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# Integration of Dew Point Measurement into the T-38 Wind Tunnel Data Acquisition System

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**In this paper a device for the measurement of the dew point in the wind tunnel T-38 and its connection to the acquisition system is presented. The dew point is the temperature at which the water vapor in a volume of humid air condenses into liquid water at a constant barometric pressure. The dew point is measured by a device named Hygromoc 770s. In the past, the dew point was measured in the T-38 wind tunnel and shown on display but it was not recorded in the data base. The dew point sensor was out of the data acquisition system. The dew point is a very important parameter during test run of the wind tunnel, especially for tests at high Mach numbers. The equipment presented in this paper enables that the sensor of the dew point is connected to the data acquisition system and that the value of the dew point is recorded into the data files with all other parameters during test runs in the T-38 wind tunnel.**

*Key words*: **wind tunnel, data acquisition system, dew point.**

## Introduction

IN the past, the dew point measuring system in the T-38 wind tunnel [1] consisted only of a dew point sensor and the Hygromoc indicator [2]. The dew point was shown on the display of the Hygromoc indicator. The Hygromoc indicator calculates a dew point and shows this value on its display. The Hygromoc indicator has an additional feature which enables remote measuring. This additional feature is realised by its current source which gives current proportional to a dew point value. This output current of the Hygromoc indicator is used for connecting the dew point sensor in the data acquisition system and recording the dew point value. Information about a dew point value is comprised in the output current of the Hygromoc indicator. The dew point is a very important parameter in blowdown wind tunnels [3-4]. The air must be dry enough so that blowing can be performed in the blowdown wind tunnel [5].

With additional equipment, it is possible to record, through the data acquisition system, the dew point values during blow run in the T-38 wind tunnel [6-7]. The schematic block diagram of new additional equipment i.e. a new dew point measurement system is shown in Fig.1.


**Figure1.** The schematic block diagram of a new dew point measuring system

The data acquisition system of the T-38 wind tunnel measures only the voltages from the sensors, so it is necessary to make conversion from current to voltage. A current voltage converter is made for that purpose. A galvanic isolator is used to eliminate interferences from the rest of the system and to make a measurement precise.

## Description of the dew point sensor and the Hygromoc indicator

The dew point sensor is built from pure aluminium. The aluminium film is coated with a thin oxide film. The dew point is a function of temperature and relative humidity. Penetration of water molecules through a porous gold layer into the aluminium oxide film depends on actual temperature and relative humidity. The penetrating molecules change the admittance of the sensor. A dew point sensor is placed in a metal box which has two holes through which air flows. One hole is for air input, and the other hole is for air output. The air from the air storage tank enters the metal box through the input hole, flows along the whole length of the dew point sensor, and leaves through the output hole. Fig.2 shows the metal box and the dew point sensor.

**Figure 2**. Metal box (left) and the dew point sensor (right)

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The Hygromoc indicator, Fig.3, measures the admittance of the dew point sensor, performs analog to digital conversion and displays a dew point value on the display. The dew point sensor is located in the T-38 wind tunnel wall near the air storage tanks, while the Hygromoc indicator is located in the control room. They are connected by a three axial cable which is about 50 meters long. In case of a removed sensor, or a broken connection cable, the digital indicator flashes. The flashing displayed value is –99.9°C. In case of a sensor or cable short circuit, the digital indicator is extinguished. The Hygromoc indicator measures a dew point temperature in the range from -80°C to 0°C. When relative humidity is less than 1%, which happens in the air storage tank of the T-38 wind tunnel, the dew point is within the range from -55°C to -30°C. The Hygromoc indicator generates current on its output which is proportional to a dew point value. The output current of the Hygromoc indicator is in the range from 0 mA to 20 mA. The output current of 0 mA corresponds to 0°C of the dew point and the output current of 20 mA corresponds to -80°C of the dew point. This proportionality between the output current and the dew point is linear through the whole range. This additional feature of the Hygromoc indicator enables remote measuring and the integration of the dew point sensor into the data acquisition system of the T-38 wind tunnel. When it is necessary to measure some electrical DC parameters at a distance, a better choice is to transmit DC current than DC voltage because of the losses when DC voltage is transmitted.


**Figure 3.** Hygromoc indicator

## Description of the equipment

The data acquisition system of the T-38 wind tunnel measures only voltages, so it is necessary to make conversion from current into voltage. A current-voltage converter is used for conversion from current to voltage. The device is mounted on the chassis of the data acquisition system. Fig.4 shows the current voltage converter mounted on the chassis of the data acquisition system.

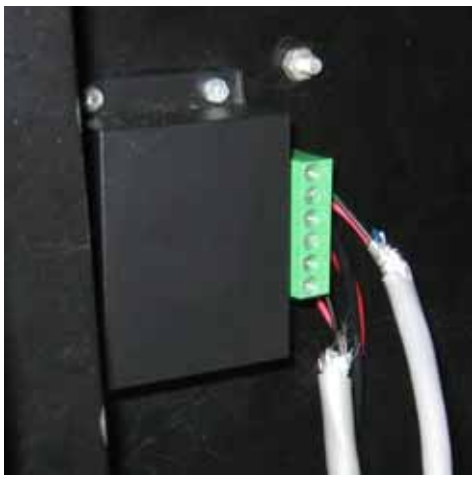

**Figure 4.** Current voltage converter mounted on the chassis of the data acquisition system

The Hygromoc indicator is mounted in the control room. It is connected by a cable about 20 meters long, with the current voltage converter located in the wind tunnel hall. The current voltage converter converts input current in the range from 0 mA to 20 mA into output voltage in the range from 0 V to 5 V. When the dew point is 0°C, then the output current of the Hygromoc indicator is 0 mA and the output voltage of the current voltage converter is 0 V. When the dew point is -80°C, then the output current of Hygromoc indicator is 20 mA and the output voltage of the current voltage converter is 5 V. Current voltage conversion is linear in the whole range. The current voltage converter consists of a resistor the resistance of which is 250 Ω, an amplifier whose gain is equal to one, electronics for power supply and indication. The output current from the Hygromoc indicator passes through the resistor with the resistance of 250 Ω and makes voltage drop on the resistor. This voltage comes to the amplifier input. The amplifier has gain equal to one, the voltage on the output of the amplifier is the same as the voltage on the input of the amplifier. The amplifier with gain equal to one is used as a separation amplifier. The LM358 amplifier is used in the current voltage converter [8]. This integrated circuit consists of two amplifiers. The second amplifier is not used; its inputs are connected to the ground,,thus eliminating interferences. Fig.5 shows the main part of the current voltage converter.

The power supply VCC of the amplifier is realized by an external voltage of 12V. The diode $D_1$ is used as protection in case of wrong connection of an external voltage source of 12V. The green LED diode shows that the current voltage converter has power supply. The power supply VCC of the current voltage converter is shown in Fig.6.

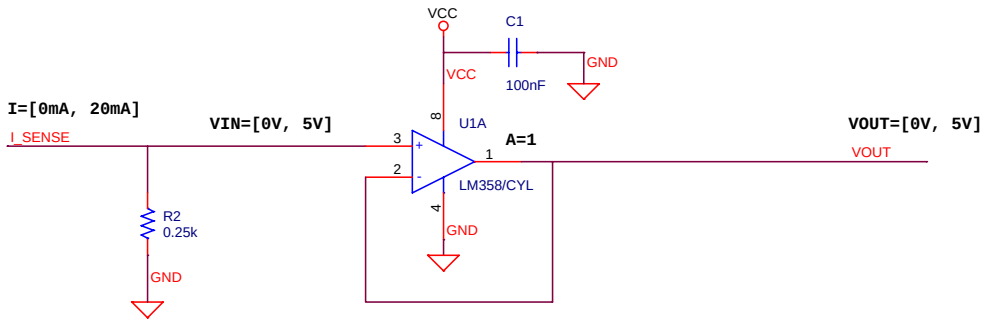


**Figure 5.** Main part of the current voltage converter

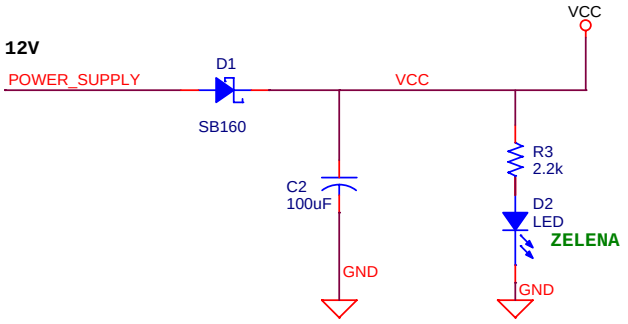


**Figure 6**. Power supply Vcc of the current voltage converter


**Figure 7.** Signal isolator model 285J of "Analog devices"

The output of the current voltage converter is connected to the input of the signal isolator. The signal isolator model 285J by "Analog devices" [9] is used. The signal isolator model 285J is shown in Fig.7.

The signal isolator has gain equal to one and works in the range from 0 V to 10 V. It is used for galvanic isolation between the dew point measuring electronics and the data acquisition system. The electrical schema of the signal isolator is shown in Fig.8.

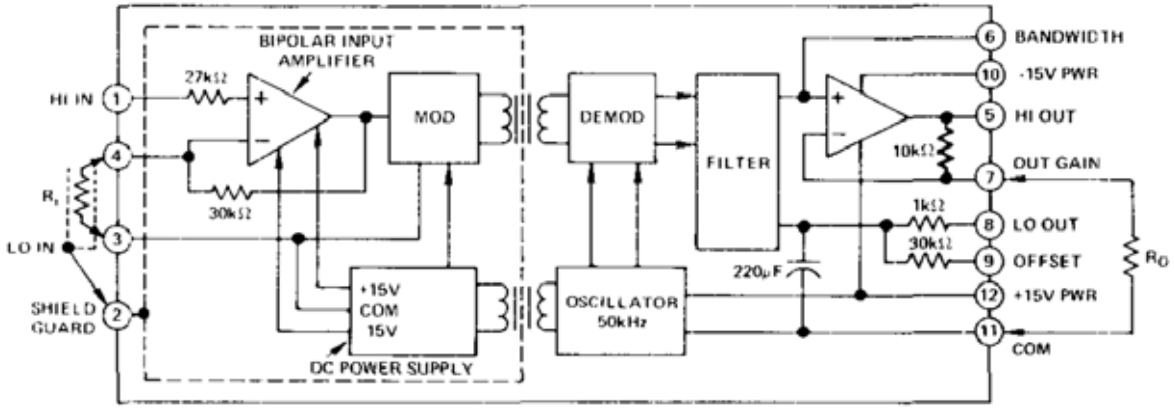


**Figure 8.** Electrical schema of the signal isolator

The gain of the signal isolator can be adjusted by the resistors $R_i$ and $R_0$ by equation:

$$A = \left(1 + \frac{30k\Omega}{R_i}\right) \cdot \left(1 + \frac{10k\Omega}{R_0}\right)$$

In the case when $R_i \to \infty$ and $R_0 \to \infty$, the gain of the signal isolator is equal to one. The gain equal to one is necessary so in this case none of the resistors is used, and in that way that $R_i \to \infty$ and $R_0 \to \infty$ is achieved. The voltage from the output of the signal isolator is inputted to the analog card which belongs to the data acquisition system [10]. Since the maximum output voltage of the analog card is 9.7 V, and because the higher voltage which comes from the signal isolator is 5 V, the analog card gain is set to one.

## Calibration of the measurement system

Since setting a specific dew point value via the Higromoc indicator is impossible, the calibration of the measurement system is done by a precise current calibrator. The calibration procedure of the system is shown in Fig.9.

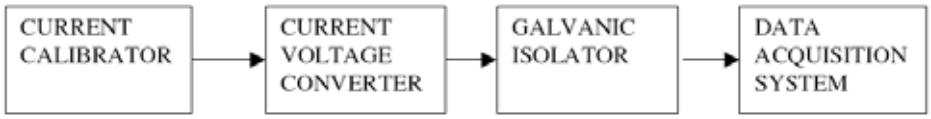


**Figure 9.** The schematic block diagram of the measurement system for calibration

**Table 1.** Results of the calibration of the measurement system

| n | Input [mA] | Measured [V] | Calculated [°C] | Measured [°C] | Error [°C] | Error [%FS] |
|---|---|---|---|---|---|---|
| 1 | 0 | -0.01519 | 0 | 0.24304 | 0.24304 | 0.3038 |
| 2 | 4 | 0.99691 | -16 | -15.95056 | 0.04944 | 0.0618 |
| 3 | 8 | 2.0146 | -32 | -32.2336 | -0.2336 | -0.292 |
| 4 | 12 | 3.0332 | -48 | -48.5312 | -0.5312 | -0.664 |
| 5 | 16 | 4.0351 | -64 | -64.5616 | -0.5616 | -0.702 |
| 6 | 20 | 5.0391 | -80 | -80.6256 | -0.6256 | -0.782 |
| 7 | 20 | 5.0393 | -80 | -80.6288 | -0.6288 | -0.786 |
| 8 | 16 | 4.0362 | -64 | -64.5792 | -0.5792 | -0.724 |
| 9 | 12 | 3.0343 | -48 | -48.5488 | -0.5488 | -0.686 |
| 10 | 8 | 2.0141 | -32 | -32.2256 | -0.2256 | -0.282 |
| 11 | 4 | 0.99955 | -16 | -15.9928 | 0.0072 | 0.009 |
| 12 | 0 | -0.015443 | 0 | 0.247088 | 0.247088 | 0.30886 |

The currents of 0 mA, 4 mA, 8 mA, 12 mA and 20 mA are generated by the calibrator. The data acquisition system measured voltage from the galvanic isolator. The software for calibrating the sensors in the T-38 wind tunnel is used for data processing and calculations of polynomial

coefficients. The results of the calibration of the measurement system are given in the table below.

The interpolation polynomial is of the first grade.

$$DP[^{\circ}C] = a \cdot I[mA] + b$$

The coefficients of the polynomial:

$$a = -4.0426$$
$$b = 0.1797$$

In order to show the dew point in the appropriate run table, data processing software is developed. After each test run in the T-38 wind tunnel, the parameters are shown in the run table. In the run table below, the parameters are shown for a typical wind tunnel test run.

**Table 2.** Parameters for a typical wind tunnel test run

| Wind tunnel T-38 – Run table | Test program: CALT38 | Run number 244 |
|---|---|---|
| Date of blowing 26-oct-2012 | | |
| Data of the primary measurement system: | | |
| MSR= 2.260 | P0SR= 6.003 bar | MRESR= 66.18 |
| QSR= 1.827 bar | PSSR= 0.511 bar | T0SR=296.1 K |
| VSR= 548.352 m/s | DEW = -45.9 ºC | |

## Conclusion

This paper presents the equipment and a method of connecting the dew point sensor in the data acquisition system. Before the dew point sensor was connected in the data acquisition system, dew point values had been written down by test engineers before every test run of the T-38 wind tunnel in a list called "T-38 wind tunnel test run summary". Very often, test engineers forgot to write down dew point values due to many other duties. Later, when test engineers wrote reports, they recalled dew point values and very often they wrote down the wrong ones. One of the opportunities to improve the quality of measuring in the T-38 wind tunnel is that the Hygromoc indicator is connected to the data acquisition system. For each test run, a dew point value is thus recorded in the data base with other recorded parameters such as temperature and pressure values. At the age of computers and sophisticated technologies, there is a tendency to connect all the sensors in the data acquisition system. In that way only, measured parameters will be preserved in the „memory“ of a computer.

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# Povezivanje uređaja za merenje tačke rose u akvizicioni sistem aerotunela T-38

**U ovom radu je predstavljen uređaj za merenje tačke rose i njegovo povezivanje u sistem za prikupljanje podataka aerotunela T-38. Tačka rose je temperatura na kojoj se vodena para u zapremini vlažnog vazduha pri konstantnom pritisku kondenzuje u vodu. Tačka rose se meri uređajem koji se zove Hygromoc 770s. Tokom proteklih godina tačka rose u aerotunelu T-38 je merena i prikazivana na displeju, ali nije snimana u bazu podataka. Senzor tačke rose nije bio povezan za sistem za prikupljanje podataka. Tačka rose je vrlo važan parametar pri ispitivanjima u aerotunelu T-38, naročito na visokim Mahovim brojevima. Koristeći opremu, predstavljenu u ovom radu, je omogućeno da senzor tačke rose bude uključen u sistem za prikupljanje podataka i da je vrednost tačke rose zapisana u „memoriju“ tokom duvanja u aerotunelu T-38.**

*Ključne reči:* **aerodinamički tunel, sistem za prikupljanje podataka, tačka rose.**

# Подключение устройства для измерения точки росы в систему сбора в аэродинамической трубе Т-38

**В этой статье представлено устройство для измерения точки росы и его подключение к системе сбора данных в аэродинамической трубе Т-38. Точка росы это температура, при которой водяной пар в объёме влажного воздуха при постоянном давлении конденсируется в воду. Точка росы измеряется измерительным прибором который называется Hygromoc 770S. За последние годы точка росы в аэродинамической трубе Т-38 была измерена и отображается на дисплее, но это не записано в базу данных. Датчик точки росы не был подключён к системе сбора данных. Точка росы является очень важным параметром в тестах в аэродинамической трубе Т-38, особенно при высоких числах Маха. Использование оборудования, представленного в данной работе, позволило чтобы датчик точки росы был включён в систему сбора данных и чтобы значения точки росы были записаны в "памяти" в процессе подувания в аэродинамической трубе Т-38.**

*Ключевые слова:* **аэродинамическая труба, системы сбора данных, точка росы.**

# Intégration de l’instrument pour mesurer le point de la risée dans le système d’acquisition de la soufflerie T-38

**Dans ce travail on a présenté l’instrument pour le mesurage du point de la rosée et son intégration dans le système pour le ramassage des données chez la soufflerie T-38. Le point de la rosée est la température à laquelle la vapeur d’eau dans le volume de l’air humide à la pression constante se condense en eau. Le point de la rosée se mesure à l’aide de l’instrument appelé Hygromoc 770s. Durant les années passées le point de la rosée dans la soufflerie T-38 a été mesuré et présenté sur l’affichage mais il n’a pas été enregistré dans la base des données. Le capteur du point de la rosée n’était pas intégré dans le système pour le ramassage des données. Le point de la rosée est un paramètre très important dans les essais dans la soufflerie T-38 surtout pour les nombres de Mach très élevés. L’usage de l’équipement présenté dans ce papier a permis au capteur du point de la rosée de s’intégrer dans le système pour le ramassage les données et à la valeur du point de la rosée d’être enregistré dans la mémoire au cours des essais dans la soufflerie T-38.**

*Mots clés:* **soufflerie aérodynamique, système pour le ramassage des données, point de la rosée.**