

On the rear end chamber wall is established the engine, to axis of which is mounted the fan blower of the type squirrel wheel. Opening in the rear wall is executed this diameter that the wheel of fan would resemble through it. This construction makes it possible to extract fan and engine in the case of failure of engine, without unloading from the camera wood. The L-shaped shutter, which is adjacent to the chamber wall, overlaps the part of this opening. The lower part of the shutter is done made of steel with a thickness of 5-7 mm and the engine is fastened to it. This shutter with the aid of the corners is attached to the end chamber wall. The vertical part of the shutter is made made of the sheet stainless steel with a thickness of 0.5 mm. If we look at the engine from the end-face, then under G with descriptive shutter is visible the semicircular part of the opening, through which is put the wheel of fan. During the work of the fan through this opening air suction from the atmosphere occurs. For the adjustment of the intensity of sucking this opening is shut by lath with the

openings (in the diagram it is not shown), which can be stopped. Necessary air suction from the atmosphere is established by the selection of a quantity of open openings. The diagram of this lath is shown in Fig. 4. In the lath there are 5 openings with a diameter of 30 mm.



Fig. 4: Planck with the openings

In the lower part of the end wall is an exhaust pipe, through which is achieved the ejection of humid air. Pipe must be made from stainless steel aluminum or plastic, since with the drying of oak the condensate, which is formed in the pipe, contains the tannic acids, which destroy usual steel. Diameter of pipe 60-70 mm. Established it should be with a certain inclination downward so that condensate resultant in it would not enter back the camera. The exterior of the pipe should be warmed so that it would not get chilled in the very cold weather. The height of the foundation of camera is selected in such a way that the external end of exhaust pipe would be above the level of soil. For this purpose before the filling of foundation and for the purpose of the savings of the utilized expendable material it is

possible to pour the earthen pillow with a thickness of ~ 10-15cm. having preliminarily packed it.

Since in the given construction air into the camera is forced, with the nonacceptance of the corresponding measures, can become unsuitable steel framework and thermoinsulation of enclosures. With the elevated pressure in the camera the humid air through the uncontrollable slots in the inner casing can penetrate the interwall space, will be there condensed moisture, which can spoil the steel framework of enclosures. Thermo-insulating material will be also saturated by moisture, losing its properties. In the given construction this problem is solved with the aid of the swivel damper. Turning it, it is possible to create additional obstacle to the air flow, whose circulation ensures fan. Therefore the highest air pressure will be observed in the ventilator section, where the wheel of fan is located. In all remaining parts of the camera, the air pressure will be lower than in this section. But since that indicated cut off connected with the atmosphere with the aid of the exhaust pipe it has atmospheric pressure, pressure in all internal parts of the camera there will be below atmospheric.

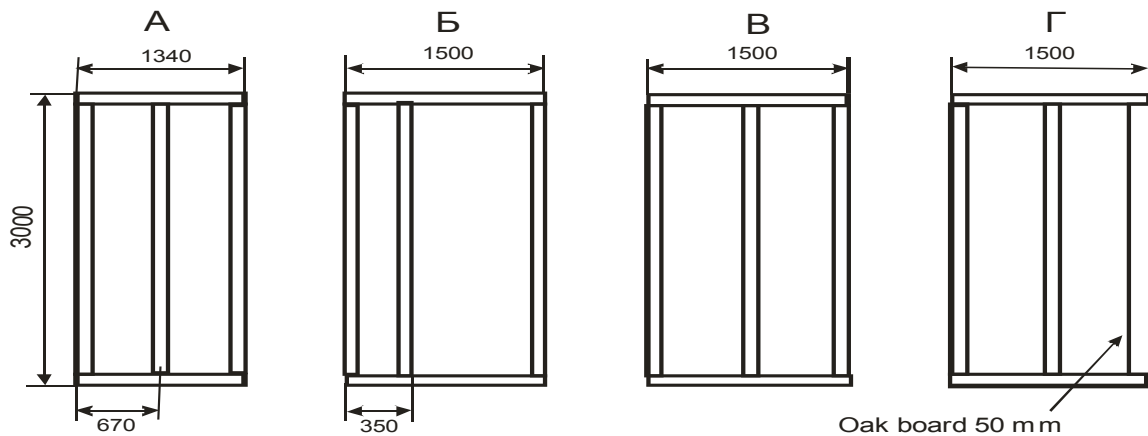
The turning of shutter must be selected in such a way that it would overlap the approximately 1/3 cross-sectional areas of ventilator section. This shutter is necessary still and in order to ensure the uniform blowout of heaters, located in the upper part of the section. In the case of its absence the straight airflow, rejected by fan blower, unevenly blow out heaters. In those places, where the tape of electric heaters is located in immediate proximity to the wheel of fan, intensive blowout can lead to its vibration, which with the prolonged operation can lead to its impulse. For the purpose of simplification the shutter can be made stationary, after fastening it to the rear chamber wall, or to the panel, which separates camera from the ventilator section.

Thus, one fan fulfills the immediately four functions: it achieves scavenging of pile, induced air from the atmosphere, ensures the ejection of humid air into the atmosphere and the reduced pressure in camera itself.

Above the shutter are established the heating elements, which can be as electrical heater, so the batteries of water heating boiler.

In the upper part of the camera is established the temperature sensor, which ensures its automatic work. Its construction and operating principle we will examine, when we will describe the regime of chamber operation.

The diagram of chamber operation we examined, now let us describe the construction of its separate units and elements. And let us begin from the enclosures, which present the hermetically sealed heat-insulated boxing, whose internal and external casing must correspond to definite requirements. External casing must be long-lived, not requiring a constant withdrawal and maintain the action of environment (rain, frost, the action of sun rays). The requirement of airtightness is not presented to the external casing. Inner casing must be airtight and maintain the action of the aggressive media, which the pairs of oak, which contain tannic acids, are. The thermal insulation material, which ensures high heat insulation, must be placed between the external and inner casing. One ought not to be fascinated by the excessively high heat-insulating properties of this layer, since. this leads to the rise in price of camera. Thermal insulation properties are selected so that the energy consumption due to the withdrawal of heat into the environment with the strongest frost it would compose ~2% of the general energy consumption of necessary for the realization of process drying. In this camera is used the foam plastic with a thickness of 40 mm, which is plotted between the skins of camera in two layers. Adaptation for cutting the foam plastic is given in the application №1.



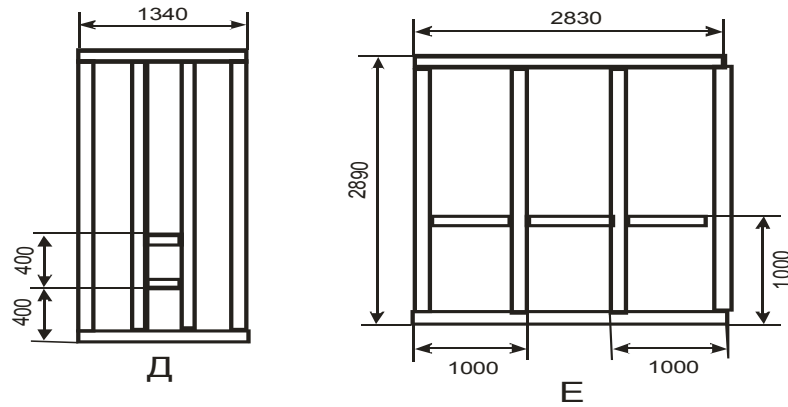


Fig. 5: Sketches of frames for preparing of walls, ceiling and door of camera.

The camera in question can have two overall dimensions: 3000x3000x4500 and 3000x3000x7500 mm. The first overall size is intended for the drying of wood with an overall working volume 8 m<sup>3</sup> and with a length of the assortment 3 m, in this case in the camera is placed one pile and is used longitudinal scavenging. With the second overall size in the camera are placed consecutively two piles of the same assortment. The requirement of the rapid assembling of camera and portability in the cargo machine forces the elements of enclosures to make with unit type. The bodies of these

blocks are made from the pine board with a cross-section of 30x140mm. One of the boards of lateral chamber walls, to which fits closely the door of camera, it is carried out from the oak board with the section of 50x140. The nuts, utilized for the sealing of door against the edge of camera, are fastened to this board. Ceiling blocks are made according to the same principle.

The sketches of all blocks of entering the assembly are given in Fig. 5. In all blocks there is a central partition, necessary for the rigid fastening of the sheets of internal and external casing.

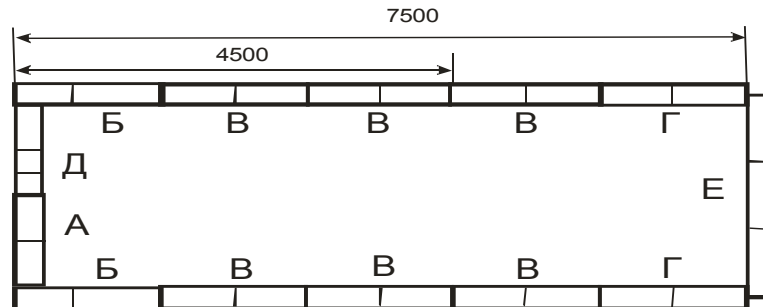


Fig. 6: Sequence of the installation of the blocks of camera.

In Fig. 6 is shown the sequence of the installation of the blocks of enclosures (top view). By thin lines on the blocks is indicated the arrangement of partitions. The units of lateral walls are established specularly. This must be considered with their production. Block Г is mounted in such a way that the oak board would fit closely to the door. In the case of the camera with a length of 4500 mm of two first of wall block from the side the doors are not mounted. All sections of the ceiling of camera are mounted from the blocks of the type v. The section, which is adjacent to the door, is exception, the block Г, turned by oak board to the door, is used for this section.

Of frame and partition in them are made from the pine board by the section of 30x140 of mm. With the cut of boards it is desirable to use mounts, since, even insignificant deviations from the size significantly complicate assembling. The sizes of the frames of

blocks are selected in such a way that in them as the external and inner casing it would be possible to use sheet slate with the size of 1500x3000. In this case should be considered the circumstance that sheets themselves are not precise rectangles, but they present parallelogram. Therefore before the skin of blocks should be sheets cut in such a way, that their diagonals would be identical. In this case the length of sheet can somewhat be reduced, that it is necessary to consider with the production of frames. Therefore the size of frames lengthwise, indicated on the sketches is reference. Sheets to the frames are attached with the aid of the wood screws. With drilling of holes under the wood screws should be the diameter of opening selected on 2 mm more than the diameter of wood screw. This is necessary in order to avoid the break of slate with a change in its size during a change in the temperature in the camera. Opening under the head of

wood screw it must be produced so that during its tightening its upper edge would be below plane of slate. After assembling of block and tightening of fastening wood screws this opening is filled up with sealing compound, this is necessary so that the aggressive pairs of oak would not destroy wood screw.

To avoid of the cancerogenic influence of internal slate skin on the wood camera from within is colored with nitrocellulose enamel. During assembling of camera all possible slots between the blocks also are sealed with the aid of the sealing compound, white or transparent silicone sealing compound for these purposes is used.

Space between the internal and external casing is filled up with heat insulation. For this is used the foam plastic with a thickness 40 mm, which is plotted in two layers. With cut and piling of foam plastic one should follow the fact so that the joints of foam plastic in the lower and upper layer would not coincide. This is necessary for that reason, that with the continuous operation the foam plastic can shrink, and if we this rule do not observe, then through seams worsen the heat-insulating properties of heat insulation.

It is possible to use other materials for the internal and external casing. For example, inner casing can be made from the sheets of stainless steel, or aluminum, which substantially raises in price camera. With the use of this skin and the standard sizes of blocks can be changed for the purpose of the more economical utilization of standard standard sizes of sheets. It is important only so that the overall dimensions of camera strongly would not exceed the limits indicated.

The important element of enclosures is the door of camera, it is its front end wall. Door must easily be opened, and with the discovery ensure the free load of camera with lumber. During the closing it must ensure the reliable hermetic sealing of camera. The reinforced rubber high-pressure hose with a diameter 20 mm, used in the hydraulic systems, is used for this. It is fastened with the aid of the U-shaped wire brackets, made from the stainless steel.

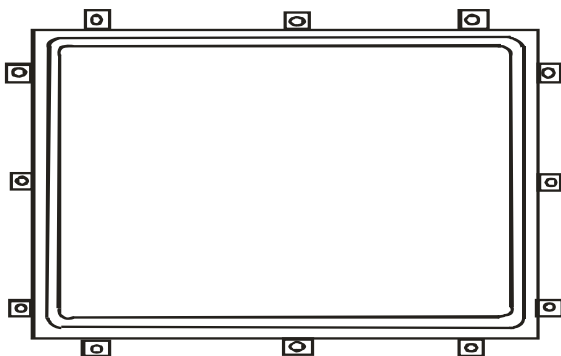


Fig. 7: Schematic of fastening the sealing hose and corners of the delay of door.

Diameter of wire 2mm. With the aid of these brackets the hose is fastened along the periphery of door frame, as shown in Fig. 7. The longitudinal section on the width of bracket is done for this in the place of the choking of brackets, in the hose. With this method of fastening the hose remains elastic for entire its elongation and provides the airtight adjoining of door to the end blocks of camera during its closing.

In Fig. 7 are shown also the corners, which are attached to the lateral ends of door with the aid of the wood screws (small small squares along the sides of door). In these corners, cut out from corner 50, are openings with a diameter 25 mm, through which are passed the steel bolt with screws M16, with the aid of which the door is attracted to the chamber end. Opposite these openings to the ends to the blocks of walls and ceiling of camera are attached the reciprocal nuts, into which are screwed up the draw bolts. These nuts present the squares of 20 x35x50, on to center which is cut the thread M16, and on the edges there are four openings, with the aid of which with wood screws the nut is attached to the oak board of wall blocks and block for the ceiling. The operation of fastening nuts must be produced with the aid of the mounts, since the absence of the coaxiality of the threads in the nuts and of openings in the corners will not make possible to screw up draw bolts after closing of door.

As the loops of door, on which is accomplished its suspension, serve the faceplates, screwed on to the upper and lower end of door with the aid of the wood screws. These faceplates will be joined with the reciprocal corners, which are attached to the lateral chamber walls. In the faceplates and the corners there are openings, through which are passed the fastening bolts. Opening in the faceplates are made by oval, as shown in Fig 16. This form of opening is necessary for that reason, that with the delay of the bolts, which force door against chamber end, occurs the shrinkage of the sealing hose; therefore loops must have the appropriate degree of freedom. The schematic of the upper and lower unit of the suspension of door to the chamber wall is shown in Fig. 8.

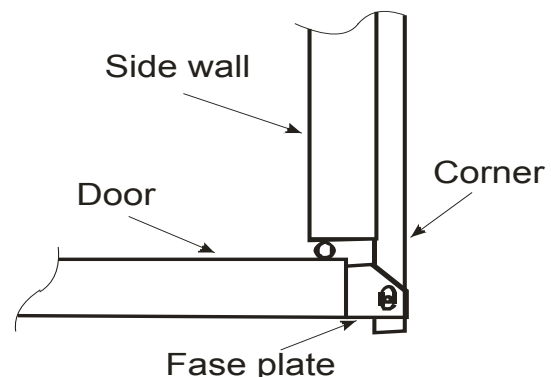
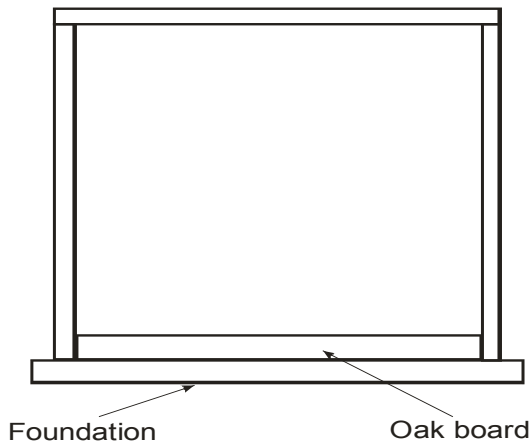


Fig. 8: Unit of the suspension of door to the chamber wall.



The camera is established on the foundation, which presents plate from the keramzit concrete with a thickness 7-10 cm. dimensions of which are selected in such a way that its edges would fall outside the edge of camera 5-10 cm. In the absence keramzit concrete as the material for the foundation can be used cement mortar with the relationship of cement to the sand 1:6. For piling the foundation it does not be required the special preparation of soil, area must be purified of grass and levelled so that there would be the small inclination to the side of the door of camera. This inclination gives the possibility to emerge to the condensate, which in the first stages of chamber operation is condensed on the foundation.



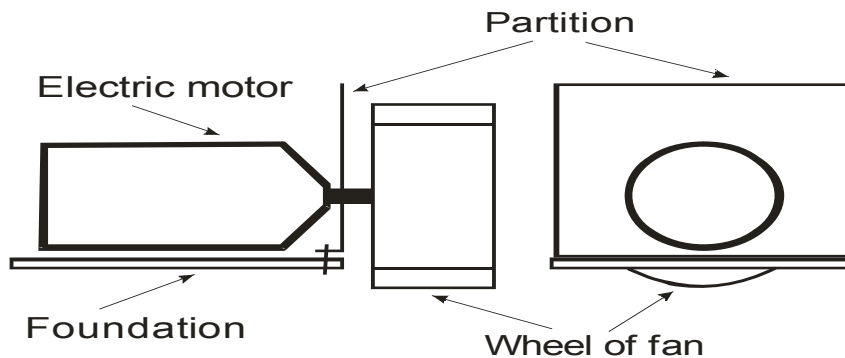
*Fig. 9:* Form of camera on the foundation from the side of door.

In the lower part of the front chamber end with this end be fastened to in range oak board with the thickness 50mm(Fig. 9).

The nuts for the bolts of the delay of the lower part of the door are attached to this board.

The first row of the padding, to which is plotted the pile to the foundation, has a thickness not less than 70 mm, the section of the remaining padding of 30x40 mm. The first pile is plotted so that between it and partition, after which is located ventilator section, would remain clearance not less than 200 mm.

Let us examine the diagram of installation of fan in the block d. As the fan is used the fan blower of the type the squirrel wheel with the diameter of the wheel of 315 mm, which is mounted to the axis of engine. Engine is established on the steel platform 5x360x400, as shown in Fig. 11 to the left. The type of layout is from behind shown on by right figure. Between the engine and the wheel the descriptive partition, made from the sheet stainless steel, which is attached to the platform with the aid of the bolts, is established by G. Size of the partition of 300x355 mm. Engine is established in the aperture of block d. The form of aperture is shown in Fig. 12 a. In the place of aperture in the inner casing of camera is an opening along the diameter of the wheel of fan. There are also lateral corners, on which is established and is fastened the platform of engine. When on these corners as on the sleds, fan begins to move to the adjusting place, the wheel of fan, it occurs inside the camera, and  $\Gamma$  descriptive partition shuts the large part of the opening for the wheel of fan. There remains only the part of the open opening under the platform. Through this opening occurs air suction into the camera. For the adjustment of the intensity of sucking under the platform is established the lath with the openings, shown in Fig. 11. Openings can be stopped up by different quantity of plugs how is regulated the intensity of sucking.



*Fig. 10:* Layout of fan on the platform

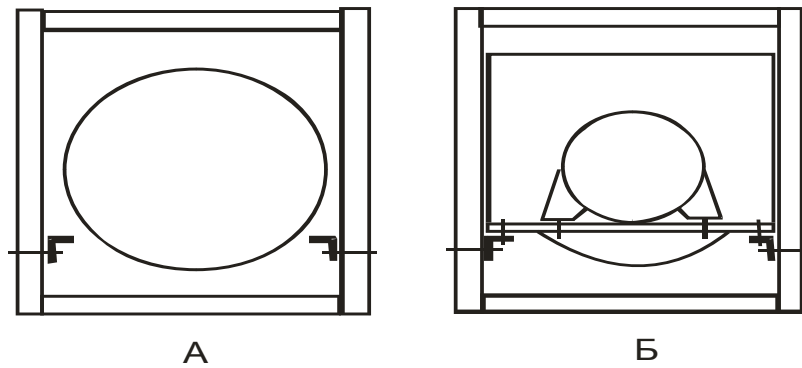


Fig. 11: Aperture for the installation of fan (form A) and the fan, established in the aperture (form B).

As the heating elements in the camera can be used both the batteries, fed from the gas hot-water boiler, and electric heater. As the water heating elements it is best to use the steel tubes, supplied with the spiral heat exchanger, made from aluminum. Such tubes are produced by industry and of them it is possible to collect batteries. Camera can be supplied with electric heaters. Is undesirable the use of plant which to high temperatures, and this is dangerous.

For the effective drying the heaters must ensure approximately with 1 kW of power to each cubic meter of wood with the drying of solid rocks and it is twice more as with the drying of soft.

Let us give the parameters and the construction of the effective safe heater, made from strip that not corroding they became 12X18H10T(it is possible to use other stamps). The tape with a thickness 0.3 mm with the width 20 mm. is necessary for this. With the presence in camera of pile with a volume  $8 \text{ m}^3$  for guaranteeing the power of heater 8kW the resistance of tape must be 6 Ohm, in this case its length will be 30 m. Unfortunately, this tape industry

does not let out and it is necessary to cut out by hand it from the roll assortment. If in the camera two piles are located, then should be established two such electric heater.

For the drying of the soft rocks, where it is necessary to increase the power of heaters approximately two times, electric heaters are included between the phases, which gives this increase in the power. The temperature of the belt of this heater with the power indicated does not exceed  $200 \text{ }^\circ\text{C}$ , which is completely safe, since dry wood begins to be charred only at a temperature  $350 \text{ }^\circ\text{C}$ . Furthermore, electric heaters are established between two slate partitions and of direct contact with the wood have they cannot.

The tape of electric heaters is located on the holders (hooks) with zigzag means, as shown in Fig. 13. The slate plates, to which are fastened the hooks, are attached to the upper and lower corner with the aid of the strips made of the sheet stainless steel. The ends of electric heaters are soldered to the lamellas from sheet copper, to the same lamellas are soldered the net wires, which through the openings in the chamber wall depart to the switchboard.

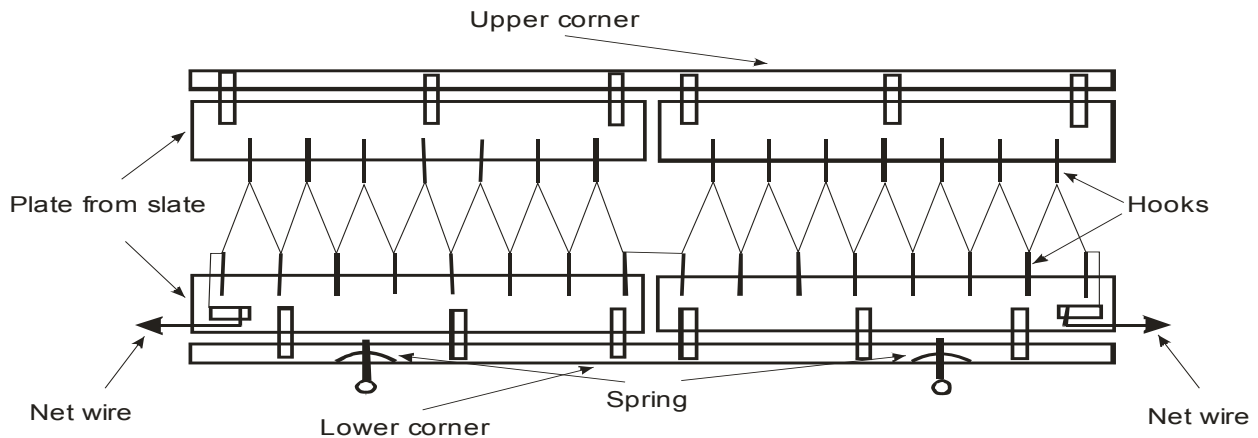


Fig. 12: Construction of electric heater.

With an increase in the temperature of belt it is enlarged in order to compensate for this expansion they are used the spring units, which shift lower corner with

this expansion. The construction of spring unit is shown in Fig. 14.

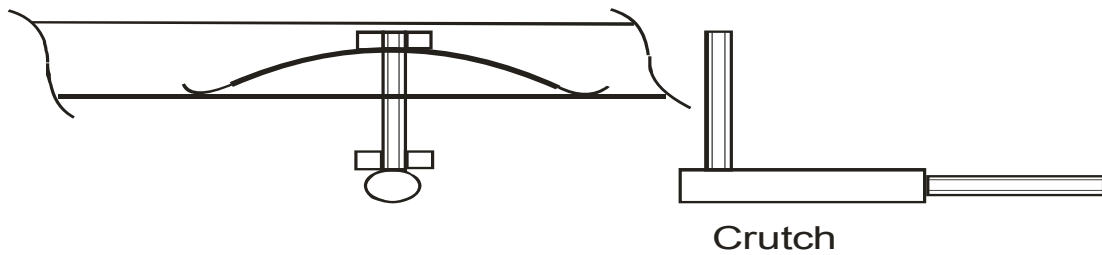


Fig. 13: Construction of spring unit.

On the crutches, which with their shank screw themselves into the rear wall, is located the pintle with the thread, on which are located two nuts. Brass flat spring is located between the upper nut and the shelf of lower corner. During assembling of electric heater lower nut turns upward to the support, completely compressing spring. After assembling it descends to the lower position, ensuring the necessary motion to lower corner with the expansion of the tape of electric heater. Openings for fastening of crutches on the rear chamber wall are bored opposite the central wooden cross connections, then in them thread is cut, and crutches screw themselves. Thus are accurately fastened the pins, to which is fastened upper corner. The length of shank in crutch and pins must be order 50-60 mm so that it reliably would be held into the board.

Fastening the hooks on the slate plates and of electric heater themselves in the camera is shown in Fig. 15.

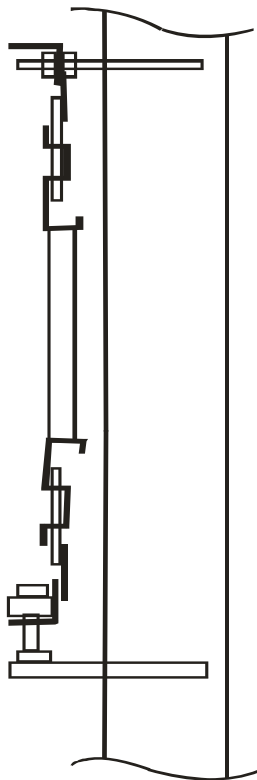


Fig. 14: Fastening the hooks on the slate plates and of electric heater themselves in the camera is shown in fig.

Hooks are made from the copper or aluminum bar or the wire with a diameter 3-5 mm.

If necessary of arrangement in the camera of two electric heaters, they are fastened in parallel to each other. In this case into the rod of crutch screw themselves two vertical pintles with the thread, and pins to which are fastened upper corners they are done such length that on them between the nuts it would be possible to fasten two corners.

## VII. CYCLIC THE METHODS OF THE DRYING OF WOOD AND ITS REALIZATION

In this camera is selected the special duty-cycle operation, which gives equally good results both with the drying of soft and solid rocks. The idea of this method consists in the fact that moisture under any conditions always strives into the colder zone. This regularity is used in the cyclic regime. Technically it is achieved as follows. After the warming up of pile and reaching in the camera of the assigned temperature of the drying agent it passes to the duty-cycle operation. With the first cycle the wood heated to the specific temperature, after reaching by which, the heaters are turned off and the temperature of wood begins to fall. In this case the cooling begins from the outer side of lumber, while its internal parts they remain more heated. In this case the moisture begins to pass from the inner layers of boards to the surface, moistening them. The external overdried crust is not formed with this regime and the uniform decrease of humidity throughout the entire thickness of board occurs. The temperature graph of this drying regime is represented in Fig. 16.

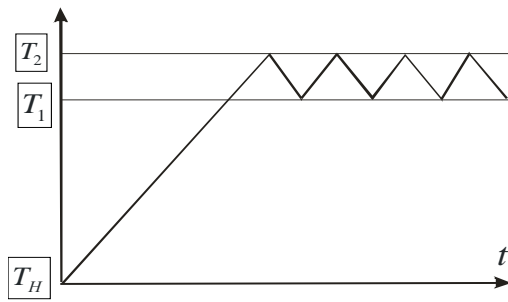


Fig. 15: Temperature graph of cyclic drying regime.

For the realization of this regime is necessary the corresponding temperature sensor and the executive system, with the aid of which is achieved the assigned cyclic regime. The corresponding temperature sensor is necessary for this. On this sensor, utilized for the realization of cyclic regime, much depends. Failures in its work can lead to the failure of regime with the irreparable consequences. Especially this concerns those cameras, in which is required the long operating time without the control from the side of operator. One should say that there are no simple and reliable

thermometers, which would ensure 100% guarantee of the reliability of operation. Therefore was developed the simple and reliable temperature sensor, which possesses such qualities. Its work is based on the use of a difference in the coefficients of the linear expansion of steel and polyethylene. The principle of the work of sensor is shown in Fig. 17.



Fig. 16: Temperature sensor

In the polyethylene tube (in the figure it is shown by black color) is located the steel bar, fixed to one of the ends of the tube. With the length of the sensor of 2000[mm] the difference in the reduction of tube and rod is 0.3 mm to one degree, which is completely sufficient for temperature control the accuracy 2-3 degrees. The tube with a diameter 20 mm, utilized for the hot-water heating, adapts as the polyethylene tube. This sensor possesses the highest reliability and the system leave cannot, with exception of any extraordinary situations.

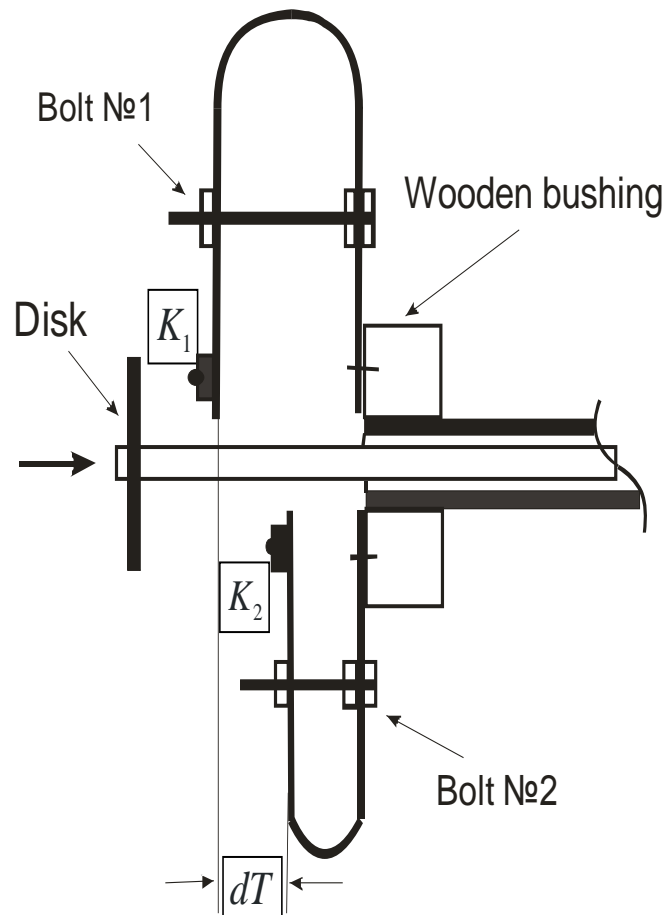


Fig. 18: Actuating mechanism of temperature sensor.

The schematic of the actuating mechanism of temperature sensor is shown in Fig. 18. To the end of the polyethylene tube is dressed the wooden bushing, to which are fastened two V - descriptive springs, at ends of which are established limit switches  $K_1$ ,  $K_2$ . From the left side from these switches is located the disk, fastened to the steel bar, that is been the part of the temperature sensor.

### VIII. ELECTRICAL CIRCUITS OF THE CAMERAS

The electrical circuit of camera with a length 4500mm, intended for the drying of hardwood is

represented in Fig. 19. Input automatic switch AP -50 on 63 A serves for the connection to the control panel of supply voltage. Still one AP -50 on 6.4 A serves for firing of the engine of the fan, which is in the diagram designated by letter M. Power of engine 3 kW with the rotational speed to 1400 turnover/minute. The diameter of the squirrel wheel of fan is 315 mm.

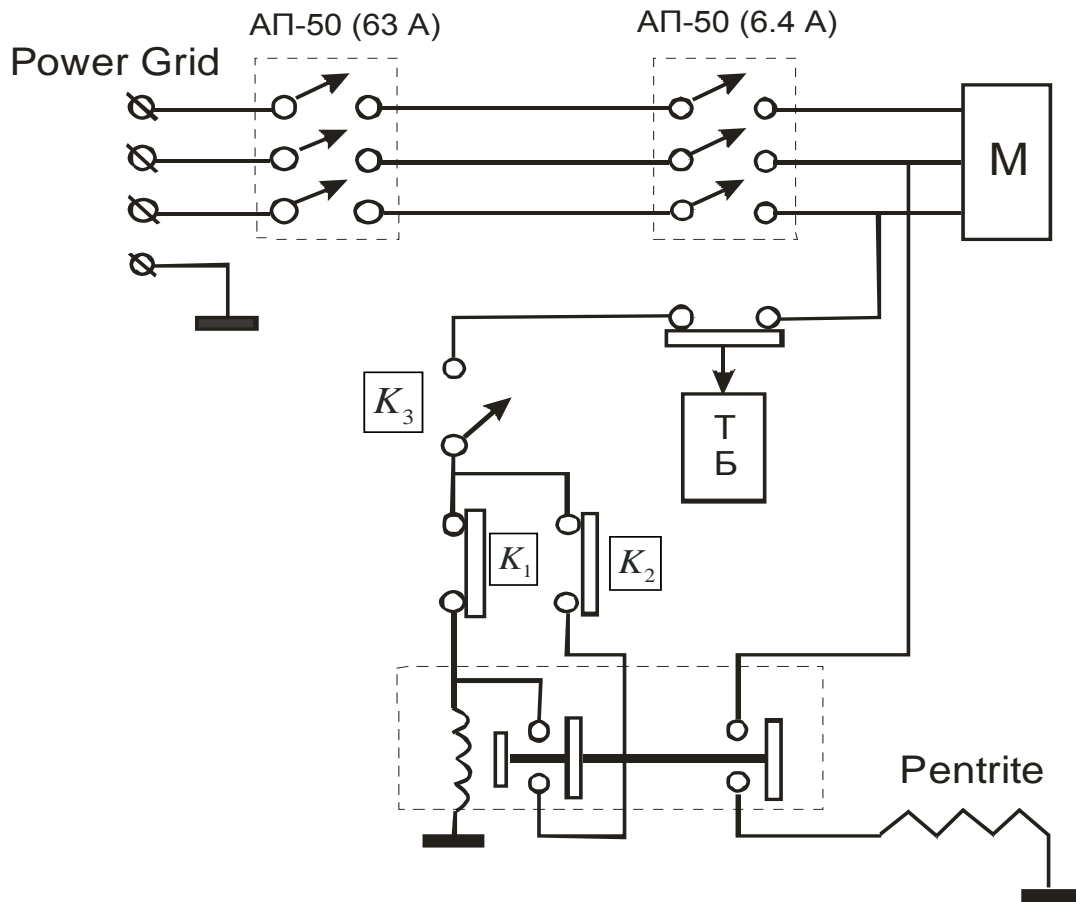


Fig. 18: Electrical circuit of camera for the drying of one pile.

Key  $K_3$ , as which is used toggle switch, serves for the switching on of control system of the temperature conditions of camera. This system includes two normally locked limit switches  $K_1$ ,  $K_2$  located on the actuating mechanism of temperature sensor (Fig. 18), and also starter PME-211. Its weak-current normally extended key  $K_4$  is connected by one end to the booster coil of starter, and by another end to the key  $K_2$ . Key  $K_5$  is three power contact pairs of starter, connected in parallel. These contact pairs serve

for the connection electric heater to one of the phases of network. Nourishment to the actuating mechanism of temperature control system will be given from one of the phase wires, which go after AP -50, which includes engine. This connection ensures turning off electric heater in the case of the wear and tear of this starter in the emergencies during the malfunction of the engine of fan.

Works temperature control system as follows. At an ambient temperature the disk of temperature

sensor is located in the end left position. In this position electric heater is connected to the network, and the temperature in the camera rises. In this case the disk begins to displace to the side indicated by pointer, also, at a specific temperature, concerning the button of end key  $K_1$  tearing up contact between its contacts. But turning off electric heater in this case does not occur since. The contact pairs of the end normally locked keys  $K_2$  and to  $K_3$  remain locked and the temperature in the camera continues to rise. In this case the disk as before continues to move to the side, indicated with pointer, compressing the spring, on which is located the key  $K_1$ . With further increase in the temperature in the camera the disk reaches the button of key  $K_2$  and it tears up its contacts. In this case nourishment the coils of starter will be opened, and proceeds turning off electric heater from the phase, is torn up also contact between the contacts of key  $K_3$ . The temperature in the camera begins to fall after this. With the reverse wobble at first are locked the contacts of key  $K_2$ , but this does not lead to the starting of starter, since the contacts of key  $K_3$  are thus far still extended. And only after the decrease of temperature to value  $dT$ , disk releases the button of key  $K_1$ , including starter. The cycle is repeated after this. Thus the position of key  $K_2$  determines the upper temperature of cycle, and the position of key  $K_1$  lower. must be  $\sim 85-90$  °C and  $65-70$  °C respectively. The

readiness of wood is determined on the difference between the dry and moist thermometer, which must be  $29-30$  °C. In this case the relative humidity of lumber will be within the limits 6-8 percent. With reaching of this temperature they turn off camera. For the more rapid cooling of wood it is possible to open slightly the door of camera. With the reaching in the camera of the temperature  $\sim 35-40$  °C the wood can be unloaded.

The cameras examined do not require the interference of operator in entire cycle of their work independent of the initial humidity of the loaded wood. The only parameter, which in the end of the drying cycle is subject to control from the side of operator, this is difference boundary by the indications of dry and moist thermometers.

With the drying of the freshlyn-saw down softwood the expenditure of electric power per one cubic meter of the loaded wood composes  $\sim 700-800$  kWchas, while with the drying of solid rocks  $\sim 900-1000$  kWchas.

For turning off of temperature control system from the power source in the case of exceeding in the camera of the temperature of higher than the assigned limits (emergency) serves blocking. For its work as the sensor are used separate temperature -sensitive element, the same, as in the temperature control system, it shown in Fig. 21.

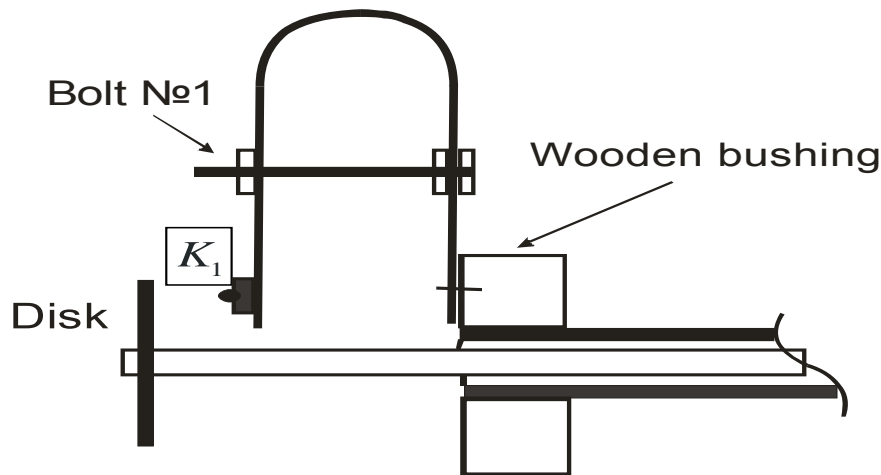


Fig. 19: Schematic of blanking sensor.

In the sensor is used the normally locked key  $K_1$ . With the aid of the nut on the bolt №1 the position of key is established so that the wear and tear of blocking would occur at a maximum permissible temperature in the camera.

Heat of vaporization of water with the atmospheric pressure is  $2260$  kJ/kg ( $540$ ) kcal/kg. But if we calculate the quantity of water, which is contained in the wood and the quantity of energy, expended for its evaporation, then even taking into account the ideal

heat insulation of camera, specific expenditure occurs 1.5 - 2 times more. This connected with the fact that for the elongation of entire cycle of drying into the camera is sucked atmospheric air, which is then, being heated to the operating temperature of camera, it is ejected outside. It is essential to decrease these unproductive losses possible in the condensing chamber, whose diagram is depicted in Fig. 22.

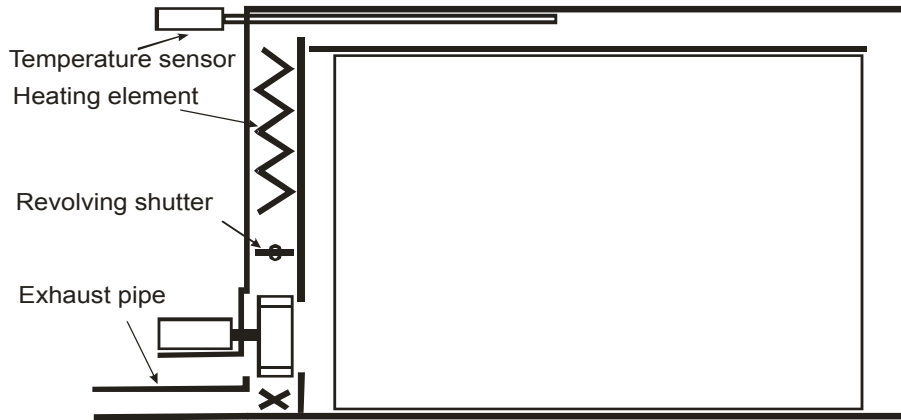


Fig. 20: Diagram of condensing chamber

This diagram is differed from the diagram, depicted in Fig. 3, by the presence of heat exchanger in the lower part of the ventilator section (it is shown by fatty cross). With the work in the condensational regime in the lath, located under the engine (Fig.4) all openings are stopped, and sucking into the camera of atmospheric air ceases. If we through the heat exchanger pass cold water, then on it will be condensed water, which will flow through the exhaust pipe. The application of this diagram of drying with the presence of the artesian well, where the temperature of water is about 9 °C and practically does not change during the year, is especially rational. For purposes cooling heat exchanger it is possible to use tap water. With a difference in temperatures in 20 degrees between the water, which enters the heat exchanger and the water, which escapes from exhaust pipe, for the drying 1 m<sup>3</sup> of wood be required ~ 10000 kg of water. The regime indicated to rationally use, when wood moisture content is not lower than 15% and the humidity of air in the camera is relatively high. With the values of wood moisture content of lower than the value indicated should be switched the camera to the cyclic regime, examined above. Application of the regime examined gives to 25% of savings according to the expenditure of electric power.

As the heating elements in the camera can be used both the batteries, fed from the gas hot-water boiler and electric heater. In the water outline of this boiler it must they stand the pump, which must be included according to the same diagram as electric heater. In this case is used the diagram of the electric power supply of camera, depicted in Fig. 19 with the only difference that instead electric heateris connected the electric motor of pump. With the use of hot-water boiler it is necessary to reduce the temperature of the drying of softwood to 80 °C, since. With the use of higher temperatures the effectiveness of the use of hot-water boiler is strongly reduced because of by the small difference between the temperature in the camera and

the temperature of water. With the work with the hot-water boiler the surface of batteries must be ~ 15 m<sup>2</sup>, while with the use electric heater their surface it is ~ 1 m<sup>2</sup>. This a difference in temperatures between air in the camera and surfaces of batteries and electric heater connected with the fact that differs approximately 15 times.

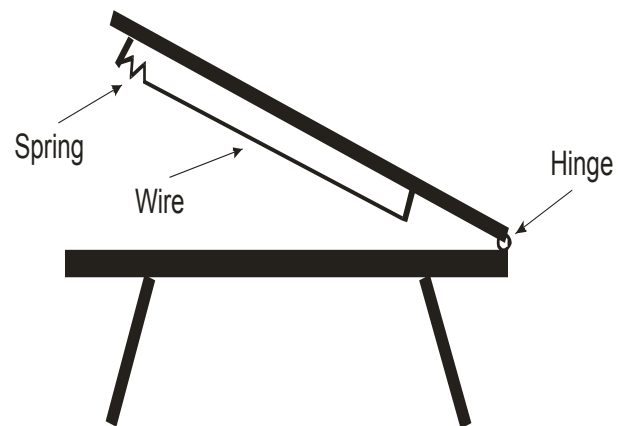
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### Application

#### Adaptation for cutting the foam plastic

The schematic of adaptation for cutting the foam plastic is shown in the figure.



to the working table to the hinge is fastened the board, on which are located two metallic pintles. The Nichrome wire with a thickness of 0.5 mm. is extended between the ends of these pintles. So that with the heating the wire would not sag, spring is used. To the wire through the step-down transformer brings the stress, which is selected in such a way that the heated wire would rapidly melt foam plastic.



GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: J  
GENERAL ENGINEERING  
Volume 19 Issue 2 Version 1.0 Year 2019  
Type: Double Blind Peer Reviewed International Research Journal  
Publisher: Global Journals  
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

## Estimation of Rainfall Erosivity Index for Auchi, Edo State, Using Lombardi's Method

By Ajayi A. S., Ehiomogue P., Kayong A. E. & Duweni E. C.

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**Keywords:** *erosivity, kinetic energy, erosion, rainfall intensity, lombardi, erodibility, auchi, soil loss.*

**GJRE-J Classification:** *FOR Code: 291899*



*Strictly as per the compliance and regulations of:*





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## I. INTRODUCTION

Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rain to runoff. This applies particularly to erosion by overland flow and rills, for which intensity is generally considered to be the most important rainfall characteristic (Morgan, 1942). Soil degradation resulting from erosion by storm water is perceived as one of the main climate-related problems worldwide since it has large environmental and economic impacts, especially in agricultural areas (Isikwe *et al.*, 2015; Angulo-Martínez and Beguería, 2009).

One of the most important factors in soil erosion by water is the erosive potential of raindrop impact. The rainfall erosivity factor (R) in the Universal Soil Loss Equation (USLE) is generally recognized as one of the best parameters for the prediction of the erosive potential of raindrop impact (Loureiro and Coutinho 2001). Various properties of raindrops, such as intensity, velocity, size, and kinetic energy, are among the most frequently used parameters to develop erosivity indices. The  $A_{r,m}$  (rainfall amount  $\times$  maximum

intensity),  $EI_{30}$  (rainfall energy  $\times$  maximum 30-min intensity), and  $KE > 1$  (total kinetic energy of all of the rain falling at more than 25 mm h<sup>-1</sup>) are the most important rainfall erosivity indices. These 3 indices were developed by Lal, Wischmeier and Smith, and Hudson (Isikwe *et al.*, 2015; Yu, 1998).

A direct computation of rainfall erosivity factors requires long-term data for both the amount and intensity of rainfall. In such a situation, more readily available types of parameters (rainfall amount-based indices) such as monthly or annual rainfall data could be utilized to predict rainfall erosivity indices. This makes it possible to adopt the correct strategies for soil conservation. Factors affecting the rate of soil erosion are rainfall, runoff, wind, soil, slope, plant cover and the presence or absence of conservation measures (Morgan, 1979).

Rainfall erosivity is the potential ability of rainfall to cause soil loss (Silva, 2004). The rainfall erosivity index represents the climate influence on water related soil erosion (Isikwe *et al.*, 2015).

Erosion is seen as a multiplier of rainfall erosivity (the R factor, which equals the potential energy); this multiplies the resistance of the environment, which comprises K (soil erodibility), SL (the topographical factor), C (plant cover and farming techniques) and P (erosion control practices). Since it is a multiplier, if one factor tends toward zero, erosion will tend toward zero. This erosion prediction equation is composed of five sub-equations, and is given as:

$$A = R \cdot K \cdot L \cdot S \cdot C \quad (1)$$

Where, A is the average annual soil loss (Mg ha<sup>-1</sup> yr<sup>-1</sup>); R is the rainfall erosivity index; K is the soil erodibility factor; L is the slope length factor; S is the slope gradient factor; C is the vegetation cover factor, and P is the conservation protection factor. Each intensity has a corresponding kinetic energy, according to the Eq. 2, (Wischmeier and Smith, 1978).

$$KE = 11.87 + 8.73 \log_{10} I \quad (2)$$

Wischmeier's index,  $EI_{30} = KE \times I_{30}$ , KE = kinetic energy of rainfall expressed in metric tons  $\times$  m/ha/cm of rainfall.  $I_{30}$  is 30 minutes rainfall intensity in mm/hr. The intensity of rainfall is determined from the rainfall amount and duration using Eq. 3 below;

$$I = \frac{\text{Rainfall Amount}}{\text{Change in Time}} \quad (3)$$

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Lombardi also related several USLE factor including rainfall erosivity and daily rainfall using Eq. 4;

$$EI = 1.03V_d^{1.51} \quad (4)$$

Where EI is the daily rainfall energy – intensity interaction or the erosivity index in MJ.mm/hr,  $V_d$  is the rainfall in mm.

The objective of this study was to compute the rainfall erosivity index of Auchi, Edo state using Lombardi method.

#### a) Materials And Method

##### i. Study Area

Auchi is one of the fastest growing urban areas in Edo State. It is located between latitude  $7^{\circ} 10'$  and  $7^{\circ} 20'$  north of the equator and longitude  $6^{\circ} 16'$  and  $6^{\circ} 36'$  east of the Greenwich Meridian with an altitude of 207m. This area is made up of several quarters; they are Abotse, Ibie, Afadokhai, Usogun, Egeroso, Akpekpe, Iyekhei, Igbe, Iyetse and Afobomhe. This area experiences the humid tropical climate, which is characterized by wet and dry seasons. The topography is relatively undulating and it slopes from the north of the area to the south. The soil type is the loose sandy soil, which makes it susceptible to erosion (Onuoha, *et al.*, 2012). Auchi gully erosion problem has become a source of worry to many people including traditional leaders in the area and Nigerians in general because of

the economic and strategic importance of the town. So far, the menace has defied all palliative measures by the community, as the situation is continually getting worse. In the 2006 census, the study area had a population of 142,819 people. It has a total land area of 358 Km

#### b) Data collection and handling

The data used for this work were from secondary sources based on rainfall occurrence. The daily rainfall data used was from manual rain gauge and was obtained from the Auchi Polytechnic meteorological station, Edo State collected over a period of ten years (2005 – 2014). The erosivity index was determined using the Eq. 4. Average annual erosivity index for rainy months was found using the equation:

$$= \frac{\text{Average annual erosivity index}}{\text{Sum total of erosivity index for the rainy months}} = \frac{\text{Number of rainy months}}{\text{Number of rainy months}}$$

## II. RESULT AND DISCUSSION

Erosivity index was estimated using Lombardi method, figures 1 and 2 show the combined plot representations of the monthly erosivity index from 2005 – 2014 and Figure 3 shows the combined plot of annual erosivity index and the annual precipitation values. For emphasis, Table 1a and b show the monthly, total and average erosivity index for the study area for 10 years.

Table 1a : Monthly, Total and Average erosivity index from 2005 – 2009

S/N	Month	2005	2006	2007	2008	2009
1	Jan	1.90	1.19	2.93	0.00	0.00
2	Feb	80.97	8.36	15.41	43.89	0.00
3	Mar	19.45	0.00	511.31	0.00	0.00
4	Apr	55.40	233.80	260.22	230.60	299.02
5	May	79.81	270.57	495.32	185.79	286.86
6	Jun	200.27	550.79	396.79	287.59	102.19
7	Jul	486.21	966.60	555.73	803.40	374.81
8	Aug	821.01	1456.27	413.52	843.84	1058.25
9	Sep	202.95	549.75	554.95	117.23	188.22
10	Oct	274.25	828.89	265.28	202.21	35.88
11	Nov	543.28	0.00	0.00	0.00	0.00
12	Dec	0.00	9.98	0.00	18.21	0.00
	Sum	2765.49	4876.20	3471.47	2732.75	2345.22
	Ave	230.46	406.35	289.29	227.73	195.43

Source: Dept. of Civil Engineering Tech. meteorological station, Auchi Polytechnic Auchi

Table 1b : Monthly, Total and Average erosivity index from 2010 – 2014

S/N	Month	2010	2011	2012	2013	2014
1	Jan	0.88	0.00	0.00	0.00	1.36
2	Feb	80.97	0.00	0.00	0.00	34.34
3	Mar	93.14	57.20	322.99	0.00	217.19
4	Apr	283.64	137.81	211.53	206.85	765.67
5	May	265.28	270.36	183.99	173.34	1075.29
6	Jun	229.24	213.41	157.78	329.51	565.39
7	Jul	663.66	814.04	432.51	368.44	909.12
8	Aug	550.79	322.99	113.41	234.48	1252.34
9	Sep	200.27	183.99	249.22	205.92	940.04
10	Oct	202.95	172.46	188.49	950.95	1191.19
11	Nov	0.00	0.00	94.21	0.00	72.95
12	Dec	24.25	0.00	33.33	0.00	22.90
	Sum	2595.06	2172.27	1987.45	2469.49	7047.78
	Ave	216.25	181.02	165.62	205.79	587.32

Source: Dept. of Civil Engineering Tech. meteorological station, Auchi Polytechnic Auchi

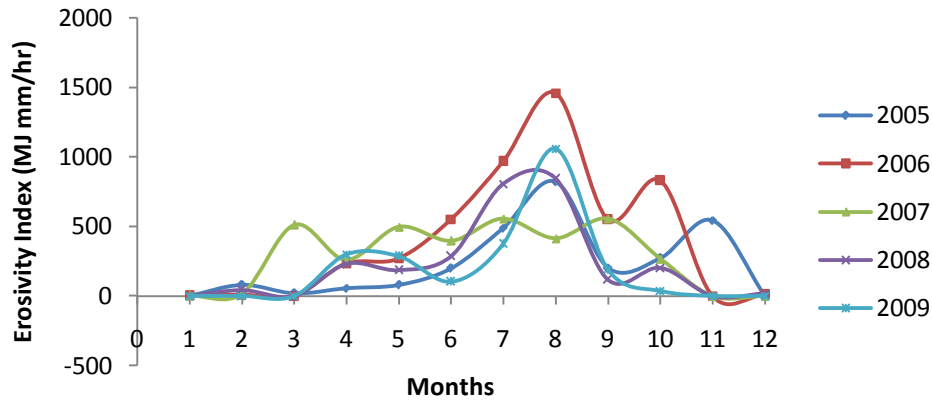


Figure 1: Monthly Variation of Erosivity Index for 2005 – 2009

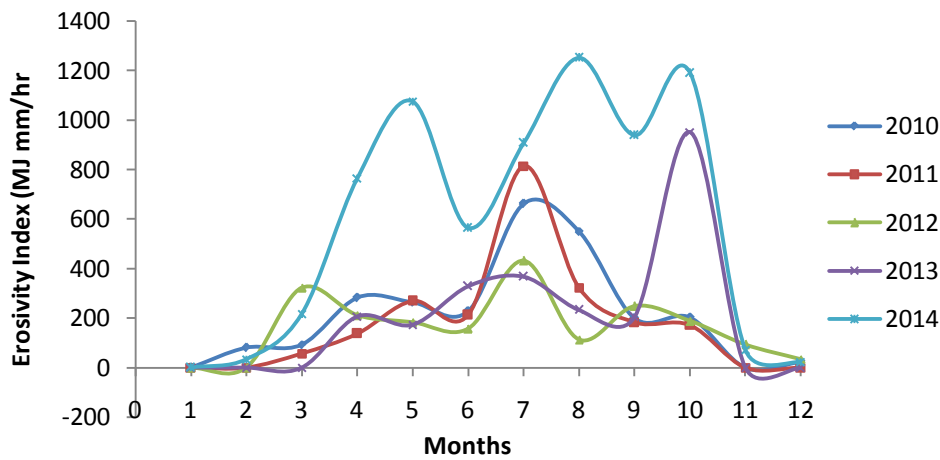


Figure 2: Monthly Variation of Erosivity Index for 2010– 2014

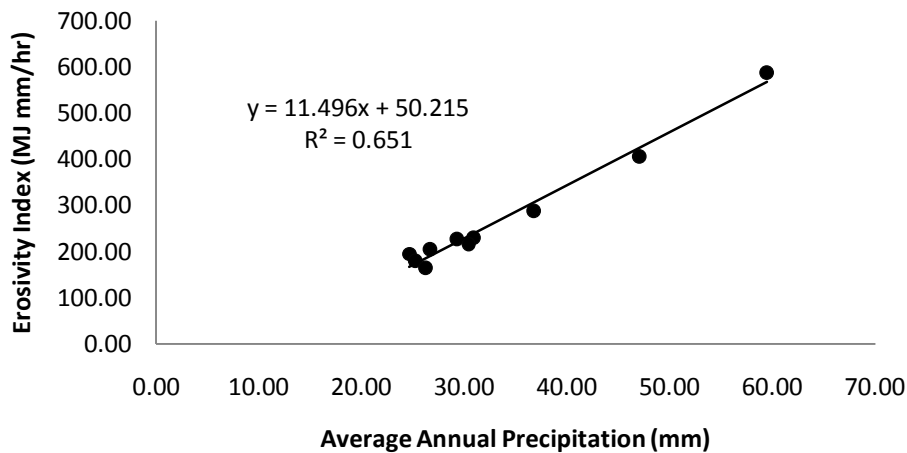


Figure 3: Correlation between annual erosivity index and average annual precipitation

From figures 1 and 2, the month of August has the highest erosivity index. The months with zero rainfall had zero KE and zero EI. As the years go by, the relationship between precipitation pattern and erosivity index becomes more pronounced, i.e higher the precipitation, the higher the erosivity index. This is confirmed by the finding of review of rainfall erosivity in Brazil by Oliveira et al., (2002), that higher erosivity values observed in the tropics are caused by the high amount of precipitation, intensity, and KE of rain. Also that the ranges of rainfall erosivity values in tropical regions are similar and they are higher than those observed in other temperate climate regions.

Figure 3 shows the correlation between annual erosivity index and average annual precipitation. The correlation between annual erosivity index and average annual precipitation was expressed as  $Y = 11.496x + 50.215$ . The coefficient of Determination  $R^2$  of 0.651 (65.1 %) is an indication that precipitation alone contributed 65.1 % of erosion hazard during the period of study. The remaining percentage could be explained by soil, conservation, management and anthropogenic factors. The increase in precipitation could be as a result of climate change.

### III. CONCLUSION

The rainfall erosivity factor (R) is one of the key factors in the USLE model and has gained increasing importance as the environmental effects of climate change have become more severe. The erosivity index for Auchi, was evaluated using Lombardi equation covering a period of 2005 – 2014. It was discovered that higher rainfall values resulted in high erosivity index values which was in line with other tropical climates. The average annual erosivity index for the city during the period of study was 587.32 MJ mm/hr. The  $R^2$  of 0.651 shows that precipitation alone contributed 65.1% of the erosion risk within the study period. The knowledge of impact of rainfall on erosivity is essential in soil erosion

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GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: J  
GENERAL ENGINEERING  
Volume 19 Issue 2 Version 1.0 Year 2019  
Type: Double Blind Peer Reviewed International Research Journal  
Publisher: Global Journals  
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

## Ecotechnological Strategies for the Reorganization of Porongo Residues in Heterogeneous Photocatalysis

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**Keywords:** *porongo(langenatiasiceraria); heterogeneous photocatalysis; eco-techniques*

**GJRE-J Classification:** *FOR Code: 060299*



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# Ecotechnological Strategies for the Reorganization of Porongo Residues in Heterogeneous Photocatalysis

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Noeli Júlia Schüssler de Vasconcellos <sup>ω</sup> & William Leonardo da Silva <sup>¥</sup>

**Abstract-** Waste management is a key issue in environmental management, as most of the waste is not reused or has an incorrect final destination. The porongo (*Langenatiasiceraria*) is a known Cucurbitaceae in the southern region of Brazil, used culturally to prepare Chimarrão, the drink of the state of Rio Grande do Sul. However, during its processing, significant amounts of residues are generated, becoming an environmental problem. An alternative for the appropriate treatment and disposal of these residues is the use of Advanced Oxidative Processes (AOPs), highlighting heterogeneous photocatalysis. In-nature and doped ferric chloride samples were prepared and later characterized by diffuse reflectance spectroscopy (DRS), nitrogen porosimetry and zeta potential (ZP). The Fe-porongo (*Langenatiasiceraria*) photocatalyst presented better photocatalytic activity, with a degradation of 50.33% ( $k = 0.0059 \text{ min}^{-1}$ , under ultraviolet radiation) and 43.23% ( $k = 0.0046 \text{ min}^{-1}$ , under visible radiation), while under the same conditions the commercial  $\text{TiO}_2$  catalyst obtained a degradation of 50.02% ( $k = 0.0057 \text{ min}^{-1}$ ) and 42.14% ( $k = 0.0043 \text{ min}^{-1}$ ) under UV and visible radiation, respectively. In this way, the present work presents eco-technical strategies for the reuse of residual biomass of porongo (*Langenatiasiceraria*), emphasizing its application in heterogeneous photocatalysis to degrade pollutants such as the one used in this work RhB.

**Keywords:** porongo (*langenatiasiceraria*); heterogeneous photocatalysis; eco-techniques.

## I. INTRODUCTION

Porongo (*Lagenariasiceraria*) comes from Africa, belonging to the cucurbit family, which have 118 genera and 825 species [1]. It is characterized by its good climate adaptation and high production of waste material during processing. It still is underexplored in the manufacture of products but could develop a primary role in sectors where materials with similar characteristics have been used in vegetable fibers produced by the textile industry, such as cotton, flax, hemp, sisal, and wood. Wood is broadly used in civil constructions and the manufacture of furniture and lumber products - serving as a potential alternative of renewable source [2,3].

This species can be found being cultivated in the Southern parts of Brazil because of the versatility of adaption according to the respective regional

climate and its usage mainly in the production of Chimarrão bowls. Therefore, it may have an essential impact on the agricultural formation, but during its processing, significant amounts of waste are generated. For instance, during the fabrication process of Chimarrão bowls only around 50% of the material can be reused while the rest of it can be burned or powdered for the production of the compound [4].

Thus, the incorrect disposal of this waste could be harmful to environment since its composition may have toxic compounds, such as petroleum compounds, pharmaceutical compounds, chlorine, nitrophenols, polycyclic aromatic hydrocarbons, organic dyes, pesticides, and heavy metals [5]. Meanwhile, biomass residues have been arousing the interests for its application in advanced oxidative, emphasizing heterogeneous photocatalysis, since these have been used as precursors of heterogeneous photocatalysts for the degradation of organic pollutants [5]. Thereby, scientific researches have sought alternatives for the conquest of ecological processes in an attempt to find suitable means for the porongo (*Lagenariasiceraria*) waste, according to Table .

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Table 1: Ecotechnological applications of porongo (*Lagenaria sicceraria*) waste

Application	Comments	Reference
Energetic exploitation	Characterization of the porongo as biomass for later use as an energy source	[6]
Biosynthesized nanoparticles	ZnO nanoparticles biosynthesized with porongo cellulose extract for application as anti-dandruff, antimicrobial and antiarthritic	[7]
Biosorbent	Biosorbent synthesized from the porongo with ZrO <sub>2</sub> for application in the removal of the textile dye RB19.	[8]
Biosorbent	Preparation, characterization and comparison of different biosorbents from the porongo for the removal of methylene blue textile dye	[9]
Activated charcoal	Study of the adsorption, using activated carbon prepared from porongo shells for the removal of fluoride	[10]

## II. ADVANCED OXIDATIVE PROCESSES (AOPS)

The advanced oxidative processes (AOPs) are physical-chemical processes based on the formation of species with high oxidizing power (2.8 V), hydroxyl radicals (OH), essential in the degradation and treatment of recalcitrant organic pollutants [11-14]. Thus, the best advantage of AOPs is that, during the treatment of the organic compounds, they are destroyed and not only transferred from one phase to another, as in some conventional treatment processes. Among the ways of obtaining the hydroxyl radicals are photochemical and photocatalytic processes.

### a) Heterogeneous Photocatalysis

Among the AOPs, the heterogeneous photocatalysis stands out, a process that involves redox reactions induced by radiation on the surface of semiconductors (photocatalysts) [15,16]. Thus, these semiconductors are characterized by two energy bands, one of low energy flow without electron movement (valence band) and another of high energy flow with free electron movement (conduction band) [17].

Furthermore, between these two bands is located a band gap that corresponds to the minimum energy required to activate the photocatalyst through the disturbance of the electron from the lower to the higher band energy [18].

Therefore, the photocatalysis process can be used on the irradiation of a photocatalyst, through the

energy absorption of a photon of greater or equal band gap energy to promote the electronic transition. The electron is displaced from the valence to the conduction band forming oxidant and reducing sites that can react with the acceptor / electron-donor species adsorbed on the semiconductor, enabling the photocatalysis of the chemical reactions [19]. In addition, the presence of oxygen is an important parameter, since the hydroxyl radicals and superoxide radicals are primary oxidants in the photocatalytic oxidation process [20].

The photocatalytic process may suffer some interferences such as the presence of large amounts of oils, greases and solids (which affect the lifespan of their energy sources), the presence of solids on the surface of the slide preventing the passage of the radiation and its contact with the oxidizing agent, concentration of the organic pollutant to be treated; concentration of the photocatalyst, and luminous intensity of the radiation source. However, due to the way the catalyst can be homogenized in the effluent, the contact of the irradiation occurs easily with the photocatalytic material [16].

### b) Application of biomass in heterogeneous photocatalysis

Biomass residues have aroused the interest for their use in photocatalysis since numerous sources of these biomasses are not sufficient and correctly used, transforming them into industrial waste. Table 2 presents some ecotechnological strategies for the use of waste and its application in photocatalysis.

Table 2: Biomasses used for application in heterogeneous photocatalysis

Biomass	Application	Reference
Rice husk, acacia and tobacco powder	Preparation of catalysts impregnated with TiCl <sub>4</sub> in the degradation of the rhodamine B dye under UV and visible radiation	[21]
Rice husk	Precursor for the synthesis of a TiO <sub>2</sub> /SiO <sub>2</sub> mixed catalyst for the degradation of terephthalic acid under UV-C radiation	[22]
Rice husk	Precursor for Synthesis of a SnO <sub>2</sub> /SiO <sub>2</sub> nanocomposite	[23]

Rice husk	Precursor for synthesis of a TiO <sub>2</sub> /SiO <sub>2</sub> mixed catalyst for degradation of methyl violet dye	[24]
Rice husk	Catalyst supported by the incorporation of titania under rice hulls and tested in the degradation of methylene blue under UV radiation	[25]
Rice husk	Catalyst supported on rice hulls to verify its influence on the degradation of phenol and 4-chloro-phenol (4-CP) under UV radiation	[26]
Rice husk	Supported catalyst prepared from the rice husk and used for determination of degradation kinetics of 2-deoxyribose	[27]
Cellulosefibers	Catalyst supported from zinc-based cellulosic fibers for the degradation of bright green	[28]
Rice husk	Precursor in the synthesis of a TiO <sub>2</sub> /SiO <sub>2</sub> catalyst for degradation of methylene blue under UV and visible radiation	[29]
Rice husk	Catalyst supported from rice huskwith TiCl <sub>4</sub> in order to evaluate the photodegradation of methylene blue, naphthalene, phenol and abamectin under UV radiation	[30]

It is possible to verify that the biomasses can be used as precursors or supports in the preparation of photocatalysts for application in heterogeneous photocatalysis. Also, the lack of scientific studies using porongo biomass (*Lagenariasiceraria*) is noteworthy and maybe a considerable sustainable source for support in the synthesis of supported photocatalysts for application in heterogeneous photocatalysis for subsequent degradation of pollutants.

### III. DISCUSSION

It is possible to identify an eco-technological potential of the reuse of the residual porongo biomass (*Lagenariasiceraria*) as a precursor or support for application in heterogeneous photocatalysis. Also, the structural, morphological and textural characterization of this residue to evaluate its applicability in the synthesis of photocatalysts for the degradation of organic pollutants has fundamental importance for the usage diversification of this raw material.

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GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: J  
GENERAL ENGINEERING  
Volume 19 Issue 2 Version 1.0 Year 2019  
Type: Double Blind Peer Reviewed International Research Journal  
Publisher: Global Journals  
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

## New Types of Transitive Maps and Minimal Mappings

By Mohammed Nokhas Murad Kaki

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*Abstract-* In this paper, we have introduced the relationship between two different concepts of maps, namely topological  $\alpha$ -transitive and  $\delta$ -transitive maps and investigate some of their properties in two topological spaces  $(X, \tau^\alpha)$  and  $(X, \tau^\delta)$ ,  $\tau^\alpha$  denotes the  $\alpha$ -topology and  $\tau^\delta$  denotes the  $\delta$ -topology of a given topological space  $(X, \tau)$ . The two concepts are defined by using the concepts of  $\alpha$ -irresolute and  $\delta$ -irresolute maps respectively. Also, we studied the relationship between two types of minimal systems, namely,  $\alpha$ -minimal and  $\delta$ -minimal systems. The main results are the following propositions.

*Keywords:* topologically  $\delta$ -transitive,  $\alpha$ -irresolute,  $\delta$ -transitive,  $\delta$ -dense.

*GJRE-J Classification:* FOR Code: 091599



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# New Types of Transitive Maps and Minimal Mappings

Mohammed Nokhas Murad Kaki

**Abstract-** In this paper, we have introduced the relationship between two different concepts of maps, namely topological  $\alpha$ -transitive and  $\delta$ -transitive maps and investigate some of their properties in two topological spaces  $(X, \tau^\alpha)$  and  $(X, \tau^\delta)$ ,  $\tau^\alpha$  denotes the  $\alpha$ -topology and  $\tau^\delta$  denotes the  $\delta$ -topology of a given topological space  $(X, \tau)$ . The two concepts are defined by using the concepts of  $\alpha$ -irresolute and  $\delta$ -irresolute maps respectively. Also, we studied the relationship between two types of minimal systems, namely,  $\alpha$ -minimal and  $\delta$ -minimal systems. The main results are the following propositions:

1. Every topologically  $\alpha$ -transitive map implies topologically  $\delta$ -transitive map, but the converse not necessarily true.
2. Every  $\alpha$ -minimal system implies  $\delta$ -minimal system, but the converse not necessarily true.

**Keywords:** topologically  $\delta$ -transitive,  $\alpha$ -irresolute,  $\delta$ -transitive,  $\delta$ -dense.

## I. INTRODUCTION

Let  $(X, \tau)$  be a topological space,  $f: X \rightarrow X$  be  $\alpha$ -irresolute map, then the set  $A \subseteq X$  is called topologically  $\alpha$ -mixing set [1] if, given any nonempty  $\alpha$ -open subsets  $U, V \subseteq X$  with  $A \cap U \neq \emptyset$  and  $A \cap V \neq \emptyset$  then  $\exists N > 0$  such that  $f^n(U) \cap V \neq \emptyset$  for all  $n > N$ , weakly  $\alpha$ -mixing set [4] of  $(X, f)$  if for any choice of nonempty  $\alpha$ -open subsets  $V_1, V_2$  of  $A$  and nonempty  $\alpha$ -open subsets  $U_1, U_2$  of  $X$  with  $A \cap U_1 \neq \emptyset$  and  $A \cap U_2 \neq \emptyset$  there exists  $n \in \mathbb{N}$  such that  $f^n(V_1) \cap U_1 \neq \emptyset$  and  $f^n(V_1) \cap U_2 \neq \emptyset$ , strongly  $\alpha$ -mixing if for any pair of open sets  $U$  and  $V$  with  $U \cap A \neq \emptyset$  and  $V \cap A \neq \emptyset$ , there exist some  $n \in \mathbb{N}$  such that  $f^k(U) \cap V \neq \emptyset$  for any  $k \geq n$ . A point  $x$  which has  $\alpha$ -dense orbit  $O_\alpha(x)$  in  $X$  is called  $\alpha$ -type hyper-cyclic point. A system is  $\alpha$ -mixing [1] if, given  $\alpha$ -open sets  $U$  and  $V$  in  $X$ , there

exists an integer  $N$ , such that, for all  $n > N$ , one has  $f^n(U) \cap V \neq \emptyset$ , topologically  $\alpha$ -mixing if for any nonempty  $\alpha$ -open set  $U$ , there exists  $N \in \mathbb{N}$  such that

$\bigcup_{n \geq N} f^n(U)$  is  $\alpha$ -dense in  $X$ . With the above concepts,

some new theorems have been introduced and studied. Furthermore, we have the following results:

- Every topologically  $\alpha$ -transitive map implies topologically  $\delta$ -transitive map, but the converse not necessarily true.
- Every  $\alpha$ -minimal system implies  $\delta$ -minimal system, but the converse not necessarily true.
- $(E_\alpha) \Rightarrow (ET_\alpha)$ ;
- $(TM_\alpha) \Rightarrow (WM_\alpha) \Rightarrow (TT_\alpha)$ ;

## II. PRELIMINARIES AND THEOREMS

**Definition 3.1** [2] A map  $f: X \rightarrow Y$  is called  $\alpha$ -irresolute if for every  $\alpha$ -open set  $H$  of  $Y$ ,  $f^{-1}(H)$  is  $\alpha$ -open in  $X$ .

**Proposition 2.2** The product of two topologically  $\alpha$ -mixing systems must be topologically  $\alpha$ -mixing.

**Proof:** Suppose that  $(X, f)$  and  $(Y, g)$  are two  $\alpha$ -mixing systems, and consider any  $\alpha$ -open sets  $W, W'$  in  $X \times Y$ . By definition of the product topology, there exist  $\alpha$ -open sets  $U, U' \subset X$  and  $V, V' \subset Y$  so that  $U \times V \subset W$  and  $U' \times V' \subset W'$ . By definition of topological  $\alpha$ -mixing of  $(X, f)$ , there exists  $N$  such that for any  $n > N$ ,  $f^n(U) \cap V \neq \emptyset$ . By definition of topological  $\alpha$ -mixing [3] of  $(Y, g)$ , there exists  $N'$  such that for any  $n > N'$ ,  $g^n(U') \cap V' \neq \emptyset$ . Then, for any  $n > \max(N, N')$ , both  $f^n(U) \cap V$  and  $g^n(U') \cap V'$  are nonempty, and therefore  $(f \times g)^n(U \times U') \cap (V \times V')$  is nonempty as well. But this implies that  $(f \times g)^n(W) \cap W' \neq \emptyset$ , since  $W$  and  $W'$  were arbitrary, this implies that  $(X \times Y, f \times g)$  is topologically  $\alpha$ -mixing.

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*Theorem 2.3* The product of two  $\alpha$ -transitive maps is not necessarily  $\alpha$ -transitive map [4].

*Corollary 2.4* The product of two topologically  $\alpha$ -transitive systems is not necessarily topologically  $\alpha$ -transitive.

### III. NEW TYPES OF CHAOS OF TOPOLOGICAL SPACES

In this section, I introduced and defined  $\alpha$ -type transitive maps[3] and  $\alpha$ -type minimal maps[3], and study some of their properties and prove some results associated with these new definitions. I investigate some properties and characterizations of such maps.

*Definition 3.1* Let  $X$  is a separable and second category space with no isolated point, if for  $x \in X$  the set  $\{f^n(x): n \in \mathbf{N}\}$  is dense in  $X$  then  $x$  is called hyper-cyclic point. If there exists such an  $x \in X$ , then  $f$  is called hyper-cyclic function or  $f$  is said to have a hyper-cyclic point. Here, we have an important theorem that is:  $f$  is a hyper-cyclic function if and only if  $f$  is transitive.

*Definition 3.2* A function  $f: X \rightarrow X$  is called  $\alpha$ -homeomorphism if  $f$  is  $\alpha$ -irresolute bijective and  $f^{-1}: X \rightarrow X$  is  $\alpha$ -irresolute.

*Definition 3.3* Two topological systems  $f: X \rightarrow X$ ,  $x_{n+1} = f(x_n)$  and  $g: Y \rightarrow Y$ ,  $y_{n+1} = g(y_n)$  are topologically  $\alpha$ -conjugate if there is  $\alpha$ -homeomorphism  $h: X \rightarrow Y$  such that  $h \circ f = g \circ h$  (i.e.  $h(f(x)) = g(h(x))$ ). We call  $h$  a topological  $\alpha$ -conjugacy. Then I have proved some of the following statements:

1. The maps  $f$  and  $g$  have the same kind of dynamics.
2. If  $x$  is a periodic point of the map  $f$  with stable set  $W_f(x)$ , then the stable set of  $h(x)$  is  $h(W_f(x))$ .
3. The map  $f$  is  $\alpha$ -exact if and only if  $g$  is  $\alpha$ -exact
4. The map  $f$  is  $\alpha$ -mixing if and only if  $g$  is  $\alpha$ -mixing
5. The map  $f$  is  $\alpha$ -type chaotic if and only if  $g$  is  $\alpha$ -type chaotic
6. The map  $f$  is weakly  $\alpha$ -mixing if and only if  $g$  is weakly  $\alpha$ -mixing.

*Remark 3.4*

If  $\{x_0, x_1, x_2, \dots\}$  denotes an orbit of  $x_{n+1} = f(x_n)$

then  $\{y_0 = h(x_0), y_1 = h(x_1), y_2 = h(x_2), \dots\}$  yields an. In particular,  $h$  maps periodic orbits of  $f$  onto periodic orbits of  $g$ . orbit of  $g$  since  $y_{n+1} = h(x_{n+1}) = h(f(x_n)) = g(h(x_n)) = g(y_n)$ , i.e.  $f$  and  $g$  have the same kind of dynamics.

I introduced and defined the new type of transitive in such a way that it is preserved under topologically  $\alpha$ -conjugation.

*Proposition 3.5* Let  $X$  and  $Y$  are  $\alpha$ -separable and  $\alpha$ -second category spaces. If  $f: X \rightarrow X$  and  $g: Y \rightarrow Y$  are  $\alpha$ -conjugated by the  $\alpha$ -homeomorphism  $h: Y \rightarrow X$  then, for each  $\alpha$ -hyper-cyclic point  $y$  in  $Y$  if and only if  $h(y)$  is  $\alpha$ -hyper-cyclic point in  $X$ .

*Proof:* Suppose that  $f: X \rightarrow X$  and  $g: Y \rightarrow Y$  are maps  $\alpha$ -conjugate via  $h: Y \rightarrow X$  such that  $h \circ g = f \circ h$ , then if  $y \in Y$  is  $\alpha$ -hyper-cyclic in  $Y$  i.e. the orbit  $O_g(y) = \{y, g(y), g^2(y), \dots\}$  is  $\alpha$ -dense in  $Y$ , let  $V \subset X$  be a nonempty  $\alpha$ -open set. Then since  $h$  is a  $\alpha$ -homeomorphism,  $h^{-1}(V)$  is  $\alpha$ -open in  $Y$ , so there exists  $n \in \mathbf{N}$  with  $g^n(y) \in h^{-1}(V)$ . From  $h \circ g^n = f^n \circ h$  it follows that  $h(g^n(y)) = f^n(h(y)) \in V$ . So that  $O_f(h(y)) = \{h(y), f(h(y)), f^2(h(y)), \dots\}$  is  $\alpha$ -dense in  $X$  so  $h(y)$  is hyper-cyclic in  $X$ . Similarly, if  $h(y)$  is  $\alpha$ -hyper-cyclic in  $X$ , then  $y$  is  $\alpha$ -hyper-cyclic in  $Y$ .

*Proposition 3.6* if  $f: X \rightarrow X$  and  $g: Y \rightarrow Y$  are  $\alpha$ -conjugate via  $h: X \rightarrow Y$ . Then

- (1)  $T$  is  $\alpha$ -type transitive subset of  $X \Leftrightarrow h(T)$  is  $\alpha$ -type transitive subset of  $Y$ ;
- (2)  $T \subset X$  is  $\alpha$ -mixing set  $\Leftrightarrow h(T)$  is  $\alpha$ -mixing subset of  $Y$ .

*Proof (1)* Assume that  $f: X \rightarrow X$  and  $g: Y \rightarrow Y$  are topological systems which are topologically  $\alpha$ -conjugated by  $h: X \rightarrow Y$ . Thus,  $h$  is  $\alpha$ -homeomorphism (that is,  $h$  is bijective and thus invertible and both  $h$  and  $h^{-1}$  are  $\alpha$ -irresolute) and  $h \circ f = g \circ h$ . Suppose  $T$  is  $\alpha$ -type transitive subset of  $X$ . Let  $A, B$  be  $\alpha$ -open subsets of  $Y$  with  $B \cap h(T) \neq \emptyset$  and  $A \cap h(T) \neq \emptyset$

(to show  $g^n(A) \cap B \neq \emptyset$  for some  $n > 0$ ).  
 $U = h^{-1}(A)$  and  $V = h^{-1}(B)$  are  $\alpha$ -open subsets of  $X$  since  $h$  is an  $\alpha$ -irresolute. Then there exists some

$$(as \ f \circ h^{-1} = h^{-1} \circ g \text{ implies } f^n \circ h^{-1} = h^{-1} \circ g^n).$$

$$\phi \neq f^n(h^{-1}(A)) \cap h^{-1}(B) = h^{-1}(g^n(A)) \cap h^{-1}(B).$$

Therefore,

$$h^{-1}(g^n(A) \cap B) \neq \emptyset \text{ implies } g^n(A) \cap B \neq \emptyset \text{ since } h^{-1} \text{ is invertible.}$$

*Proof (2)* We only prove that if  $T$  is topologically  $\alpha$ -mixing subset of  $Y$  then  $h^{-1}(T)$  is also topologically  $\alpha$ -mixing subset of  $X$ . Let  $U, V$  be two  $\alpha$ -open subsets of  $X$  with  $U \cap h^{-1}(T) \neq \emptyset$  and  $V \cap h^{-1}(T) \neq \emptyset$ . We have to show that there is  $N > 0$  such that for any  $n > N$ ,  $f^n(U) \cap V \neq \emptyset$ .  $h^{-1}(U)$  and  $h^{-1}(V)$  are two  $\alpha$ -open sets since  $h$  is  $\alpha$ -irresolute with  $h^{-1}(V) \cap T \neq \emptyset$  and  $h^{-1}(U) \cap T \neq \emptyset$ . If the set  $T$  is topologically  $\alpha$ -mixing then there is  $N > 0$  such that for any  $n > N$ ,  $g^n(h^{-1}(U)) \cap h^{-1}(V) \neq \emptyset$ .  $\exists x \in g^n(h^{-1}(U)) \cap h^{-1}(V)$ . That is  $x \in g^n(h^{-1}(U))$  and  $x \in h^{-1}(V) \Leftrightarrow x = g^n(y)$  for  $y \in h^{-1}(U)$ .  $h(x) \in V$ . Thus, since  $h \circ g^n = f^n \circ h$ , so that  $h(x) = h(g^n(y)) = f^n(h(y)) \in f^n(U)$  and we have  $h(x) \in V$  that is  $f^n(U) \cap V \neq \emptyset$ . So,  $h^{-1}(T)$  is  $\alpha$ -mixing set.

*Proposition 3.7* Let  $(X, f)$  be a topological system and  $A$  be a nonempty  $\alpha$ -closed set of  $X$ . Then the following conditions are equivalent.

1.  $A$  is a  $\alpha$ -transitive set of  $(X, f)$ .
2. Let  $V$  be a nonempty  $\alpha$ -open subset of  $A$  and  $U$  be a nonempty  $\alpha$ -open subset of  $X$  with  $U \cap A \neq \emptyset$ . Then there exists  $n \in \mathbf{N}$  such that  $V \cap f^{-n}(U) \neq \emptyset$ .
3. Let  $U$  be a nonempty  $\alpha$ -open set of  $X$  with  $U \cap A \neq \emptyset$ . Then  $\bigcup_{n \in \mathbf{N}} f^{-n}(U)$  is  $\alpha$ -dense in  $A$ .

*Theorem 3.8* Let  $(X, f)$  be topological dynamical system and  $A$  be a nonempty  $\alpha$ -closed invariant set of  $X$ . Then  $A$  is a  $\alpha$ -transitive set of  $(X, f)$  if and only if  $(A, f)$  is  $\alpha$ -type transitive system.

*Proof:*  $\Rightarrow$ ) Let  $V_1$  and  $U_1$  be two nonempty  $\alpha$ -open subsets of  $A$ . For a nonempty  $\alpha$ -open subset  $U_1$  of  $A$ , there exists a  $\alpha$ -open set  $U$  of  $X$  such that  $U_1 = U \cap A$

$n > 0$  such that  $f^n(U) \cap V \neq \emptyset$  since the set  $T$  is  $\alpha$ -type transitive subset of  $X$ , with  $U \cap T \neq \emptyset$  and  $V \cap T \neq \emptyset$ . Thus  $h^{-1}(T)$  is  $\alpha$ -type transitive subset of  $Y$ .

Since  $A$  is a  $\alpha$ -type transitive set of  $(X, f)$ , there exists  $n \in \mathbf{N}$  such that  $f(V_1) \cap U \neq \emptyset$ . Moreover,  $A$  is invariant, i.e.,  $f(A) \subset A$ , which implies that  $f(A) \subset A$ . Therefore,  $f(V_1) \cap A \cap U \neq \emptyset$ , i.e.  $f(V_1) \cap U_1 \neq \emptyset$ . This shows that  $(A, f)$  is  $\alpha$ -type transitive.

$\Leftarrow$ ) Let  $V_1$  be a nonempty  $\alpha$ -open set of  $A$  and  $U$  be a nonempty  $\alpha$ -open set of  $X$  with  $U \cap A \neq \emptyset$ . Since  $U$  is an  $\alpha$ -open set of  $X$  and  $U \cap A \neq \emptyset$ , it follows that  $U \cap A$  is a nonempty  $\alpha$ -open set of  $A$ . Since  $(A, f)$  is topologically  $\alpha$ -type transitive, there exists  $n \in \mathbf{N}$  such that  $f(V_1) \cap (U \cap A) \neq \emptyset$ , which implies that  $f(V_1) \cap U \neq \emptyset$ . This shows that  $A$  is a  $\alpha$ -type transitive set of  $(X, f)$ .

#### IV. NEW TYPES OF CHAOS IN PRODUCT SPACES

We will give a new definition of chaos for  $\delta$ -irresolute self map  $f : X \rightarrow X$  of a compact Hausdorff topological space  $X$ , so called  $\delta$ -type chaos. This new definition induces from John Tylar definition which coincides with Devaney's definition for chaos when the topological space happens to be a metric space.

*Definition 4.1 [4]* Let  $(X, f)$  be a topological dynamical system; the dynamics is obtained by iterating the map. Then,  $f$  is said to be  $\delta$ -type chaotic on  $X$  provided that for any nonempty  $\delta$ -open sets  $U$  and  $V$  in  $X$ , there is a periodic point  $p \in X$  such that  $U \cap O_f(p) \neq \emptyset$  and  $V \cap O_f(p) \neq \emptyset$ .

*Proposition 4.2* Let  $(X, f)$  be a topological dynamical system. The map  $f$  is  $\delta$ -type chaotic on  $X$  if and only if  $f$  is  $\delta$ -type transitive and the periodic points of the map are  $\delta$ -dense in  $X$ .

*Proof:*  $\Rightarrow$ ) If  $f$  is  $\delta$ -type chaotic on  $X$ , then for every pair of nonempty  $\delta$ -open sets  $U$  and  $V$ , there is a

periodic orbit intersects them; in particular, the periodic points are  $\delta$ -dense in  $X$ . Then there is a periodic point  $p$  and  $x, y \in O_f(p)$  with  $x \in U$  and  $y \in V$  and some positive integer  $n$  such that  $f^n(x) = y$ , so that  $y = f^n(x) \in f^n(U)$  therefore  $f^n(U) \cap V \neq \emptyset$ .

$\Leftarrow$ ;) The  $\delta$ -type transitivity [5] of  $f$  on  $X$  implies, for any nonempty  $\delta$ -open subsets  $U, V \subset X$ , there is  $n$  such that for some  $x \in U$ ,  $f^n(x) \in V$ . Now, define  $W = f^{-n}(V) \cap U$ . Then  $W$  is  $\delta$ -open and nonempty with the property that  $f^n(W) \subset V$ .

But since the periodic points of  $f$  are  $\delta$ -dense in  $X$ , there is a  $p \in W$  such that  $f^n(p) \in V$ . Therefore,  $U \cap O_f(p) \neq \emptyset$  and  $V \cap O_f(p) \neq \emptyset$ . So, the map  $f$  is  $\delta$ -type chaotic.

We will define some concepts as follows:

1.  $(TT_\delta)$  if for every non-empty  $\delta$ -open set  $D \subset X$ ,  $\bigcup_{n=1}^{\infty} f^n(D)$  is  $\delta$ -dense,
2. Weak  $\delta$ -Mixing  $(WM_\delta)$  if  $f \times f$  is topologically  $\delta$ -transitive.
3. Exact  $\delta$ -Transitive  $(ET_\delta)$  if for every pair of non-empty  $\delta$ -open set  $D, W \subset X$ ,  $\bigcup_{n=1}^{\infty} (f^n(D) \cap f^n(W))$  is  $\delta$ -dense in  $X$ ,
4. Topologically  $\delta$ -Mixing  $(TM_\delta)$  if for every pair of non-empty  $\delta$ -open set  $D, W \subset X$ , there exists an  $N \in \mathbf{N}$  such that  $f^n(D) \cap W \neq \emptyset$  for all  $n \geq N$ .
5.  $\delta$ -Exact  $(E_\delta)$  if for every non-empty  $\delta$ -open set  $D \subset X$ , there exists  $N \in \mathbf{N}$  such that  $f^N(D) = X$
6. Then the following implications hold:
  - $(E_\alpha) \Rightarrow (ET_\alpha)$ ;
  - $(TM_\alpha) \Rightarrow (WM_\alpha) \Rightarrow (TT_\alpha)$ ;

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GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: J  
GENERAL ENGINEERING  
Volume 19 Issue 2 Version 1.0 Year 2019  
Type: Double Blind Peer Reviewed International Research Journal  
Publisher: Global Journals  
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# Space and Art: In Collaboration with the Public in Public Spaces

By Yuri Tanaka

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**Abstract-** Space and art may seem separate – in the same ways that humans seem to be. Furthermore, both space and art are usually not easily accessed by the public. This paper proposes that through the practices of creating public installations, space and art can be much better integrated. Aiming to create this in an accessible form for anyone, ‘local co-operation’ between experts and the public – making an installation together – becomes a fundamental methodology. In this paper, the author will discuss two cases: *Moons of Naoshima* (2013-2014) in Naoshima, and *Uy-uni-verse ⇌ Multiverse* (2014) in Tanegashima Space Center. In summary, these cases show how this methodology works for the public collaborators to deepen their mental connections with space and art.

**Keywords:** *collaboration, space, art, public installation, art and science.*

**GJRE-J Classification:** *FOR Code: 091599*



*Strictly as per the compliance and regulations of:*



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# Space and Art: In Collaboration with the Public in Public Spaces

Yuri Tanaka

**Abstract-** Space and art may seem separate – in the same ways that humans seem to be. Furthermore, both space and art are usually not easily accessed by the public. This paper proposes that through the practices of creating public installations, space and art can be much better integrated. Aiming to create this in an accessible form for anyone, ‘local co-operation’ between experts and the public – making an installation together – becomes a fundamental methodology. In this paper, the author will discuss two cases: *Moons of Naoshima* (2013-2014) in Naoshima, and *Uy-universe*  $\rightleftharpoons$  *Multiverse* (2014) in Tanegashima Space Center. In summary, these cases show how this methodology works for the public collaborators to deepen their mental connections with space and art.

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## I. INTRODUCTION

Since the 1960s were when humans started to go into outer space, the relationship between outer space and humans has been getting closer. From ancient times, people have been intuitively utilizing the laws of the universe by capturing the rhythms and patterns of nature, for instance in agriculture and navigation. In the current era, is the relationship between our culture and the universe getting closer? Or – is the universe somehow conceived of as being separate to humans? Such a question also applies to think about our relation to art, especially as a way of life which takes the universe as its concept.

Along with the aim of the author’s project which is to mediate the dimly perceived nexus connecting the universe, humans, and art, the author would like to use the term ‘the universe’ that denotes all life forms and environments, and that also includes ‘space’ that refers to outer space.

The truth of this universe remains a mystery, though the scientific research of astronomy, particle physics, astrophysics, and space science has been trying to erode a mountain of an enigma over the centuries. This enigma can be one of the reasons why our curiosity persists. Either consciously or unconsciously, some of us intuitively recognize that science and art have sprung from the same origin. Then, we are led to ask: why not make art through ‘the

universe’ as a mutually acceptable idea that everyone can share?

In this paper, the author will discuss a way of collaboration through two of her projects: *Moons of Naoshima* (2013-2014) in Naoshima, and *Uy-universe*  $\rightleftharpoons$  *Multiverse* (2014) in Tanegashima Space Center.

## II. LOCAL CO-OPERATION

‘Local co-operation’ as a methodology, a unique way of making an art festival, has developed in Japan. In this, artists/designers/architects are invited to propose a plan that is to create an artwork with residents and volunteers. Using *Echigo-Tsumari Art Triennale* and *Setouchi Triennale* as case studies, the author explores this methodology.

### a) Collaboration model I: *Echigo-Tsumari*

Since 2000 when *Echigo-Tsumari Art Triennale* was inaugurated in Niigata, Japan (in an abandoned local town with a predominantly aged population, heavy snow in winter, and frequent earthquakes), art as a means to reconstruct community has become well-recognized throughout the world. Following the success of this project, hundreds of art projects have launched throughout the land of Japan. For the first launch of this art festival in 2000, approximately 162,800 visitors and 10,440 supporters have committed to participating through the period of 53 days [1].

With the constant concept, ever since the inauguration of the festival, of “humans are part of nature” [2], the professional artists/designers/architects create a site-specific project inevitably on someone’s land, and this leads them to work with residents and also to build a new community. Using what is called ‘local co-operation,’ residents and volunteers engage in making artworks together with professionals as well (Fig. 1), and this process evokes a feeling of appreciation, co-operation, and empathy among them. This unique method of collaboration has initially led by Fram Kitagawa (1946-) – an art director of the festival. With his profound skills and wholehearted enthusiasm, the festival has dramatically succeeded in provoking Japanese society to reconsider how to join our lives with nature and art in this era of disaster – both natural and human-induced. Furthermore, this methodology which is called the Tsumari-method, and named after *Echigo-Tsumari Art Triennale*, has become a prototype of city

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planning and local revitalization for many other places in Japan.



Fig. 1: A scene from the volunteer activity for *Echigo-Tsumari Art Triennale*, photo: Satoka Ogaki

b) *Collaboration model II: Setouchi*

With the extraordinary development of *Echigo-Tsumari Art Triennale*, Kitagawa was invited to direct another art festival called *Setouchi Triennale* starting from 2010. The Setouchi area, where people and nature are living in harmony, holds 727 islands in the dimension of 23,203km<sup>2</sup> in the Seto Inland Sea [3]. This festival aims to restore vitality to the islands in the inner sea of the Setouchi area and to create an opportunity for everyone to find genuine beauty in their culture and life. Despite the difficulties in the accessibility to this area (e.g., most venues are in the small isolated islands), this festival attracts not only people throughout Japan but also those from around the world. In 2016, at the second festival of the *Setouchi Triennale*, approximately 1,040,050 visitors were recorded for 108 days in total [4].

In 2016, this festival succeeded in gathering approximately 7,000 volunteers to co-create it [5]. The volunteer group named 'Koebi-tai' has become an NPO, which carries out diverse tasks. For instance, cutting glasses and bushes to make a better environment as a part of the artworks, making the artworks together with the artists and residents, welcoming visitors, maintaining the artworks, and most importantly, communicating with residents through those activities and their ordinary lives (Fig. 2). Consequently, their involvements lead to the creation of unity in the community. These encourage people to find a pure richness in their daily lives on the island. And to naturally be attracted by the charm of the site.

With the local co-operation model at Echigo-Tsumari and Setouchi, and with the author's three-year work experience in Naoshima (one of the venues of *Setouchi Triennale*), the author applies these elements to conduct another project, fostering her aim to create a deeper relationship between the universe, humans, and art.



Fig. 2: A scene from the volunteer activity for *Setouchi Triennale*, photo: Yamato Fukui

### III. ART PRACTICE I: *MOONS OF NAOSHIMA*

In the island called Naoshima, the author produced a project entitled *Moons of Naoshima* for December 6, 2013 - January 13, 2014. In collaboration with an artist/professor Takaharu Ito and the local entities of Naoshima, they created the light installation through a workshop with an elementary school there. This installation was designed to enhance the beauty of the winter environment and to bring warmth to the minds of residents and visitors.

a) *Background*

The origin of *Setouchi Triennale* is rooted in Naoshima, a small isolated island in the Seto Inland Sea of approximately 3,000 population and 8.14km<sup>2</sup> dimension (the main island of Naoshima) [6]. It was back in 1985 when the vision was derived from creating an artistic site there. The museums and public art around the island have been attracting worldwide visitors. Winter is quiet. This silence is mostly because of the meteorological conditions and the absence of the winter season in *Setouchi Triennale* (it consists of three seasons: spring, summer, and autumn).

Meanwhile, during the Christmas and the New Year's holiday seasons, the town of Naoshima has been organizing an illumination project at the Miyanoura Port; the main entrance of the island, apart from *Setouchi Triennale* and also apart from any support of artists. Considering these situations, the author proposed that the town of Naoshima reconsider this illumination project in collaboration with the artists and residents. In the end, her proposal made with an artist/professor Takaharu Ito was accepted. Besides, for an educational purpose, the town suggested that Ito and her work with Naoshima elementary school.

b) *Concept*

With this as a background, the basic concept of the project developed along the following lines:

1. Create space and time which enhance people's ability to realize the beauty of the environment (which residents tend to take for granted)
2. Use the moon as a motif of the installation, to provide an experience of feeling that the universe becomes closer
3. Enrich the beauty of the winter landscape, and winter life in Naoshima

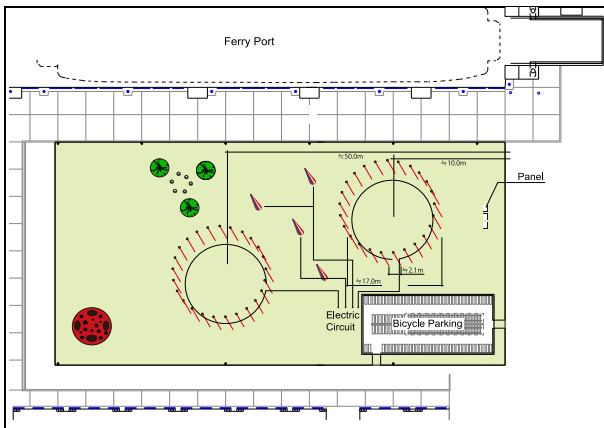
With these concepts, the plan was to make an installation of the imaginary 'moons' as if they were floating in the night sky. Each moon was to be made by the pupils of Naoshima. Therefore the installation was entitled *Moons of Naoshima*.

*c) Design*

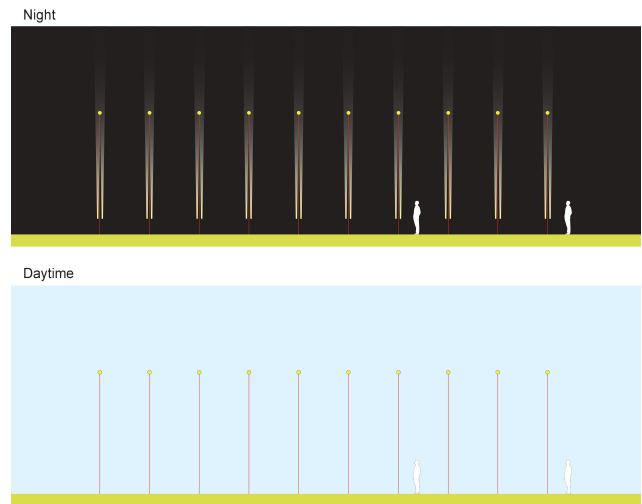
Fig. 3 shows the layout of the installation. Two 25m-diameter (approx.) circles are located at the park just beside the ferry port.

With 24 rods (of approximately 6m height that give visibility for ferry passengers as well) for each circle, 'moons' (spherical styrofoams on the top) become illuminated by LED in the night (Figs. 4 and 5). As with the real moon, these moons wouldn't emit light by themselves. It is common nowadays that most illumination works don't look nice during the daytime. Therefore the installation was designed to be appreciated in the daytime as well. In the daytime, viewers can enjoy the colorful moons that have been painted by pupils.

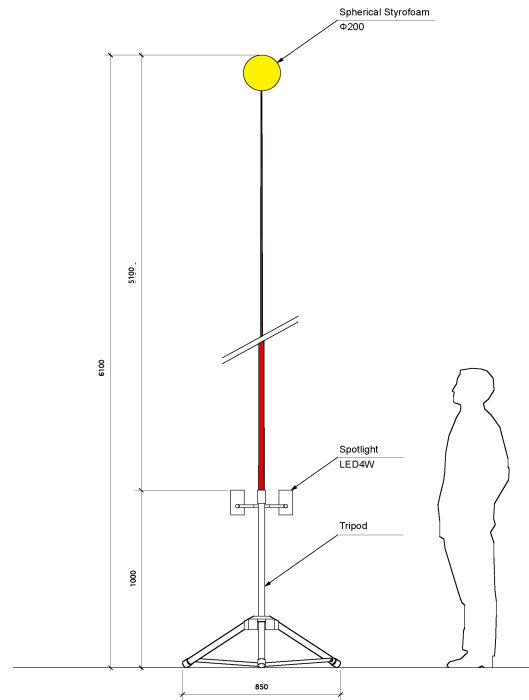
In terms of the material used, the glass fiber rod allows the whole installation to be kinetic; to naturally move with the wind.



*Fig. 3:* A layout of the installation, credit: Takaharu Ito. (\*These small cones indicate an additional tree-like light object for a Christmas season.)



*Fig. 4:* Images of the installation, credit: Takaharu Ito



*Fig. 5:* Technical Rider of the installation, credit: Takaharu Ito

*d) Methodology*

In collaboration with Naoshima elementary school, Ito and the author organized the workshop. With 48 pupils from the third (9-10-year-old) and the sixth grade (12-13-year-old), the idea was to let each of them create an original 'moon' – his/her only 'moon' in the universe, imagining this floating in the sky of Naoshima.

To enhance their imagination, Ito wrote a short Poem about the moon.

The workshop took place in Naoshima elementary school on July 31, 2013, during the summer vacation. With support from residents and schoolteachers, the author carried out the workshop described in the following:

1. The author explains the concept of the installation and recites Ito's poem for pupils with their eyes closed
2. Pupils sketch a moon on a piece of white paper based on their imagination (with watercolor and color markers)
3. With white spherical styrofoam for each person, pupils draw their moons with watercolor (Fig. 6)
4. Pupils decide the title
5. Reflection with all participants (pupils describe their works with all the participants) (Fig. 7)



Fig. 6: A scene from the workshop, photo: Yuri Tanaka



Fig. 7: A scene at the end of the workshop, photo: Yuto Hosoya

After the workshop at the elementary school, Ito's studio (in Tokyo) puts a waterproof coating on the moons. They led the production of the installation (e.g., making the rods and the other equipment).

An installing process was also led by Ito's studio with the support of the town of Naoshima.

#### e) Result

On December 6, 2013, the opening ceremony was held at the site, accompanied by the mayor of the town. With music (a Japanese song on a theme of the

moon) led by a chorus group of residents, many residents seemed to be delighted in the atmosphere that this installation had created (Fig. 8).

Figs. 9 and 10 show the daytime/night scenes of the installation. During the daytime, as Ito and the author expected, the colors of the moons nicely matched the color of the transparent blue sky (the weather in this region is mostly sunny during winter). In the night, these moons become illuminated reflecting the light below, as if they are floating in the night sky, or even in space. The winds are typically hard in winter there, and this gives a natural kinetic movement to the installation.

Over Christmas and the New Year's holidays, many visitors (many of them are relatives of residents, and travelers from diverse regions and countries) appreciated this occasion.



Fig. 8: A scene from the opening ceremony, photo: Daisuke Aochi



Fig. 9: The daytime scene of *Moons of Naoshima*, artwork: Takaharu Ito, photo: Yuri Tanaka

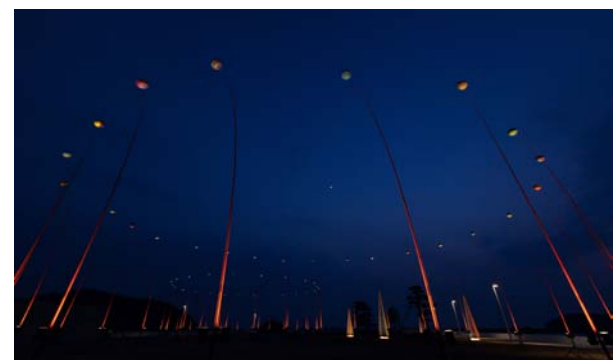


Fig. 10: Night scene of *Moons of Naoshima*, artwork: Takaharu Ito, photo: Daisuke Aochi

#### IV. ART PRACTICE II: *UY-UNI-VERSE* $\rightleftharpoons$ *MULTIVERSE*

For August 10 - September 15, 2014, the project entitled *Mission in Tanegashima* took place in Tanegashima, where the rocket range of Japan Aerospace Exploration Agency (JAXA) is located. Led by Tanegashima Space Art Festival Promoting Committee with the cooperation of the town administration, JAXA and the other entities, the author was in charge of curating/co-organizing this project. This project was a preliminary event for the purpose of building a cornerstone for the future festival. In this section, the author discuss *Uy-uni-verse*  $\rightleftharpoons$  *Multiverse*, one of the installations for this project.

##### a) *Background*

Tanegashima, where JAXA set the rocket range and the space center in 1969, has a population of 29,847 within an area of 445.1km<sup>2</sup> [7]. Since the author was invited by JAXA in 2011 to create a new artistic project in Tanegashima, JAXA, local entities and residents, the artists, and the author (2011-2014) have been working on the project in collaboration [8].

The background of the island shows a unique environment, initially developed by JAXA where space development has become a symbol of the town. With the vision of reconnecting the universe, humans, and art and creating a new value of the idea of 'the universe' beyond the idea of 'space' which indicates 'outer space,' intuitive communication through local co-operation was developed.

For the project *Mission in Tanegashima* (2014), eight artists and designers had their residency on the island to make installations together with residents. From this, the project of the Cosmic Art Research Committee – of which the author act as a head –, including artists/designers Ryu Sakurai, Hajime Shimoyama, and Ryo Takahashi, is examined.

##### b) *Concept*

Starting from a dialogue between residents, the members of this Committee firstly tried to capture their feelings through staying on the island to make the installation suitable in their culture. Tanegashima has extraordinarily beautiful scenery formed by its geographical features combined with the Sea of Japan and the Pacific Ocean, where the Black Tide has brought new cultures and natural resources from overseas. Surprisingly, war has never happened on this island mainly because all the late rulers wanted its enriching resources and the fields where the rice grows to produce sufficient food for the inhabitants. Despite such a peaceful environment, as the island is 40km far away from the mainland of Kyusyu [9] (the large southern island of Japan), residents inevitably face to some difficulties in their ordinary lives, derived from the

sense of being such a small community. Inhabitants have little chance to find the time to be alone and are socially engaged with each other most of their time. One resident told the members that he needed space and time to relieve himself. The members, therefore, came up with the idea that it would be meaningful if they could make a space for residents to look at themselves from both micro and macro perspectives. In other words, to examine the microcosm within themselves and the macrocosm of the entire universe.

To this end, the members located the most appropriate site where anyone could be just by himself/herself surrounded by the beautiful clear sky, especially the starry evening sky, and the sound of water resonating with the rhythms of the universe. The location chosen was the large lawn area of the Tanegashima Space Center, which everyone can access without any permission and at any time, and is located some distance from the residential area in the town.

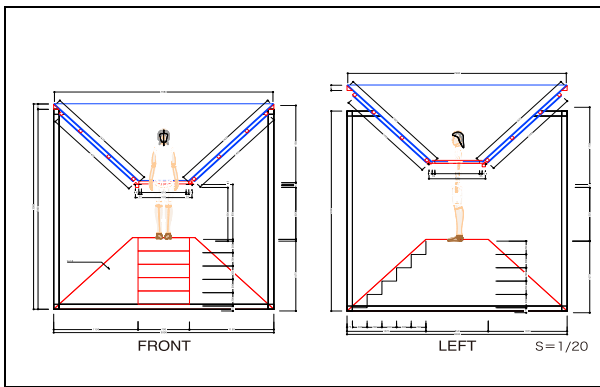
Finally, the installation was entitled *Uy-uni-verse*  $\rightleftharpoons$  *Multiverse*, a combined term which evokes the universe and the Uyuni salt flat in Bolivia, where people can feel as if there is no border between the sky and the lake, in the same way, that there are no borders in outer space. As the members considered Uyuni salt lake as a metaphor of the cosmic environment, this title reflects their hope to create space and time for people to experience a feeling that they are part of the vast universe.

##### c) *Design*

The next step is designing the structure. In this process, Shimoyama chiefly led the design. In collaboration with Yoshiharu Terada, a local architect on the island, the members gave gradual form to the installation.

First of all, the members collected the meteorological data from the chief certified weather forecaster at the Tanegashima Space Center. The members had to carefully examine the data to meet the criteria of JAXA for the site, and perhaps most importantly, to make the installation strong enough to withstand the harsh weather conditions of the island where the wind blows very forcefully – especially during the summer typhoon season. The members then used the data to calculate the resistible strength required to design the form of the structure.

Considering the one month of the exhibition and the possibility of a destructive typhoon, they decided to make it detachable in two parts. As shown in Fig. 4, this work consists of the upper frame covered by mirror-finished stainless steel, the bottom frame with wooden stairs, and the pillars made of square cedar timber. Furthermore, taking into consideration the average height of residents as a human scale, it is designed to fit for one person to be surrounded by the sky. Therefore, it has no ceiling to allow the mirrors to be able to reflect only the scenery above.



*Fig. 4:* The structural design of *Uy-uni-verse*  $\rightleftharpoons$  *Multiverse*, credit: Cosmic Art Research Committee

#### d) Methodology

Aiming to create a bond between residents and the installation, the members gathered local technicians, carpenters, and volunteers to work together (Figs. 5 and 6). For this installation, approximately 20 people in total joined in collaboration. Since the residential period was limited to a week, the members decided to let residents make the object to give them a sense of unity through this project. However, the members gave great importance to communicating with residents to encourage mutual understanding and to enhance further creativity. Since the members found that most residents tended to be unconscious of their environment because they were too familiar with it, the members tried to provoke their sense of curiosity and creativity towards the universe and art.



*Fig. 5:* A scene from the installing process (Tanegashima Space Center, 2014), photo: Yuri Tanaka



*Fig. 6:* A scene from the installing process (Tanegashima Space Center, 2014), photo: Yuri Tanaka

#### e) Result

Following the installing process, the installation became as shown in Figs. 7 and 8. Fortunately, there were no critical incidents throughout the period, and it remained in good condition. To their surprise, Terada had often voluntarily come to maintain it by himself. In this project, it seemed that a sense of unity derived from intuitive and heartfelt mutual understanding, beyond logic and the practicalities of physical work. Terada's motivation and positive attitude towards the project was unexpectedly grateful.

To analyze the results of this project, the author interviewed residents, visitors, and the staff of JAXA aiming to capture their feelings and attitudes towards the installation. The two comments below most aptly express the sentiments of the viewers:

"It was so comfortable inside the installation, with the sound of the water waves. It was like being in the real universe." (Resident)

"I have never realized it is such a beautiful night sky spreading out of the Range Control Center where I always work. I felt like I was floating in the universe." (Staff member of JAXA)

In the light of these responses, not only the image of the objects but also the whole experiences of communication with other humans and the universe remains in the minds of the viewers.



*Fig. 7:* The daytime scene of *Uy-uni-verse*  $\rightleftharpoons$  *Multiverse* (Tanegashima Space Center, 2014), credit: Cosmic Art Research Committee



*Fig. 8:* Night scene of *Uy-uni-verse*  $\rightleftharpoons$  *Multiverse* (Tanegashima Space Center, 2014), credit: Cosmic Art Research Committee

## V. CONCLUSION

Through the 'local co-operation' method, with such a sincere dedication from all the collaborators – both experts and the public – these projects have created unity among the community which may lead to the further development of society. This methodology helps us to deepen a mental connection with space and art by physical experiences. With ever-explorable space, the universe, and art, further projects that touch on human minds would grow.

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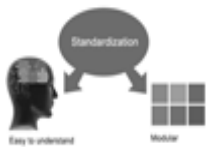






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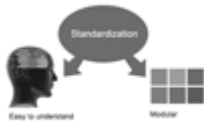


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Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

### **Keywords**

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

### **Numerical Methods**

Numerical methods used should be transparent and, where appropriate, supported by references.

### **Abbreviations**

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

### **Formulas and equations**

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

### **Tables, Figures, and Figure Legends**

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.



## Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

## PREPARATION OF ELETRONIC FIGURES FOR PUBLICATION

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

## TIPS FOR WRITING A GOOD QUALITY ENGINEERING RESEARCH PAPER

Techniques for writing a good quality engineering research paper:

**1. Choosing the topic:** In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

**2. Think like evaluators:** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

**3. Ask your guides:** If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

**4. Use of computer is recommended:** As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

**5. Use the internet for help:** An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow [here](#).



**6. Bookmarks are useful:** When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

**7. Revise what you wrote:** When you write anything, always read it, summarize it, and then finalize it.

**8. Make every effort:** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

**9. Produce good diagrams of your own:** Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

**10. Use proper verb tense:** Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

**11. Pick a good study spot:** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

**12. Know what you know:** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

**13. Use good grammar:** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

**14. Arrangement of information:** Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

**15. Never start at the last minute:** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

**16. Multitasking in research is not good:** Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

**17. Never copy others' work:** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

**18. Go to seminars:** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

**19. Refresh your mind after intervals:** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

**20. Think technically:** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.



**21. Adding unnecessary information:** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

**22. Report concluded results:** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

**23. Upon conclusion:** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

## INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

### **Key points to remember:**

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

### **Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

### **The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

### **General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

**To make a paper clear:** Adhere to recommended page limits.

### *Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

#### **Title page:**

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

#### **Approach:**

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

#### **Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

*The following approach can create a valuable beginning:*

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.



**Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

**Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

**Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

**Methods:**

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

**Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

**What to keep away from:**

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.



**Content:**

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.





**Approach:**

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

## THE ADMINISTRATION RULES

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*Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.*

*Segment draft and final research paper:* You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

*Written material:* You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.



CRITERION FOR GRADING A RESEARCH PAPER (COMPILATION)  
BY GLOBAL JOURNALS

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	C-D	E-F
<i>Abstract</i>	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form  Above 200 words	No specific data with ambiguous information  Above 250 words
<i>Introduction</i>	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
<i>Methods and Procedures</i>	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
<i>Result</i>	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
<i>Discussion</i>	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



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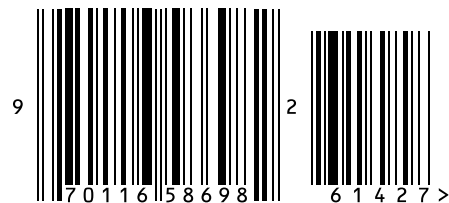


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ISSN 9755861

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