Automatic inspection and diagnostic systems (AIS) play an important role in the operation of flexible industrial systems and automatic production plants. Their application makes it possible to control production quality in the course of manufacture and supervise equipment efficiency and production conditions. The papers published below on the design and practical introduction of AIS were discussed at the Interdisciplinary Scientific and Operative Conference on "Automatic Inspection and Diagnosis in Flexible Production Systems" (Leningrad 1989). The selection of papers offered to the readers can be arbitrarily divided into three sections corresponding to three major topics discussed at the conference: fundamental problems of metrological support of automatic industries and general problems of AIS design and operation, design of subsystems and components of equipment diagnosis of AIS in various technologies, and development and application of AIS for different production sections and modules of mechanical processing plants.

OPTIMAL DESIGN AND OPERATION OF AUTOMATIC INSPECTION SYSTEMS
IN FLEXIBLE INDUSTRIAL SYSTEMS

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Automatic inspection and diagnostic systems (AIS) constitute a part of flexible industrial systems (FIS) and are called upon to inspect and control the quality of manufactured products, the equipment efficiency, and to provide the necessary production conditions. AISs are the most dynamically evolving and expensive parts of an FIS which collect and display information on the properties, technical state, and location of the inspected objects, compare the actual values of monitored parameters with established norms and generate correction data when these values exceed admissible norms, transmit information on parameter disagreement to the FIS inspection system to react correspondingly, and generate and display information on the execution of operations by FIS components.

The objects of AIS are raw materials, manufactured products, spare parts, and semifinished products; technological processes, environments, production conditions, instrumentation; basic and auxiliary technological, transportation, monitoring, measuring and test equipment, program blocks and packages, communication channels, computing and automatic systems, as well as facilities for accident prevention and environmental protection.

Technical support of AISs includes measuring instruments; monitoring, identification, and diagnosis facilities; computing systems, interfaces between AIS components and between the AIS and external devices; verification, self-checking, and self-diagnosis systems; devices for establishing and implementing norms; facilities for displaying, recording, and storing diagnostic data; devices allowing fast reorganization of the inspection system; and technological, supply, and instrumentation units elements belonging to the AIS proper.

The considerable cost of development and operation of AISs (which may reach up to 40% of FIS production cost) makes it necessary to search for methods that optimize the structure and operating algorithms of inspection systems and their component parts. To problems of AIS optimization may also be relegated to the selection of the composition and amount of measuring and inspection equipment, the choice of parameters to be checked and of the order of inspection operations.

Problems of optimal organization and operation of an AIS include selection of the period and number of repeated inspection, optimization of sampling inspection schemes, optimization of the sequence of test operations, and organization of products flows for output production quality inspection, and selection of optimal technological margins (plant norms) in functional and output inspection.

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Optimization of an AIS for an automatic line, plant, or industry on the whole is a complex problem because of the large number of variables and influencing factors involved; the most important of which are the quality of product material and technology, technical possibility of performing inspection procedures at different production stages, and the performance of the inspection system that uses the measurement and diagnostic information at different inspection levels.

The first step is to formulate and solve optimization problems on the level of individual production modules or small sections including several such modules. The most suitable optimization criterion is economical (maximum profit or minimum production cost of the total annual output of a given product) provided the objective function takes into account all factors associated with the given inspection operation including the quality of production supplied to the customer. The experience gained in the development and application of optimization methods for operational and output inspection indicated that, as a rule, these methods lead to a considerable reduction of production costs (of the order of hundreds of thousands rubles in a single workshop) without incurring any significant cost on additional monitoring and measuring equipment.

In the following are given certain inspection optimization algorithms and the results of their implementation in the conditions of already working industrial plants.

### SELECTION OF OPTIMAL SEQUENCE OF INSPECTION OPERATIONS

The method allows considerable cost reduction of multiparameter output inspection of mass-produced complex products in final quality inspection sections. Typical examples are such functionally complex devices as integrated circuits (IC).

Optimal selection of the sequence of inspection operations at the outgoing (quality) inspection and testing stage or of the sequence of tests at functional inspection stage is based on the condition that the set of these operations (inspected parameters and metrological characteristics) has been fixed.

If the set of these operations must be modified, e.g., by using an inspection method which provides more information, the problem of optimal sequence selection must be solved again for the new set of inspection operations [1].

The objective function of an optimization problem is the sum of the costs (Z) of all inspection operations (tests) depending on the labor (time) consumed by all kinds of inspections (tests) and on their inspection capability:

\[
Z = \sum_{i=1}^{m} Z_{ci},
\]

where \( Z_{ci} \) is the cost of an \( i \)-th inspection operation in rubles/piece; and \( i = 1, \ldots, m \) is the number of inspection operations:

\[
\begin{align*}
Z_{c1} &= C_{c1}; \\
Z_{c2} &= \delta_1 C_{c2}; \\
Z_{c3} &= \delta_1 \delta_2 C_{c3}; \\
&\vdots \\
Z_{cm} &= \delta_1 \delta_2 \cdots \delta_{m-1} C_{cm};
\end{align*}
\]

(1)

\( C_{ci} \) is the unit (per one product) normalized cost of an \( i \)-th inspection operation in rubles/piece, and \( \delta_i \) is the yield of good products (the fraction of products assumed to be serviceable) of the \( i \)-th (in order) inspection operation (\( \delta_i \) is determined experimentally for each inspection operation provided the entire batch of products passes it).

Any suspected interdependence between the results of type \( i \) and \( j \) inspection operations (parameters) in (1) can be accounted for all \( Z_{cm} \) (beginning with the third) as follows:

\[
Z_{cm} = \delta_i \delta_2 \cdots \delta_{i-k_{rel}j_i} \delta_{m-1} C_{cm},
\]

where \( k_{rel}j_i \) is a factor accounting for the relation between the parameters \( j \) and \( i \) determined experimentally as \( k_{rel}j_i = \delta_{j(i)}/\delta_j \) (\( \delta_{j(i)} \) being the yield of good products in the \( j \)-th operation preceded by the \( i \)-th operation related to it).