



# Quality management in heat treatment process

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## ABSTRACT

**Purpose:** The purpose of this paper is to present the specifications of the CQI Heat Treat System Assessment, together with a discussion of the importance, development, implementation and use of this specification. An analysis of the quality management system of the selected organization was performed, which takes care of the thermo-chemical treatment-nitriding, as regards to the specification AIAG CQI-9. The study was carried out to compare the standards based on the scope of the organization covered by individual standards and their hierarchy, where the levels are adequate for the scope of the quality management system.

**Design/methodology/approach:** An assessment of the compliance with the requirements of the CQI-9 based on the criteria closed in the documentation of the specification was performed, by evaluated according to the requirements imposed by the CQI-9, and determining the compliance of the quality system with the requirements determined in the documentation of the specification, with the subscription in the documentation.

**Findings:** As a result of the audit of the nitriding process of selected part of the technology in relation to the requirements of the CQI-9 specification, the deficiencies were identified in relation to the requirements of the CQI-9 specification, and suggestions for their solutions were provided.

**Research limitations/implications:** The paper presents the steps and how to verify the quality management system in the process of heat treatment.

**Practical implications:** The result of the audit specifications CQI-9 detected non-compliance to requirements of the specification. The improvement of the quality management system, with some recommendations, allows to target the activities of the process to the needs and expectations of customers.

**Originality/value:** The paper presents some requirements concerning the quality of the selected part of the thermo-chemical treatment process.

**Keywords:** Quality; Quality systems management; ISO9001; ISO/TS16949; Heat Treat System Assessment

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## MATERIALS MANUFACTURING AND PROCESSING

## 1. Introduction

The increase in the quality of life is associated with the increase of the quality of products and services offered by the commercial market. Improving the quality of the individual industries and the service sector is related to the demanded requirements: ease to use, reliability and security. The expectations of the customer concerning the product, and the willingness of manufacturers aimed at their satisfying, is a kind of a drive mechanism, forcing manufacturers and service providers to compete and create competitive products. This view changes the way in which the manufacturers think about cooperation in the market. With the appearance of new demands from customers, the manufacturers are forced to improve the quality, including the attractiveness and competitiveness of their products / services what directly is related to the improvement of the quality of the individual processes involved in the offered value of the product. [7,8,15,16]

Such an approach creates a self-reinforcing mechanism, continuous chain reaction, in which more and more innovative technologies and achievements implemented in an organization improve the quality of the manufactured product, thereby setting a new, higher standard, establishing a level of the quality and customer satisfaction. It creates also some risk, as evidenced by the positive market demands, continuous improvement, providing a non-decreasing level of customer satisfaction. Any reduction of this level is regarded as an error of the manufacturer, fault to maintain the market position and shift showing declining condition of the company, and the deterioration of the image of their products, as well as the organization. To prevent such a state, the manufacturers tend not only to maintain the quality presented by their products, but also try to move ahead opposition, creating new trends in the industry, and ultimately unattainable for most competitive manufacturers. The means for this direction of ourselves presentation in the market is to maintain the customer confidence, ensuring about the reliability of his actions as an organization and providing services and products that meet the quality criteria [19,20]

The means of obtaining customer satisfaction is to implement and maintain the certified quality management system, proving the realization of actions aimed at customer satisfaction. This is one of the main goals of any organization that wants to win and retain the most loyal customers, good condition, a prosperous competitive position in the market, and demonstrate compliance with the applicable standards aimed at the needs of the customer. The basic standard specifies requirements for the organization's activities in the field of quality management is standard ISO 9001 Quality Management Systems. It is a quality management system implemented in order to [11,16]:

- Pay more attention to purposes of the organization and the expectations of customers,
- Increase customer satisfaction,
- Achieve and maintain the quality of products fulfilling the requirements imposed by the recipient (customer),
- Reduce losses resulting from the difference of the product to market needs, including lowering costs associated with the errors of production organization,
- Creating the competitiveness and credibility in the market,
- Creation of new prospects for development, new areas for the effects of continuous improvement, the possibility of

participation of their products and ensuring the future of the organization by adapting to the changing market conditions.

Due to the general character of the requirements of the ISO 9000 standards, directed to any organization, regardless of the nature of its action, there is a need to develop new standards with strict guidelines for targeting specific areas of industry. There is also a need to determine the quality standards for the specific business activities, in particular for special processes [11].

The automotive industry is a specific area of the market, developing intensively, with a great significance for the economy. Due to the complexity of the manufacturing processes, the automotive industry is an area of the market widely covered by the standards and specifications. The car companies constantly tend to increase the quality and customer satisfaction. Most prosperous manufacturers in the car market constantly tend to improve its products, developing technologies of the production and new standards of quality products. The development shall be accompanied by the provision that any action of the production process and auxiliary processes are able to meet the requirements dictated by the market advances. Intensive development of the areas involved in the production of automotive products, ranging from material engineering, electronics, computer science, chemistry or medicine, contributes to changes in the final product, and in the end - to the changes in the organization of production processes [7,10].

For all the requirements of the customer before buying the car (including safety, reliability, costs of exploitation, after-sales services), the most important is the manufacturing process, which is the process of giving the specific form to the semi-product. This process has the greatest impact on interferences of the course, resulting in the production of the product non-compliant with the assumptions. In the production process there are features assigned described by the parameters and indications defined by the norms, standards and specific customer requirements. On the other hand, the operations of the manufacturing process should be defined by the organization alone, describing the procedures, actions, and parameters suitable to obtain the expected quality of the process. To achieve a product satisfactory for the customer, the organization should provide controls and monitoring to ensure the reproducibility of production of selected parameters. The implementation and management according to guidelines of ISO 9001 quality management system helps to achieve this goal, which purpose is to monitor the activities to obtain the required properties of the product, eliminating those that lead to the formation of defective products [8,10,13].

According to the quality management system it is important to prevent the formation of defects at the earliest stage of production. This approach allows to avoid the formation of irregularities in the early stages of production, such as design phase or preparation of production. Costs associated with the removal of defects are highest when the causes were not detected in the early stages of production. This contributes to reproduction of undetected errors in the subsequent production processes leading to increase its meaning in the final product quality. Undetected irregularities are exponential in the later stages, often making it impossible to correct them or reject and exclude from the production, or at worst, provide in this form to the client. The control in the early stages eliminates the final correction of the faults and allows to minimize disturbances during the manufacturing process, what determines the reproducibility of the quality of the product [9,11,13,21].

In the approach of the quality management, in which the supervision and control were not specified, the determination of the proper product completing is done in the final stage of production. Such action is based on the separation of the products which do not fulfill the criteria from those that fulfill. The decisions are taken then on the distribution of the product, taking into account the risk of a claim by the client, or rejection of the product. Such an approach exposes the organization to excessive losses of raw materials, energy and information, establishing the production of defective products as a matter of course, and the implementation of the management process aimed at producing of the greatest number of products and the greatest degree of capture of incorrect products, not using the quality control but only post-operative detection of irregularities. It leads to ignore the requirements of the customer, without taking into account their needs, focusing on making the product itself rather than on the production of a product which the customer expects [6,9].

To avoid this situation, efforts should be made to ensure the quality at every stage of production, which affects the quality of the manufactured product. It can be achieved by collecting information from different points of production line, providing information about the current state of the process, allowing to determine the accuracy of these procedures compared to the initial parameters and avoiding the formation of defects. For the proper functioning of the system of quality assessment, the goal is not to collect and store information about the state of technological processes, but their active participation in the form of feedback, giving an immediate result, being the input information for the decision of changes in the process which prevent irregularities. They should provide information to the simplest actions, such as correction of technological parameters for the activities of the production system, concerning the changes in the structure and organization of the production line. Therefore it is required that all the production processes affecting the quality of the product should participate in the supervision [6,9,12,18,20,22].

From the point of view of avoiding the cost of acquisition of specialized equipment it is important to carry out outsourcing of production, allowing to use the knowledge about equipment and experience of external organizations. By standardizing of operations, the company with the specialized area of manufacturing operations/services are able to provide a higher level of quality, which maintenance could be associated with very high costs. Thanks to the outsourcing, the quality management system is focused on the resources and basic activities of the company generating profits. In order to ensure the accuracy and efficiency of the quality control of the production processes, the company, which has the tools of the quality assurance system, gets the formal confirmation of the quality of production/services carried out compatible with the requirements in the company. For this purpose, an audit is performed, the supervision of the quality is entrusted to the dedicated employee. The result is information about the quality of the service, obtained during the monitoring at fixed intervals. The aim is to carry out corrective actions in units of time, what will allow the more dynamic process of improving the processes and increasing the customer satisfaction using the outsourced services [8].

The manufacturing process includes cooperating factors, mainly energy, information, and materials used in the collaborative production line, performing their own tasks.

All together they form an ordered sequence of actions, identified and distinguished, depending on the nature of the achieved semi-product (Fig. 1). The manufacturing process could function properly, resulting in a final product, when auxiliary processes are required, without which the whole production cycle could not reach the intended efficiency. The basic manufacturing process includes [11,18,22]:

- processes of the production preparation,
- manufacturing processes,
- processes of the distribution and customer service.

The production system might incorrectly be treated as a single process. This is associated with the insufficient level of control of the product in the various stages, resulting in a quality analysis of the final product, and the entire analysis will only determine whether the product is well made. To meet the requirements of the customer, every production process should be controlled, which results in information whether all the operations and activities carried out at the technological line are made in such a way that gives features to the product, corresponding to the requirements of the customer. In order to ensure quality control of not only the final product but also the quality control of semi-products during the manufacturing process, split into sub-processes is required, which would have a significant impact on the quality of the product (Fig. 1).

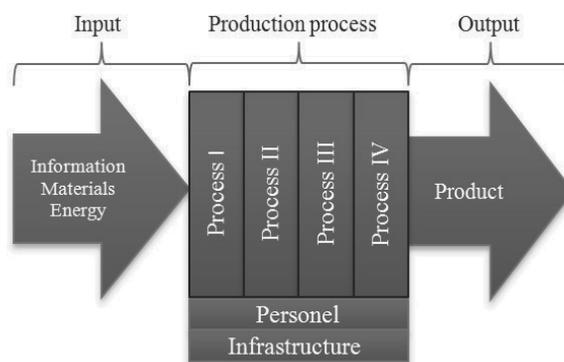


Fig. 1. Diagram of the production process

Through division, the production area could be regarded as a series of processes, being a definite sum, in which each component is treated as a system of input (for the stream of information, material and energy) and output (appearance of the finished product). The sub-process would be a sequence of activities that contribute to the transformation of the factors in the product expected by the customer. All together a sequence of cause and effect relationship is created, in which the basic results in the output of one process are at the input of the next process (Fig. 3). The collection of actions performed decides on input resources and required factors depending on the needs for the creation of the product (Fig. 2). The factors might include:

- Material - properties of the product,
- The man - skills of the employee,
- Machine - technological capabilities,
- Methods - manufacturing techniques,
- Environment - conditions of production,
- Flow of energy - kind of energy medium.

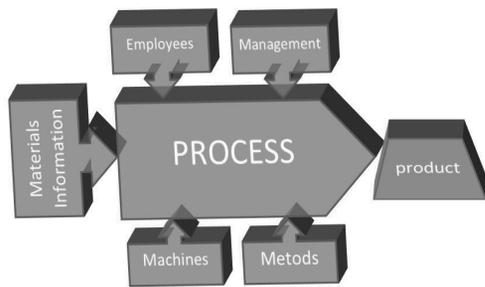


Fig. 2. Factors influencing the result of the manufacturing process

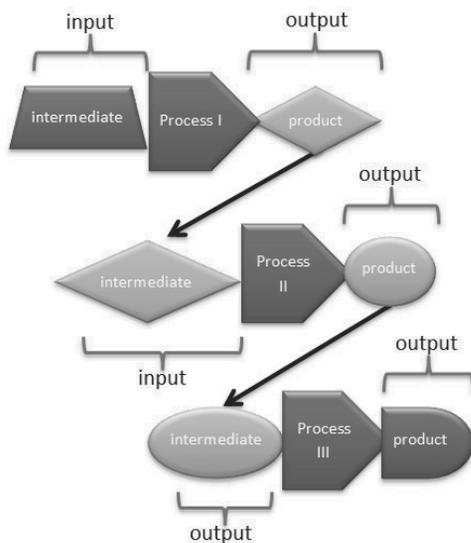


Fig. 3. Scheme of dependences in the production line

Through transformation of the input values, the process approaches the form of the product to the final state, defined by the purpose of the process. This purpose is the result of the actions of the process, enriching the input values with the added value.

The identification of the sub-processes is carried out based on the limits of the process, where comes to significant top-up in the input resources, then undergoing transformation, and on the other side of the area, it ends with the output, which is forming the place of sale as a result of the distribution of the created value. The sequence of the entire production process is divided into sections, which results should be defined as the value desired by the customer. It means that the output of the first process is the input of the next process. By this reasoning the next processes are treated as customers, and the entire chain as a series of supplier-customer relationships or manufacturer-to-customer (Fig. 4).



Fig. 4. Relationship manufacturer- customer

Such a point of view tends to treat the next process as a customer defining his requirements for the manufactured product, defining the guidelines to the preceding processes. On the other hand, every customer is also a producer (service provider) and must carry out activities in a way that ensures the quality expected. It is obvious that in such a specific sequence *supplier - customer - the final quality*, obtained by the last process is the result of the actions of all the processes. Each process is treated as a customer who should have the requirements for the product to make its quality allowed to transform such features which are expected for the next process. The quality is determined by the client, verifying the level of the quality. This is done by controlling the quality of inputs, outputs and activities within the process. According to the guidelines of the quality standard, the customer should determine which parameters should be controlled. Depending on the nature of the process, and what is the result of actions, the activities of verification should be established. As the result of this control, there is the information that the input values have been transferred according to the plan guarantying the customer satisfaction and that all the activities are carried out in the direction of the quality assurance. The control of the partial qualities allows you to correct deviations in the preceding process reducing the deflections from the intended quality. In such a way the variability of the quality of the final product is diminished.

The way in which the quality of the final product is determined, according to the definition of the external client, influences the requirements of each process. The organization, which aims are the needs of the external client, should firstly identify his needs, and then going back through the chain of processes that define the requirements, methods, and their satisfaction in internal processes. This ensures that actions will be identified to meet the expectations of other clients of the same chain. If the proper quality will be maintained in every part of the process it is produced right quality in every step of production, or in any process, it will also ensure that the customer's satisfaction with the quality of the final product.

## 2. Requirements for manufacturing

Creation of the product, ensuring the needs of the people, is characterized by a dynamic transformation of the enterprise resource in the end result, is to carry out business in the manufacturing process [9,13].

The widespread perception takes into account all the necessary steps, including:

- Research and development - forecasting and planning of business development, identify customer needs, develop strategies, provide resources and analysis of process improvement opportunities.
- The manufacturing process - taking into account the basic processes, auxiliary and service. The main objective is to produce a product in which the change is made dependent on the nature of the process.
- The distribution and customer service - includes preparation of the product for distribution, distribution channels, provide after-sales services such as repairs, maintenance and recycling.

In order to ensure the quality of the production company should properly choose the factors involved in the production processes, which include:

- object of labor, which is the end product,
- means of work, as a tool, machinery and energy used in the process,
- human labor.

Proper selection of these factors is to ensure the production of the product in the shortest possible time with the greatest efficiency. Identification of these factors is necessary in the design and modernization of the production process.

It is important to the production process would be subject to continuous monitoring. The result of this work is the assessment issued by the certification unit, or by making a voluntary assessment of internal controls and subsequent registration of the certification of the results by the certification body. All the results of the checks and procedures are carried out should be documented in a systematic manner in the form of written documents. This will allow for a uniform definition of the concept of quality of manufactured products in the production process and to ensure the effective operation of the production process. Necessary to this is to supervise the operation of production equipment, raw materials, inspection, materials, and auxiliary measuring devices, and in the final stage of the finished product [4,7,10,13,18].

As applicable technical specifications of selected manufacturing processes, the company should ensure that the equipment and facilities contained therein, measuring equipment, and to ensure dignity of the findings of the monitoring, checking and calibration. It becomes necessary, the employment or training of personnel in the infrastructure checks [9].

It is important that the monitoring was carried out in the production process for compliance of the product produced on the major stages of its production. In the case of the determination of non-quality product with the requirements necessary to develop corrective actions, including the isolation and appropriate indication of lack [9].

### 3. The quality management system in the automotive industry

With the balanced needs to be determined by market as possible to meet the various organizations it was possible to spread the applicability of ISO 9000 standards. This averaging requirements gave rise to difficulties in the use this standard in industries with a specific, different requirements resulting from the compliance of customers expectations. That industry is the automotive industry, for which a number of standards have been developed to comply with the was a number of manufactures and suppliers of semi-finished products or equipment. In order to avoid multiple certification standards, which ensure the operation of the company in accordance with the specified standards, developed ISO/TS 16949, which takes into account the requirements of all automotive manufactures.

The range of ISO/TS 16949 includes [4,10]:

- Products associated with the automotive industry in the design, development, production installation and servicing.

- Production area in which products are manufactured, having regard to equipment and instrumentation.
- Support Unit - laboratories, R&D centers, distribution centers, which are not subject to self-certify.
- The entire supply chain in the automotive industry including suppliers of parts, materials and services.

Implementation of ISO/TS 16949 can take any company involved in the supply chain, implementing production processes, service and distribution in the automotive industry.

The main objectives for which it was developed ISO/TS 16949 is [1,3,4,5,7,13]:

- Ensuring the safety of the final product.
- Avoiding the need for multiple certification, depending on the relationship with foreign customers. Ensure a common approach to quality systems in the automotive industry manufactures and providers of service organization.
- Facilitated collaboration and access to domestic and foreign markets.
- Presentation of the requirements for a quality management system with the requirements of enterprise customers.
- Reduction of losses, volatility and manufacturing defects, improving the reliability of supply and cooperation with our customers through continuous improvement

#### 3.1. Quality Management in heat treatment processes

Standard CQI-9 Heat Treat System Assessment is a supplement to ISO/TS 16949:2009 for quality management systems in heat treatment processes. The creator of this specification is organization AIAG - Automotive Industry Group. Aim of this institute is to promote new developments in the automotive industry, along with the co-operation and technology development in this field. It aims to collect many manufacturers to unify standards and improve cooperation between corporations of the industry. Specification of CQI-9 apply to companies carrying out heat treatment implemented for the needs of automotive industry [3,14,17].

The objective of developing standard CQI-9 can be understood by analyzing the structure of standards creating a quality management system, presenting a complete picture of the activities of the production company aimed to achieve and demonstrate a certain quality, and continuous improvement of its (Fig. 5). Creating an aggregation of standards due to the need for international trade, contributing to the development of signs of unification and classification of concepts and research methods. The basis of the hierarchy of the quality management system is ISO 9000 implementation of systems that are the foundation for all organizations, regardless of the field of activity. It is geared to meet the requirements specified by the customer, the product done by the organization wishing to demonstrate a system providing a specific, consistent quality. ISO 9001 includes all areas activities of the company, having regard to organizing activities, their implementation, monitoring and carrying out records the required documentation [1,2,5,11].

Refinement of specification is ISO/TS 16949 created as a result of the needs, specifications and experience of the automotive industry.



Fig. 5. The hierarchy of quality management systems

The requirements contained herein apply to the engineering of effective and efficient management quality system. Specification provides detailed, specific requirements for the automotive sector [14].

The purpose of a quality management system based on the specifications of CQI-9 is to demonstrate and evaluate the ability to meet the requirements that are placed by customers. Its mission is to develop control systems heat treatment through continuous improvement of emphasis on manufacturing defects and overstates the losses in the supply chain. This standard is to provide a uniform approach to the quality management system processes heat of the automotive industry and the organization which is performing the maintenance services. CQI-9 Standard contains requirements and recommendations for the realized processes within the organization and related third-party vendors, operating in the thermal treatment who:

- Needs to demonstrate the ability to consistently providing product that meets customer needs and requirements of applicable laws and other.
- Efforts to enhance customer satisfaction through the effective application of the quality management system.

Specification of CQI-9, as well as the ISO standards, is addressed to the needs and expectations of the customer. To get the desired purpose effective agreement between the supplier and the customer, in addition to the documentation contained in the tables of guidelines, the organization should adapt the process and method of assessment carried out in heat treatment processes against the requirements set out by the client. Supplement to the specifications of the customer's recommendations is a complete set of evaluation criteria targeted to meet their needs(Fig. 6)

The requirements set by the standard CQI-9 apply to general use in all organizations carrying out heat treatment processes, regardless of the product and the volume of production. The guidelines contained in the specification include the five basic areas of heat treatment [1]:

- Heat treatment of ferrous alloys with particular emphasis on carburizing,
- Heat treatment of ferrous alloys with particular emphasis on the nitriding,
- Aluminum heat treatment,
- Induction heat treatment of ferrous metals,
- Heat treatment processes including complete annealing, normalizing, relaxing.

These relate to issues of monitoring applications, the frequency of measurements within the process control and end,

including verification of cooling liquids and solutions and check processing equipment and testing.

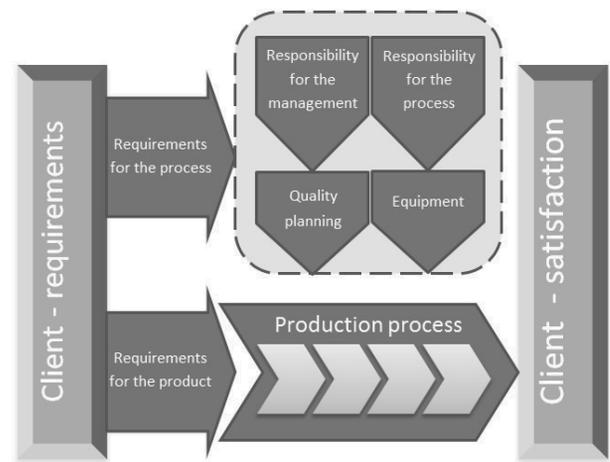


Fig. 6. Scheme of assessment of process in regards to specification of CQI-9

#### 4. Application requirements for selected CQI-9 heat treatment process

Executed analysis of the heat treatment process in order to assess the quality management system requirements specification for AIAG CQI-9 Heat Treat System Assessment. Analysis refers to the process of thermo-chemical treatment of nitriding in a specific organization in the selected section of line technology (Fig. 7). The purpose of the analysis process, carried out during the pre-audit was to control process equipment and processes, including management responsibility, planning and quality improvement.

Selected section of the production line includes nitriding furnace containing saline solution and the cooling bath.

##### 4.1. Methodology of analysis

Verification of compliance with the requirements was carried out according to the following procedures:

- Identify a specific part of a technological process being appraised relative to the specifications CQI-9,
- Determination of quality management system compliance with the requirements determined by specification,
- Elaborate documentation specifying compliance and non-compliance,
- Determining the level of compliance with the requirements,
- Identification of non-compliance that require immediate attention, requiring corrective action immediately.

Determination of compliance with the requirements was made on the selected section of the processing line including nitriding furnace and the cooling bath (Fig. 7).

Table 1.  
Some specifications CQI-9 [AIAG CQI-9 Special Process: Heat Treat System Assessment

Question number	Question	Requirements and guidance
1.9	Is management reviewing the heat treat monitoring system every 24 hours?	Management shall review the furnace monitoring systems at intervals in no more than 24 hours. The heat treat monitoring system includes but is not limited to temperature strip charts, atmosphere strip charts, computer data logs, furnace and operator logs, etc. The management review shall include efforts to detect out-of-control conditions or alarm conditions. The process of reviewing the furnace data shall be documented and this requirement also applies to computerized data.
2.7	Is furnace loading specified, documented and controlled?	Furnace loading parameters shall be specified, documented, and controlled. Examples include feed rate, belt speed, number of parts per fixture, and load weight. Refer to Process Tables, Section 3.0, for frequency of checks.
2.14	Are process control parameters monitored per frequencies specified in Process Tables?	Process control parameters shall be monitored per frequencies specified in Process Tables. Refer to Process Tables, Section 3.0. Computer monitoring equipment with alarms and alarm logs satisfy the verification requirement. A designated floor person shall verify the process parameters, e.g., by initialing a strip chart or data log. Management review is required per Question 1.9.
3.2	Are process equipment calibrations and/or verification certified, posted, and current?	The calibration and certification of the process equipment shall be checked at regular specified intervals. Refer to the applicable Process Tables, Sections 1.0 and 2.0, for equipment calibration or certification time tables.
3.14	Is the quenching medium analyzed?	The heat treater shall periodically have the quenching medium analyzed for specific quenching characteristics, e.g., cooling curve, water content, salt concentration, as specified in the applicable Process Tables, Section 5.0. <ul style="list-style-type: none"> <li>• The quench media characteristic tolerances shall be specified by the quench medium supplier or the heat treater.</li> <li>• Analysis shall be reviewed for conformance by the heat treater. This review shall be documented.</li> </ul>

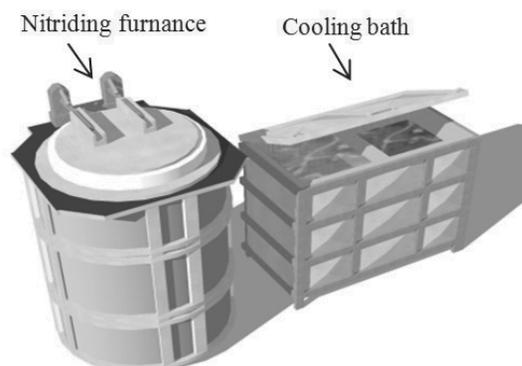


Fig. 7. Analyzed fragment production line thermochemical treatment of nitriding

## 5. Results

Following the evaluation of the quality management system in relation to the requirements of the five selected CQI-9 (Table 1) were based on the incompatibility of section 3.2 specification CQI-9.

Incompatibility is evidenced by lack of calibration marks used for the furnace to heat treatment - nitriding. Calibration is performed by means of peripheral diverted for this purpose, but it is not regularly performed.

Recommendation is to implement a determination to improve the calibration process that was carried out of the furnace heat treatment and to establish a schedule of regular calibration of equipment.

## 6. Conclusions

Implementation specifications CQI-9 Heat Treat System Assessment is a step towards the improvement of the quality of which the organization has certified compliance with the requirements of the deployed providing ISO / TS 16949, and refers to the resulting reduction in the amount of flaws and defects, in particular, the production for the automotive industry, which is the heat treatment. CQI-9 Specification developed by the organization AIAG CQI-9 makes specific demands on the organization conducting the operations of heat treatment processes, operations in the quality management system with enhanced customer-oriented activities, increases satisfaction and customer confidence, production and quality of products and improves the firm on market.

The need to achieve a higher quality of heat treatment processes contributed to the specification of CQI-9, giving the chance to work with strictly separate group of automotive manufacturers, creating a structure of relations organization seeking to produce a product of higher quality for the customer. Following the assessment of conformity of quality management system in the selected section of thermo - chemical - treat - nitriding production line were obtained results showing the degree of compliance with the requirements of the specification CQI-9. As a result, the organization receives information about areas needing improvement, application corrective action, representing the picture of the functioning of processes.

By improving the quality of production will be reduced number of deficiencies, which contribute to the reduction of production costs by eliminating excessive wear of time and energy. Increasing efficient use of resources organization, resulting forward in the improvement, reduce production costs, the price of services and increase customer satisfaction with fixed receiving the product, consistent quality at lower prices. Performed periodically checks processes, especially in areas with identified deficiencies, will prevent the occurrence of irregularities in the functioning of the manufacturing process and ensure quality. Increasing the reliability of the production process creates the products and services more competitive in the market in the automotive industry. This allows you to get larger group of customers, especially those who require suppliers to comply with the specifications of CQI-9, as a confirmation of the level of quality in the processes of heat treatment.

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