

Michal JURČIŠIN  
Pavol CABÚK  
Stanislav SLOSARČÍK

## AUTOMATION MEASUREMENT OF INTRA-ABDOMINAL PRESSURE

**ABSTRACT** *The article deals with the design of capacitive pressure sensor for automated measurement of intra-abdominal pressure by a non-invasive method. A capacitive pressure sensor consists of a glass tube with evaporated thin film electrodes. The capacity change is given by the level change of displaced fluid in the tube. For capacitive sensors with different inner diameter of tubes calibration curves were experimentally found. A capacitive sensor is a subpart of an automated measuring system for clinical application of intra-abdominal pressure measurement.*

**Keywords:** *automation, measurements, capacitive pressure sensors, calibration, intra-abdominal pressure.*

### 1. INTRODUCTION

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An abdominal compartment syndrome (AbCS) is caused by the increase in intra-abdominal pressure (IAP) caused by tissue tumescence or by accumulation of free liquid in abdominal cavity. AbCS is a very severe complication that may influence many organ systems of patients. When it is not timely diagnosed and it is not cured, it may result in multi-organ collapse

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**Michal JURČIŠIN, Eng.**  
e-mail: Michal.Jurcisin@tuke.sk

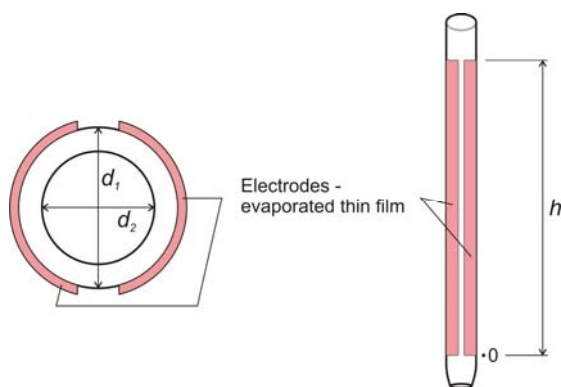
**Pavol CABÚK, Stanislav SLOSARČÍK**

Department of Technologies in Electronics,  
Faculty of Electrical Engineering and Informatics Technical University of Kosice, Slovakia

and death [1]. The most precise method of IAP measuring is applying pressure sensor through abdominal wall directly into abdomen cavity. Measuring pressure directly in the abdomen cavity via catheter is a hazardous invasive method, which is not used in clinical practice [2]. An indirect method of IAP measuring is based on applying the Foley catheter inside the urinary bladder. This method is based on the fact, that the urinary bladder works like a passive transmitter of IAP on internal water filling. Empty urinary bladder is filled by 20-50 ml of sterile saline via catheter [2]. Pressure in the abdomen cavity is transferred across the bladder to the filling solution and to the water column of the catheter which is connected to the water column in a manometer or a pressure sensor [3]. The measurement is realized in one hour intervals with filling and emptying all systems. For measurements of IAP commercial systems are used. An advantage of commercial systems is that they are delivered in assembled state, a disadvantage is the necessity of manual operation after each cycle.

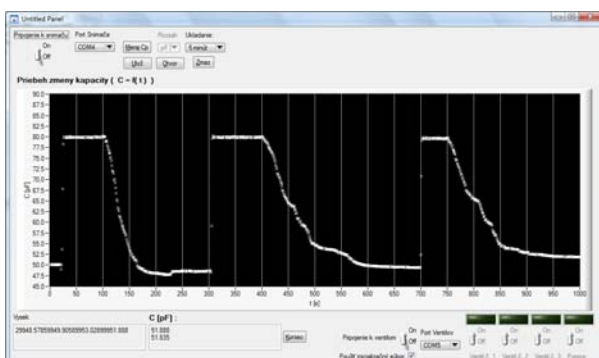
## 2. CAPACITIVE SENSOR

For the realization of capacitive pressure sensors glass tubes with inner diameter 4-9 mm were used. On the outer surface of the glass tube a thin film was applied for two electrodes by vapour deposition. Copper was used as a material for deposition. Evaporation was carried out through a prepared cylindrical mask that was placed on the glass tube in vapour atmosphere. The shape of the electrodes is shown in Figure 1. Saline (0.9% NaCl aqueous solution) was used as dielectric of the capacitance sensor.



**Fig. 1. Capacitive pressure sensor:**  
 $d_1$  – outer tube diameter,  $d_2$  – inner tube diameter,  $h$  – evaporated electrode height

Capacity change of a capacitive sensor is measured using an RLC bridge MT4090. An LCR meter MOTECH MT 4090 can be connected to a computer via an RS 232 interface. Using a special development environment LabWindows/CVI designed for development of laboratory applications, test software was created allowing graphical display of measured capacity (pressure) versus time. Any time interval between measurements can be set while using the created application.



**Fig. 2. Measurement course in the created test program**

the level of dielectric is located in the maximum and minimum height respectively. The time interval  $t_{inc}$  is obtained by forced change of level height and  $t_{dec}$  is given by the spontaneous decrease in dielectric level height.

The application created (Fig. 2) enables us to show the measured capacity in 1 s intervals. The maximum and minimum value of Y axis, on which the measured values of capacity (pressure) are plotted is dynamically changed according to measured values. Distribution of intravesical pressure grades used in clinical practice is listed in Table 1. In the second grade i.e. at a pressure of 2.66 kPa it is necessary to decompress the abdominal cavity what is reached by cutting the abdominal wall and keeping it open. Measurement of IAT is carried out at one hour intervals using the following procedure:

- system preparation for measurement – pre-filling of bladder and system tubes with exact volumes of saline,
- realization of measurement in the time interval of several minutes,
- drying the system.

**TABLE 1**

Grade distribution of intravesical pressures used in clinical practice

Grade	cm H <sub>2</sub> O	p [kPa]
1.	16 – 20	1.59 – 1.99
2.	21 – 27	2.13 – 2.66
3.	28 – 34	2.79 – 3.33
4.	> 35	> 3.33

In Table 2 parameters of used glass tubes are listed. Measured capacity varied depending on the tube diameter in the range of 11.7 – 25 pF without dielectric corresponding to the pressure 0 kPa, and 14,3 – 132 pF with a dielectric at

On the basis of the measurements it is possible to characterize the capacitive sensor directly. The analyzed parameters were the value of maximal ( $C_{MAX}$ ) and minimal ( $C_{MIN}$ ) capacity and the time interval of increase ( $t_{inc}$ ) and decrease ( $t_{dec}$ ) in capacity after which the capacity is measured in steady state. Capacity  $C_{MAX}$  and respectively  $C_{MIN}$  are capacities measured on the assumption that

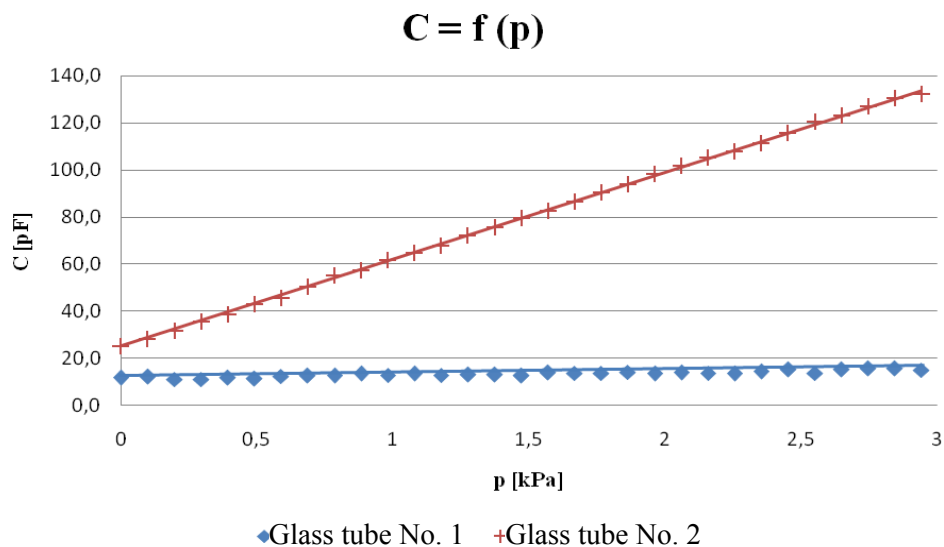
height 300 mm corresponding to the pressure 2.94 kPa according to Figure 3. A block diagram of the measuring system for automated measurements of IAP is shown in Figure 3.

**TABLE 2**

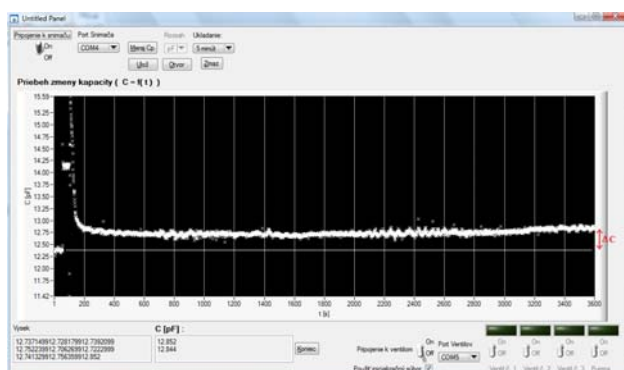
A review of the tested glass tube parameters

	Tube No. 1	Tube No. 2
$d_1$ [mm]	7,3	10,6
$d_2$ [mm]	3,6	8,65
$h$ [mm]	300	300
$C_{MIN}$ [pF]	11,7 – 12,2	25
$C_{MAX}$ [pF]	14,3 – 14,9	132
$t_{inc}$ [s]	5	10
$t_{dec}$ [s]	460	65

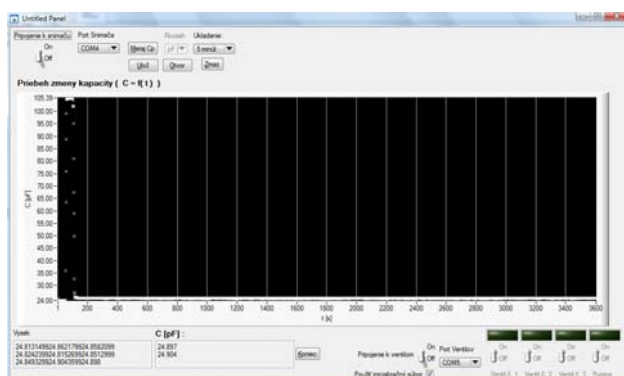
Calibration of capacitive sensors was realized in temperature stabilized conditions at 20°C. Control measurement with temperature changes in the range from 20°C to 50°C does not prove temperature impact of electrical parameters on capacitive pressure sensor.

**Fig. 3. Calibration curves of tested glass tubes**

Capacity course changes of glass tube No. 1 with spontaneous level decrease is shown in Figure 4. At the beginning of the measurement the dielectric level of the capacitive pressure sensor was at the zero point.



**Fig. 4. Capacity course changes of glass tube No. 1 of capacitive pressure sensor with spontaneous level decrease (measurement duration 1 h)**



**Fig. 5. Capacity course changes of glass tube No. 2 of capacitive pressure sensor with spontaneous level decrease (measurement duration 1 h)**

The dielectric level was then changed up to the height of  $h$ . The time interval necessary to stabilize the capacity at a maximum value was 5 s. After the capacity stabilized the water level was spontaneously decreased. Figure 4 shows the longest period permissible for stabilizing the sensor capacity at a minimum value, which is permitted for the developed measuring system. During the 460 s the capacity comes to a stable and a constant value which did not correspond to the capacity value of  $C_{\text{MIN}}$ . The remaining capacity  $\Delta C$  was approximately 0.5 pF. The used glass tube is characterized by changes in  $C_{\text{MIN}}$  and  $C_{\text{MAX}}$  during several measurements (Tab. 2).

The changes in capacity courses of glass tube No. 2 with spontaneous level decrease are shown in Figure 5.

At the beginning of the measurement the dielectric level of the capacitive pressure sensor was at zero point. Then the level was forced to the height of  $h$  and stabilized at a maximum value after 10 s. After capacity stabilization the level of dielectric spontaneously decreased. Figure 5 shows the longest time interval for capacity (pressure) stabilization at minimum value, which is permitted for the developed measuring system. The decrease of capacity to the  $C_{\text{MIN}}$  value occurred during 65 s.

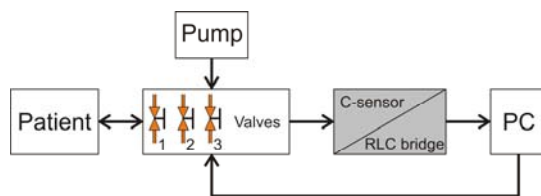
In the case of the glass tube No. 1 the capacity range is unstable in terms of measurement repeatability. For tubes with these dimensions it can be assumed that the capacity range is too small for easy allocation of a unique value of capacity corresponding to the level of liquid.

Capacitance pressure sensor realized by glass tube No. 2 is considered to be suitable in terms of all examined parameters. Examined parameters

improve with diameters greater than the diameter of glass tube No. 2. Using tubes with larger diameters cause increase in internal volume of the tube making them unsuitable for the application with limited volume of saline filled into the bladder.

### 3. DESCRIPTION OF SYSTEM FOR MEASURING INTRA-ABDOMINAL PRESSURE

A block diagram of the measuring system for automated measuring of IAP is shown in Figure 6.

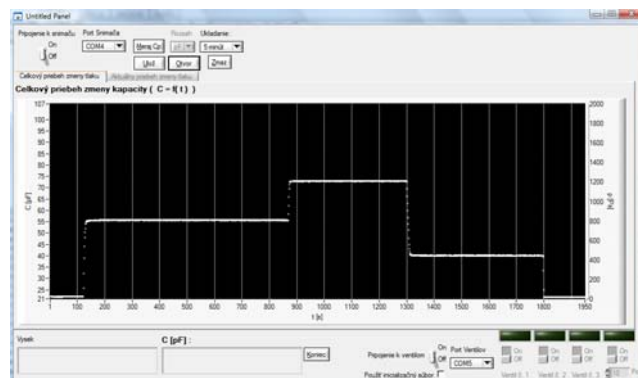


**Fig. 6. Principal block diagram of the measuring system**

In time intervals between measurements all valves are opened therefore it is possible to empty all the system and it enables continuous flow of urine to the waste. After emptying the system it is possible to close valve No. 2 for isolation of the patient from the non-used part of the system. This condi-

tion decreases the possibility of infection. The first step of the measurement process is filling the tubes between sensor and pump with defined volume of saline. In the next step valves No. 1 and No. 3 are closed and valve No. 2 is opened. Bladder is filled with 25 ml volume of saline. The measurement starts after the filling by opening the valve No. 2. Pre-filling tubes around valve No. 3 ensures the continuity of the liquid column and the urine interference on the sensor is eliminated.

The valves consist of servomotors which can be logically controlled. This solution was realized in order to ensure the sterility of the measuring system. The mechanical parts of the motor were modified for the purposes of the developed system. The throttling is realized by rotation of the arm, which presses the required tube.



**Fig. 7. Stability of pressure values measurement**

The developed measuring system was tested in laboratory conditions. Test measurements consist of one measuring cycle without drying the system. Within this test the pressure changes were carried out in order to verify the stability of measured values. Test results are shown in Figure 7. From the course it results that if the external pressure force is fixed at one value then there are not any changes in measured pressures. This measurement confirms that the system of valves used is functional and without any leakage.

## 4. CONCLUSION

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All the system will simplify the measurement process in focus for the medical staff and eliminate human mistakes. In the first step the sterility of the system, measurement via capacity sensor and the realization of valves were solved. The second step focused on the specification of optimal dimensions of the capacitance sensor of pressure. The automated measuring system was tested in laboratory conditions. Long-term functionality and repeatability of the automated system was verified by tests. (Project VEGA 1/0108/09)

## LITERATURE

1. Molčányi T., Magdo J., Raši R., Cestická T., Michlík J., Molčányiová A.: Možnosti ošetrovania laparostomie pri abdominálnom kompartment syndrome, *Novinky v anesteziológii, intenzívnej medicíne a algeziológii*, Prešov, Náuka, p. 122-127, 2005.
2. Obeid F. et al.: Increases in intra-abdominal pressure affect pulmonary compliance, *Arch Surg*, 130(5): p. 544-7; discussion 547-8, 1995.
3. Kron I.L., Harman P.K., Nolan S.P.: The measurement of intra-abdominal pressure as a criterion for abdominal re-exploration, *Ann Surg*, 1984.
4. Gudmundsson F.F., Viste A., Gislason H., Svanes K.: Comparison of different methods for measuring intra-abdominal pressure, *Intensive Care Medicine* 2002; 28: 509-514.
5. Malbrain M.L.: Different techniques to measure intra-abdominal pressure (IAP): time for a critical re-appraisal. *Intensive Care Med* 2004; 30: 357-371.
6. Onichimowski D., Podlińska I., Sobiech S., Ropiak R.: Measurement of intra-abdominal pressure in clinical practice. *Anaesthesiology Intensive Therapy*, 2010, XLII, 2; 96-101.

## AUTOMATYZACJA POMIARÓW CIŚNIENIA WEWNĄTRZBRZUSZNEGO

Michal JURČIŠIN, Pavol CABÚK,  
Stanislav SLOSARČÍK

**STRESZCZENIE** *Artykuł dotyczy budowy pojemnościowych czujników ciśnienia do automatycznego pomiaru ciśnienia wewnątrzbrzusznego metodą nieinwazyjną. Pojemnościowy czujnik ciśnienia składa się ze szklanej rurki z naporowanymi cienkwarstwowymi elektrodami. Zmiana pojemności objawia się przez zmianę poziomu przemieszczonej cieczy w rurce. Wyznaczono doświadczalnie krzywe wzorcowania dla czujników ciśnienia z różnymi średnicami wewnętrznymi rurek. Czujnik pojemnościowy jest podzespołem automatycznego układu pomiarowego w klinicznym zastosowaniu pomiaru ciśnienia wewnątrzbrzusznego.*