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RTA Rail Tec Arsenal Fahrzeugsversuchsanlage GmbH
Group 7

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Abstract

This paper illustrates why it is important to use climatic tests in different forms and describe the basis measurement for the flow rate, humidity and temperature measurement. The aims of these measurements are: to improve the comfort for passengers, reduce the energy consumption and ensure the safety of these vehicles (trains, busses, trams, metro-trains). Rail Tec Arsenal can perform these tests in the biggest climatic wind tunnel all over the world. Furthermore the energy demand of the testing facility was evaluated the possibilities to reutilise this energy were analysed. Finally this paper provides insight into the main climatic impacts of aviation and compares the RTA in Vienna with the McKinley Climatic Laboratory in Florida regarding this industry.

Content

1 Introduction (David Scherzer) 6

2 Drivers for and methods of climatic testing (David Scherzer) 7

2.1 Drivers for climatic testing 7

2.1.1 Rail Vehicles 7

2.1.2 Road Vehicles 9

2.1.3 Other Vehicles 9

2.2 Methods of climatic testing 10

2.2.1 Outdoor testing in real weather 10

2.2.2 Testing in a climatic wind tunnel 11

3 Weather Conditions (Alexander Falk) 13

3.1 Introduction 13

3.2 Solar Simulation in the CWT 14

3.3 Rain Simulation in the CWT 16

3.4 Snow/Ice Simulation in the CWT 17

3.5 Clouds/Ice simulation in the new Icing Wind Tunnel 18

4 Flow rate and humidity measurement (Bernhard Spielberger) 22

4.1 Flow rate measurements 22

4.1.1 Wind anemometer 22

4.1.2 Vane anemometer 23

4.1.3 Hot wire anemometer 24

4.1.4 Laser Doppler anemometer 25

4.1.5 Sonic anemometer 26

4.1.6 Plate anemometer 27

4.1.7 Tube anemometer 28

4.2 Humidity measurements 28

4.2.1 Absorptionhygrometer 29

4.2.2 Psychrometers 29

4.2.3 Chemical hygrometers 30

4.2.4 Coulometric hygrometer 31

4.3 RTA: Why is the pressure-based flow rate measurement used? 32

5 Temperature measurement (Eva Mairitsch) 33

5.1.1 Thermal comfort 33
5.2 Equipment for temperature measurement 34
5.2.1 Resistance thermometer 35
5.2.2 Thermal imaging camera 37
5.3 Measurement points 38
5.3.1 Measurement out of the test vehicle 39
5.3.2 Measurement in the test vehicle 41
5.3.3 Drivers cap 46
5.4 ISO Standards for ISO 9000 family and ISO 9001 48

6 Current energy demand (Benedikt Wanke) 50
6.1 Small wind tunnel 50
6.2 Large wind tunnel 51
6.3 Total energy demand 51

7 Waste heat (Benedikt Wanke) 52
7.1 Current use of the waste heat 52
7.2 Potential usage of the waste heat 52
7.2.1 Ecological advantages 53
7.2.2 Economical calculation 55
7.2.3 Challenges 56

8 Climatic impacts and test facilities for the aviation industry (Tobias Reith) 58
8.1 Climatic impacts in the aviation industry 58
8.1.1 Crosswind, gale and thunderstorms 58
8.1.2 Icing during flights 59
8.1.3 Turbulences 60
8.1.4 Visibility 60
8.1.5 Snow and ice 60
8.1.6 Heavy rain 61
8.1.7 Volcanic ash and sand storms 61
8.1.8 Conclusion regarding the environmental impacts 61
8.2 Climatic tests for the aviation industry at the Rail Tec Arsenal in Austria 61
8.3 Climatic tests at the McKinley Climatic Laboratory in Florida 64
8.3.1 Overview of the McKinley Climatic Laboratory 64
8.3.2 Climatic tests at the McKinley Climatic Laboratory 65

8.4 Comparison of the RTA in Austria and the McKinley Climatic Laboratory in Florida 65

List of literature 66

List of figures 71

List of tables 72

8 Climatic impacts and test facilities for the aviation industry (Tobias Reith)

8.1 Climatic impacts in the aviation industry

The weather and climatic differences display the biggest problems in the aviation industry. Dozens of flights are cancelled or accidents happen due to storm, snow, sleet and more, resulting in a total loss of over 3 billion US dollars only in the USA. According to Gloria Kulesa, the Team Leader for the "FAA's Aviation Weather Research Program", the main dangers for aircrafts are thunderstorms, in-flight icing, turbulences, visibility, ground de-icing and volcanic ash. (63) The " Arbeitskreis Luftverkehr und Wetter" adds snow, ice, heavy rain and sand storms to the list. (64) In the following the climatic and weather impacts on aviation is explained in detail, summarizing the points mentioned by the "FAA's Aviation Weather Research Program" under Gloria Kulesa and the "Arbeitskreis Luftverkehr und Wetter" under Thomas Hauf, Herbert Leykauf and Ulrich Schumann. (63) (64)

8.1.1 Crosswind, gale and thunderstorms

The major problem with wind in general is the fact that the airplanes are not always able to fly with the prevailing wind direction. Especially during the take-off or landing procedure the wind impact is over-average. For instance getting a perfect landing involves a banking in against the crosswind. Is the wind speed hitting a certain level a safe landing is not possible normally. However the biggest risk in aviation is not normal wind but thunderstorms due to their different weather phenomena included. (64) Kulesa states that according to American Airlines nearly 55 percent of turbulences are related to convective weather. Through this predictable risk ground operations often stop immediately eventuating in rerouting, lost passenger time and operating costs. (63) Thermal instability emerged by thunderstorms causes a vertical wind flow. In the area of this flow, which reaches a length of 10 km and a wind speed of 65 m/s on average, the whole variety of weather phenomena take place, ranging from hail over fall winds and turbulences to icing. The thunderstorm in general reaches a length of about 50 to 100 km. A problem faced especially by planes near the ground, are wind shears. This effect happens when convergent wind flows encounter downdrafts. It might happen really suddenly leaving the pilot only seconds to fly a safe manoeuvre. Wind shear detection systems mounted around the airport should help with additional information in advance. Another phenomenonregarding the wind during thunderstorms is the clear air turbulence. It is caused by the abrupt collapsing of the vertical winds and may result in an airplane drop of several hundred meters. Lightings are standard features of thunderstorms occurring in clouds or between the clouds and the ground. Commonly every aircraft is hit by lightning one time a year on average. Due to the metal fuselage working as a "Faraday-cage" they passengers in the plane are usually safe. The problem is not eliminated utterly regarding the fact that more and more non-metallic components are used to reduce the weight and heat generations up to 32000 Kelvin are possible. Thunderstorms are also predestined for icing due to the vertical wind reaching beyond the tropopause where temperatures under -40°C are possible. Additional phenomena being not uncommon during thunderstorms are hail, heavy rain and tornados. (64)

8.1.2 Icing during flights

Ice accumulation displays a major problem in the aviation industry. In reference to Kulesa there are different dangers related to icing. First of all the icing on structures like the surfaces and wings causes aerodynamic disadvantages, an increase in weight and a prevention of accurate controlling of the plane. Other major problems are the consequences of icing in the mechanical components, like the carburettors or the air intake. The effectiveness of the engine can drop or even become inoperative. (63) In general about 100 deaths in aviation are attributable to the icing during flights every year. The " Arbeitskreis Luftverkehr und Wetter" differs between several types of icing, undercooled liquid water drops freezing after hitting the plane, rain (over 0°C) which

Figure 35 Ice acceleration on the frontside of a wing after a flight (64)

freezes at the sub cooled airplane or the accumulation of consistent snow or ice particles. A special risk display drizzle drops or SLD (super cooled large drops), which have a diameter of 20 µm. The reason is on the one side the non-classical formation and on the other side the fact that airplanes are only approved for drops with a diameter of 50 µm. Despite these bigger drops freezing at the stagnation point the smaller drops are able to reach up to 1 m behind the leading edge. Primary smaller airplanes have to face this problem, because they are not able to fly over the cloud ceiling. The icing on these smaller airplanes can only be removed pneumatically by boots (rubber membrane). The SLDs mentioned before are able to accumulate after this membrane, leaving the pilot no possibility to get rid of the ice. An improvement to protect the plane against icing problems, are more accurate weather forecasts, further metrological training for the pilots or special ice detector systems. (64)

8.1.3 Turbulences

Hauf, Leykauf and Schumann explain in their thesis that turbulences are mainly caused by shear, convection and thermic. This phenomenon is especially dangerous when airplanes fly close to the ground. An evasion manoeuvre in low height is often not possible and the uplift can be impaired due to differences in the horizontal wind speeds. An additional type of turbulence mentioned by Hauf and Kulesa are the Clear Air Turbulences (CAT), part of the non-convective turbulences. The problematic reason of the non-convective turbulences are the appearance at nearly any altitude and under several weather conditions. The CATs occur at clear conditions without any premonition resulting in sudden ups and downs with the possibility of discomfort or even injuries for the passengers. (63) Furthermore the structure and materials of the plane are under heavy stress, which might eventuate in signs of fatigue. These CATs are caused either by strong shears at jet streams, breaking waves in mountainous regions or convective weather systems. (64)

8.1.4 Visibility

According to statistical analyses of the Aviation Accident Database & Synopses (NTSB) about 24 percent of all the accidents in the aviation industry from 1989 to 1997 are attributable to limited visibility and ceiling. Often the pilot did not have the needed knowledge of special situations and instruments for these situations were not available or became inoperative. (63) The reasons for limited visibility are primarily the ceiling, heavy rain and atmospheric aerosol (colloid of fine solid and liquid particles).

8.1.5 Snow and ice

Snow and ice can also influence the visibility, but the main problems of them are on the ground. Big airports need a special system for the de-icing of the surface area and for the airplanes itself. Popular standard institutes like the ISO, SAE and AEA try to set specifications for icing means and procedures. Snow and ice conditions can result in heavy delays on the airport or even dangerous accidents. The “Arbeitskreis Luftverkehr und Wetter” displays three major problems connected to snow and ice. Ensuring the safety of the start and landing strips as well as the circulation area is the first one. The second problem is the calculation of the stopping distance during wet, snowy or icy conditions. The third problem need to be solved is the ensuring that every plane is sufficiently freed from snow and ice before the starting sequence. (64) Kulesa devotes an extra part to “Ground De-Icing” stating that the snow and ice is not only a problem for the strips or the visibility, but additionally for the control surfaces, engines and propellers. Actually even small amounts of snow or ice on the wings are able to decrease the uplift by a factor of 25 percent.

8.1.6 Heavy rain

In comparison to Kulesa, Hauf, Leykauf and Schumann add rain to the list of climatic impacts as a separate part. They use different arguments to qualify that action. The first argument is that an extreme volume of rain is able to cause a "flame-out", which would be one of the worst scenarios. Rain in general causes sloppy slips or aqua planning. An additional danger lies in the accumulation of rain, snow and ice in the induction manifold or in the engine, which might result in an imbalance or damage. (64)

8.1.7 Volcanic ash and sand storms

Volcanic ash is mentioned in both articles as an individual point by the authors. To put it in numbers there are way more than 500 active volcanoes on the globe. A few erupt every year resulting in a big volcanic ash cloud, which reaches the altitude of long-haul aircraft. Volcanic ash has not caused deathly accidents yet, but a material damage of more than $250M was registered from 1982 to 2002. (64) Volcanic ash consists of small rock particles. According to Kurdesa these rock particles combined with acidic gases (sulphur dioxide and chloride) can effectively decrease the performance of an engine. (63) Hauf, Leykauf and Schumann explain that the damage is caused due to the glazing of ash in the engines resulting in a plugging of the nozzles. The more harmless problem is the decreased air throughput, whereas there is still the possibility of an engine breakdown. Sand storms are a phenomenon mainly in desert regions. They should not be underestimated; nevertheless winds can take them several thousand kilometers to different regions. A breakdown of the engine is the usual result of an airplane flying into a sand storm. For this reason all air traffic is stopped under these conditions normally. (64)

8.1.8 Conclusion regarding the environmental impacts

There a lot of different climatic impacts influencing the whole aviation industry. Some are harmless and annoying, others can be dangerous. It will not be possible to shut down all the risks, but maybe reduce them to the minimum with the help of simulations and tests. In the next chapters the climatic wind tunnel in Vienna (Rail Tec Arsenal, RTA), regarding the aviation tests, is explained. In addition to that the McKinley Climatic Laboratory in Florida is presented. The end focuses on a comparison between the RTA and the tests in Florida.

8.2 Climatic tests for the aviation industry at the Rail Tec Arsenal in Austria

Next to rail vehicles, road vehicles and technical systems, aviation displays the fourth industry sector, which is tested in the Rail Tec Arsenal in Austria. The aviation sector might be even the most important one to examine due to disastrous consequences regarding airplane accidents. Reproduction and time-consumption represent additional difficulty in the view of field tests. According to Rail Tec Arsenal various tests are available regarding the aviation. Cold start tests on aircraft engines, air-conditioning of cockpits and cabins, testing of components under special temperatures and solar radiation or flow analyses of aircraft engines and wings display the typical tests. In addition to those, new icing tests can be performed in the new Icing-Wind-Tunnel. An icing spray bar system and a calibration system was installed in 2013 enabling the usage in the large Climatic-Wind-Tunnel. The main examinations, which are conducted here, are full-scale tail rotors on helicopters and components on a rotorcraft fuselage in icing conditions. Two different test setups are available which are mainly distinguished by their size of the cross section. The big one reaches 16.1m² and focuses on big components like the cockpit of an airplane or a big helicopter (Figure 36), while the smaller one reaches 8.75m² and focuses on smaller components. Due to this disparity and the Bernoulli's principle it is possible to reach a wind speed up to 80 km/h in the small setup and only about

Figure 36 Helicopter in the Icing Wind Tunnel at the RTA (1)

20 km/h in the big setup. Other parameters do not differ between the two setups. The temperature ranges from -2°C to -30°C, the droplet size ranges from 15 µm to 40 µm. The air and water pressure reaches up to 4 bar while a water flow is available hitting up to 4 l/min. Under these circumstances there is the possibility to conduct certain certifications, which are required for helicopter engines. One simulation should show the repercussions when flying through super-cooled clouds. Particular standards are required like a certain droplet distribution and special wind speeds. The important results are the pressure losses at the turbine engine, which are operating under stormy and icy conditions. Getting out of these circumstances can result in a sudden release of ice, which was collected on the rotor blades. These ice accretions can now be drawn into the engine and damage the whole system. The main obstacle is creating the right conditions for water droplets to stay liquid even under

subzero temperatures. These circumstances come close to the real conditions in some clouds. Another important aspect for checking is the condensation in the fuel tank. A congestion of the fuel filter might happen due to an agglomeration of ice droplets during long flights at low temperature. The worst case would be the stalling of the engine. According to Rail Tec Arsenal they have the only facility, which is capable to test engines up to 1800 HP at full throttle. A lot of helicopter tests and certifications take place with the new icing system, but only one airplane was tested yet. The main reason might be the limited size of the tunnel. It would be possible to test different parts, but definitely not the wings in lateral position or even a whole airplane. For this purpose the aviation industry has its own test facility and simulations or they fly to Florida, where the McKinley Climatic Laboratory is located. This is the most important climatic test facility for the aviation industry across the globe. (1)

8.3 Climatic tests at the McKinley Climatic Laboratory in Florida

This chapter should offer a closer look at the McKinley Climatic Laboratory in Florida. At first

Figure 37 Airbus A350 at the McKinley Climatic Laboratory during a climatic test (65)

there is an overview of the whole facility followed by the test setups, which are possible and frequently used by the aviation industry.

8.3.1 Overview of the McKinley Climatic Laboratory

According to Ian Goold the McKinley Climatic Laboratory is the largest test facility enabling environmental impacts of different kinds and is located at the Eglin Air Force Base in Florida. The facility was built during the World War II and finished in 1947. (65) The main advantage of the McKinley Lab is the main chamber with an area of about 65000 square feet and a height of 70 feet in the center. Due to this size even large aircrafts like the Airbus A350 can be tested as a whole, while the engine is running (Figure 37). The main chamber is completely insulated and equipped with three R-22 refrigeration units and three natural gas-fired boilers offering the possibility to simulate variant climatic situations. (66) The materials used in the doors and walls for the insulation are glass-wool (13 inches) and galvanized steel on both side. (67) Additionally an Air Make-Up System is installed to provide the test setup with enough fresh air, which is especially important during propeller/turbine tests and after cooling down the air with chemicals. Due to different setups it is not only possible to change the air temperature, but simulating different wind speeds, rain scenarios or snow. (66) There are different smaller rooms at the McKinley Lab designated for the testing of different parts of an aircraft. Frequently used are the “All-Weather Room”, the “Temperature Altitude Chamber” (for altitude pressure up to 80,000 ft) and the Engine Test Cell. (67)

8.3.2 Climatic tests at the McKinley Climatic Laboratory

It is not possible to describe every test procedure in detail due to the limits of this paper and literature publicly available. For this reason the major focus lies on an overview of the most frequently used test setups in the main chamber.

Before starting the different environmental scenarios the airplane get fixed to the ground leaving the wheels able to stir. The overall temperature in the main chamber is regulated by three R-22 refrigeration units and three natural gas-fired boilers achieving -40°C up to 45°C. An open-circuit wind tunnel with seven fans should simulate the relative wind speed during flights. For the bad weather a spray water system is able to splash water on the airplane, which freezes under cold conditions. All the systems are constantly monitored and equipped with different measurement systems. (66) Even normal snow machines known from skiing are used to generate snow. After the simulation of cold and icy conditions the McKinley Lab is able to totally change the environment to exactly the opposite. Increasing the temperature up to 45°C and the humidity from 10 % up to 100% while irradiating the aircraft with solar radiation, should display the process when airplanes fly from cold conditions to warm countries or vice versa. (68)

8.4 Comparison of the RTA in Austria and the McKinley Climatic Laboratory in Florida

For a detailed and accurate comparison between the Rail Tec Arsenal and the McKinley Climatic Laboratory way more inside information would be needed. The test procedures available at both facilities are really similar, ranging from jungle-like humidity and solar radiation to severe winter and sleet. The reasons for the importance of climatic tests for the aviation industry have been explained at the beginning showing the dangers of thunderstorms, wind, turbulences, sand, heavy rain, ice and snow. The main advantage of the McKinley Lab however, is the amount of space allowing tests even to large aircrafts. Regarding aviation the Rail Tec Arsenal is only dimensioned for different parts of an airplane or helicopters. Nevertheless for the target audience of the RTA (rail, road and other technical systems) the specific shape of the main chamber has advantages as well. Less energy is needed to achieve the circumstances needed for a test environment. Additionally the whole area can be monitored and measured getting similar environmental impact on the whole test subject. Overall it can be said that both facilities have different advantages in specific industries. Nevertheless the aviation industry will still depend on the McKinley Climatic Laboratory for climatic test of a whole airplane in the future.

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List of figures

Figure 1 Data about Ford's new climatic wind tunnel (18)..12
Figure 2 Relevance of different climatic conditions for different vehicle components (18).....14
Figure 3 Solar Simulation Side Panel (1) 15
Figure 4 Coupling tests under snow condition (1) 18
Figure 5 Different cloud types according cloud level (24) 19
Figure 6 Test Setup 1 in the Icing Wind Tunnel (1) 20
Figure 7 Test Setup 2 in the Icing Wind Tunnel (1) 20
Figure 8 Robinson anemometer (27) 22
Figure 9 Hand helded vane anemometer (29) 23
Figure 10 Schematic of a laser doppler anemometer (33) 25
Figure 11 Principle of a plate anemometer (36) 27
Figure 12 Principle of tube anemometers (36) 28
Figure 13 Phsychrometer (40)..30
Figure 14: Influences on an rail vehicle (source: (44)) 34
Figure 15 PT1000 resistance / temperature graph (source: (48)) 36
Figure 16: Thermal imaging camera (source: (49))...37
Figure 17: Measuring points for outside measurement (source: (52), Annex H)....................39
Figure 18: Measuring points for outside measurement 1 (source: (53), Annex F) 40
Figure 19: Temperature measuring points in different vehicles (source: (52), Annex C) 41
Figure 20: Temperature measuring points in department vehicles to measure the extreme temperature and relative humidity (source: (52), Annex D)...42
Figure 21: Temperature measuring points of one seat (source: (52),Annex E) 43
Figure 22: Temperature and humidity measuring points for vehicles without joints (source: (53), Annex D) 44
Figure 23: Temperature and humidity measurement points for vehicles with joints (source: (53), Annex D) 44
Figure 24: Surface temperature measurement points in the vehicle (source: (53), Annex E)45
Figure 25: Influence of the sun radiation (left), measuring surrounding parameters (right) (source: (54))..46
Figure 26: Drivers cap measuring points (source: (54)) 47
Figure 27: Relationships of the standards in the ISO 9000 family (source: (55))...................48
Figure 22 RTA and the three office buildings (Google Maps) 52
Figure 23 EnergyBase (46) 53
Figure 30 Refrigerant medium temperature level (60) 54
Figure 31 Heating potential of the waste heat (green) and energy demand (blue - TechBase; orange - EnergyBase; red - FutureBase) (59)...54
Figure 32 Utilisation ratio of the facility (green=running; red=stand) (59) 56

Figure 33 Tank with 140 m³. Directly used waste heat (green); Energy from the tank (blue); Backup-energy (red)....57
Figure 34 Tank with 1,720 m³. Directly used waste heat (green); Energy from the tank (blue); Backup-energy (red)....57
Figure 35 Ice acceleration on the frontside of a wing after a flight (64)....59
Figure 36 Helicopter in the Icing Wind Tunnel at the RTA (1)....62
Figure 37 Airbus A350 at the McKinley Climatic Laboratory during a climatic test (65)....64

List of tables

Table 1: Solar Simulation Characteristics (1)....15
Table 2: Classification of Rain with its characteristics (22)....16
Table 3: Characteristics Rain Simulation in both wind tunnels (1)....17
Table 4: Specifications Test Setup 1 (1)....20
Table 5: Specifications Test Setup 2 (1)....21
Table 6 Variables (assumptions)....50
Table 7 Calculation of the energy demand (small wind tunnel) [own calculation]....50
Table 8 Calculation of the energy demand (large wind tunnel) [own calculation]....51
Table 9 Total energy demand over one year [own calculation]....51
Table 10 Calculation of the earnings per year - Price taken from (62)....55