# THERMISTOR NTC SENSOR INACCURACIES IMPACT ON THE HVAC/R COMPRESSOR PERFORMANCE

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**Abstract.** Electricity consumption for thermal comfort in urban buildings is estimated to an average of 35%. The aim of this article is to evaluate, theoretically, the impact of sensors inaccuracies on the performance and efficiency of HVAC equipment. Different types of temperature and pressure sensors are considered. The measurement tolerance, from manufacturer's technical data sheet, will be used for the theoretical evaluation of the range in which the operating point of the equipment can vary. Compressor selection software are used for evaluating theoretical COP and electrical energy consumption change in the range of sensor inaccuracies. The study evaluates theoretically the impact on performance of scroll, piston and screw compressors, considering refrigerants used in chillers (R717, R134a, R410A, R32). The operating point of the compressor is considered as normal chiller scenario, with evaporation temperature of +4°C and condensing pressure corresponding to +35°C. The conclusion of the theoretical evaluation is that resistance tolerance bigger than 1% brings a 1% or more variation of compressor's performance.

**Keywords.** HVAC, sensor impact, COP
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## 1. Introduction

Electricity consumption for thermal comfort in urban buildings is estimated to an average of 35% from global consumption [1] . Recent study [2] shows that there is an increasing trend for residential buildings. That's why research work for better efficiency in HVAC sector is still needed.

This study evaluates, theoretically, the impact of NTC thermistor sensor inaccuracies over the HVAC equipment. In this case is evaluated the theoretical COP and electrical consumption variations due resistance tolerance for a chiller with a cooling capacity of 100 kW.

## 2. Sensors in HVAC equipment

HVAC equipment like chillers use temperature and pressure sensors for control loop [3] like shown in figure 1.

There are different methods for control loop [4] . In this theoretical evaluation is considered that the compressor is controlled based on the outlet water temperature sensor. The logic diagram is presented in figure 2.

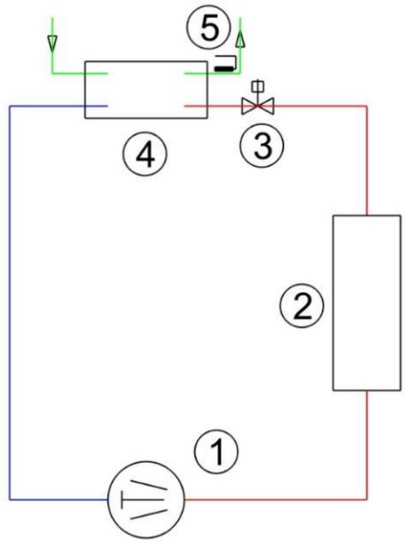


**Fig. 1 –** System drawing (1-compressor, 2-condenser, 3-expansion device, 4-water heat exchanger, 5-temperature sensor

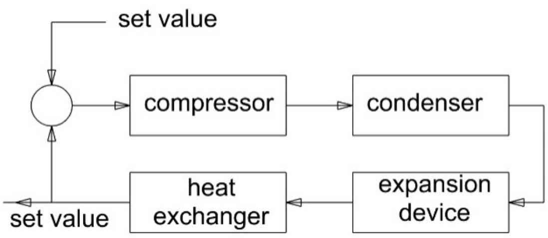


**Fig. 2 –** Control loop diagram

Thermistor type sensors are one of the most common types [5] used in this kind of application.

One of the main characteristics for thermistor sensor is resistance tolerance and for NTC type this tolerance is in the range of 0.5-10% [6] . For this study was selected, as a reference, a 10kΩ NTC sensor (MEAS PRO4) [7] with main characteristics presented in table 1.

**Tab. 1 –** NTC sensor characteristics [7].

| Nominal resistance at +25°C | Tolerance at +25°C | Temperature range |
|---|---|---|
| 10kΩ | ±1% | -35°C to 105°C |

The theoretical values of resistance, based on temperature, were extracted from technical data sheet[7] from the manufacturer. Figure 3 represent the theoretical resistance-temperature curve.

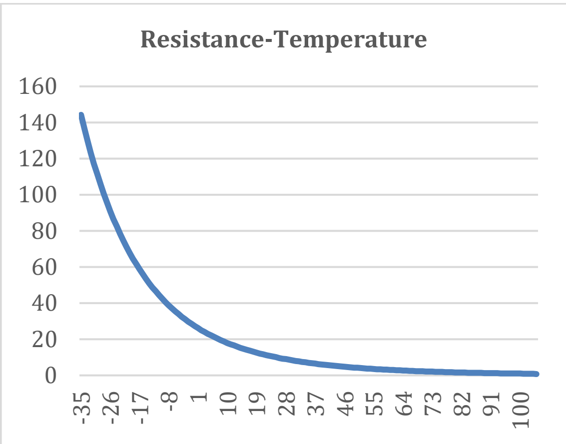


**Fig. 3 –** Resistance-Temperature curve for NTC sensor.

## 3. Evaluation method

First step of this theoretical evaluation is to define the temperatures values variation due to the resistance tolerance. Equation (1) is used to calculate the interpolated values.

$$t_3 = (R_3 - R_2)\frac{t_1 - t_2}{R_1 - R_2} + t_2 \qquad (1)$$

Calculations were made for resistance tolerance values in the range of 0.5%-10% with steps of 1%.

The values resulted from equation (1) are used to define the range of possible operating points when the reading of evaporating temperature is +4°C.

Using different selection software [8] [9] the theoretical COP range for each situation was extracted. The theoretical electrical power consumption can be calculated using theoretical COP values in equation (3).

$$COP = \frac{Q}{P} \qquad (2)$$

$$P = \frac{Q}{COP} \qquad (3)$$

The extraction of theoretical COP values was made for different refrigerants: R32 (scroll compressor), R134a (pistons), R717 (pistons), R410a (scroll). The reference operating point is considered $t_o$=+4°C, $t_c$=+35°C, $\Delta t_{sh}$=10K, $\Delta t_{sc}$=2K.

The theoretical COP values and electrical power calculation were made based on 100kW cooling power compressor.

## 4. Results and discussions

Table 2 present the results for evaporating temperature variation. For each 1% step of resistance tolerance it can be seen the possible theoretical minimum and maximum value of evaporating temperature for a sensor reading of +4°C.

**Tab. 2 –** Temperature range for operating point.

| Resistance tolerance | Temperature resulting values [°C] | | |
|---|---|---|---|
| | Max value | Reading | Min value |
| 0.5% | +4.122 | +4 | +3.878 |
| 1% | +4.244 | +4 | +3.755 |
| 2% | +4.489 | +4 | +3.510 |
| 3% | +4.734 | +4 | +3.266 |
| 4% | +4.978 | +4 | +3.021 |
| 5% | +5.223 | +4 | +2.777 |
| 6% | +5.468 | +4 | +2.532 |
| 7% | +5.712 | +4 | +2.287 |
| 8% | +5.957 | +4 | +2.042 |
| 9% | +6.202 | +4 | +1,798 |
| 10% | +6.446 | +4 | +1.553 |

Tables 3, 4, 5 and 6 presents the extracted theoretical values for COP using compressor selection software [8] and calculated values for electrical power consumption variation for different refrigerants (R134a, R32, R410A, R717). The 4th column of these tables shows the variation, in percentage, of electrical power consumption considering the theoretical value, calculated for evaporating temperature of +4°C, as a reference.

The maximum theoretical electrical power consumption variation is about 10% in case of systems with $NH_3$.

**Tab. 3 –** R32 results.

| Resistance tolerance | COP | Electrical power for 100kW cooling power | |
|---|---|---|---|
| | [-] | [kW] | [%] |
| Reference | 5.37 | 18.62 | 0 |
| 0.5% | ±0.02 | ±0.07 | ±0.37 |
| 1% | ±0.04 | ±0.14 | ±0.75 |
| 2% | ±0.08 | ±0.28 | ±1.5 |
| 3% | ±0.12 | ±0.41 | ±2.2 |
| 4% | ±0.16 | ±0.56 | ±3.0 |
| 5% | ±0.21 | ±0.70 | ±3.76 |
| 6% | ±0.25 | ±0.83 | ±4.45 |
| 7% | ±0.29 | ±0.95 | ±5.1 |
| 8% | ±0.33 | ±1.08 | ±5.8 |
| 9% | ±0.38 | ±1.23 | ±6.6 |
| 10% | ±0.42 | ±1.35 | ±7.25 |

**Tab. 4 –** R134a results.

| | [-] | [kW] | [%] |
|---|---|---|---|
| Reference | 4.78 | 20.92 | 0 |
| 0.5% | ±0.02 | ±0.09 | ±0.43 |
| 1% | ±0.04 | ±0.18 | ±0.86 |
| 2% | ±0.08 | ±0.36 | ±1.72 |
| 3% | ±0.11 | ±0.47 | ±2.25 |
| 4% | ±0.15 | ±0.64 | ±3.0 |
| 5% | ±0.19 | ±0.80 | ±3.82 |
| 6% | ±0.23 | ±0.96 | ±4.58 |
| 7% | ±0.27 | ±1,12 | ±5.35 |
| 8% | ±0.3 | ±1,23 | ±5.88 |
| 9% | ±0.34 | ±1.39 | ±6.64 |
| 10% | ±0.38 | ±1.54 | ±7.36 |

**Tab. 5 –** R717 results.

| Resistance tolerance | COP | Electrical power for 100kW cooling power | |
|---|---|---|---|
| | [-] | [kW] | [%] |
| Reference | 5.93 | 16.86 | 0 |
| 0.5% | ±0.03 | ±0.08 | ±0.5 |
| 1% | ±0.06 | ±0.17 | ±1.00 |
| 2% | ±0.12 | ±0.33 | ±1.98 |
| 3% | ±0.18 | ±0.50 | ±2.95 |
| 4% | ±0.25 | ±0.68 | ±4.05 |
| 5% | ±0.31 | ±0.84 | ±4.97 |
| 6% | ±0.37 | ±0.99 | ±5.87 |
| 7% | ±0.44 | ±1,16 | ±6.91 |
| 8% | ±0.51 | ±1,34 | ±7.92 |
| 9% | ±0.57 | ±1.48 | ±8.77 |
| 10% | ±0.64 | ±1.64 | ±9.74 |

**Tab. 6 –** R410A results.

| Resistance tolerance | COP | Electrical power for 100kW cooling power | |
|---|---|---|---|
| | [-] | [kW] | [%] |
| Reference | 5.36 | 18.66 | 0 |
| 0.5% | ±0.02 | ±0.07 | ±0.37 |
| 1% | ±0.04 | ±0.14 | ±0.74 |
| 2% | ±0.08 | ±0.27 | ±1.47 |
| 3% | ±0.12 | ±0.41 | ±2.19 |
| 4% | ±0.16 | ±0.54 | ±2.90 |
| 5% | ±0.21 | ±0.70 | ±3.77 |
| 6% | ±0.25 | ±0.83 | ±4.46 |
| 7% | ±0.29 | ±0.96 | ±5.13 |
| 8% | ±0.33 | ±1,08 | ±5.80 |
| 9% | ±0.38 | ±1.24 | ±6.62 |
| 10% | ±0.43 | ±1.39 | ±7.43 |

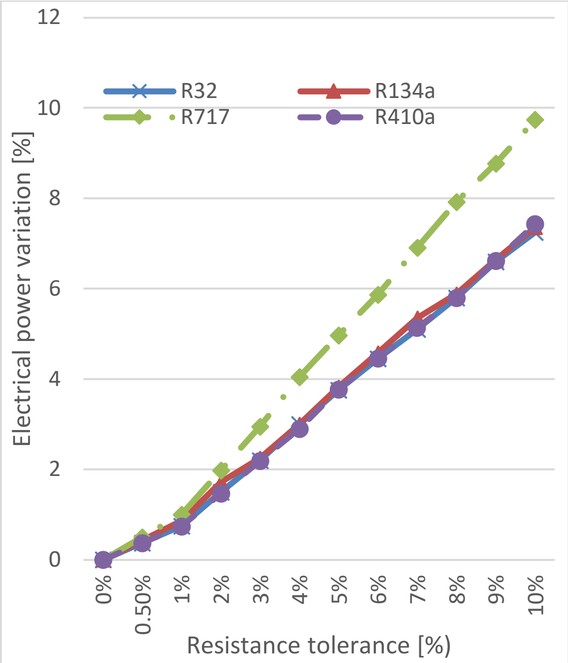


**Fig. 4 –** Variation of electrical power due to resistance tolerance value.

Figure 4 represents the electrical power consumption variation depending on tolerance. This shows the influence of sensor resistance tolerance on electrical power consumption It seems that systems using R134a, R32 and R410a have similar variations and are very different than NH3 systems.

Also it can be observed that the electrical power consumption has a linear variation, proportional to the resistance tolerance values.

## 5. Conclusions

When resistance tolerance is bigger than 1%, the electrical consumption variation is bigger than 1%.

The bigger the COP of the system the more influence from resistance tolerance on electrical power consumption.

Depending on application and cooling power, proper temperature sensors must be selected to have an efficient system, preferably with resistance tolerance around 1%.

In case of big resistance tolerance sensors the efficiency can vary until 10%.

Further research regarding the influence from pressure sensor inaccuracies must be done to have a larger view of what inefficiencies can bring sensor tolerances in a HVAC system.

Considering that electricity consumption for thermal comfort in urban buildings is estimated to an average of 35% from global consumption, means that the selection of proper sensors can have a significant impact on global consumption.

Further research that counts together other influences, like time depreciation, should show bigger values, so sensor quality should be neglected for efficiency HVAC systems.

## 6. Nomenclature

| | | |
|---|---|---|
| COP – coefficient of performance | (-) |
| P – electrical power | (W) |
| Q – cooling power | (W) |
| R – electrical resistance | (Ω) |
| t – temperature | (°C) |

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