

HARDWARE AND SOFTWARE STRUCTURES FOR PROCESSING  
THERMOPHYSICS EXPERIMENT DATA

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Aspects of thermophysics experiment automation are considered. The structures of the hardware and software are examined for a system for automatic data processing.

Research on nonstationary thermophysical phenomena involves performing numerous experiments concerned with the thermophysical characteristics of materials, the physicochemical processes at the boundaries of bodies, the thermal loading conditions, etc. The results from such experiments are processed and interpreted by methods involving inverse heat-transfer treatments [1]. These methods are usually designed for computers and are most effective in automated processing.

Automated processing requires the design of data-acquisition systems DAS, which include specialized software that as far as possible eliminates manual processing. Here we consider an automatic system working with experimental systems in thermophysics studies.

The following are major tasks that can be handled by the DAS: management of the test system and the course of the experiment, acquiring and preprocessing the data from the transducers, testing and monitoring the system, secondary processing, including the use of hybrid systems and interpretation, and accumulation and classification of the data for use in automating thermal design. These tasks are handled by DAS subsystems with appropriate hardware and software.

The configuration of the DAS hardware enables one to transfer from one of these tasks to another without change in structure or the use of intermediate media, which can reduce the liability. An important specification for the DAS hardware is that the working time should be acceptable in the acquisition and processing, while the cost should be minimal.

The subsystems are linked up in the DAS in such a way that they can operate independently and jointly without modification in the hardware via the appropriate organization of the software. Figure 1 shows the DAS structure, and this provides for operation of the subsystems while meeting these requirements.

This DAS is a hierarchic computing system with two levels, with an ES computer of medium or high speed at the upper level, which handles the secondary processing and also the storage and classification in a data bank with a view to use in thermal design. The upper-level computer in the ES series is best chosen as an ES 1033 with an executive memory of 1 Mbyte or an ES 1045.

At the lower level in the hierarchy there are two universal computers of type SM1403.03, which are interconnected. The computers in the lower and upper levels are linked via the computer interface device CID, which is connected on one side to the bus segment of the SM switched lines and to the selector channel in the ES computer on the other. An AVK-32 analog computer is also connected to the bus, which involves three AVK-32 racks. This connection to the switched bus lines enables one to switch the universal computers in order to select one of them to work with the ES 1045 and AVK-32.

The universal computer No. 1 (Fig. 1) is the basic one for the experiment management subsystem and has a 2K interface. Two pairs of RIM-1-RIM-2 interface branches allow one to connect up to 64 of the 2K modules. The 2K modules are chosen in accordance with the number and characteristics of the detectors and the effectors in the experimental system. The

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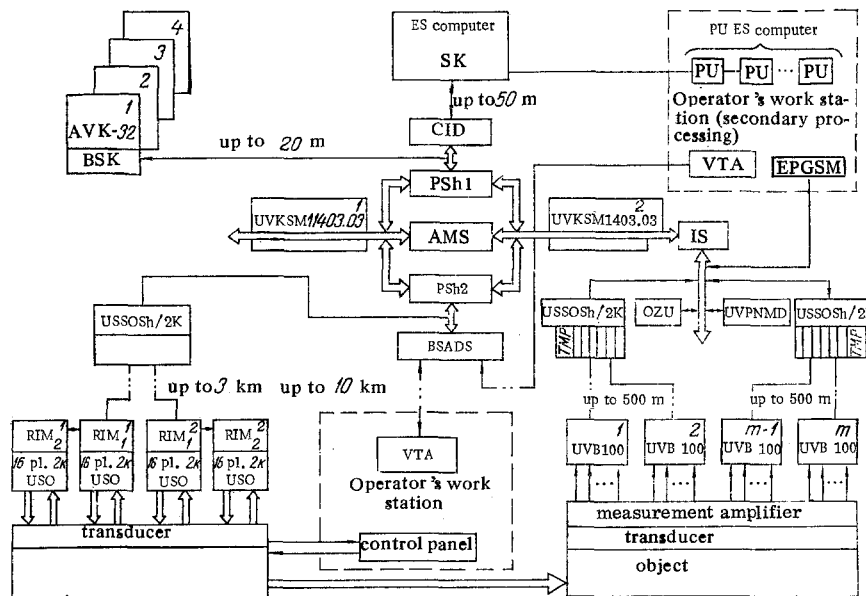


Fig. 1. Structure of the hardware in the automated system for processing thermophysics data.

operator's work station is organized by means of a VTA-2000-13 remote video terminal, which is connected to universal computer No. 1. To improve the viability of the DAS and to prevent emergency situations in the experimental system when there is a breakdown in one of the universal computers, the peripheral equipment serving the experiment control subsystem is connected to the two universal computers via the switched bus.

Universal computer No. 2 (Fig. 1) is the basic one for the subsystem for acquiring and preprocessing the data. This is connected to the SMZ 102 memory and UVPNMD disc memory, which provide for acquiring the data. The signals from the amplifiers connected to the temperature transducers are handled by the appropriate number of UVB-100 analog input units. The measurements are synchronized by an AI29-2 timer.

Additional UVB-100 units with their corresponding transducers and converters can be used if it is necessary to record other physical parameters in the experiment.

The interpretation of the results is usually graphical, so the DAS includes an EPGSM graphics display (SM3700). This device regenerates the image by means of the SM-4 bus and the executive memory. This absorbs up to 50% of the computing power of the SM-4. This deficiency is eliminated by an interface segmenter IS. The graphical display is usually provided at the stage of secondary processing or after the primary processing, so one IS can provide initially for data acquisition and then for graphical interpretation. At the operator's work station there is a video terminal from the ES computer (ES 7920). The universal computers are in the same location together with the ES peripherals such as the printer (ES 7032), punch card input and output (ES 6012 and ES 7012), and drum and flatbed plotters (ES 7052 and ES 7054).

The software is modular and consists of a set of standard operating systems and packages providing for the use of the various system resources. The software manages the operation of the DAS and also handles the transfer and processing of all forms of data. The user interacts with the software by means of compilers for FORTRAN IV and MACROASSEMBLER, which are the basic programming languages for the ES and SM computers. The software provides for real-time and time-sharing operation.

The operating system enables one to handle several jobs in time sharing, or else to run a single job on the upper and lower processors in real time, as well as to handle hybrid processing with the hierarchic computing system. For example, at the lower level in the DAS the software allows one to use the real-time operating system RAFOS of the SM 4 universal computers [2, 3].

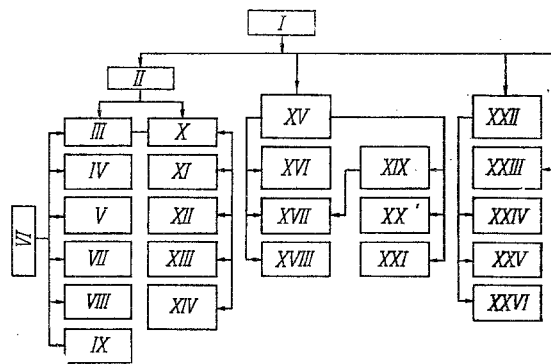


Fig. 2. Software structure: I) ADCS software; II) ADCS operating system; III) RAFOS real-time operating system; IV) FORTRAN IV translator; V) MACROASSEMBLER translator; VI) SM-4 software; VII) service programs; VIII) T MOS test monitor system; IX) applications packages; X) ADCS monitor; XI) DC-user station exchange programs; XII) interrupt-processing programs; XIII) user-stationpreparation programs; XIV) programs supporting operation of two-level ADCS; XV) APCS automatic program compiling system; XVI) service-information language translator; XVII) job-description language translator; XVIII) parameter-description language translator; XIX) simulation-object description language translator; XX) calculation programs; XXI) programs for locating circuits in analog computer; XXII) applications-program library; XXIII) test-program library; XXIV) integrated differential-equation processing; XXV) optimization programs; XXVI) statistical processing.

The RAFOS operating system is used in setting up detailed versions of particular operating systems for problem oriented computing units based on the SM-4 processor. RAFOS is a real-time system and provides response time shorter than that with other disc operating systems. A resident part of the RAFOS monitor occupies very little memory (4 kwords). RAFOS can operate with a universal computer with a memory of from 16 to 124 kwords and enables the user to prepare programs in MACROASSEMBLER, FORTRAN IV, DIASP, and BASIC. RAFOS also contains a large number of service programs that facilitate the development of application software.

The other computer is based on the ES processor and uses the OS ES 6.1 operating system. Rapid response is provided in the upper-level computer by including a real-time supervisor, which substantially reduces the response time for peripheral interrupts, these being provided by the lower-level computers.

Software in the management system and for the acquisition and preprocessing (Fig. 2) is constituted by a set of systems, applications, and test programs providing for operation under various conditions, including in real-time mode. The software in the subsystems is modular and includes the following:

- 1) an experiment-control subsystem containing subroutines for processing operator commands with the VDU, subroutines for managing the current and voltage digitizers, and code-control modules connected by the RIM-1 interface branches;
- 2) a subsystem for acquiring and preprocessing the data, including subroutines for inputting analog data and providing preprocessing and storage on magnetic media; and
- 3) a testing and monitoring subsystem, which enables one to check and test the equipment.

During the preprocessing, the input data are monitored and statistical analysis is performed. Methods from mathematical statistics are applied in the preprocessing to provide a detailed analysis of the data in order to identify useful data and to evaluate the accuracy.

This automatic system is used in thermophysics experiments, and therefore the data in the main represent realizations of nonstationary random processes [4].

When high-temperature experiments are performed, it is necessary to record time-varying parameters  $\{x(\tau)\}$ , and this involves a fairly long apparatus chain. The data can then be represented as the following model for a nonstationary random process:

$$\{x(\tau)\} = A(\tau) + \{y(\tau)\}, \quad (1)$$

where  $A(\tau)$  is a deterministic function (in the present, the useful information), while  $\{y(\tau)\}$  is an unknown random process with mean  $M[y(\tau)] = 0$  and variance  $D[y(\tau)] = 1$ .

The preprocessing software uses methods of generating statistical estimators for random processes for which the model of (1) applies.

The software in the secondary processing subsystem includes packages for processing the experimental results, which involves joint operation of the upper and lower computers, and also the hierarchic hybrid system (Fig. 2). The secondary-processing subsystem includes the data bank, which is involved in the accumulation and classification of the data.

Inverse heat-transfer treatments used in the automated system substantially extend the scope for examining thermophysical processes and for designing thermally loaded constructions. The most characteristic areas of use for these inverse treatments include optimal thermal design, which can be constructed as an inverse heat-transfer problem in an extremal formation. The model is then constructed by means of models for the individual elements and the heat-transfer processes. Experimental data are used in selecting, editing, and checking the models, i.e., the inverse treatments are used not only in the identification of thermal objects but also in processing the experimental results.

If the design of the object has been completed, experimental tests are performed on prototypes. In that case, the use of inverse treatments provides the necessary data, and in some cases it would be impossible to obtain the experimental information without the use of inverse treatments.

#### NOTATION

$x(\tau)$ , recorded parameter;  $A(\tau)$ , deterministic function;  $y(\tau)$ , unknown process;  $\tau$ , time.

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