

AUTOMATIZATION SYSTEM AND SOFTWARE FOR EXPERIMENTAL INVESTIGATIONS IN HYPERSONIC WIND TUNNELS

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Introduction

The modern aerophysical experiment assumes simultaneous measurement of many dozens of parameters. During the experiment, the free-stream characteristics or geometry of the model under study may vary. As a rule, the measurement of the pressure distribution (or other parameters) of the flow under study goes together with the visualization of some flow regions. Therefore, experimental researches in hypersonic wind tunnels require development of automatization systems of processes of control, data acquisition and processing of the information both in a mode of real time for a blow-down wind tunnel and in a mode of fast-acting processes in hot-shot wind tunnel. At the same time, from the economic point of view and for convenience of the users, standardization of devices and programs of acquisition and processing of experimental data for test rigs of different types is very important.

Comparatively small duration of experiment in hot-shot wind tunnel (till 0.2s) puts forward the serious requirements to system of data acquisitions from a measuring system:

- not less 10kHz for interrogation of each measuring channel;
- high accuracy of measurement;
- simultaneous measuring parameters of different types;
- defense from different noise;
- coordination of measuring systems by time.

At the same time, the modern technology of tests demands the use not less than 100-150 transducers and devices of various functions, such as:

- pressure transducers of a various nominal values, gauges of a heat flux, gauges of friction;
- Schlieren and oil visualization of stream lines on internal and external surfaces of the model;
- visualization and integration of emission of the active radicals arising at combustion of fuel;
- multi-component balance for measurement of the forces acting on model vehicle or its engines, and their elements;
- devices for measurement of gaseous and liquid fuel at its injection in the chamber of combustion with a required time delay.

For a software development, the environment of graphic programming of LabVIEW and hardware of National Instruments Corporation are recognized all over the world, as the effective and accessible tools for the application and the decision of different problems of automatization, including different tasks, which are also occurring in scientific researches, were selected.

AIR FLOW software

AIR FLOW software allows using 128 channels simultaneously with interrogation rate of each measuring channel $6\mu\text{s}$ and maximum of switching frequency 250 kHz. Accuracy of interrogation is depends from an amplification factor of differential multiplexer module. Time rang of signal establishment lie in region from $6\mu\text{s}$ (with accuracy 0.012% and amplification factor 100) to $195\mu\text{s}$ (with

accuracy 0.0015% and amplification factor 2000). Software allows operating both measuring physical values and electrical signal from transducer.

Graphical user interface of AIR FLOW was designed in 3 basic windows: "Configuration", "Calibration" and "Measurements".

Configuration

System configuration is realized by means of infill of rows of channels configuration table and input of general parameters for all channels or loading of configuration file obtained earlier.

Fig. 1 shows configuration window. Statistic data are located at the top part of this window. At the middle part of window the configuration table located. Every row of this table corresponds to sequence number of channel and every column corresponds to certain configuration parameter. The elements of configuration control are located in the bottom part of window.

In configuration mode for each channel, following parameters of configuration are available:

- utilization of each channel in data acquisition ("on / off");
- coefficient of amplification (overall module and each channel);
- units and a scale of measurement;
- the necessity of input of the correction for temperature of cold thermocouple junction and a method of definition of this correction (for channels of measurement of temperature);
- symbol and the brief description of the channel.

The following opportunities are provided:

- configuration command of groups of the single-type channels;
- navigation over the table of channels with the help of a marker;
- saving and reading of a configuration of system in a file or from a file.

Some service information, namely, total number of the channels included in a configuration, time of their interrogation, step of interrogation can be screened.

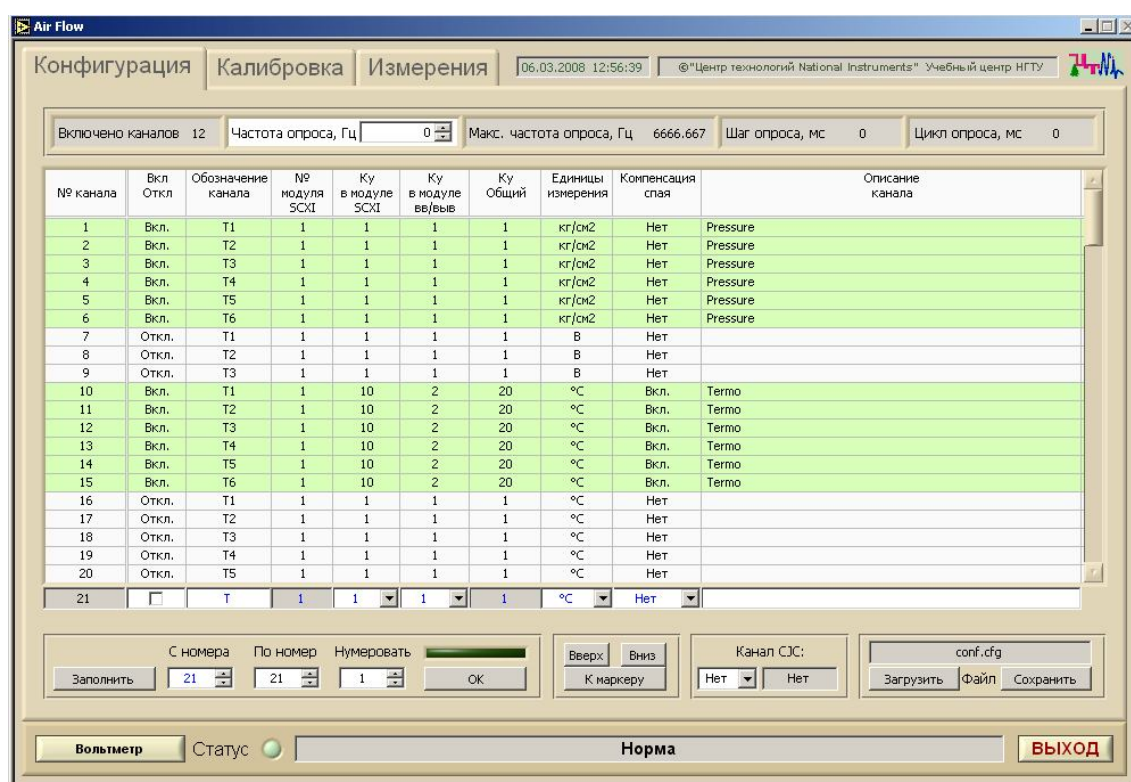


Fig. 1. Measurement system configuration.

Calibration

Calibration process consists in consecutive supply of known physical values on the calibrated transducers with simultaneous registration of measured data from these transducers. At calibration, approximating curve with the tilt of (pressure)/(signal) must be obtained on diagram in window. It shows dependence of pressure value from electrical signal value. This diagram is very useful for further experimental data processing.

Calibration is carried out only for the channels, which included in configuration. Previously, approximate values of physical value assigns manually in control points. During the calibration process, accurately measured values give on the measuring channels of physical value. Coefficients of polynomial are calculated on base of data obtained and they describe dependence of experimental data from physical value. Possibility to select polynomial degree (1st or 2nd) is also exists. Results of measurements, received during experiment, are displayed in the tabular or graphical form. Furthermore, mean-square deviation of approximating curve from given values of physical value in calibration process are calculated for each calibrated channel.

In case if transducers with the known characteristic of transformation are used, its parameters can be directly manually entered into the table without fulfillment of calibration procedure.

After the calibration process finish, coefficients of approximating polynomial are saved in the file and can be used again by means of loading from the file.

Fig. 2 shows the calibration window. The table of channels select and coefficients indication is located at the upper-left part of window. In this table measuring channels that included in configuration and its coefficients of approximating polynomial are presented. It is possible to calibrate both each transducer individually and group of one-type transducers. Under this table, the table with accurately measured values of physical values obtained from calibrated transducers is located. At upper-right part of window, the diagram of approximating polynomial, which was obtained on base of results of calibration process, is located.

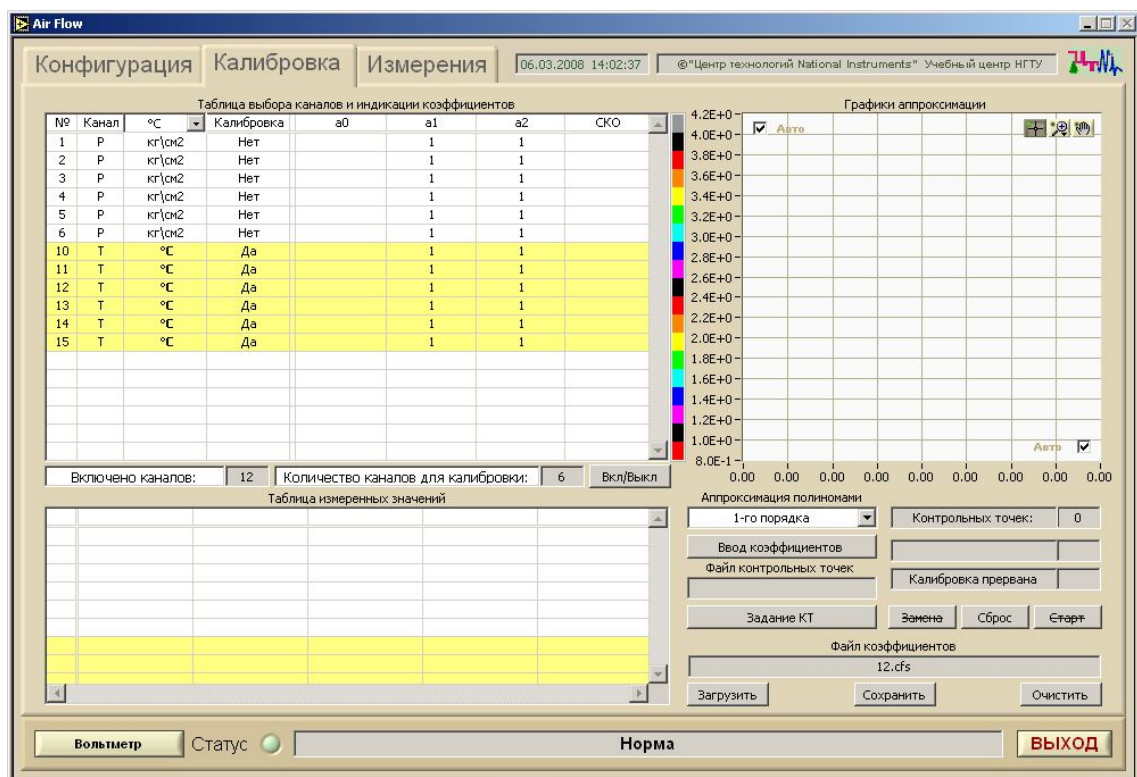


Fig. 2. Calibration of measurement channels.

Measurements

AIR FLOW supports 2 types of experimental realization: «fast» (for hot-shot wind tunnels) and «slow» (for blow-down wind tunnels). From user point of view, work with both this types is identical.

Measurements in «slow» mode are made with preliminary time averaging over the 50 measuring points. Periodical data readout can be initiated manually or automatically (by installed preliminary sampling interval). In addition, to manual start, software could start from external signal. Experimental results can display both in graphical and tabular forms.

Fig. 3 shows window with tabular form of experimental results for «slow» mode. Every row of table corresponds to sample number and every column of table corresponds to data scan time, channel number and experimental data.

№	Время	T1	T2	T3	T4	T5	T6
977	12:11:24	6.013E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
978	12:11:25	5.960E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
979	12:11:26	5.923E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
980	12:11:27	5.897E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
981	12:11:28	5.881E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
982	12:11:29	5.891E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
983	12:11:30	5.865E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
984	12:11:31	5.834E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
985	12:11:32	5.823E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
986	12:11:33	5.797E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
987	12:11:34	5.781E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
988	12:11:35	5.771E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
989	12:11:36	5.750E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
990	12:11:37	5.693E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
991	12:11:38	5.709E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
992	12:11:39	5.616E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
993	12:11:40	5.668E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
994	12:11:41	5.647E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
995	12:11:42	5.647E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
996	12:11:43	5.606E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
997	12:11:44	5.580E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
998	12:11:45	5.606E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
999	12:11:46	5.560E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0
100	12:11:47	5.534E+3	0.000E+0	0.000E+0	0.000E+0	0.000E+0	0.000E+0

Fig. 3. Tabular form of experimental results.

Graphical form of experimental results shown in Fig. 4. At the upper-right part of window the list of channels, involved in experiment, are located. Every channel can be excluded from visualization without data readout stoppage. Individual color can be appropriated to every channel. At the bottom part of window change mode switches are located: slow/fast mode, external/internal start, simple/cyclic channel interrogation.

At «fast» mode time, averaging is absent and experimental data are visualizing in graphical mode only. Graphical user interface and principle of operation for «fast» mode are equal to «slow» mode.

The «voltmeter» function is realized for both experimental modes. This function is assigned for permanent readout of experimental data from channel or group of channels and shows these data in additional window. This function does not depend on selected channels in main window (fig. 5).

In this window nature and measurement amount of selected parameters could be visual operated without preliminary registration. This mode could be of interest of measurement conditions select. This function very important during investigation with experiment process operating.

Function of saving measurement results in file for following possible export and function of measurement results loading and visualization also realized in AIR FLOW software.

The application of the software complex AIR FLOW has permitted to increase significantly the effectiveness of scientific investigations. Software proves its reliability and handiness. At the software use, the researchers' work efficiency rises considerably, the quality of experimental data analysis grows. The accumulation of the experimental results and following export in the database allows performing wide-range analysis and generalization investigations.

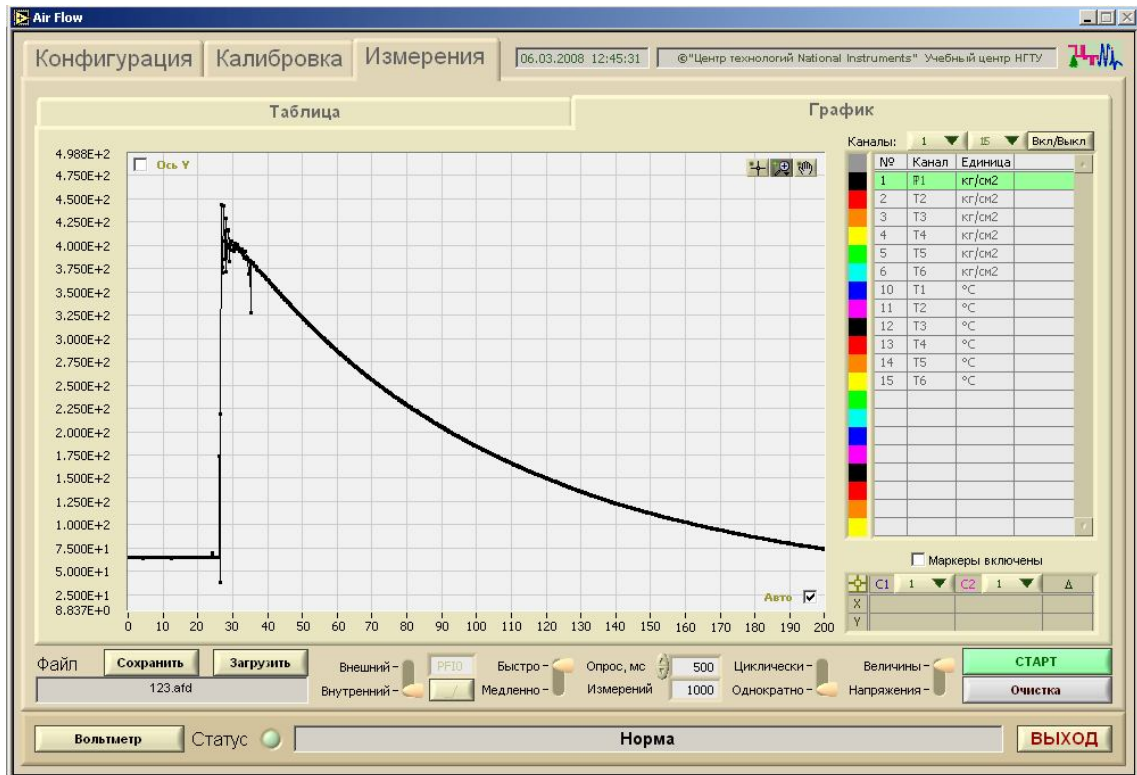


Fig. 4. Graphical form of experimental results.

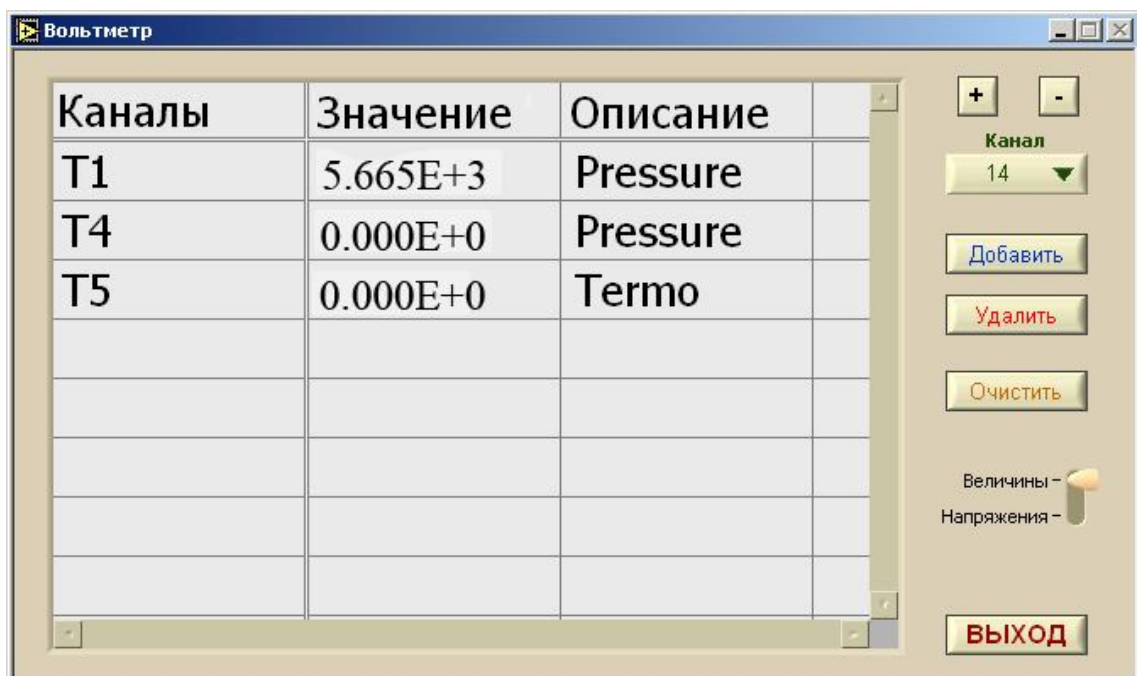


Fig. 5. Additional «voltmeter» window.