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SYSTEM OF SCHEDULED PREVENTIVE REPAIRS: THE LESSONS OF HISTORY

In 2013 it was 90 years since the first steps were made toward organizing the repair of industrial hardware on a schedule basis, and 80 years since developing and testing the system of scheduled preventive repairs (SPR) based on periodical repairs at plants. The goal of the paper is to remind of the first steps and milestones of development of SPR system. The author believes that some lessons from those bygone days are still valid today.

Keywords: *system of scheduled preventive repairs, SPR.*

This date could have gone unnoticed since few know about the history of emergence of SPR system today. Although witnesses of events of those distant years have not been with us for long, there are still numerous publications (some of them are referred to in the reference list of the paper) that allow us to reconstruct those events in detail.

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Instead of the epigraph

"Comrade Ordzhonikidze in his directive No. 268 for Stalingrad tractor plant dated 30 April 1931 noted that one of the causes in failing to realize the plan of production of tractors was the absence of scheduled preventive repairing of equipment at the plant."

Spiridonov V. In favor of scheduled preventive repairing. 1932 [4] (see Figure).

"Scheduling and due production output can only take place if the equipment works regularly, steadily and without delays as clockwork. Instead, a high percentage of equipment at our plants is rather old, while there is no well-organized system of repairing. New foreign equipment without due care also gets soon working with interruptions.

This happens because maintenance is not organized, and due to the lack of spare parts at disposal downtimes are often that leading to the plan failure. Equipment undergoes overhaul only when all its parts are completely out of order, and the machine absolutely fails to work. <…>

At the majority of our plants there is an opinion that "the equipment of our plant should long have been utilized; renewal won't help not to speak about preventive measures, so, the conclusion is that new equipment is needed."

Of course, this is the simplest solution but we can't afford it as we can't and shouldn't rely entirely on getting foreign equipment."

Spiridonov V.V. Rationalization of plant equipment repairing. 1931 [3].

Repairing before the revolution and during the first years to come after

Prior to the revolution and soon after the revolution the majority of plants didn't have any specific system of repairing. Repairs were not scheduled and were done in case of failure of equipment. Repair shops were unavailable at the majority of plants, and when there were any, they were used only for repairing plant equipment. For the majority of cases repair orders were serviced on shop floors using the common production equipment. It was possible only because of the individual and small-scale nature of production.

As the intensity of equipment use and its complexity grew, repairing starts to turn into a serious handicap for production development by the middle of the 20-s substantial wear and tear of equipment, its degradation drew attention to repairing issues.

It was the start of organizing repair shops, providing the available shops with extra staff and equipment. Designs of newly built plants started to include mechanical repair departments with the volume of machines from 3 to 12 per cent of the total amount at a plant. For example, it was seriously debated whether to stop using the term "capital overhaul" and to consider all repairs as maintenance (in view of various sources of financing).

First steps in organizing repairs

The first work as to SPR organization documented in the literature was the work related to rationalization of repairing launched in 1923 by District bureau of NOT (scientific organization of labour) of the former Prioksk mining district and carried out under the guidance of the engineer A.G. Popov during the period of 1923-1928 [1]. This work was made at Vyksa and Kulebaky smelters. The results of the work were published in 1927 in the form of instruction for scheduling maintenance.

Based on the material of the work, in 1931 A.G. Popov published a brochure under the title "Rationalization of repairing at a plant" [2]. The brochure provided a rather detailed analysis of drawbacks of maintenance management existed at plants, stated the principles of rational repairing organization and outlined the measures to be taken at plants in this field. Among the key principles of rational repairing organization, the brochure listed the following ones:

1) maintenance shall ceaselessly keep equipment in renovated state;

2) maintenance of equipment at plants is separate manufacturing selling its products to shops consuming repair;

3) the arrangement of repairing shall be done in accordance with the methods of preventive and compulsory maintenance;

4) the system of scheduling shall be part of repairing.

The same year saw the publication of a brochure by V.V. Spiridonov "Rationalization of plant equipment repairing" [3] that was also based on the results obtained by A.G. Popov and developed his approach. And next year, in 1932 a new brochure by Spiridonov using the words "scheduled preventive repair" for the first time was published.

In works by Popov and Spiridonov [1-5], arrangement of maintenance intended to be done by "turning it into the system of planning by means of spare parts". The main focus was made on defining a life cycle of equipment parts subject to wear and timely manufacturing spare parts. Such approach leading to alternative replacement of worn parts turned out to be practically unfeasible. However the ideas of scheduling repairs were fruitful. At about the same years there appeared first publications wherein a repairing strategy was proposed to be based on introducing periodical inspections. Equipment state was identified through regular inspections, and based on that terms and amount of repairing were defined. Such strategy was called as a system of post inspection repairs. At the period of 1933-1938 this strategy got a wide application in the country and became a forerunner of the strategy of on-condition maintenance well known today.

The main setbacks of such system were the lack of norms for repair and the impossibility of planning resources (financial and natural ones) for quite a long period of time. Also, without diagnostic means available, equipment state identification was rather arbitrary and didn't prevent from unscheduled failures. On the other hand, since any repair in the system (including repairs owing to bad maintenance) happened to be unscheduled, the system didn't inspire to increase the quality of repair and maintenance.

In 1934 Yu.S. Borisov and G.P. Zhukov developed an alternative system named as a system of scheduled predictive periodical repairs [7]. The main features of the system were as follows.

1) Scheduled repairs of each object are to be done periodically, in a specified number of hours worked. Sequential repairs of various types make up a periodically recurring repair cycle.

2) Planning resources necessary for repair is based on "normal amount of repair works" that in turn is defined by repair difficulty of objects divided into groups, each of which combines machines with presumably the same labor consuming amount of repair and maintenance.

3) In between periodical scheduled repairs each unit underwent scheduled checks-up (or inspections). In the process of checking-up one eliminates minor defects are eliminated, does tuning and cleaning as well as defines a list of parts that could be subject to replacement by a next scheduled repair.

Part of the system was a budget piecework system of payment for labour for repair shop workers. The essence of it is that payment is provided not for an actual amount of works done but for a normative amount [7]. Piecework payment motivated workers to fulfill all scheduled works. A high quality of works done was secured by workers' concern about the fact that in the conditions of normative piecework payment interrepair periods were a warranty life of equipment after scheduled repair for them. During that period a team should carry out all repair works for certain equipment arising due to poor scheduled repair for gratis. (This system of payment existed till the middle of the 50s).

Prewar years

In the middle of the 30s a huge number of new plants were constructed and substantial refurbishment of the existed ones were done. Instructions for SPR fulfillment were developed for a number of ministries and bodies [8-10].

Prewar years are characterized by some sort of fight between the system of post inspection repairs and the system of periodical repairs and by gradual substitution of the former by the latter.

In parallel there was a process of making the organization of repair services at plants more sophisticated, creating all-plant repair shops, centralizing the planning of repairs and in part theirs execution under the guidance of chief mechanic offices, singling out the service of an electric superintendent at some plants.

The year of 1938 was a critical mass transfer from the system of post inspection repairs to the system of periodical compulsory repairs. The system actively supported by plant workers got to be implemented in the main industries (engineering, defense, aviation etc.). The system of financing repairs underwent change, repair funds started to be established at plants, where part of amortization deductions were directed. Along with this, technical refurbishment of repair floors of plants was under way, and they were turned from primitive workshops into well-equipped spacious repair floors. Leading plants developed standardized technological processes of repair. Parts for repairs got to be manufactured more and more often according to drawings rather than to samples as before.

Great attention paid to the issues of repair management is illustrated by a huge number of books and articles related to that. For instance, a reference list "Scheduled preventive repair in metallurgy and engineering" [10] published by the State scientific library in 1939 includes 189 titles of domestic and foreign publications for the period of 1930 – 1938.

In 1939 there appeared a book that covered the issues of practical arrangement of repair as to SPR system as well as theoretical principles of the system [9].

By the beginning of the Great Patriotic War almost all plants had a scheduled preventive system of repairs.

SPR system during the war

Equipment use in the conditions of intense operation characteristic for the war years was a serious challenge for the system of periodical repairs. On the one hand, load on equipment increased, while workers' qualification decreased. On the other hand, the possibility to do repairs was radically restricted. The system stood the checkup, however it turned to be necessary to introduce changes in the structure of repair cycles as well as the arrangement of repairs. Introduction of extra scheduled current and middle-term repairs into the cycle increased the interval between capital overhauls. For equipment that could not be put into long repairs, alternative execution of scheduled repairs for different units and elements got wide application (mostly during days-off and night time).

In relation to substantial qualitative and quantitative increase of electrical equipment, the State committee of Defense decreed to establish departments of an electric superintendent at plants with the electrical power 1 MW and above (in case of 3 MW an electric superintendent had position of chief engineer deputy) [16].

Postwar years

The war was still in motion but considerate attention was again paid to the issues of repair arrangement. A number of instructions and guidelines defining or correcting SPR procedure at plants of some industries considering the accumulated experience was released. For instance, in February of 1945 a revised instruction for Narkomkhimprom (People committee of chemical industry) equipment SPR was approved and introduced. And in November of 1945 a repair conference took place in Moscow that had in fact all the Union character. It hosted 420 persons, including 32 chief mechanics of people committees, 65 chief mechanics of ministry departments and 323 plant delegates (chief engineers, chief mechanics, heads of workshops etc.) who presented the majority of industrial centres of the USSR. The conference strengthened the positions of the system of periodical repairs as the main SPR system in the USSR industry and confirmed the necessity of its further implementation while expressing the wish that the system should be standardized and in particular common standard structures of repair cycles should be established for types of equipment as well as common norms etc should be provided.

In 1955 all enterprises of the country had to follow "Common system of scheduled preventive repair of equipment" that made them to replace the normative piecework system of payment of repair workers' labour with the system of payment based on pay by the hour and bonus principles using the following parameters: SPR plan fulfillment, reduction of equipment downtimes, absence of accidents caused by repair workers.

In the USSR standard SPR systems were developed by ministries and special institutes. Standard system was to be revised and corrected every five years. Functions of controlling and improving SPR, Common (1967) [12] and Standard (1988) [13] repairing systems were imposed by the government on ENIMS (Experimental Research Institute of Metal-cutting Machines).

SPR standard systems were developed on the basis of analysis of data about failures and changes in parameters of state of elements and time normative for executing preventive maintenance with the specifics of production and growing complexity of applied equipment taken into account.

The soviet system of SPR should be idealized. Attempts to regulate everything and everywhere faced substantial differences of local conditions. Also, SPR instructions for various ministries and bodies were not always coordinated with each other and sometimes even contradicted each other. It was especially evident in organizing SPR of power equipment which, on the one hand, was to comply with the

standards of Ministry of Energy and, on the other hand, with the standards of Ministry of Electrotechnical Industry. The situation with arrangement of power equipment SPR was described in detail in the paper [17].

A number of other causes that influenced the degradation of the soviet SPR system were discussed in the paper by A. Samsonov [15]. In particular, A. Samsonov believes that among the reasons of the degradation of the SPR system were the norms for repair execution overstated in the 60s as well as transfer to the system of payment for repair workers' labour based on pay on the hour and bonus principles. However, these issues are out of scope of the paper. One more issue highlighted in the paper by A. Samsonov is that academic discipline "Equipment repair" studied till the end of the 60s began to disappear from the programs of higher and special secondary technical schools. Specialists graduated from them don't know the basics of SPR system and come to production with belief that equipment should be maintained only in case of its crash or failure.

Situation after the collapse of the USSR

In the 90s radical changes took place in the system of equipment repair management at the country's plants and enterprises. Along with reduction of the majority of industrial ministries, industrial offices of chief mechanics and electric superintendent supervising equipment repair arrangement stopped to exist. All the Union and industrial repair organizations (repair associations, trusts etc.) used for centralized repair of specific equipment were disbanded. Practically all industries stopped to develop, revise and issue Guidelines for scheduled preventive repairs that served as a methodological and normative basis for enterprises in respect with planning and arranging equipment repair. There was no more revising norms of amortization deductions (equipment life cycles), repair norms, materials use norms, repair execution and financing norms (see foreword to guide [14]). There was no more collecting and analyzing data on equipment failures that existed in a number of industries in a centralized way, including power industry. (For information about the situation with collection of failure data in nuclear power industry see [17]).

The system of centralized supply of enterprises with equipment, spare parts, repair machines and materials fell down. There appeared firms producing spare parts of poor quality, counterfeit products. But together with the negative side of the process, there was intensification of activities of equipment manufacturers in production of spare parts, and consumers who had financial resources could buy required materials and spare parts without funds on the market.

Compared to western countries, post delivery maintenance by equipment manufacturers didn't develop in the majority of industries in the USSR. It is demonstrated by the fact that the majority of normative documents in relation to repair of various types of equipment were developed by industrial structures. When producing complex equipment, manufacturers didn't provide any maintenance documents for it. Due to that, manufacturers were not motivated to increase maintainability of produced equipment. Attempts of manufacturers to go into service didn't bring any success for the most part since they had no service experience and qualified staff. Nowadays, the market of equipment maintenance service has got a corruption character to a great extent. Tender procurements widely introduced today only seem to be transparent but in fact are designed for specific contractors for the most part who have insufficient qualification.

Time to gather stones. Back to the origins?

The well-structured SPR system of the soviet times corresponded to the administrative command system and was supported by it. So, its fall was logical. New property relations made it necessary to build much anew.

When the havoc of the 90s was over, the interest grew in planning and systemization of maintenance and repair arrangement (and that reminding of the situation of the beginning of the 20s of the last century – escape from the havoc of the First World War and Civil). Some attempts to organize a countrywide process started to be taken at the beginning of our century. There appeared a requirement of the State Committee of Mining and Safety Supervision of Russia PB 05-356.00 stipulating that each enterprise should have its own Guidelines for scheduled preventive repair of owned equipment.

In 2003 the works were started to develop Guidelines "Common instruction for scheduled preventive repairs of equipment of engineering enterprises of Russia". But they were soon stopped due to reorganization of the final customer of the development – Ministry of Engineering and Science of Russia.

However, the situation in different industries and at different enterprises is rather diverse. It is not a secret that a system of repair organization at the majority of Russian enterprises is completely unavailable. Frankly speaking, we have returned to the situation of about a hundred years ago. First of all, this applied to small- and medium-size enterprises appearing before our eyes. "If it breaks we'll fix it" – and here we go with our system. For these enterprises transfer to SPR system is the first and primary step to straighten things out. At the same time SPR system is still in action but is considered as obsolete in leading industries (extraction and transportation of gas and oil, petroleum chemistry, energy) and at many large enterprises. In some companies there are works being done to move to repairing on condition based on wider application of diagnostics means (see, for example, [18, 19]). There appear industrial guiding documents for accounting, collection, preliminary processing, registration and transmission of information about defects, damages and failures (e.g. [20]). However, many problems in the field of organization of repair activities, including such industries as energy, remain unsolved [21, 22]). And very slow rates of implementation of new repair strategies are defined by

several key factors: lack of understanding on behalf of top managers, unpreparedness of staff for changes and lack of motivation for such changes. Detailed discussion of the current state of repair management issues is in [21, 22] (as regards power equipment) and is out of scope of the paper. It is also worth to note the publication [23] also covering the state-of-the-art situation in the field of maintenance and repair management.

Of vital interest is implementation of new advanced repair strategies combined under the term RCM [24-25]. In 2014 ISO 55000 standards for physical assets (production funds) management [25-26] are expected to appear. By order of Rosstandard No. 979 as of 29.08.2013, a national Technical committee for standardization No. 086 "Assets management" (www.tk086.ru) was established. The committee will be involved in developing a Russian version ISO 55000. The committee is established on the basis of the firm NPP "SpecTek' which has been dealing with the issues of technical maintenance and repair and automation of these processes during over 20 years.

We now start to see some understanding that rational organization of equipment service in today conditions is impossible without application of information technology [27]. At present over five hundred enterprises in Russia use information systems for maintenance and repair management with the power industry being far ahead of all other industries [28].

RCM important integral part is on-condition repair. Diagnostics means used wider and wider allow providing objective information about the state of equipment and predicting possible failures. In some cases we can use accumulated statistics of failures and their forerunners – defects (through want of other statistics – at least within an enterprise) to predict failure time. Application of information systems provides an effective tool to integrate information about equipment, its state, diagnostics data as well as its defects and failures [29]. In other words, at some new level the ideas of 30s about accumulation and use of statistics about spare parts failures as well as return to the system of post inspection repairs are again in demand. But this is some other story…

Some lessons

What can we learn from looking back at the past? This should be part of serious discussion, and "the forgotten jubilee" will be able to trigger it. I can dare to indicate some directions where serious efforts should be taken. Quality observance in maintenance and repair management for potentially hazardous production facilities (inclusive of power facilties) shall be secured by supervision of state regulating bodies. Support from the side of the state and large corporation (inclusive of big power generating and selling companies) is required for researches in maintenance and repair organization. Collection of statistics about equipment defects and failures should be resumed at the level of corporations and for energy industry and some other industries – at the industrial level. Knowledge about advanced strategies of maintenance management and standards in the field should be disseminated. There should be training of basics of maintenance and diagnostics arrangement (including application of information technology for maintenance and repair management) (training courses at higher schools and refresher courses for staff). Implementation of information systems of assets management should be supported by top managers. We also need introduction of maintenance and repair management guidelines as well as guidelines for identification and elimination of defects and failures into manufacture documents. Responsibility of repairing companies (gratis defect elimination, repair insuring) should be enhanced. There should be compulsory consideration of Russian specifics and specifics of an individual enterprise (implementation context) when attempting to adopt western achievements in the field.

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