REPUBLIC OF UZBEKISTAN
MINISTRY OF HIGHER AND SECONDARY SPECIAL EDUCATION

INSTITUTE OF ENGINEERING AND ECONOMICS

FACULTY OF "OIL AND GAS".

"TECHNOLOGICAL MACHINES AND EQUIPMENT" DEPARTMENT

"I APPROVE"
Vice-rector for academic affairs
_________ R. Eshankulov
"_____" __________2022

# 5320300 - for students of "Technological machines and equipment" undergraduate education

# "OIL AND GAS INDUSTRY TECHNOLOGY EQUIPMENT RELIABILITY"
## from science

# EDUCATIONAL METHODOLOGY COMPLEX

Karshi – 2022 year

This development was prepared to create an educational methodological complex on the subject "Reliability of technological equipment of the oil and gas industry" were developed on the basis of work programs and recommendations for creating an electronic modular complex and an electronic folder of science.

Developer F.E. Buronov -KIEI "Technological machines and
senior teacher of the "equipment" department

Reviewers: E.S. Mirzayev - KIEI "Technological machines and
Associate Professor of the Equipment Department

O. Murtozayev - "Shortan Gas Chemical Complex" LLC
The head of the ethylene production shop.

This educational methodical complex was approved at the meeting of the "Technological machines and equipment" department (statement No. __ ___ ___ 20___ ) and the Stylistic Commission of the Faculty of Oil and Gas (statement No. ___ "____"______20___) and the Stylistic Council of the institute (statement No. __ ___ ___ 20___) was considered at the meeting and recommended for use in the educational process.

Head of educational and methodological department __________ A.R. Mallayev
Chairman of the Faculty's Methodological Commission __________ B. Yu. Nomozov
Head of the department __________ F.E. Buronov

# SILLABUS

# Sillabus

Karshi Institute of Engineering and Economics, Faculty of "Oil and Gas".
Address: Karshi city, Shibayeva Street, 6 (building 2 of the institute).
**1. Buronov Firdavsiy Eshburiyevich**. Teacher of the department of "Technological machines and equipment" of the "Oil and Gas" faculty.
Contact phone: (+99890) 333-68-66 (mobile)
Email: firdavsiy.buronov@mail.ru
**Scientific interests**: the process of repairing and installing machines and equipment of oil and gas production and processing enterprises, as well as mastering their practical skills in terms of the methods of effective use of production process techniques and technologies.

2. "Reliability of technological equipment of the oil and gas industry"

**3. Venue and time:** Building 2 of the Institute, according to the 5th semester of the academic year.

**4. Interrelationship of academic subject with other subjects (prerequisites):**
"Chemistry", "Mathematics", "Physics", "Materials Science", "Petrochemistry and oil-gas processing equipment", "Resistance of materials and corrosion", "Theory of machines and mechanisms", "Theory of potentials"

**5. Application of the subject to the subjects to be transferred to the next subjects (postrequisites):**
Installation and repair of oil and gas processing equipment, oil and gas fields machines and equipment, oil and gas technological machines and equipment.

**6. Description of the subject:**

6.1. Orientation of the academic subject.

In oil and gas extraction and processing enterprises, we need highly qualified engineers to process hydrocarbon raw materials based on modern technologies, to organize and manage the production of products important for the national economy, and to always use scientific and technical achievements in practice. is born. Based on the requirements of the Law on Education of the Republic of Uzbekistan and the National Personnel Training Program, a bachelor should be well-versed in all aspects, closely familiar with the experiences of advanced countries, and have the ability to create new scientific ideas and technical solutions. , which is oriented towards the task of educating them to be modern-minded, educated, qualified and at the same time high spiritual perfection qualities, responsible for our future, passionate, selfless, deeply and solidly educated specialists. .

6.2. Purpose:

The main goal of teaching the subject "Reliability of technological equipment of the oil and gas industry" is to provide students with knowledge and skills about the repair and installation of technological machines and equipment within the framework of the requirements for a bachelor's degree in the relevant field of study. students to study optimal technological and constructive methods to ensure their long-term operation depending on the operating conditions of technological equipment used in oil and gas production and processing processes, methods of effective use of production process

techniques and technologies in addition to theoretical mastery, it consists of helping them acquire practical skills and so on.
6.3. Duties:
The task of the subject - the student who has mastered the subject will learn the theoretical basis of machine reliability, evaluation methods and effective ways to increase it; to know the causes of malfunctions and defects; the need to know the methods of increasing the unbroken operation, durability, repairability and durability of machines, the student mastering the science of oil and gas processing, repair and maintenance systems of machines and equipment of chemical and petrochemical enterprises, modern methods of restoring machine details It consists of such things as the need to have perfect knowledge of technological processes.

## MONITORING THE KNOWLEDGE OF STUDENTS IN SCIENCE

**Requirements for obtaining a loan:**
Full mastery of theoretical and methodological concepts related to science, ability to correctly reflect the results of analysis, independent observation of the processes being studied, and completion of tasks and tasks given in the current and intermediate control forms, according to the final control pass the test.

Criteria for evaluating students' knowledge based on the rating system

| № | Type of supervision | laximum grade | Assessment criteria Grade | Mark |
|---|---|---|---|---|
| | | **Current control – CC** | | |
| 1.1 | ctiveness in actical training | 5 | he student fully completes and explains the tasks of practical ining using his independent theoretical knowledge; makes nclusions and decisions; creative thinking; if he walks in lependent observation; can apply the acquired knowledge in ctice; if he understands the essence of science; if he knows; n express; if he tells; if he has an idea about science and the ic | 5 |
| | | | he student completes and explains practical training ignments using independent sources; if he walks in lependent observation; can apply the acquired knowledge in ctice; if he understands the essence of science; if he knows; n express; if he tells; if he has an imagination in science | 4 |
| | | | e student will teach the tasks of practical training | 3 |
| | | | e does it with the help of, he explains; can apply the acquired owledge in practice; if he understands the essence of science; if knows; can express; if he tells; if he has an imagination in ence | 2 |
| | | | he student performs the practical assignments directly from the rces, if he cannot explain them; does not master the science gram; if he does not understand the essence of science, if he es not have an idea about science | 0 |

| | | | | |
|---|---|---|---|---|
| 1.4 | ompletion and ubmission of independent work assignments | 5 | he student does not complete practical training tasks, does not omit them, does not fully participate in training, does not come supervision | 5 |
| | | | he student fully completes and explains independent work ignments using his independent theoretical knowledge; makes nclusions and decisions; creative thinking; if he walks in lependent observation; can apply the acquired knowledge in ictice; | 4 |
| | | | ie understands the essence of science; if he knows; can oress; if he tells; if he has an idea about science and the topic | 3 |
| | | | he student completes and explains independent work ignments using independent sources; if he walks in lependent observation; can apply the acquired knowledge in ictice; if he understands the essence of science; if he knows; ı express; if he tells; if he has an idea about science and the ic | 2 |
| | | | he student performs independent tasks with the help of the cher, he explains them; apply the acquired knowledge in ictice | 0 |
| **II. INTERMEDIATE CONTROL – ON** | | | | |
| **tudents who have been evaluated positively (with 3, 4 or 5 grades) from practical training and independent work assignments will be evaluated from control (oral, test, written) on the theoretical part of the subject. Inthiscase, accordingtothetheoreticalpart:** | | | | |
| **In the case of a midterm (IN) test: Correct answers to general questions are determined and scored against the number of correct answers.** | | | | |
| If IN is oral or written: | | | | |
| .1. | Intermediate control control of the eoretical part of e subject (oral, test, written) | 5 | he student answers ON questions completely and clearly; kes conclusions and decisions; creative thinking; if he walks in lependent observation; can apply the acquired knowledge in ictice; if he understands the essence of science; if he knows; ı express; if he tells; if he has an idea about science and the oject; if he received exemplary grades from practical training. | 5 |
| | | | he student answers ON questions almost completely; if he lks in independent observation; can apply the acquired owledge in practice; if he understands the essence of science; if knows; can express; if he tells; if he has an idea about science l the subject; if he got good grades in practical training. | 4 |
| | | | he student partially answers ON questions; can apply owledge in practice; understands the essence of science; can oress; if he tells; if he has an idea about science and the oject; if he received satisfactory grades from practical training. | 3 |
| | | | he student answers ON questions incorrectly, if it is found that ias been copied; does not master the science program; does not lerstand the essence of science; if he does not have an idea | 2 |

| | | | | |
|---|---|---|---|---|
| | | | out science and the subject; if he received unsatisfactory grades m practical training. | |
| | | | he student does not answer ON questions, does not participate supervision, does not have a positive assessment of practical ining and independent work assignments. | 0 |
| **III. FINAL CONTROL - YAN** | | | | |
| **TUDENTS WITH A POSITIVE ASSESSMENT FROM YAN GA ON WILL BE ADMITTED** | | | | |
| **In the case of a YAN test: Correct answers to general questions are determined and evaluated according to the number of correct answers** | | | | |
| **If it is oral or written:** | | | | |
| .1. | Final control control of the eoretical part of e subject (oral, test, written) | 5 | he student fully completes and explains the YAN assignment ng his independent theoretical knowledge; makes conclusions d decisions; creative thinking; if he walks in independent servation; can apply knowledge in practice; understands the ence of science; can express; if he tells; if he has an idea about ence and the topic. | 5 |
| | | | he student completes and explains the assignment using lependent sources; if he walks in independent observation; can ply the acquired knowledge in practice; if he understands the ence of science; if he knows; can express; | 4 |
| | | | he student completes the YAN task with the help of the cher, | 3 |
| | | | he explains; can apply the acquired knowledge in practice; if he derstands the essence of science; if he knows; can express. | 2 |
| | | | ıdent YAN assignment directly from sources | 0 |

**REPUBLIC OF UZBEKISTAN**
**MINISTRY OF HIGHER AND SECONDARY SPECIAL EDUCATION**

**INSTITUTE OF ENGINEERING AND ECONOMICS**
**FACULTY OF OIL AND GAS**


**"TECHNOLOGICAL MACHINES AND EQUIPMENT"**
**department**

# "OIL AND GAS INDUSTRY TECHNOLOGY EQUIPMENT RELIABILITY"

**from science**

# TEXT OF LECTURES

**Karshi-2022 year**

Developer: "Technological machines and equipment" assistant of the department F.E. Buronov

**Reviewers:**

Kh.B. Rakhmatov - associate professor of the department "Oil and gas processing technology" of QarMII, Ph.D.

O. Murtozayev - Head of the Ethylene Production Department of "Shurtan Gas Chemical Complex" LLC.

The text of these lectures was presented at the meeting of the "Technological machines and equipment" department (report No. __ ___ ___ 20___ ) and the Stylistic Commission of the Oil and Gas Faculty (report No. __ ___ ___ 20___) was considered at the meeting and recommended for use in the educational process.

# Introduction.

Natural reserves of minerals are limited on the ground, and a lot of metal is used in machine building and cooling technology. Therefore, reducing the metal consumption and cost of newly created machines, while increasing their power, requires careful evaluation of indicators.

The accuracy of machines and equipment depends on time. As the details are eaten away, their accuracy decreases. Machine theory is the science of the gradual loss of machine performance.

In the early days, the calculation was made only to make the details unbreakable under the influence of the applied load. By the end of the 21st century, an idea about the service life of objects appeared.

The science of accuracy of machines and equipment has developed in two directions: ensuring reliability and calculating it. Ensuring reliability relies on traditional design and technology methods to create high-quality machines and their correct use, while accuracy calculation is mainly related to the use of mathematical methods.

The main task of the maintenance of machines and equipment is to study the laws of machine failure and to develop measures aimed at ensuring that the machines perform their tasks at the lowest possible cost.

Implementation of measures set by our government, resolute implementation of the National Personnel Training Program and laws "On Education", a new approach to the education and training of students, including preparing them for work and profession. requires consideration. The most important thing is to pay special attention to the issue of transition to a creative approach to education.

At the current stage of scientific-technical and socio-economic development, in the conditions of accelerating production, qualified personnel, who have a high level of professional, technical and economic training, who can manage complex and high-performance equipment, who work with creativity and pleasure, People who conscientiously perform their duties are extremely necessary. In order to fulfill these tasks, it is necessary to fully implement the principle of combining education with practice, more firmly achieve the improvement of teaching efficiency, fundamentally improve the preparation of young people for independent life, and be creative, conscious of work, which is their first social duty. relationship formation is required.

In this regard, the text of these recommended lectures plays an important role in the training of engineer-pedagogue personnel.

Lecture #1

Topic: Basics of reliability theory.

Plan:

1.1. Tasks of science

1.2. Working conditions of machines and equipment and durability of details

1.3. Corrosion, wear and tear of materials.

1.4. A philosophical aspect of reliability
1.5. The economic aspect of reliability

1.1. Tasks of science

 to create an idea about reliability indicators and diagnostic system in the operation of machines and equipment;
 to learn to ensure the reliability and performance of machines and equipment, to assess their reliability and to learn to apply diagnostic methods and tools in practice;
 experimental determination of the main operational characteristics of machines and equipment, formation of skills in data collection, processing and analysis in operational conditions.
In general, the problem of reliability is related to issues of predictability. At the first stages of the creation of machines and equipment, reliability assessment is required for specific operating conditions. The science of reliability studies the process of changing the quality indicators of objects (accuracy, power, productivity, resource, etc.) over time.

Specific characteristics of reliability problems include:
 1. During the operation of the object, the change of the initial parameters is evaluated by the time factor;
 2. The technical condition of the facility is predicted (predicted) in terms of maintaining its output parameters (quality indicators).

1.2. Working conditions of machines and equipment and durability of details.

During operation and storage, any machine is exposed to various internal and external influences. As a result, its main parameters and characteristics are violated. The main reasons for the violation of the initial characteristics of the machine are the violation of its working conditions, lack of timely maintenance, low quality of repair, etc.
Usually, damage to parts occurs as a result of violation of the rules of use and maintenance of machines, and only in some cases due to exhaustion of metal or hidden defects in it (cracks, voids). When the rules of operation are followed, the consumption of adjacent parts increases gradually depending on the time of their operation. More than 80% of machine parts fail due to corrosion.
The accuracy of the machines depends to a large extent on the vibrations of the machines when the crankshafts, flywheels, and pulleys work. During the repair and replacement of some parts, their balance is disturbed, which causes the frame of the car to vibrate. The vibration that occurs during the operation of fast-rotating parts creates additional loads on various parts and bearings.
There are several reasons why the parts are not balanced: they may be due to incorrect dimensions, uneven density of the material, errors during assembly. As a result of a violation of ball bearing, the load on the bearings of the shafts increases sharply, which leads to a decrease in the useful work coefficient of the details and their excessive wear.
1.3. Corrosion, wear and tear of materials.

During the operation of the machines, due to the eating of adjacent parts, gaps of impermissible size appear between them, which disrupt the normal operation of the machines.

The rate of consumption is the ratio of the amount of consumption to the time taken for this consumption.

The rate of erosion is the ratio of the amount of erosion to the path along which this erosion occurred or the amount of work performed.

In the process of operation of technological machines and equipment, their working bodies are affected by different physical and chemical properties. As a result, machine parts gradually wear out, as a result of which the working ability of working bodies decreases. One of the main factors that lead to a decrease in performance is friction and wear.

Friction is a wonderful phenomenon of nature. He gave mankind heat and fire, thanks to the braking system, he made it possible to stop a fast-moving train and car in a short time, speed up a chemical reaction thousands of times, record the human voice on a record, hear the sounds of musical instruments, and many other things.

Friction is a process that occurs when almost any mechanism works. Technically, it has two meanings. Friction in bearings, gears, and piston systems leads to wear of surfaces and loss of power. Therefore, friction in this place is a harmful factor. Brakes and clutches also benefit from friction, so wear is allowed here.

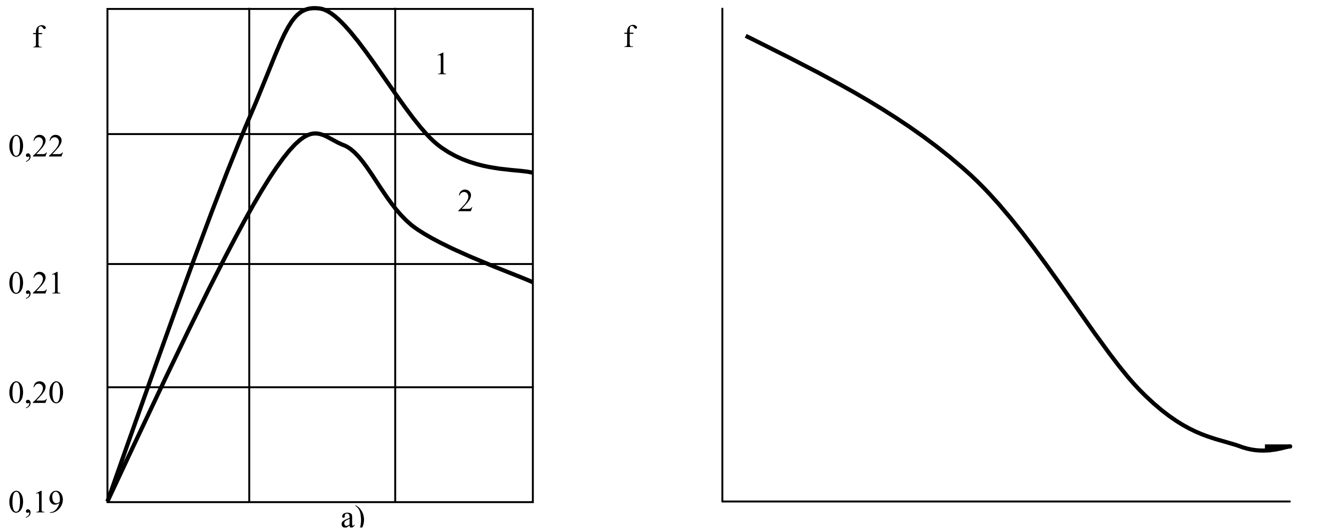



Figure 1.4 a) Dependence of the friction coefficient of steel on pressure and speed of movement in a cast iron sample b) Dependence of the change of the friction coefficient on the thickness of the oxidized (copper-copper) layer.

Types of friction. According to the kinematic signs of the relative movement of bodies, the following types of friction are more common.

Friction at rest is friction in micromovements before two bodies move relative to each other.

Friction in motion is friction between two bodies in relative motion.

Friction without friction is the friction of two bodies when no friction material is applied to the rubbing surface (Fig. 2). During the use of machines and mechanisms, the destruction of details in them is not always uniform. Rapid decay is observed during the initial period of operation. The duration of this condition depends on the quality of the rubbing surfaces and the mode of operation of the mechanisms.

If the hardness of the rubbing parts and the material used are selected correctly, it will go to uniform wear at speed. This situation continues until the size of the rubbing parts changes and the mode of operation changes.

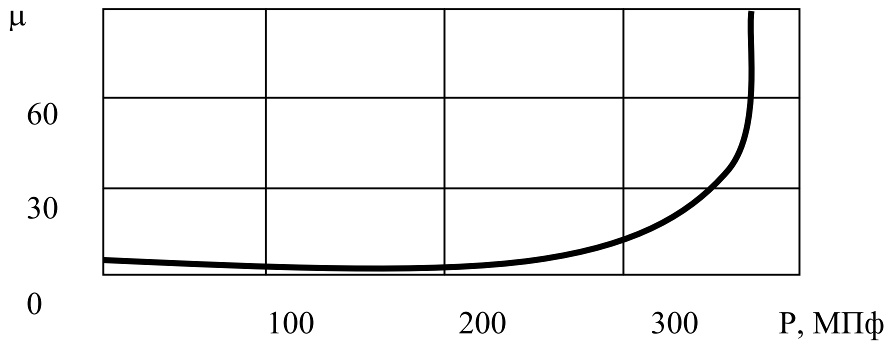



Figure 1.2. Friction of parts during operation without lubricating oil.

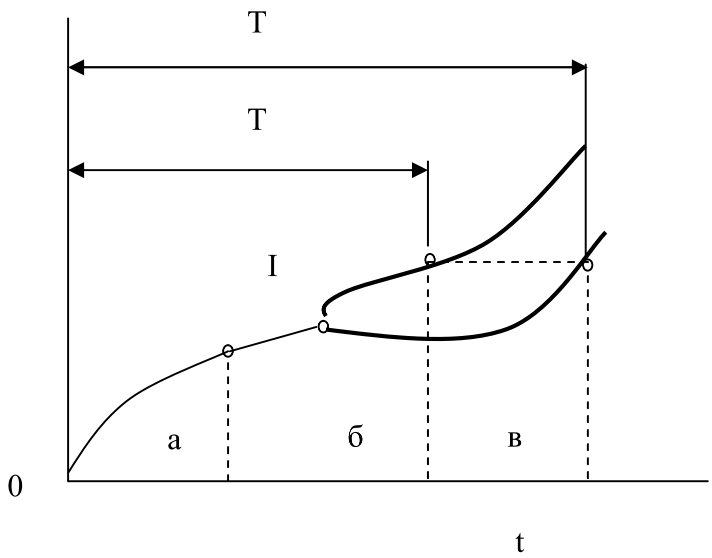



Figure 1.3. Degradation of details during operation.

As a result, the period of progressive degradation may begin and lead to an emergency situation.

Currently, there are several hypotheses for studying the nature of the decay phenomenon. According to the nature of the most influencing factors, the following types of decay can be seen: mechanical, molecular-mechanical, corrosion-mechanical.

Abrasive erosion. One of the main factors of the intensive course of erosion is caused by the falling of abrasive particles on the rubbing surface. As a result of these particles being harder than metal and falling on the surfaces of the parts, the phenomenon of decay occurs. Such decays can often be observed in open working bodies of machines, open rolling bearings, open moving parts, etc.

The most dangerous type of corrosion is called sticking, which is said to stick the rubbing surfaces together through friction. In this case, metal fragments move from one surface to another and adhere to a harder surface, and as a result, zasdaniye occurs.

The reasons for such interconnection of metals arise from the characteristics of interconnected surfaces.

Seizure occurs mainly due to the friction of non-lubricated surfaces.

In order to prevent malfunctions in technological machines and equipment, it is necessary to eliminate the condition of jamming as much as possible. The only way to do this is to choose the right oil raw materials and lubricate at the right place and at the right time.

Fatigue decay. The reason for this situation is the metal decay due to fatigue, and as a result of the appearance of cracks on the working surfaces of the details, rubbing occurs.

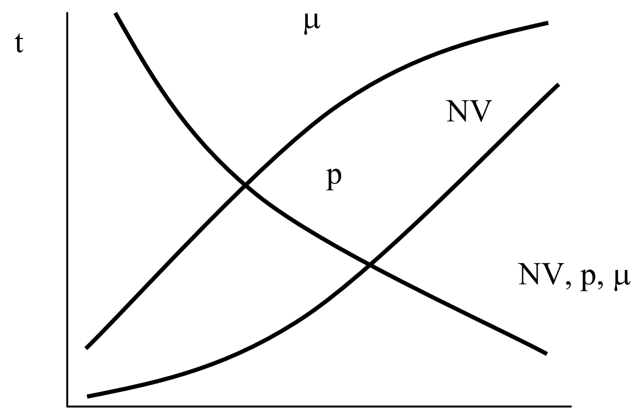



Figure 1.4. The influence character of detail material hardness NV, operating load ρ and oil viscosity  before the appearance of fatigue decay.

Fatigue fatigue occurs mainly on lubricated surfaces that work under high stress, such as gears, rolling bearings.

The intensive process of fatigue wear takes place in the following order: first, a crack appears on the rubbing surfaces due to fatigue, and the lubricant falls into this crack, gradually forming a powder, and as a result, small particles appear on the surface of the rubbing part.

The main reason for the development of fatigue wear depends on the friction conditions (temperature and stress), the properties of the materials of the friction parts (physical-mechanical properties) and the lubricants.

Residual crushing in details. Residual crushing in parts occurs in the following cases:

1. Under the influence of high volume falling on the surface;

2. When the stress induced by a large load is at or near the limit of the part material.

In the first case, there is crushing on the surface, and in the second case, twisting and bending occurs.

The appearance of crushing on the surface of the parts occurs mainly in the parts that work with impact. Examples include crushing of teeth on gears, crushing of keys and splines.

Plastic crushing of the surfaces occurs gradually, first of all, due to the increase in the density of the working surfaces, intermediate cracks appear, as a result of which the dynamic load on the teeth increases, cracks and pitting are formed.

Twists and bends are mainly caused by high stresses in the material. Such situations are mainly observed in elastic elements, for example: springs, springs.

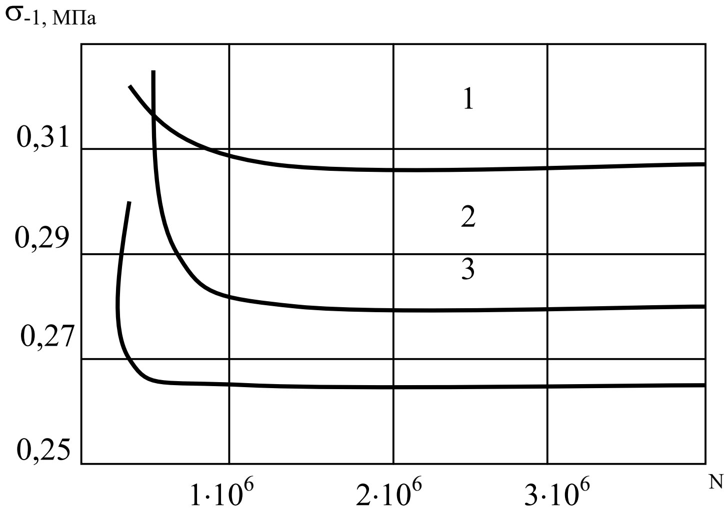



Figure 1.5. The influence of the number of loading cycles on the fatigue strength of the material (steel 45): 1- in the oscillating friction in an acidic environment; 2- in vibrational friction with the participation of lubricant; 3. In the absence of friction.

Fatigue of materials is defined as the gradual appearance of cracks in metals due to the stresses that appear under the influence of variable forces or high loads. Examples of this include torsions (body parts, frames), springs, crankshafts, etc.

Fatigue strength of materials refers to the resistance of materials to failure through fatigue. It is determined by the strength limit. The durability limit depends on the quality of the surface of the working part and the factor of working conditions: corrosion (rust), corrosion (wear), mechanical damage. The highest fatigue strength is observed in rolling friction surfaces operating in an active environment.

Thus, the fatigue strength and durability depend not only on the constructional structure and manufacturing technology of the details working under cyclic loading conditions, but also on the working conditions and character. For example, oil-free operation and corrosion of parts, scratches on parts, and damage on surfaces have a great impact on the working resource of parts.

Changes in the mechanical properties of materials lead to wear and tear, in addition to fatigue.
Due to changes in the physical and chemical properties of materials under the influence of the environment (light, oxygen, low temperature), products wear out. As a result, the flexibility and strength properties of the details decrease, and cracks appear. The state of wear and tear leads to a sharp decrease in the service life of machines and mechanisms.
In order to assess and predict the technical condition of machines and mechanisms, it is necessary to determine the wear of friction parts. Currently, the methods of determining the level of consumption are divided into two groups:
1. Method of periodic measurement of consumption;
2. Constantly measure the level of wear during the operation of machines.
Periodic measurement method. In order to assess the accuracy of the machine elements, periodically (periodic) measurement works are carried out to determine the level of corrosion.
The method of periodic measurement of wear includes the following methods: the method of measuring with a micrometer; artificial base method; the method of losing mass due to eating; a method of measuring the particles of detail consumed in the composition of lubricants.
Micrometer measurement is carried out by controlling some parameters of details. These works are carried out with the help of a micrometer, barbell circle, nutrometer, microscope and other tools.
The measurement accuracy is 0.01-0.001mm depending on the type of tools used.
The method of measuring by creating an artificial base, a geometric shape is drawn on the working surface of the detail at a certain depth, and the degree of spreading is determined through this depth, these works are determined using optical measuring devices.
In the method of weighing the mass of the food, the rubbing parts are periodically weighed with the help of scales and measured by the volume of lost mass. PR-500 accessory scales, VLA-200 analytical scales, ATV-200 and other scales are used as measuring instruments.
In the method of lubricants, it is determined by the amount of metal particles in the used oils. This amount is determined using the detailing mechanism.
A method of continuous measurement of food intake. Continuous measurement of wear during the operation of machines and mechanisms is carried out by various methods:
• measure the working environment by consumption;
• by changing the pressure in the working environment;
• through radioactive isotopes;
• through electromagnetic induction.
In the method of measuring the consumption by the consumption of the working medium, the machines are equipped with special devices, and with their help, the consumed liquid (lubricant) is transferred to the rubbing surfaces through a special slot, and the amount of consumption is measured. An increase in the consumption of lubricants indicates an increase in the gap, which means that the wear surfaces of the parts have increased.

The difference between the method of determining wear by operating pressure and the previous method is that the decrease in operating pressure indicates the increase of cracks on the rubbing surfaces. This happens due to the corrosion of the rubbing surfaces.
In the method of measurement using radioactive isotopes, a radioactive substance is firmly placed on the surface of the rubbing parts at a certain depth. The material of the radioactive substance should not be too different from the material of the detail. This material is cylindrical in shape, the diameter should not exceed 0.7-1.0 mm, 1.0-1.5 mm.
With the help of this method, it is clear not only that the erosion is intensive, but also which part of the rubbing surface is eroded the most.

## 1.4. A philosophical aspect of reliability

The philosophical aspect of the reliability problem requires answering two questions:

1) Is it a necessary process for the vehicle to lose its initial characteristics over time?
2) What philosophical concepts and laws determine the problem of reliability from the point of view of success?

machine and equipment environment, people, objects, etc. interacts with There are various cause and effect connections. An increase in the number of factors affecting machines and equipment changes its quality indicators gradually (evolutionarily) and leads to a different quality state based on the laws of dialectics. Therefore, the changes that take place in the vehicle in the process of exploitation, from the point of view of philosophy, the most important quality of all material objects is the legal manifestation of movement, because there is nothing in nature that does not change. Unpleasant changes can be slowed down, but they cannot be completely eliminated. Therefore, it is advisable to study the following:
- the source and causes of damage to machines and equipment;
- the physical nature of processes that reduce the performance of machines and equipment;
- reaction of machines and equipment against various impacts;
- to create systems that can perform the given tasks for the required time based on the factors mentioned above.

Product reliability is one of its main quality indicators.
From the point of view of philosophy, a quality is a set of signs that express the uniqueness of an object and its difference from other objects and phenomena. Reliability, which studies changes in quality indicators over time, can be called "quality dynamics".

## 1.5. The economic aspect of reliability

The need to evaluate the achieved level of reliability and increase it should be solved from the point of view of economy, because the economy serves as the main criterion for solving reliability issues.
In order to achieve the required level of reliability, when comparing different options, it is necessary to ensure the fulfillment of the condition of obtaining the maximum overall

economic efficiency, taking into account the costs of production and operation of vehicles, as well as the efficiency of their use.
The change of the total economic efficiency during the operation of machines and equipment over time depends on the following factors:

1. Expenses for new machines and equipment (design, production, testing, adjustment, transportation, etc.) - QI; and operating expenses (maintenance, current repairs) - QE(L).

QI and QE are always a negative number in the efficiency balance.

2. The use of machinery and equipment provides economic benefits QP(L).

Over time, QE(L) begins to increase as machinery and equipment wears out and costs increase to restore lost capacity (Figure 1.6).

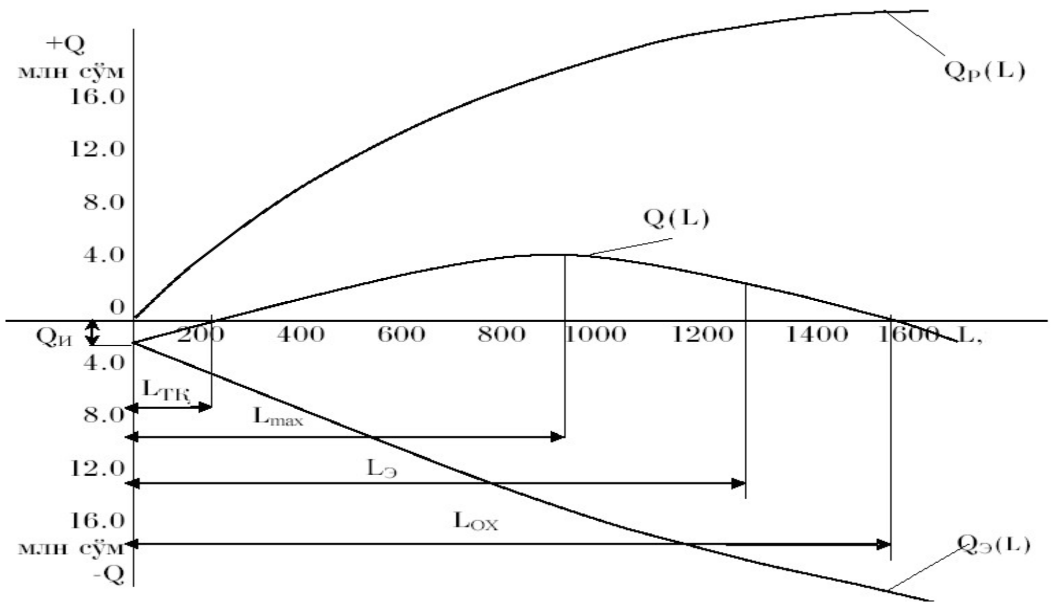



Figure 1.6. Changes in the economic efficiency of machines and equipment over time
LT.+. - cost recovery time; Lox is the time of operation until the limit state;
Lmax is the time when the highest efficiency is achieved; Le - economically acceptable time in use.

Control questions

1. Explain the goals and objectives of science?
2. Tell me the reasons and sources of material wear, wear and tear?
3. Explain the physical basis of the accuracy of technological machines?
4. Describe the causes and sources of the harmful effects of the environment on technological equipment?
5. What factors cause the friction of technological machine parts?
6. What are the ways to increase detail durability?

Lecture #2.
Topic: Basic information about reliability

Plan:
2.1. Reliability Basics.
2.2. Continuity. Fault. Concepts of performance.
2.3. Features of the goods.
2.4. Combined operational volume of technical service and repairs.

2.1. Basic information about reliability.

Reliability theory, like all disciplines, relies on a number of concepts and definitions. The basic terminology of precision is determined by the state standard 13377-75.
All reliability terms together with their general concepts can be divided into four groups:
- objects;
- events and circumstances;
- features;
- numerical indicators.
Objects mean technical systems, machines and mechanisms and their elements designed to perform the specified operation.
A technical system means a set of mutually moving elements aimed at independent performance of a specified practice.
An element is a part of a technical system (detail, node, aggregate) that performs a specific operation.
In the process of studying the accuracy of technological machines, one can be sure that machines and mechanisms are seen as a technical system and consist of a number of nodes, aggregates and elements.
A product means a technical system or its elements. What every industrial enterprise produces is a product. Therefore, the main object of the process of studying the theory and practice of precision is the industrial product.
Depending on the types of products, many accuracy indicators and levels are determined, that is, repairability or non-repairability.
Non-repairable products work until they first fail and cannot be repaired (bulb, fuse, etc.).
And repairable products have the property of continuing their operation after repair despite several failures (gear wheels, crankshafts, etc.).
Events and circumstances. The concept in this group represents three types of definitions: serviceability, failure (defect), unfit for work.

Serviceability is the state of the object in such a way that it is ensured that the specified task is performed at the level of the requirements specified in the regulatory and technical documents.
When assessing the serviceability of technological machines and equipment, it is necessary to take into account the specific working conditions during operation:
external environment (temperature, humidity, dust, etc.);
speed mode and machine shift mode;
qualifications of management personnel;
the level of supply of spare parts and their quality.
The main indicators of technological machines are determined by labor productivity and the quality of the work performed.
The main indicator of uninterrupted performance determines the probability of failure in the process of performing the specified amount of work within the specified period;
P(t)q1-N0/N,

where N is the number of cars in the batch; N0 is the number of damaged (failed) machines in time t.
The machine may not lose its functionality due to the fact that it is defective, but it can be used in transport mode.
Unfit for work. Refers to the process that occurs as a result of a breakdown in the state of unfitness for work.
One of the main tasks of the theory of accuracy is to study the cases of unfitness for work and to determine the reasons. The reasons for the frequent repetition of such situations are the change of details under the influence of physico-chemical processes during operation, the ability to learn the operating mode of the machines, etc.
Property - this condition includes the following concepts: thoroughness, durability, maintainability and maintainability.
Reliability is determined by ensuring the fulfillment of tasks given by machines and mechanisms at the level of requirements specified in technical documents, maintenance, conditions of use, possibility of repair, maintainability and ability to carry out deep sports, etc.
Reliability is determined only through the process of using machines and providing maintenance.
The following types of determination of reliability characteristics are known in science:
• accuracy calculation method, calculations and testing during the product design process;
• technical accuracy - determined by testing the product in a given mode;
• operative thoroughness - determined by the time spent on repair work;
• uninterrupted operation means the ability of the product to continue working continuously for a certain period of time or to work up to a certain hour.
The concept of uninterrupted operation means that the product (machines and mechanisms) should not break down during the specified period or during the specified hours.
Durability means that machines and mechanisms do not lose their ability to work when they are carried out in a timely manner and repaired at the required level. The latest

condition of machines and mechanisms is recorded in normative and technical documents.

Repairability - the feature of the repairability of machines and mechanisms is that they are carried out through timely maintenance and repair, along with early warning of the consequences of breakdowns and identification of the causes of breakdowns.

Repairability of machines and mechanisms is one of the important indicators of operational characteristics. The higher the repairability of machines and mechanisms, the more the cost and time spent on it will be saved, and the less the state of incapacity for work of machines and mechanisms.

The repairability of machines and mechanisms is closely related to the characteristics of undamaged operation and durability.

Quantitative indicators are measured by the amount of work performed by machines and mechanisms, which are determined by hours, etc.

Calculation of numerical indicators and determination of nomenclature is carried out by the types of machines and mechanisms and their work.

The equipment is divided into repairable and non-repairable types depending on the possibility of repair at the place of operation and economic expediency. Depending on the process of loss of performance of scheduled maintenance devices:

1) Worn out due to corrosion and metal exhaustion;
2) wear due to corrosion;
3) It is divided into combination wearers.

The condition of the details can be good, defective, serviceable and unserviceable.

## 2.2. Continuity. Fault. Concepts of performance.

Consistency - in which the technical parameters of the product satisfy all the requirements of regulatory technical documents.

Failure - in which the technical parameters of the product do not meet at least one requirement of the technical documentation.

Functionality is the product's ability to perform the functions set by the requirements of technical documents. The compressor is determined by the performance of the unit, machine, cooling performance, power consumption, noise and vibration levels.

The concept of integrity is broader than the concept of workability. A working item may be defective.

Failure to work is the event of partial or complete loss of the product's ability to work.

The event of damage to the product is called damage.

## 2.3. Features of the goods.

The accuracy of products is the most important indicator of their quality, because during operation, the maintenance of devices and the replacement of some parts lead to large expenses.

Accuracy (reliability) is the ability of the product to perform the given functions while maintaining the working parameters during the required time.

Working time (narabotka) - the volume or duration of work of an item, measured in hours or other units of measurement.
Non-failure (bezotkaznost) is the property of maintaining the ability of the product during a certain period of operation without forced stops.
Long service life (dolgovechnost) is the property of maintaining the product's ability to work until it reaches the limit state when the necessary repair service is provided.
The limit state is the state of stopping operation due to the fact that the main technical parameters of the product have exceeded the permissible limits.
Repairability (remontoprigodnost) - the ability of the product to identify and eliminate malfunctions through technical maintenance and repair.
Durability (sokhranyayemost) is the property of the product to always maintain its integrity and performance during storage and transportation.
An increase in accuracy indicators reduces the material damage that may occur due to unfitness for work, and reduces the costs of maintenance and repair during operation. At the same time, indicators of accuracy - non-failure, long service life, increase in repairability lead to an increase in the production costs of devices and the cost of the product.
Sometimes it may not be appropriate to create a device with a high level of detail, due to its moral wear and tear and not justifying part of the cost spent on it.
Accuracy indicators are determined by testing a certain number of items on stands or by conducting observations during actual operation.
A group of n items is tested to determine the precision indicators of non-repairable items.Repaired items (refrigerators, appliances, compressors) continue to work after some components are replaced, so the number of items n does not change during the entire test period.
The main indicators of non-failure of cooling devices: time of operation without defects (failure or failure); fault current parameter (for devices under repair); defect intensity (for non-repairable devices).
Defect-free operation time - determines the average operation time without defects, determined according to statistical data by the ratio of the sum of the operation time of the items to the total number of defects.
Standard operating time of refrigerator compressors without defects (1000 hours): screw - 3.5; ammonia with a capacity of more than 116 kW - 2.3; ammonia with a capacity of up to 116 kW - 5.4; with freon capacity up to 36 kW - 10.3.
The failure flow parameter - is determined by the ratio of the average number of defects during the short working time of the repaired item to this working time.
Failure intensity is equal to the ratio of the number of defects in a certain time interval to the number of non-repairable items that were in perfect condition at the beginning of this interval. The physical meaning of the indicator indicates the probability of failure within a short time unit.
The resource is the sum of the working time of the product up to the limit state specified in the technical documents.
Gamma percentage resource - the probability of the item not working up to the limit state is expressed

The fixed resource is the sum of the operating time of the item, during which its operation is stopped, regardless of its technical condition.
Service life until deregistration is the duration of operation of the product until it is deregistered when it reaches the limit state.
The main indicators of long-term operation of refrigeration equipment (□% resource) □% resource until decommissioning (combined aging and non-repairable devices), specified resources until certain types of repair (indicated) until decommissioning average service time.
Indicators of repairability of scheduled repair cooling devices: average operational volume of capital repair, combined comparative operational volume of maintenance and repairs.

2.4.. Combined operational volume of maintenance and repairs

The average operating volume of capital repair - characterizes the adaptation of the device to repair and is estimated by the labor spent on capital repair.
Capital repair refers to the repair performed with the help of restoring and replacing parts of the product in order to fully restore its condition and resource.
The combined comparative operational volume of technical maintenance and repairs is determined by the ratio of the sum of the volume of work of all repairs and technical services in the repair cycle to the resource before capital repair.
The accuracy of machines and equipment is increased by the following constructive and technological methods: the sizes and shapes of details that provide optimal initial damage (notching) are selected, types of oils with improved properties are used, high-quality materials are selected for production, vibration of machines is reduced, heat the required level of cleanliness and dryness of the internal working surfaces of compressors of exchange devices is ensured, corrosion resistance of parts surfaces is increased by thermal and chemical-thermal methods, corrosion resistance of heat exchange devices is increased, etc.

During operation, the accuracy of devices is ensured by the following methods:
Traditional systems of technical service and repair are used, devices are not allowed to be used in operating modes not specified in technical documents, devices are modernized in time, the qualifications of workers and employees are constantly being improved, etc.

Control questions.

1. What are the categories of accuracy?
2. Explain the main concepts and definitions of accuracy theory

Lecture #3.
Topic: Classification of dismissals

Plan:
3.1. Classification of dismissals
3.2. Distribution of random variables
3.3. Intensity of layoffs.
3.4. Breakdowns and malfunctions

3.1. Classification of terminations.

It is convenient to use an eight-digit code for classification. The scheme of the universal classifier of failures:

The device is divided into 9 major compounds (1-9) to indicate the location of the failure, and other compounds (external sources) are marked with the number "0". Each large compound is divided into 9 small compounds (number 2), which in turn are divided into 9 main details (number 3).
Depending on the nature of the failures, they are divided into the following: mechanical (1-10 for details, 11-20 for connections); physical and chemical (21-40); quantitative change of components in the system (41-60); electricity (61-80); in external supply sources (81-90).
External symptoms of failure (number 6 of the code) include the stop of KM, high temperature in the object, increase in electricity consumption and power consumption, knocking, etc.
The reason for failure (7th number of the code) may be structural, technological installation. These reasons are not always detected when examining the crash (the number "0" is assigned to the code).
The percentage relationship between major, medium and minor failures, that is, the amount of work required to eliminate the failure (8th digit of the code), is characterized by repairability.
Depending on their nature, layoffs can be simple and unexpected. Normal failure can be detected and eliminated during the next inspection of the device. Unexpected failures are usually determined by emergency situations during operation.
From the point of view of the age of the machine and the statistical distribution of the frequency of breakdowns, they are divided into three types:
Start-up failures - occur during the initial period of machine operation, mainly due to insufficient inspection at the manufacturing plant. It will have a high rate in the first-second month of operation and will completely disappear in the following months.
Random failures are caused by various hidden defects, which cannot be eliminated by the existing inspection methods. These outages will have a small but constant intensity throughout the operation period.

Corrosion-induced failures usually begin to occur after several years of operation. At the end of operation, the intensity of these failures increases suddenly and quickly reaches 100%. The occurrence of such failures is different for different cooling machines: from 2-3 years to 15-20 years.

## 3.2. Distribution of random variables

When solving engineering tasks, for example, determining the demand for replacement of parts and units of machines and equipment, or planning the production of spare parts, it is necessary to know the average service life (resource) of items and how certain resources are grouped around this average amount. Therefore, it is important to know the distribution laws of random variables

$$p = \frac{m}{N} \tag{3.1.}$$

where:

- p is the percentage of relative violations;
- m is the number of violations in the interval; N is the number of items under observation.

The distribution laws of random variables depend on the causes of disturbances.

## 3.3. Breakdowns and malfunctions

A key concept in reliability theory is distortion.

Disruption is defined as complete or partial loss of machine and equipment (aggregate, node or system) functionality. In this case, machines and equipment cannot perform their tasks at the level of the requirements of the parameters specified in the regulatory and technical documents.

Malfunction is defined as the deviation of at least one of the parameters characterizing the technical condition of the machine and equipment (aggregate, unit or system) from the permissible limits.

Classification of disorders

When analyzing the reliability of machines and equipment and aggregates, the classification of violations is always carried out. Violations are classified as follows.

During the operation of machinery and equipment, its technical condition gradually deteriorates, the rate of wear and tear, maintenance and current repair work increases, ease of management and reliability decreases, etc. k.

Attrition. During operation, the parameters of the technical condition of the machine and equipment change under the influence of the external environment. For example, rubber-technical products lose their strength and elasticity due to oxidation, hot or cold temperatures, moisture, solar radiation, and the chemical effects of oil, fuel, or liquids. Oil-oil materials are contaminated with corrosion products, the viscosity characteristics deteriorate, the strength of the additives in it is lost, etc.

## Control questions.

1. Explain the classification of layoffs?

2. How many digits will the classification of dismissals consist of?
2. Describe breakdowns and failures?
3. What does the classification of violations look like?

Lecture #4.
Topic: Reliability indicators of repaired items

Plan:
4.1. Tendency to repair and its indicators.
4.2. Reliability indicators of repaired items.
4.3. Working time until leaving work.

4.1. Tendency to repair and its indicators

Serviceability or ease of use refers to the tendency of machines and equipment to prevent, identify and eliminate breakdowns and malfunctions during maintenance and current repair processes.
The main indicators of the tendency to repair:
- average repair time;
- average and comparative values of money spent on labor and technical service;
- general reliability indicators;
- possibility of repair in conditions of given technical preparation and technical usage coefficients. In addition, other private indicators can be used to assess the tendency to repair:
- the number of impact points on machines and equipment or aggregates; location; easy loosening of aggregates; degree of interchangeability; aggregate, node, detail, system, degree of unification of fastening details.

The average repair time is the mathematical expectation of the vehicle's serviceability. If the distribution law is clear, then the average repair time is determined as follows:

$$T_B = M\left[t_в\right] = \int_0^\infty t f_в(t)\,dt \,, \qquad (4.1)$$

where: - the sign of the mathematical expectation of the repair time, hours (thousand km).
- repair time distribution density, 1/hour (1/thousand km).
The average repair time of a vehicle is determined based on statistical data as follows:,

$$(4.2)\ \overline{T}_в = \frac{1}{m}\sum_{i=1}^{m} t_{вi}$$

where: - the time taken to correct the i-th violation, hours
m is the number of violations that occurred during the control.
According to this indicator, the labor volume of each type of technical service and the comparative labor volume of current repair works are determined.

Probability of repair in a given time - represents the probability that the time taken to detect and correct a violation does not exceed the given time:

$$R_{в}(t) = \int_{0}^{t} f_{в}(t)\,dt \quad , \qquad (4.3)$$

Based on statistical data, the probability of repair at a given time is determined as follows:

$$R_{в}^{*}(t) = 1 - \frac{n_{в}(t+\Delta t)}{N_{в}(t+\Delta t)}, \qquad (4.4)$$

where: - the number of items repaired in time; - the number of items that need to be repaired in time.

To determine the probability of repair, it is necessary to know the distribution law of damage. The probability of repair depends on the design features of each vehicle and the condition of its repair.

The coefficient of technical availability KT shows the probability of the product's ability to work for a certain time taken by chance (except for planned maintenance periods):

$$K_{T} = \frac{T}{T + T_{в}}, \qquad (4.5)$$

where: T is the product's service life before failure, hours;

Tv - to repair an item for a certain period of time that was accidentally received time spent, hours

This indicator expresses the reliability of machines and equipment not only through the function of non-destruction, but also through indicators of repairability.

The coefficient of technical utilization Ktf is determined as follows:

$$K_{TФ} = \frac{t_{И}}{t_{И} + t_{T} + t_{TX} + t_{ТИК}}, \qquad (4.6.)$$

here: - the sum of the operating periods of the vehicle in the considered period of time, hours (thousand km);

- time required for restoration, repair and technical service when the item is damaged during the considered period of time, hours (thousand km).

Economic indicators of tendency to repair are mainly the average costs of maintenance and current repairs - Stx-jt; average labor costs - Ttx-jt; sum of expenses - ; the sum of labor costs - .

Depending on the task and issues, these indicators can be used to determine whether a vehicle is prone to maintenance or repair, and to compare machines and equipment.

4.2. Reliability indicators of repaired items.

The frequency of failures is the ratio of the number of failures per unit of time to the number of items put to the test.

$$fi = \frac{\Delta m_{i}}{N \cdot \Delta t_{i}} \qquad (4.7)$$

N-test item batch.

- each time interval.

-the number of outages.
- working time until leaving work.

Out of order items are not replaced with new ones. when passing to the limit, instead of a statistic, we find a characteristic of the frequency of possible failureswhich is called the probability density.

$$f(t) = \frac{1}{N} \cdot \frac{dm}{dt} \qquad (4.8)$$

The density of extimolars determines the distribution of the running time to failure, which is a random variable.

Failure intensity is equal to the ratio of the number of failures in the time interval to the number of items remaining in operation until the start of the interval N(t).

$$\lambda_i = \frac{\Delta m_i}{N(t) \cdot \Delta t_i} = \frac{\Delta m_i}{\left[N - m(t)\right] \cdot \Delta t_i} \qquad (4.9)$$

Control questions.

1. Tell us about the tendency to repair and its indicators?
2. Accuracy indicators of repaired items.
3. How is the working time until leaving work defined?
4. How is the coefficient of technical use determined?

Lecture #5.
Topic: Determining reliability indicators according to test results.

Plan:
5.1. Purpose of reliability testing
5.2. Types of reliability testing
5.3. Reliability test object
5.4. Characteristics evaluated in reliability testing
5.5. Testing of experimental and serial samples
5.6. Reliability testing methods
5.7. Reliability test plans
5.8. Methods of determining the number of items to be tracked
5.9. Types of information (information) about resignations.
5.10. Accounting for failures during the warranty period.

5.1. Purpose of reliability testing
The purpose of reliability testing is to determine the level of reliability of an item and evaluate its numerical values. Knowing the level of reliability of the item helps to solve many issues, i.e. confirming the established reliability characteristics, developing measures to increase them, applying a reasonable system of technical maintenance, efficiency of the item and the appropriateness of its further operation, identifying weaknesses, calculating - the book allows you to check the quality of predictions and technological processes of their creation.
Using the test results, one of the following characteristics can be obtained:
1. The law of distribution of the product's service life before failure. This characteristic is fully calculated and allows you to determine the main reliability indicators, including the probability of uninterrupted operation for a given period of time. But this work requires a lot of statistical material and costs. The distributive law can be obtained only for simple items with low costs.
2. The probability of an item's failure-free operation is determined for a given time, but the failure characteristic may be unknown for a longer period of operation of the item. Based on such limited information, it is possible to draw a conclusion about the level of reliability of the product.
3. The complexity and long duration of the tests deprives us of the opportunity to evaluate the change of the product's output parameters over time. In this case, the "confidence margin" for each parameter serves as an indicator. The results of these tests using predictive methods are used to determine the level of reliability of the product.
4. Due to the complexity of the issue, in many cases it is impossible to determine the reliability level of the product in absolute quantities, in this case it is necessary to compare it only with the indicator of a similar product. As a result, the question of the actual level of durability cannot be solved by answering the question of how many times the durability has increased in tests, working without breaking. For high-reliability products, only the time factor serves as the main criterion in determining the methods and volumes of tests.

5.2. Types of reliability testing

Special reliability tests:

1. Research tests - tests conducted to study the factors affecting the reliability of the product.
2. Control tests - tests conducted to assess the level of reliability of a specific item.

The tests are divided by the venue as follows:

1. Tests under bench conditions - provide information about the loss of machine or aggregate performance, that is, about their reliability characteristics. When developing test methods, it is necessary to take into account the compatibility of test conditions and procedures with operating conditions. Bench tests are usually continued until a failure occurs or until the item has run for a specified period of time.
2. Operational and polygon tests are used for experimental and serial samples. Experimental samples of technological machines and equipment are tested in harsh operating conditions on specially selected and artificially created fields and in various climatic conditions. Such tests have the following disadvantages:

a) the duration of the experiments is not always sufficient, similar to the actual operating conditions;

b) the test result determining the object's reliability parameters cannot provide information about at least the average value of the service life of technological machines and equipment. Therefore, accelerated tests are used, in which reliability information is obtained in a very short time.

When conducting control tests, items are individually tested for their integrity, durability, repairability, and maintainability.

5.3. Reliability test object

The object of reliability tests can be:

1. Samples - if the characteristics of products or materials that determine their durability are tested (fatigue strength, anti-erosion and corrosion properties, etc.);
2. Details (joints, kinematic pairs) - if construction and technology
if there is a need to take into account the influence of biological factors on the service life of this part (bearings, gears, guides, hinges, etc.);
3. Machine, assembly and units - if it is necessary to take into account the interaction of some mechanisms and structural elements and their influence on performance indicators (gearbox, reducers, engines, control systems, etc.);
4. Machine - testing the interaction of all aggregates, nodes and mechanisms in the machine in operating conditions and work procedures (vehicles);
5. Machine system - if the interaction of some machines that make up one production complex is evaluated through reliability indicators (automotive enterprise).

5.4. Characteristics evaluated in reliability testing

They are mainly divided into two groups:

1. Characteristics of wear (deterioration) processes and degree of deterioration of items. In the tests, the passage of corrosion processes, corrosion, shape changes, fatigue

disorders, etc. are studied. These factors are the main reasons for the loss of machine performance.
2. Characteristics of changes in output parameters of the device over time (accuracy, efficiency, load capacity, etc.). Exceeding the allowed limits of these characteristics leads to violations.

The more complex the test object, the more output parameters will have to be evaluated for a large number of tests.

5.5. Testing of experimental and serial samples

When conducting reliability tests, it is necessary to divide their volume between experimental and serial production in such a way that the necessary information can be obtained as a result of it, and appropriate changes can be made to the design of the product as soon as possible. However, many issues cannot be solved in experimental production, only serial samples can give the desired results. In addition, when testing serial samples for reliability, the following should be taken into account:
a) experimental verification of whether the necessary structural changes have been made to the machine as a result of bringing the layout up to standard;
b) expansion of work procedures and other studies of items in actual operating conditions;
v) to determine the causes of damage of items during the operation of the first serial samples.
When testing prototypes, only a small number of items (maybe even a single item) are placed because these items are made in small quantities. But these tests are not enough, because the reliability indicators obtained from a small number of items and based on insufficient information do not reflect the actual condition of the items.

## Control questions.

1. What is the purpose of testing the reliability of products?
2. What are the types of product reliability testing?
3. What are the test objects?
4. What are the requirements for the test plan?
5. How are experimental and serial samples tested for reliability?
6. What are the types of test plans?
7. How to account for failures after the warranty period?
8. In what groups can the information about the reviewed work be divided?

Lecture #6.

Topic: Factors affecting reliability. Quitsseasonality. Verification method.

Plan:

6.1. Construction factors

6.2. Technological factors

6.3. Operational factors

6.4. Factors affecting reliability. Seasonality of layoffs

6.5. Test for reliability

Factors affecting reliability can be conditionally divided into three groups:

construction, technological and operational factors.

6.1. Construction factors

The group of design factors affecting the reliability of the vehicle includes: reliability level; the level of complexity of the construction; degree of homogenization (unification).

Confidence levelIt is estimated by the ratio of the costs of manufacturing the vehicle and maintaining it in technical condition. The main design factors affecting the level of reliability:

a) the shape and size of the details, the comparison falling on the surfaces of the details

pressures, stresses, fatigue strength of metal;

b) strength of construction, operational loads of details

change its shape under the influence;

c) relative to each other of the surfaces and axes of the parts working in the joint

exactlocation;

g) ensuring reliable operation of movable and immovable joints correct selection of transfers (posadka);

d) equipping engines with efficient oil pumps; e) performance of the oil pump oil suction mesh without bubbles;
j) crankcase to reduce oil temperature and slow down its wear use of ventilation system, oil radiators and quality oil cleaning;

z) in engines with a hydro-reactive treatment that cleans the oil a second time

application, other factors also occur.

6.2. Technological factors

The group of technological factors affecting product reliability includes: manufacturing industry technology; maintenance and repair, quality of operational materials and spare parts, etc

Technological of the manufacturing industryLet's look at some of the factors:

1. Fastener effects of operational loads of compounds the ability to maintain its reliability for a long time in conditions is achieved by making parts from high-quality steels, processing them, increasing their accuracy, using various fastening devices (lock washers, fasteners, etc.). Some parts are made of alloy steel and heat treated (for example, propeller shaft flanges, bolts of the rear axle reduction gear wheel, etc.).

2. Good implementation of technical control in machine-building enterprises prevents poor quality parts from entering the assembly line.
3. The corrosion resistance of the parts depends on how to process them,

and less wear of rubbing surfaces depends on their roughness.

4. During the adaptation period, the ability of the surfaces to train to the initial wear rate

affects. For this purpose, the rubbing surfaces are covered with particles of tin, lead, copper, and iron.

5. High-frequency currents of crankshaft necks in the mechanical engineering industry

Quality of vehicle maintenance and current repairs. Technical maintenance should be performed in such a way that there are no malfunctions in the vehicles being put into operation, for this, technical maintenance should be carried out on the basis of a schedule, with full completion of all work (control diagnostics, fastening, adjustment, lubrication and other works). increase is required.

The order of technical maintenance (volumes of technical maintenance work, periodicity and list of tasks to be performed) should correspond to the type of content in motion, its technical condition, operational conditions, the quality of operational materials, and the driver's increases the repair work of vehicles. Therefore, it is necessary to develop its own maintenance procedures for different operating conditions. Carrying out current maintenance work with high quality is the only guarantee of vehicle reliability.

## 6.3. Operational factors

Quality of consumables and spare parts.During work and maintenance processes, aggregates and mechanisms of the vehicle are in constant interaction with operating materials (oils, fuels, cooling liquids). Depending on the properties of the materials and the conditions of their use, their interaction also changes: the corrosion or rusting of the parts accelerates, the consumption of materials increases, and the overall performance of the vehicle decreases.

Use of operational materials transport of the tool

should be in accordance with construction and technological features, its technical condition and operating conditions.

The reliability of the vehicle is affected by the quality of many lubricants. In order to increase the anti-corrosion properties of the oil, additives are added to it, which reduce the rate of corrosion of the parts.

Spare parts to be replaced during operation may be overhauled,new, used, repaired and prepared in the farm, and taken from another model of the vehicle. Therefore, the quality of spare parts will be different and will negatively affect the reliability of the vehicle.

## 6.4. Factors affecting reliability. Quits seasonality.

Non-maintenance operational factors that significantly affect accuracy are ambient temperature, product loading and proper operation.

Important factors of technical service are timely preventive maintenance and proper operation of automatic devices that ensure optimal operation of the machine.

An increase in the ambient temperature, a large load and a departure from the optimal mode lead to an increase in the condensation pressure, as a result, the accuracy of the machine decreases, because the load on the moving mechanism of the KM increases, it becomes difficult to ensure the density of the system, and the coefficient of operation increases due to the decrease in the cooling performance of the KM. An increase in the operating time factor causes the marginal consumption of most KM details to start faster.

winter, due to the increase in the ambient temperature and the load on the equipment. Due to the fact that 30% of the population leaves the city in large cities, the number of unemployment decreases significantly in the summer months. The increase in calls (vizov) corresponds to the months of April-May, because in these months preventive work is carried out to prepare cooling machines for the summer season. The minimum number of calls falls on January and February.

A "seasonality factor" must be introduced to consider the curve of the parameters of the flow of outages. Thiscoefficientiscalculatedasfollows.

:

= - 1)

Here:w- -from$_i$ the work corresponding to 100 cars in this month of the year

number of exits, %/month.

—

w- -average monthly number of outages %/month

$k_i$-values are almost constant in different years. He is basically another

may differ by 6-8% compared to years. But in May, this difference reaches 16%.

Because the weather in May every year is very different from each other.

The seasonality coefficient represents the effect of the sum of many factors. We also need to determine the individual impact of each operating factor. There is no way to determine this in operational conditions. In laboratory experiments, the number of machines is only 5-10.

The main method of determining operational factors affecting accuracy is as follows. The results of 10-15-year operational tests are collected, in which the following main factors are indicated: ambient temperature, equipment loading, equipment indicators, operating time coefficient, electricity consumption, ice thickness in the evaporator, temperature in the object , the number of failures. In the processing of the results, the test with a single factor is isolated. The results of these isolated tests allow determining the influence of factors on accuracy.

In the summer months, the number of outages is twice as large as in the

## 6.5. Test for reliability

The information given to determine the long service life is the wear rate or resources of the friction parts.
Active experimentit is based on conducting special tests for non-failure in the test stands of the manufacturing enterprise and in laboratory conditions. Active experiment is mainly used in tests of small and medium machines (power 15-20 kW).

Passive experiment(for large cooling machines) is carried out on the basis of creating monitoring bases in the operational areas. In-service monitoring of the same type of machines on a large scale allows obtaining information with high accuracy.
In the process of generalized research, elements with low operational accuracy are determined, the level of operation and maintenance of cooling devices is determined, the degree of influence of operating conditions and maintenance system items on the accuracy indicators is evaluated.

Dismissals are recorded based on the following conditions:

if there is one failure, one failure is considered to have occurred; if the malfunction is repeated several times, it is considered that the failures have occurred as many times;

if several related failures occur at the same time, one failure is recorded, if the failures are not related, several failures are recorded.

Absences are not taken into account in the following cases:

if the failure is caused by major errors of the service personnel;

if failures occur due to violation of the normal operating mode; if a breakdown occurs due to the failure of devices that are not part of

the refrigerator.

## 6.6. Try not to quit.

Test plans are a set of rules, based on which the scope of testing (the number of items under test and the duration of the test) is determined, the repair and non-repair of broken items is decided, and a decision is made on the termination of the test.

The test program includes the following:
types and methods of conducted tests;

metrics to be determined or verified;
test mode characteristic; proper

operation verification methods;

failure detection methods.

Accuracy indicators obey the theoretical laws of distribution of random indicators: exponential, normal and Weibull laws.
The test size is the probability that the indicator is correctly identified, given the distribution law assumed-and depends on the relative accuracy of its detection.

In the exponential and normal laws of distribution, t of N itemsc will be tested over time.

For the Weibull distribution, N items are scheduled to be tested until each of them fails. Testvolumeaccordingtotheexponentiallaw (hours).

$$c = \frac{m-To.o'r}{r3} \quad 2)$$

m- the number of expected failures.

$r_3$-and-determined from mathematical tables depending on the values coefficient.

The duration of the test is calculated depending on the number of selected machines.

$$= \frac{o.o'r}{r_3} \quad 3)$$

The volume of the test, where the intensity of the failure is determined:

$$tc= \overline{\cdot r3} \quad 4)$$

-k-expectedoutageintensity.

t is the number of samples to be tested in order to determine the probability of failure.

$$= \;t)\ \overline{-r3\quad} \qquad .5)$$

P(t)- the expected probability of uninterrupted operation.

The number of samples tested to determine the mean time to failure according to the normal distribution law:

= --o 6)

Za-- is an auxiliary determined from mathematical tables depending on

indicator.
--is the expected root mean square of the mean running time until failure
o

estrangement

--the accuracy of finding the average running time until failure.

Test size to determine the average run time until breaking down for Weibull's law-,- andb(coefficient of variation) depending on the math

determined from the tables.

## Resource tests

Resource tests are conducted on the basis of certain test programs. The duration of the tests will not be less than eight thousand hours. Machines, parts and assemblies that have passed factory inspections and factory tests corresponding to technical conditions are taken into the tests.

Detail eating is usually determined by compressor detailing techniques. The most universal method is to measure from time to time with standard measuring instruments with high accuracy.
Corrosion measurement results are entered into a general measurement card, where only the most corroding surfaces and planes are taken into account.
The detailed decay graphs are plotted for each compound. Such construction of the graph allows to determine the regularity of wear of each detail in the joint, to determine the rate of wear of details during the period of compaction and normal operation.

A detailed wear graph of the sleeve-piston assembly allows you to see the effect of the frequency of revolutions and the oil used on the wear.

Most refrigeration compressor parts have two decay periods: the compression period, the period in which the decay rate stabilizes.

The compaction period is characterized by a very high rate of consumption. This rate is much higher than during the period when the rate of consumption stabilized. Intensive leveling occurs during this period. The duration of the compression period depends on the geometric dimensions of the rubbing surfaces.
The wear rates of parts are calculated according to the results of two consecutive measurements at each time interval.

In the process of statistical processing, distribution laws, mean square deviation and dispersion are determined.

## Control questions

1. What factors affect the reliability of technological machines and equipment?
2. Which influencing factors are included in the construction group?
3. Which influencing factors are included in the production group?
4. Which influencing factors belong to the operational group?
5. How is the level of complexity of the construction based?
6. How does the level of unification affect the reliability of equipment?
7. How are active experiment and passive experiment tests carried out

—

Lecture #7.

Topic: Determining reliability indicators.

Plan:

7.1. Purpose and tasks of information collection and processing

7.2. Rules of information collection and processing

7.3. General requirements for the content of the monitoring program

7.4. Basic requirements for information collection methods

7.5. Requirements for information analysis and processing

7.6. General requirements for recorded information content and record forms

7.7. Calculating the optimal warning replacement period of replaceable parts

7.8. Calculation of the preventive examination period

7.1. Purpose and tasks of information collection and processing

The information collection and processing system is a set of organizational and technical measures to obtain the necessary and truthful information about the product's reliability.

The purpose of the system is to:

- its construction to increase the reliability of the product improvement;
- improvement of preparation and collection technology, control tests;
- improving the quality of repair and reducing its costs

development of activities on;

- compliance with the rules of operation, maintenance and current

development of activities aimed at increasing the efficiency of repair;

- itemcertification;

- control of reliability indicators, etc. The tasks of the system are as follows:
- determination and assessment of the reliability characteristics of the product;

- construction and technological that reduce the reliability of the product identify deficiencies;
- details and assembly that limit the overall reliability of the item

identify compounds;

- the effect of operational conditions and procedures on the reliability of the product

determination;

- determining the laws of origin of violations;

- making corrections to standard indicators of reliability;

- optimization of spare parts consumption, maintenance and current

improvement of the repair system;

- aimed at increasing the reliability of products to the optimal level

determining the effectiveness of activities.

7.2. Rules of information collection and processing

Information collection and processing must meet the following requirements set by industry regulatory technical documents:
- structure of information collection and processing system by industry;

- controlplanandmethods;

- determination of values of information processing methods and reliability characteristics;
- plans for conducting control tests by product types;

- informationgatheringmethods;
- technical provision of information collection and processing;
- the procedure for developing activities and evaluating their effectiveness;
- information exchange and transfer procedure;
- procedure for using information in industry enterprises;
- waystoautomatework.

7.3. General requirements for the content of the monitoring program

The system of information collection and processing applies to the following organizations and enterprises:

- head of reliability information gathering and processing

toorganizations;

- organizationsperformingdevelopment;
- tomanufacturingenterprises;
- tooperationalenterprises;
- torepaircompanies.

The system should include continuous, periodic or one-time observations, information accounting, collection, collection, processing and analysis, development of activities aimed at increasing product reliability.

The operation of the system is regulated by the following regulatory and technical document:

- applicability of the system to a specific item;
- conditions of information exchange within the enterprise and between enterprises;
- informationprocessingmethods;

- methodsofplanningobservations;

- the need to use technical means in the monitoring process and to them

requirements;

- the procedure for developing measures to increase reliability. The collection and processing of information about the reliability of the item is carried out based on the

technical assignment and working methods.

The terms of reference for conducting information gathering specify the following:

- listofmonitoreditems;

- numberofitems;

- head of reliability information gathering and processing

toorganizations;

- organizationsperformingdevelopment;

- tomanufacturingenterprises;

- tooperationalenterprises;

- torepaircompanies.

The system should include continuous, periodic or one-time observations, information accounting, collection, collection, processing and analysis, development of activities aimed at increasing product reliability.

The operation of the system is regulated by the following regulatory and technical document:

- applicability of the system to a specific item;

- conditions of information exchange within the enterprise and between enterprises;

- informationprocessingmethods;

- methodsofplanningobservations;

- the need to use technical means in the monitoring process and to them

requirements;

- the procedure for developing measures to increase reliability. The collection and processing of information about the reliability of the item is carried out based on the

technical assignment and working methods.

The terms of reference for conducting information gathering specify the following:

- listofmonitoreditems;
- a list of standard indicators of reliability;

- informationgatheringmethods;

- order and operating conditions in the brochure;

- periodicityofinformationtransmission.

The working methods of information collection and processing define the following;

- observationplans;

- parameters determining work procedures and their measurement methods;

- criteria of disturbances and limit states;

- informationcodingmethods;

- on payment of initial forms of information accounting

- taking into account the volume of work and the availability of computers programs for processing information about the reliability of products.
-

- head of reliability information gathering and processing

toorganizations;

- organizationsperformingdevelopment;

- tomanufacturingenterprises;

- tooperationalenterprises;

- torepaircompanies.

The system should include continuous, periodic or one-time observations, information accounting, collection, collection, processing and analysis, development of activities aimed at increasing product reliability.

The operation of the system is regulated by the following regulatory and technical document:

- applicability of the system to a specific item;

- conditions of information exchange within the enterprise and between enterprises;

- informationprocessingmethods;

- methodsofplanningobservations;

- the need to use technical means in the monitoring process and to them

requirements;

- the procedure for developing measures to increase reliability. The collection and processing of information about the reliability of the item is carried out based on the

technical assignment and working methods.

The terms of reference for conducting information gathering specify the following:

- listofmonitoreditems;

- numberofitems;

- a list of standard indicators of reliability;

- informationgatheringmethods;
- order and operating conditions in the brochure;
- periodicityofinformationtransmission.

The working methods of information collection and processing define the following;

- observationplans;
- parameters determining work procedures and their measurement methods;
- criteria of disturbances and limit states;
- informationcodingmethods;
- on payment of initial forms of information accounting

guidelines;

- taking into account the volume of work and the availability of computers programs for processing information about the reliability of products.

- checking that the information is different;
- statistical processing of information and assessment of reliability indicators;
- measures to improve reliability based on the results of reliability analysis development.

During the analysis of the causes of the breakdown and the last state, the following is

carriedout:

- signs of receiving primary data (operational conditions, systematization by duration, types of breakdowns, etc.);
- identification of details limiting the reliability of the item;
- determining the causes of the violation;
- effectiveness of construction-technological and organizational measures

assessmet;

7.4. Basic requirements for information collection methods

a) Collection of information on reliability operational and maintenance

should be conducted by the organization that conducts information collection in enterprises;

b) Collecting information and transferring it to the collecting organization centrally,

should be done by inspection and questionnaire;

c) Initial data collection base point or operational and should be carried out by repair companies;
g) The investigation is conducted by the organization that collects the information. In this case, of the item

the technical condition is studied in operating conditions, the forms of initial information recording (operation and repair documents, accident inspections, protest documents, etc.) are analyzed, and its results are reflected in data collectors;

d) Questionnaire is a special request of the organization that collects information

implements by sending leaflets to operational and repair enterprises;

e) Selection of base enterprises should provide information for operational conditions in the brochure.

7.5. Requirements for information analysis and processing

Informationprocessingincludes:

- coding and classification of primary data;

- accuracy, completeness and uniformity of information about product reliability

ensurecompliancewithrequirements;

- ensuring that all information undergoes qualitative and quantitative analysis; Qualitative and quantitative analysis includes:

- exclusionofunclearinformation;

- checking that the information is different;

- statistical processing of information and assessment of reliability indicators;

- measures to improve reliability based on the results of reliability analysis development.

During the analysis of the causes of the breakdown and the last state, the following is

carriedout:

- signs of receiving primary data (operational conditions, systematization by duration, types of breakdowns, etc.);

- identification of details limiting the reliability of the item;

- determining the causes of the violation;

- effectiveness of construction-technological and organizational measures

assessmet;
(Appendix 1);

- a journal of maintenance and current repair of the product.

The log contains the item's passport information, company name, name of the damaged part, type and frequency of maintenance, method of eliminating the damage, maintenance and current repair costs, taking into account the value of the replaced parts. should be;

- one-time documents for the operation of goods (waybill, aggregate repair sheet (Appendix 2), information on product failure, spare part application (Appendix 3), etc.).

Collector-forms are designed to record the information entered into a system and are filled out with the help of specially trained personnel and on the basis of preliminary documents or in the process of operational observations. Basicforms:

- a map-collector of violations (information map Appendix 4)

- on maintenance and current repair of the product information mapper.

Forms for recording the results of product reliability analysis are designed to record quantity and quality results, work procedures, spare parts consumption, reasons for failures, and a list of details that limit the reliability of the product. Basic forms:

- determination and reliability of distribution laws for statistical information evaluation of characteristics indicators;
- processing of information on the consumption of spare parts;

- determination of the duration and reasons for the retention of items

and systematization;

- the information obtained was obtained in normative and other conditions

data comparison etc

7.6. Recorded information content and record forms

general requirements

The following forms of records are used for collecting and processing information:

1. Recording operational information about reliability is a preliminary

forms;

2. Operationalinformationcollectorforms;

3. Forms for recording the results of reliability analysis.

the initial registration forms are designed to record information that has not been recorded in a single system, and they are filled in during operation. The main ones of such forms are:
- a logbook for recording the road traveled and violations. Article in the magazine

passport information, company name, work order and operating conditions, date of tracking and removal of the item, route since the start of operation, name of the damaged part, reason for the damage, time and method of its elimination, etc. need

- general assessment of product reliability characteristics

list;

- assessment of reliability characteristics of parts of the product general list;

- a general list of types of product damage;

- a general list of spare parts consumption;

- technical service and current repair of labor volume and cost general list;

When refrigerating machines are operated for a long time without maintenance and repair, their main technical characteristics decrease: the cooling efficiency decreases significantly, the specific power consumption and oil consumption increase, the level of vibration and noise increases, which reduces the efficiency of the machine. and leads to deterioration of working conditions. In addition, the wrong choice of preventive inspection and maintenance period or none at all leads to the increase of failure of the cooling machine and the increase of the costs of standing. But while preventive inspections are carried out in a short period of time, reducing operational characteristics and maintenance costs, premature replacement of parts leads to economic inefficiency,

7.7. Optimum prompt replacement of interchangeable parts

calculate the period

According to statistical data, it obeys resources of many details the normal law (Figure 7.1).

Different options for the replacement period of replaceable structural parts are used: t=TM,that is, at the end of the average resource;

The statistical characteristics of the resources of the associations, the costs of preventive replacement of parts and the costs of eliminating failures are considered as data for making calculations.

7.8. Calculation of the preventive examination period.

Preventive inspection was carried out to prevent accidental failure of compressor connections and details. This includes: timely detection and elimination of malfunctions, hardening and adjustment of fasteners, replacement of some parts.
In the preventive inspection, the replacement of parts and assemblies is carried out according to their condition.

During operation, the compressor can be in 3 states: the word is faulty (but operable), inoperable (failure state). A compressor with defects and defects in individual joints and details is considered defective, but the compressor can perform its main functions. The development of these disturbances leads to random failures.

It is not possible to fully identify all malfunctions by preventive inspection in real operating conditions, due to the limited capabilities of diagnostic tools and accessories. Therefore, only the parts that are found to be faulty during preventive inspections are replacedIn the method of calculating the optimal period of preventive inspections, the failure occurrence process is considered as consisting of 2 parts: the time of occurrence of failure, the time of occurrence of failure.

The first part is the random time T from the time of compressor operation to failure1continues until After that, part 2 is the development of the fault
part begins, random for a period of time and ends when the failure occurs.
failure occurrence frequency with compressor failure flow parameterw(t) is characterized.
Number of resignationsMnumber of preventive examinationsndepending on
Period between repairsTt.othe number of failures in preventive inspections
does not depend on the number.
In order to economically optimize the period of preventive inspections, the cost of eliminating breakdowns and conducting preventive inspections should be minimal.

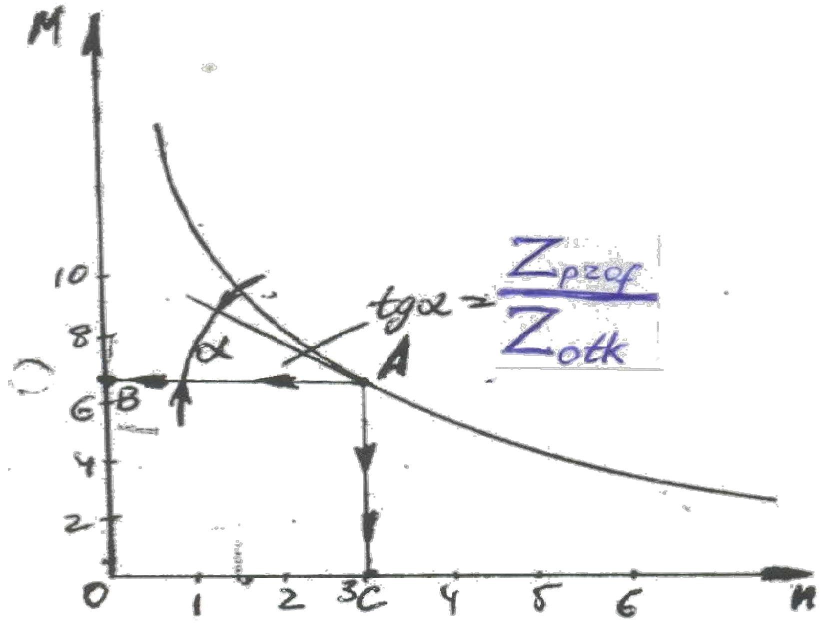


Figure 7.2. Graphical method of determining the optimal period of preventive examination.

Data required for the calculation: parameter of failure flow-experimental graph of, the intensity of detected failures (based on statistical data), periods between repairs.

Based on the result of integration of the experimental graph of the flow density of failures, a graph of the dependence of the number of failures on the number of preventive inspections is constructed.
Correct selection of the period of conducting preventive inspections extends the life of the compressor up to 2.5...4 times.

## Controlquestions

1. In what cases is information about the reliability of the product collected?

2. How to process information collected on product reliability

given?

3. What forms of records are used to collect information on product reliability

used?

4. What kind of data is the information map on the reliability of the item includes?
5. Information collection and processing system on product reliability What are the goals and objectives?
6. The graphic method of determining the optimal period of preventive examination

**Lecture #8.**
**Topic: Calculation of the structure of the repair cycle.**

**Plan:**
**8.1. Proper organization of repair and assembly works**
**8.2. Project-warning repair system.**
**8.3. Repair system.**
**8.4. Planning and organization of repairs.**
**8.5. Calculation of the structure of the repair cycle.**

8.1. Proper organization of repair and assembly works
Enterprises include shops and sections that ensure its normal operation, although they do not directly participate in the process of processing raw materials and obtaining finished products. They include commodity, raw material and transport shops, electrical and heat engineering sections, repair and other auxiliary departments. The work of such workshops, sections and departments is also based on the operation of various types of general and specially designated equipment.
The continuous serviceability of any equipment is achieved through its proper operation and timely, high-quality repair.
In order to launch an industrial enterprise, all construction and assembly works approved in the project must be completed, and the problems that arose during the implementation of this project must be solved.
The construction part of the work is performed by special construction organizations or workshops in three stages:
1) allocated for the construction site before starting the installation of equipment (vertical and horizontal design of the site, roads, foundations and supports, transmission pipes, warehouses, assembly areas, utility rooms for builders and installers, etc.);
2) simultaneously with the installation of equipment (construction of buildings and structures, finishing works, etc.);
3) after completion of the main assembly works (improvement of the internal and external yard of the enterprise).
Installation of equipment means a complex of works related to bringing the equipment into working condition. For this, the equipment being assembled must be completely assembled, built in the project state and connected to a single technological system using appropriate communications.
The variety of equipment and communications serves as the basis for the specialization of the assembly - the increase in the quality of work andproduction. Currently, special

assembly works (electricity and heat, production automation tools and control-measuring equipment system assembly, corrosion protection, wrapping the surface of equipment with heat insulating material, etc.) are separated from the general assembly works of technological and auxiliary equipment.

Installation of technological equipment is carried out by reconstruction of existing industrial enterprises and construction of new ones, as well as replacement of obsolete equipment with new and efficient ones. In the last two cases, disassembly is the first step, which is the opposite of assembly.

Despite the similarity of the technological elements of assembly and disassembly, it is necessary to take into account some features of equipment disassembly in the process of operation related to the need to ensure special safety measures and the sequence of work.

Knowledge of assembly and disassembly works related to the design, construction and operation of equipment of chemical and oil refining enterprises, as well as knowledge of advanced methods and the classification of their application methods, is a requirement for every mechanic. At the time of design, the characteristic of the equipment's tendency to assembly is taken into account, that is, the possibility of carrying out assembly and disassembly works without much labor and in a short period of time is taken into account. The duration of the construction and reconstruction of the facility often depends on the correct operation and optimal organization of the installation of equipment.

Careful and safe operation of equipment within the limits of certain operating parameters - carried out by strict execution of precise, timely planned activities on the use and control of equipment, as well as the necessary maintenance. is increased. This complex of technical and organizational activities forms a single system in the chemical and oil refining industry, which is called a project-alert repair system (LOT) or an equipment repair and maintenance system.

Enterprises have relevant services and departments (chief mechanic, chief power engineer, control and measuring instruments, architecture and construction, etc.) for implementation of project-warning repair or maintenance and repair systems. The service of the chief mechanic department (non-special technical and general equipment) provides the LOT system of communication and transport, and in the absence of the services of the chief architect or chief builder in the enterprise - all buildings, structures and roads provide the LOT system .

The main component of the LOT system or maintenance and repair system is the equipment that embodies the main part of labor and **material costs.** carrying out and organizing the repair of buildings.

Appointment of repair is effective operation of equipment and achievement of a high level of technical and economic indicators. For this purpose, repair includes a number of works, which are aimed at stopping or preventing the wear and tear of equipment. Also, some details and parts of the equipment, physical-mechanical properties, shapes, sizes of the materials will be completely or partially restored. All equipment is no exception.

The basis of the proper organization of repair and assembly work is their maximum industrialization based on the use of advanced technology of repair and assembly, exchange of parts and details, unification and categorization. is the direction.

In order to improve the repair system and increase the productivity of workers-repairers, a reserve is a large enterprise, a combine, and even several factories and combines that are close to each other in terms of territory are centralizing repair work.

Centralization allows rational use of material and labor resources, as well as the use of mobile means of mechanization and industrialization using their high efficiency. Centralization of production of spare parts and, on this basis, creation of the basis of the replacement fund of equipment, parts and details, allows to reduce as much as possible expenses related to on-site detail repair in the preparation of individual parts and details.

Among the main requirements for the equipment, the following can be added: to be free from complete destruction, that is, to prevent accidental failure and to work carefully within the limits of the parameters introduced in the technological map. The requirements for the desired structural characteristics of the equipment, even when the highest quality is achieved in their preparation, can be satisfied for a long time only by the implementation of strict measures called planned maintenance.

Equipment repair is divided into project-mandatory and project-warning repairs. The first two types are used in individual sections of some branches of industry and transport. Projected - post-inspection maintenance is a pre-planned inspection of equipment during this period. In this process, repair work is carried out on the entire volume. Carrying out such repairs requires the use of additional labor for disassembly and assembly, and leads to long-term downtime of the equipment. Project-standard repair provides for the equipment to stop for a pre-planned period, and its repair is carried out according to strict instructions. At the same time, some details and parts of the equipment are forcibly replaced, that is, regardless of their exact condition, with new or restored ones. Such repair guarantees the high operational accuracy of the equipment, but the cost is high and the amount of work to be done is large.

In many industrial enterprises, chemical and oil refineries, the system of project-initiated maintenance (LOT) is used. LOT combines the advantages of the two previously listed systems: minimal downtime and high accuracy when operating equipment with low labor and material costs.

8.2. Project-warning repair system.

A project-warning maintenance system refers to a set of regularly designed measures for equipment repair, control and monitoring, aimed at keeping the equipment constantly ready for operation and warning of accidents. This system must ensure the quality indicators of equipment operation specified in the relevant production normative documents.

The project-warning repair system is not only technological, but also extends to auxiliary equipment, buildings and structures, pipelines and other communications, as well as company vehicles. In other words, the LOT system covers all the main funds (means) of production enterprises.

Repair services in all chemical and oil refineries are managed through the equipment repair and maintenance system and the guidelines approved by the relevant ministries on financial and alert maintenance. In addition to these documents, enterprises also use other LOT guidelines approved by relevant institutions, for example, ventilation equipment of auxiliary equipment (metal cutting machines, presses, etc.), production

Appointment of repair is effective operation of equipment and achievement of a high level of technical and economic indicators. For this purpose, repair includes a number of works, which are aimed at stopping or preventing the wear and tear of equipment. Also, some details and parts of the equipment, physical-mechanical properties, shapes, sizes of the materials will be completely or partially restored. All equipment is no exception.

The basis of the proper organization of repair and assembly work is their maximum industrialization based on the use of advanced technology of repair and assembly, exchange of parts and details, unification and categorization. is the direction.

In order to improve the repair system and increase the productivity of workers-repairers, a reserve is a large enterprise, a combine, and even several factories and combines that are close to each other in terms of territory are centralizing repair work.

Centralization allows rational use of material and labor resources, as well as the use of mobile means of mechanization and industrialization using their high efficiency. Centralization of production of spare parts and, on this basis, creation of the basis of the replacement fund of equipment, parts and details, allows to reduce as much as possible expenses related to on-site detail repair in the preparation of individual parts and details.

Among the main requirements for the equipment, the following can be added: to be free from complete destruction, that is, to prevent accidental failure and to work carefully within the limits of the parameters introduced in the technological map. The requirements for the desired structural characteristics of the equipment, even when the highest quality is achieved in their preparation, can be satisfied for a long time only by the implementation of strict measures called planned maintenance.

Equipment repair is divided into project-mandatory and project-warning repairs. The first two types are used in individual sections of some branches of industry and transport. Projected - post-inspection maintenance is a pre-planned inspection of equipment during this period. In this process, repair work is carried out on the entire volume. Carrying out such repairs requires the use of additional labor for disassembly and assembly, and leads to long-term downtime of the equipment. Project-standard repair provides for the equipment to stop for a pre-planned period, and its repair is carried out according to strict instructions. At the same time, some details and parts of the equipment are forcibly replaced, that is, regardless of their exact condition, with new or restored ones. Such repair guarantees the high operational accuracy of the equipment, but the cost is high and the amount of work to be done is large.
In many industrial enterprises, chemical and oil refineries, the system of project-initiated maintenance (LOT) is used. LOT combines the advantages of the two previously listed systems: minimal downtime and high accuracy when operating equipment with low labor and material costs.

8.2. Project-warning repair system.

A project-warning maintenance system refers to a set of regularly designed measures for equipment repair, control and monitoring, aimed at keeping the equipment constantly ready for operation and warning of accidents. This system must ensure the quality indicators of equipment operation specified in the relevant production normative documents.
The project-warning repair system is not only technological, but also extends to auxiliary equipment, buildings and structures, pipelines and other communications, as well as company vehicles. In other words, the LOT system covers all the main funds (means) of production enterprises.
Repair services in all chemical and oil refineries are managed through the equipment repair and maintenance system and the guidelines approved by the relevant ministries on financial and alert maintenance. In addition to these documents, enterprises also use instructions on LOT approved by relevant institutions, for example, ventilation equipment of auxiliary equipment (metal cutting machines, presses, etc.), production, housing and general buildings and structures, etc. traction equipment
8.3. Repair system.
All types of repairs are carried out in a predetermined sequence in a certain processed unit (machine) - number of hours. Inter-repair (or repair) cycle refers to the time from one major repair to the next major repair. This time includes all types of scheduled maintenance and equipment downtime.

The duration of the repair cycle of the main equipment is determined in most cases by the single sector regulations. According to the same norms, the duration of the equipment's operation is determined by the period between two consecutive current repairs, which is called the inter-repair period or the distance traveled between repairs. Permissible deviation from the standard is ±10% for the inter-repair cycle, ±15% for the inter-repair period. Deviation from the established norm is possible only after a thorough inspection of the condition of the equipment, in which case an act will be drawn up in the prescribed form.
Normative results refer to the equipment of one construction and certain conditions of its operation. If the specific equipment under consideration is distinguished by these signs (great aggressiveness of the environment, relatively severe working conditions), the norms approved by higher organizations for this equipment are accepted. Local norms are also defined for equipment that does not have a single norm. It is based on the constructive and technological features of the equipment, the conditions of its operation, and specific organizational and technical measures that increase the durability and extend the service life of the equipment.
The regulations also provide for the length of downtime of the equipment being repaired, from the time it is disconnected from the system to the time it is connected to the cycle. The time of downtime for the repair of a technological device (shop) is determined from the time when the transfer of raw materials to this device is stopped until the device (shop) is brought to normal mode.
Determining the scope of repair work. The volume of repair works and their sequence are determined by the structural and technological characteristics of the equipment and specific parameters of the equipment's operation between two consecutive repair works. If these factors remain unchanged (which is likely for chemical and oil refinery equipment), the amount of repair work for the same equipment will be approximately constant. Therefore, when drawing up a repair plan and calculating the required manpower, it is necessary to put in place the norms of labor costs for each type of repair. Such regulations are given in the relevant instructions on LOT and it is necessary to follow them.
Normatives contain information given for generally accepted structural formalized equipment operating under certain average conditions. The average values of the repair conditions given in the regulations are given. Therefore, in each specific case, the given regulatory information should be determined taking into account the experience gained in the operation of similar equipment in such enterprises. In mutual calculations with the organizer-executors and setting the prices of repair works, it is necessary to proceed only from the volume of the completed works.
It is advisable to constantly reduce the practical volume of repairs at the enterprise and to reduce the time spent in repairing equipment by conducting various organizational

and technical measures. In enterprises where the volume of repair work is less than the norm, it is necessary to plan only on the basis of experience.
The calculation of the demand for workers of all specialties is considered by regulations as a percentage of the total work volume of the work structure for each type of repair by equipment groups (labor cost structure). This information is the basis for planning the repair work. The total demand for repair workers for the entire enterprise is determined by taking into account any types of repairs that each unit of equipment must undergo according to a specified plan for a year.
8.4. Planning and organization of repairs.

Schedules of repairs Planned-warning maintenance of plant equipment, as well as other main funds (buildings, structures, roads), is carried out in strict accordance with the previously drawn up and approved plan. This plan may be different for different businesses depending on its structure and content. However, it is the same for all plots within one enterprise.
Annual plans and schedule-warning maintenance schedules of technological devices or individual equipment are the main starting documents when drawing up a general maintenance plan. Plans and graphs are drawn up in strict compliance with the repair regulations and production plan, as well as taking into account the capabilities of the repair service's forces and tools. The composition of the inter-repair cycle, the inter-repair interval and the duration of equipment maintenance are determined by the repair regulations.
The capital repair schedule project is agreed in advance with all organizations that should participate in the repair work from the beginning of the contract.
Records of repair works. In order to prepare for the repair and carry it out in a short period of time, repairers should know all the ins and outs of their tasks and the scope of the repair work. Therefore, before starting work, records should be drawn up, in which all the work related to this planned repair will be listed in every detail. The structure of these records may vary, but they will provide information on the materials and spare parts required to accurately determine the required labor, as well as the cost of all repairs, including the cost of its individual elements. must have.
In addition to repair work, it is aimed at improving working conditions (nomenclature work on technical safety), work necessary for production (interruption of communications, structural changes, etc.), as well as partial maintenance of the technological device. work on modernization or complete modernization of specific equipment (replacement of old with new) may also be included.
The record of repair work (record of defects) cannot be considered as a document that is required to be completed on time. Upon careful inspection, disassembly, and

disassembly of the equipment being repaired, new defects may be revealed that are not covered by the record, or, on the contrary, the intended defects may not be present.
Work developers. All works carried out according to the LOT procedure are carried out either by the enterprise itself or jointly with special organizations from outside. Organizations participating outside the contract based on the contract are called contractors; and the enterprise concluding the contract is called the customer.
Methods of development of repair work. Depending on the size, weight and structural complexity of the equipment, repair works are carried out in different ways. The most advanced method is the aggregate method. Its essence is that the equipment being repaired in this method is removed from the foundation and sent to the mechanical repair shop. This method makes it possible to reduce the cost (especially in terms of labor costs), and also drastically reduces the maintenance of technological equipment.
In the repair of large-sized equipment, the large-part method is used. In this case, the worn out part is replaced with a new, previously assembled part. This method can only be used if the interchangeability is strictly observed.
For advanced equipment, as well as in cases where it is impossible to use both of the above methods, the individual repair method is used. The essence of this method lies in the fact that after disassembling the parts of the equipment being repaired, the worn parts and details are restored according to the technology that is more convenient in these conditions. In this case, the wide use of spare parts is a reliable basis for reducing the repair period.
Specialization of work. Specialization of repair workers is the most necessary condition for increasing work productivity. Specialization - allows improving the skills of locksmiths, boilermakers, riggers, welders, etc., improves the quality of repair work. In some large repair bases, a narrow specialization is recognized as appropriate: the worker performs work on only one or two types of equipment, for example, only compressors or centrifugal pumps.
Structure of enterprise repair service. Repair service of main technological, mechanical and transport equipment, communications, buildings and structures is a factory, combine or production association.
U yana bosh mexanikbo‘limi (BMB) boshlig‘i ham hisoblanadi. UningThe task includes solving all questions and issues related to the implementation of the LOT system, the modernization of equipment, the mechanization of technological and repair operations requiring labor, and the improvement of the organizational forms of the development of repair work. . In small factories without a capital construction department, the chief mechanic is also charged with current capital funds and new construction works. The chief mechanic is directly subordinated to the chief engineer of the enterprise and coordinates with him the duration of the repair, the operation system, as well as the reconstruction of the main funds.

The central repair bases of the enterprise are subordinate to the chief mechanic. Sections or bases of technological and auxiliary-additional shops subordinated to the head of the repair shop are also subject to BMB from a technical point of view. According to the law, all workshops and sections of the enterprise are obliged to follow the instructions of the BMB on the issues of equipment operation, repair, necessary accounting and reporting.

Technical control. The factories have a technical control department to control the technical condition and operation of the main funds. This department is subordinate to the chief mechanic of the enterprise. The technical control department consists of engineering and technical workers who have expertise in special types of equipment, pipes, buildings, etc.

Technical control is based on ensuring absolute compliance with the rules and norms applicable in the enterprise regarding the safe operation and construction of the main funds (equipment, means of production, buildings and structures).

The technical control department systematically and plannedly conducts inspections, checks, tests and technical performance of existing equipment, as well as checks the completeness and correctness of the repairs carried out and the technical condition of new equipment. checks that it matches the conditions. A high level of control depends on the equipment of control-measuring devices and special control laboratories.

Organization of the palace of spare parts. High-quality and timely repairs in the short term can only be achieved if there is a sufficient supply of spare parts and repair materials. However, their excessive storage for a long time has a significant impact on the suspension of the company's working capital and the technical and economic indicators of the company. Therefore, it is necessary to clearly solve the issues of determining the minimum amount of spare parts and materials that protect the continuous supply of repair work.

It is very important to use spare parts sparingly, as well as to strictly control the recovery of replaced parts for reuse. Only in such cases it is possible to moderate spare parts at a nominal level and reduce the total cost of repairs.

Preparation of equipment for repair is of particular importance in chemical and oil refineries. Explosion and fire hazards and working with toxic substances are obvious factors in these factories. Therefore, the composition of the activities to prepare for the repair and the sequence is discussed in the instructions for installing the equipment on the technological card or operating each equipment. When drawing up the maps, the properties of the environment filled with the equipment or system, the dimensions of the equipment, as well as the selected type of repair are given importance.

Stopping the equipment, disconnecting it from the system and preparing it for repair is carried out by technological personnel (apparatus technician, operator). Sudden changes in temperature, pressure and load during shutdown can cause serious equipment failure.

Therefore, the shutdown of large equipment or technological objects is managed by the head of the site (installation, block, workshop).
Suspended equipment is released from the surrounding environment using drains, steam and air blasting, water flushing, etc. to drain. After that, the equipment is reliably disconnected from the system, at which time it is installed in the opening and closing fittings, and after them, the noise-absorbing flanged joints. Silencers must be clearly marked with numbers. Each silencer installed shall be recorded in the shift log. This log shows the dates it was installed and removed, as well as the name of the performer. Silencers are installed by on-duty locksmiths, and during major work, locksmiths assigned by the factory repair base.
The further preparation of the equipment depends on its structural properties, specific conditions and the nature of the required repair. This preparation includes washing and evaporation, exact number of repetitions of the procedure, use of special reagents, etc. The technological service provides an official document guaranteeing the readiness of the equipment to the repairers. During the capital repair of the equipment, a document of a specific form is drawn up. It emphasizes the readiness for repair of equipment and communications and mentions the main measures to ensure safety during repair.
The task of submitting and preparing the equipment for timely repair is entrusted to the head of the production workshop. A written permit for welding and other flammable works on the equipment itself or in the area where it is installed is drawn up based on the approved form. Such a permit signed by the chief engineer (head of the plant) is signed by the fire safety representative, who before the start of work and during the work, all mentioned in the issued permit and the general technical safety rules of the enterprise amallargaqat’iyrioyaqilinishinitekshiradi.

8.5. Calculation of the structure of the repair cycle.

To construct the structure of the repair cycle, that is, to determine the main quantitative indicators of thoroughness, the percentage resource values of the friction parts and the number of preventive inspections are used.

The repair cycle is the time interval between two major repairs of the device or from the start of operation to the first major repair. The structure of the repair cycle ensures that the order and sequence of repair types are carried out within the specified period of time, and that the period of planned repairs coincides with the time when they are needed. The structure of the repair cycle is constant for the same type of cooling devices, and it does not depend on the operating mode of the device and the place of application.

Inter-repair period is the time between two consecutive repairs or from the beginning of operation to the first planned repair.

The inter-inspection period is the time between two consecutive preventive inspections or between an inspection and scheduled maintenance.

The structure of the repair cycle of refrigerating machines is built on the basis of the following methodology:

the value of the percentage depends on the cooling efficiency of the cooling device: if the cooling efficiency is up to 10 kW; % if up to kW; It can be more than 100 kW.

Each type of cooling devices is divided into several groups of elements whose percentage resources are approximately the same. The number of repair types in the repair cycle is equal to the number of these groups. It is desirable that the number of these groups does not exceed 3-4, otherwise the structure of the repair cycle will become complicated.

The duration of the maintenance period is determined by the percentage resource of the group of elements with the shortest service life. This allows to reduce the failure of cooling machines.

The number of inter-repair periods in the repair cycle is taken to be equal to the ratio of the percentage resource of the longest operating element group to the size of the inter-repair period, the obtained value is rounded to the nearest whole number.

Long-term operation of the cooling device without accidental failure (during the inter-repair period) is ensured by conducting preventive inspections.

The maintenance and repair strategy is the same for all types of refrigeration machines, as follows: inspections and repairs are carried out at the specified time, in the event of breakdowns in the inter-repair period, repairs and preventive inspections non-disruptive restoration works are carried out.

The volume of preventive inspections and repairs is unchanged (the same) regardless of their position in the repair cycle.

Refrigeration equipment repair and maintenance is carried out during the entire operation in returnable repair cycles.
Materials necessary for operation: the structure of the repair cycle, the list and volume of repair work, the norms of the work volume of repairs, the norms of maintenance of devices during repair, the number of repair personnel, oil consumption, etc.

***Control questions***

***1. How to properly organize repair and installation work?***
***2. Explain about the project-warning repair system?***
***3. What do you know about the repair system?***
***4. How to plan and organize repairs?***
***5. Methods of calculating the structure of the repair cycle?***

**Topic: Standardization of reliability indicators.**
**Plan:**

**9.1. Standardization of reliability indicators.**
**9.2. Standardization of equipment durability (long-term operation) indicators.**
**9.3. Standardization of failure indicators of refrigeration compressors**

9.1. Standardization of reliability indicators.
Among the main quality indicators, the accuracy indicators that characterize the ability of the technical device to perform the given functions during long operation have a special place.
The compressor goes to the limit state as a result of the process of wear, failure of structural elements due to fatigue, corrosion, etc., which is called physical (physical) wear of the machine. Physical wear complications are eliminated by repair.

Unrepairable equipment is removed from the register when it reaches the limit state. Limiting service life determines the long-term operation of refrigerator compressors, in accordance with the safety point of view. Optimum service life refers to the period of operation optimized according to economic criteria.
Over time, the compressors in operation lag behind the newly produced ones in terms of their technical and economic indicators, they become morally obsolete even if they are in technical condition.
The period of moral obsolescence is determined by the intensity of development of the refrigeration engineering around the world. Practice shows that compressors in our country are updated every 12-15 years.
During the depreciation period, the amount of funds allocated for renewal corresponds to the initial cost of the car.
The amortization period is connected with other indicators as follows:

In this case, the amortization period is A, the economic optimal exploitation period is Topt, the service life before retirement is Tr.ch, moral wear is Tm.esk, and the marginal service life is Tcheg.
The amortization period is related to the write-off resource through the average annual operating time (operating time ratio). This technical-economic indicator characterizes the long-term operation of the structure, which depends on the number of repair cycles and the structure. For the same type of equipment, the decommissioning resource is unchanged regardless of the place of use.
If the accuracy and long-term performance of cooling devices are normalized, their depreciation periods should be changed accordingly.
When standardizing the cleanliness indicators of cooling devices, it should be ensured that the funds spent on repair, prevention and elimination of breakdowns correspond to the depreciation funds.
Long-life indicators are associated with random failures, and long-life indicators are related to the wear process and gradual failures.
The costs of eliminating accidental breakdowns are added to the cost of the product, the costs of planned maintenance are covered by the amortization funds allocated to the repair.

9.2. Standardization of equipment durability (long-term operation) indicators.

Long-term performance indicators are standardized based on the following: the entire number of repair cycles should correspond to the amortization period.
The period of carrying out minor repairs should be greater than one year, because the costs of carrying out these repairs must be covered by depreciation funds, otherwise these costs will be added to the cost of the product. Cooling devices with a capacity of up to 35 kW must be operated without major repairs during the amortization period.
In different areas, the intensity of use of devices is different, the operating time coefficient is different (from 0.11 to 0.8). For example, the low coefficient of operation of cooling devices in railway transport is related to the technological mode of operation. But the low coefficient of operation of ammonia compressors with a capacity of more than 116 kW indicates the presence of excess reserve machines. This is a lack of economy. In this case, it is recommended to increase the coefficient to 0.5-0.6.

9.3. Standardization of failure indicators of refrigeration compressors.

Normalization of failure indicators of repaired compressors is carried out on the basis of the criterion of minimizing total costs. The costs of eliminating Zum breakdowns are equal to the sum of Zish.chik and the costs of conducting preventive inspections.
Dependence of the output flow parameter on the operation time:

and k coefficients are obtained separately for each type of compressor.
When the number of terminations is M k=2

(9.2)

If we determine from (9.1) and integral (9.2).

$$T = k \cdot T_{t.o} \cdot \frac{Z_{ish.chiq}}{Z_{prof}} \qquad (9.3)$$

This relationship can also be applied to non-repairable devices. In this case, the compressor will be replaced with a new one, and the cost of repairing the failure will be equal to the price of the new compressor.
In the above case, the intensity of failures requiring the opening of the compressor shell

The coefficient k is determined from the experimental graph of the failure flow parameter.
The proposed amortization cost norms will prolong the operation of large expensive compressors, the short operation of such compressors is not economically justified.

It is recommended to shorten the amortization period of compressors of small performance, which are useless for capital repair. Such compressors should be removed from operation sooner, approximately in 8-10 years.
The recommended amortization cost norms allow companies to cover all costs incurred due to maintenance and reduce the cost of manufactured products.

The frequency of rotation, the number of cylinders and the mode of operation have a significant impact on the cleanliness indicators of piston compressors. These are given in the tables.

## Control questions

1. What period is called optimal service life?
2. Give an understanding of standardization of accuracy indicators?
3. How to standardize the durability (long-term performance) indicators of refrigerator compressors?
4. How is the amortization period implemented?
5. Normalization of failure indicators of refrigeration compressors?

**Lecture #10.**
**Topic: The influence of reliability indicators on the economy of machines.**

**Plan:**
**10.1. The influence of cleanliness indicators on the economy of machines.**
**10.2. Methods of increasing reliability indicators.**
**10.3. Methods of ensuring the necessary care in operation**

10.1. The influence of reliability indicators on the economy of machines.

The ratio of annual operating costs Z or annual comparative operating costs Z0 to 1 million kCal (1160 kW) produced in one year can be divided into the following three main groups:
1. Energy costs Z01, which includes electricity and cooling water costs.
2. Maintenance and repair costs Z02, which includes maintenance and repair personnel costs, operating materials, and cooling equipment breakdown elimination costs;
3. Equipment costs and capital costs Z03, which includes cooling equipment costs, cooling agent and oil costs, production room construction, installation and transportation costs.

Total relative costs decrease from small chillers to large chillers. As the productivity of machines increases, energy costs Z01 increase from 20 to 70%, equipment costs Z03 decrease from 50-55 to 15-20%. Maintenance and repair costs will decrease from 30% Z02 to 8-10%.

The cost structure is as follows:
Provision of repair personnel - 20-25%;
For spare parts and auxiliary materials – 10-20%;
To eliminate failures of the cooling device - 3-7%;
40-60% to provide service personnel;
Optimizing the optional accuracy rate will reduce maintenance and service costs. For example, if we increase the indicator "Resource before capital repair" by 25%, the total costs can be reduced by 10-12%.
During the operation of the refrigerator, various malfunctions can occur, and their elimination can have various costs. In this case, the average cost of eliminating the outage is accepted**.**O'rtachaunumdorlikdagikompressorlaruchun "Ta'mirlararoresurs" va "Texnikxizmatko'rsatilgungaqadarishlashvaqti" ko'rsatkichlarinioshirishmaqsadgamuvofiqbo'ladi. Chunkibuholdaasosiyharajat-ta'mirpersonalinita'minlashharajatlarisezilarlikamayadi.

In large-piston, centrifugal and screw compressors, it is desirable to increase the "Resource before overhaul" indicator. In this case, the costs of replacing expensive and large parts during major repairs will be reduced.
Increasing the "Time to Failure" of low-maintenance compressors will increase their accuracy, as the failure of such machines can lead to large costs.

10.2. Methods of increasing reliability indicators.
The cleanliness of machines is increased by the following constructive and technological methods:
1. the initial stresses, loads, speeds of the frictional joints of the main parts are optimized;
2. the friction properties of the materials in the friction pair should be low;
3. the optimal working mode of the friction pair is ensured due to improved lubrication;
4. oils with improved working properties are used, where great importance is attached to their film-forming properties;
5. high-quality materials are used;
6. the number of elements working under cyclic load in the compressor is reduced;
7. the vibroactivity of the machine is reduced;
8. the obkatka mode is perfected so that the details of the movement mechanism of the compressor can be clarified more quickly;
9. repairability is increased;
10. methods of technical diagnostics without opening the car are developed and used;
11. the level of cleanliness and dryness of internal working surfaces of compressors and heat exchangers is increased;
12. the accuracy of the geometric shapes of the details in the friction pair is ensured;
13. modern methods of strengthening the surfaces of the parts in the friction pair are used;
14. corrosion resistance of heat exchange devices is increased.

10.3. Methods of ensuring the necessary care in operation

The necessary accuracy in operation is ensured by the following methods:
1. technical maintenance and repair systems that reduce rational operational costs are used;
2. technical maintenance and repair works are carried out according to the planned-warning repair schedule;
3. it is not allowed to use cooling devices, cooling agents and oil in a mode not specified in the technical documents;

4. restoration of small compressors and aggregates will be carried out in centralized repair enterprises;
5. Centralized repair of crankshafts and connecting rods of medium and large reciprocating compressors, parts that are difficult to restore at the site of operation;
6. modern methods of restoration of the main parts with worn friction surfaces are used;
7. replacement parts are replaced with factory-made ones;
8. all cleaning works are carried out on time;
9. used oil regeneration devices are used;
10. cooling devices are updated on time;
the qualification of repair and service personnel is constantly improved, work modes are automated.

Control questions

1. List the methods of ensuring the necessary care in operation.
2. Explain the work carried out according to the schedule of repair work - warning repair schedule.
3. The sequence of repair of parts that are difficult to restore at the place of operation.

**Lecture #11.**
**Topic: Laws of distribution of violations**

**Plan:**
**11.1. Random sizes**
**11.2. Distribution of random variables**
**11.3. Distribution characteristics of random variables**
**11.4. Distribution laws. The law of normal distribution**
**11.5. Weibull-Gnedenko distribution law**
**11.6. The law of logarithmic normal distribution**
**11.7. The law of exponential distribution**

**11.1. Random quantities**

The processes occurring in nature and technology can be divided into two large groups:

1. Processes determined by functional connection;
2. Random or probabilistic processes.

Processes determined by functional connection

If two values (X and Y) are related to each other by a certain expression such that for each value of X there is exactly one value of Y, then the value of Y is a function of the value of X , that is, X is called an independent independent variable value or argument. Example: dependence of fuel consumption on the distance traveled (x).

Probabilistic processes arise under the influence of many variables, and their quantities are often unknown. Therefore, the results of probabilistic processes have different numerical values and are called random variables. For example, the amount of travel per failure, the initial and assembly quality of the part, the accuracy of the treatment given to it, the skills of the workers, the maintenance, the quality of the current maintenance and operational materials, the operation conditions etc. are random variables and depend on many factors. Among the random variables, the volume of work to eliminate a malfunction, the consumption of materials, the amount of technical condition parameters at certain times, etc. also includes

In order to carry out high-quality operation of machines and equipment, it is necessary to know the following laws of changes in their technical condition: the change in the technical condition of the vehicle unit and its parts according to the route; the extent of deterioration of technical condition parameters; the number of breakdowns of vehicles during the entire service life, etc.

When solving engineering tasks, for example, determining the demand for replacement of vehicle parts, units and assemblies, or planning the production of spare parts, it is necessary to know the average lifetime (resource) of items and how certain resources are grouped around this average amount. Therefore, it is important to know the distribution laws of random variables.

where: p – percentage of relative violations;

m is the number of violations in the interval;

The laws of the distribution of random variables depend on the reasons for the occurrence of disturbances.

Most research studies show that wear and tear disorders follow a normal (Gaussian) distribution. Defects caused by erosive forces (fracture, puncture, burn, break) according to the exponential distribution law, defects caused by wear according to the Weibull-Gnedenko distribution law, and defects caused by the combined effect of corrosion and wear are logarithmic. -distributed according to the normal distribution

law. Each law of distribution has specific characteristics, so their application allows to predict the breakdown of elements and to develop the necessary measures.
e) The probability density of a random variable (failure) f(L) is a function that represents the probability of failure when an aggregate or detail works without replacement during a small unit of time.

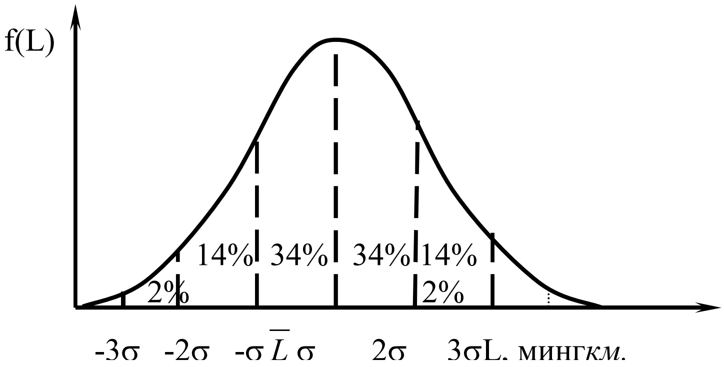
Therefore, 4 breakdowns can be expected in the interval (L1- L2) when 50 vehicles are in operation (Figure 11.1, dashed surface).

The differential distribution function - f(L) is also called the distribution law of a random number.
If the breakdown probability density f(L) is multiplied by the size of the road interval, the probability of a vehicle breakdown in this interval can be found. The probability of failure is measured by the area under the curve of the differential distribution function in Fig.

Knowing the distribution laws of random numbers allows you to carry out maintenance and current repairs on time, to determine their working volumes, and to calculate the amount of necessary spare parts.
11.4. Distribution laws. The law of normal distribution
This law appears when the process under investigation and its result are affected by many factors that are not related or weakly related to each other. The effect of each factor taken separately is very small compared to the sum of the effects of the remaining factors. The law of normal distribution is one of the main distribution laws of mathematical statistics. Its distribution density is determined by the following expression:

$$f(L) = \frac{1}{\sigma\sqrt{2\pi}} \times \exp(-\frac{(L-\bar{L})^2}{2\sigma^2}), \qquad (11.14)$$

The distribution density graph of the normal law has a symmetrical shape (Fig. 11.1).




f(L)

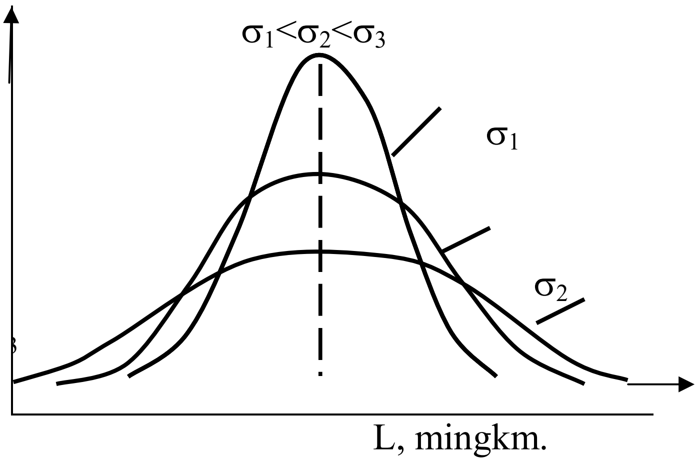
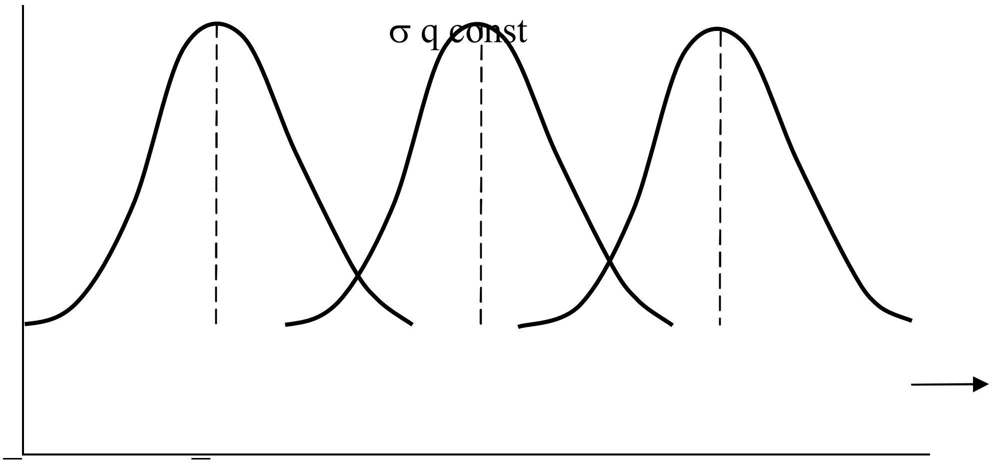



Figure 11.2. The mean square deviation of the density of a random number distribution change depending on the value

If the value of the average arithmetic quantity changes without changing the value of the mean square deviation □, then the graph of the distribution density shifts without changing its shape along the abscissa axis (Fig. 11.3).

Thus, the mean squared deviation represents the appearance of the graph, and the arithmetic mean represents its position.f(L)




$\overline{L}_1$ $\overline{L}_2$ $\overline{L}_3$ L, ming km.

Figure 11.3. Shift of the distribution density function depending on the change in the arithmetic mean

Some indicators of reliability characteristics are determined according to the law of normal distribution as follows:

Probability of unbroken operation:
$$R(L)=\frac{1}{\sigma\sqrt{2\pi}}\int_{L}^{\infty}\exp\left(-\frac{(L-\overline{L})^2}{2\sigma^2}\right)dl$$
, (11.15)

$$F(L)=\frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{L}\exp\left(-\frac{(L-\overline{L})^2}{2\sigma^2}\right)dl, \qquad (11.16)$$

:

$$L_{\gamma\%} = \overline{L} - U_p \sigma, \qquad (11.17)$$

Control questions

1. Methods of determining random variables?
2. Distribution of random variables?
3. Explain the characteristics of the distribution of random variables?
4. Distribution laws. Explain the law of normal distribution?
5. Explain the Weibull-Gnedenko distribution law?
6. Explain the law of logarithmic normal distribution?
7. Explain the law of exponential distribution?
8. Explain the formula for the probability of failure?

## Lecture #12.
## Topic: Theoretical foundations of repair technology of technological machines and equipment

**Plan:**

**12.1. The theoretical basis of the repair technology of technological machines and equipment**
**12.2. Classification of repair methods**
**12.3. Content of the project and its development procedure**

12.1. The theoretical basis of the repair technology of technological machines and equipment

During repair works, the car is partially or completely disassembled. Car disassembly begins with the removal of casings, covers, and enclosures, spending little time. Then the transmission mechanism and chains, as well as the sprocket drive mechanism, are removed. Units and parts removed from the car are placed on racks and in special boxes designed for cars of any brand.

Do not confuse assembled parts, otherwise it will be difficult to assemble them, the correct arrangement of details will be broken.

After washing, complex aggregates and assembled parts are sent to a technical replacement point or a repair enterprise, and less complex ones are partially or completely disassembled into details and components, depending on their technical condition and repairability.

After washing and cleaning, the parts are sorted into usable and unusable, that is, they are checked for defects and divided into three groups:

1. Usable
2. Invalid
3. It is repaired and sorted into details.

Identifying the defects of parts and dividing them into usable and unusable ones has a great impact on the production efficiency, as well as the quality and accuracy of the repaired machines. Therefore, these works must be carried out strictly following the technical conditions.

Defects in details are determined by examining them, as well as using special tools, devices and equipment. Details that can be used later are marked in green, unusable in red, and details that require restoration are marked in yellow. The results of sorting parts into valid and invalid are recorded in the list of defects or calculated using special calculating devices. This data allows to determine or correct the coefficients of serviceability, interchangeability and recovery of details after processing them in statistical methods.

After the workable parts are sorted, they are sent to the assembly (assembly) section of the enterprise, then to the assembly of machine units, and the unusable ones are sent to the waste warehouse. Repaired parts are sent to the parts warehouse awaiting repair and to the appropriate restoration sites.

The technical conditions for separating and sorting parts into valid and unusable are in the form of a card (paper), which contains the following information about each detail: general information about the detail; list of defects in detail; troubleshooting methods; allowable dimensions without repair and recommended methods of eliminating defects.

In order to save time, the separation of details into valid and invalid is carried out in the following order. By examining the details from the outside, large cracks, punctures, cracks, broken, scratched, scratched, and rusty areas are identified. Defects in the mutual location of the work surfaces of the details and in the physical and mechanical properties of the details are detected using special devices. After detecting invisible defects (invisible cracks and internal defects), the dimensions and geometric shape of the working surfaces of the details are checked.

Assembly of details is considered one of the most important processes in the technology of car repair. Assembling is the selection and assembly of the appropriate details necessary to assemble the items. The following operations are performed during assembly of details: collection of details, assembly parts and components,recording and storage, selective collection of details by name and number, selection of details by size, weight and mutual balance. After solving the first two issues, it will be possible to continuously provide the car assembly sites with the necessary parts, and therefore the process of repairing parts will go smoothly.

When assembling details, choosing them by size is an important task. In the repair of machines, they use three groups of details: new, repaired and serviceable details. All of these parts have different sizes, so it's a difficult task to get the right size of the parts and ensure that the parts are assembled correctly.

Control and selection of details in order to facilitate accurate and quick assembly of details in accordance with technical conditions is called assembly. It is known that in the repair of cars, parts of different technical conditions (used, but usable later, restored, new) are used.

Details according to line marks: depending on the list of details used at the assembly point; by size groups and repair dimensions (to ensure the necessary clearance and tension in joints), by weight (to ensure the balance of mechanisms); the rest is selected according to the duration of work (to ensure the equal strength of the assembled parts). All these works are carried out in the assembly department.

Some details of the engines are selected only by their weight. Such details include connecting rods and pistons. The difference in the weight of parts with the same name installed on one engine should not exceed the standard specified in the technical specifications.

Assembling parts is considered preparation for assembling units and some parts of machines. High-quality and timely assembly of parts for machine parts and workplaces ensures high-quality assembly work, high productivity of assemblers, and quick completion of the production cycle.

Repair enterprises use new and repairable size parts. Therefore, the control and selection of details is a very important task.

The main requirement for assembly is to ensure accurate assembly of parts, and the size chain of compounds must meet technical requirements. These requirements can be met in the following ways:

1) full reciprocity method. In this method, the sizes of all the details should be within the tolerance limits. It is appropriate to use this method in the process of continuous production and when the size chains are short (consisting of 2-3 details);

2) method of partial (partial) reciprocity. This method is used when the tolerance limit of dimensions is extended.

3) adjustment method. An auxiliary link is used to assemble the parts. With the help of this link, the necessary deviation is ensured. Bushings, washers, gaskets, etc. are used as auxiliary links.collecting cars. The process of assembling machines is an important task and it takes a lot of time to repair machines, especially the assembly of threaded, platen, ball bearing and rotating assemblies. The joint consists of a bolt, a nut, and a splint.

Threaded joints must be assembled with a certain force. A special tool - dynamometric (force meter) wrenches are used to determine the tightening force of threaded joints.

The parts sent for assembly differ in terms of dimensions, tolerances and the width of the tolerance limit of the dimensions. Parts are assembled according to series designations: size groups and repair dimensions, the purpose of which is to ensure that the joints are assembled with the necessary clearance or tension. It is necessary to assemble the details in such a way as to meet the technical conditions of the notch in the joints. The parts are assembled according to the size and weight of the repair:

1) assembly of details by size. For example, size 1 elbows and size 1 bushings must be assembled together (these are nominal size, size 1, 2, 3 and 4 ladi). In addition, some parts are manufactured with wide tolerances, so they are sorted by size groups.

2) the mechanism of assembly of parts (parts in the connecting rod-piston group) by weight is very important in ensuring its operation in a balanced state. All car engines have rotating parts. Therefore, they vibrate and vibrate. If the components are not balanced in terms of weight, they cause vibrations and vibrations.

3) completion according to the remaining working period;

4) assembly of parts or machines according to the list of details specified for assembly workplaces. These works are performed in a special assembly section. This section is equipped with special equipment for placing details: racks, pallets, mobile carts, assembly boxes and containers.

Assembly is the final work. During assembly, it is necessary to perform the work specified in the technology of assembly of machines in order and strictly observe the general rules for assembly work. First, the parts are paired, then they are combined in a certain order, the assembled parts are created, adjusted, and finally, the car is assembled from the assembled parts and details.

Assembling means combining details in pairs and individual parts, combining parts and details to create units (large parts that can work independently), units, parts and details, their technical specifications and kinematic schemes shown in the assembly drawings, placing It is understood to combine the chains of type and size according to their value to produce a machine.

The car is assembled from three groups of parts: worn but still usable, repaired and new parts. Since the machine is assembled from different groups of parts, it is necessary to carry out additional adjustment and control work on them.

The repair of the car is completed by assembling it. The quality, thoroughness and durability of a repaired car depends on the quality of its assembly. The technological process of assembly consists of combining details into parts. aggregates are assembled from parts and separate details, and machines are assembled from aggregates and parts.

Assembling accuracy can be ensured using the following methods: full interchangeability, partial interchangeability, group interchangeability, alignment, matching.

Full interchangeability method - in this method, the required accuracy in the assembly of the part, that is, the required accuracy of the connecting link of the size chain in all items, without selecting the links that make up this size chain or changing their sizes. provided by input without modification. The advantages of this method are the simplicity of the assembly and assembly process.
It is appropriate to use the full interchangeability method when assembling parts made up of a small number of details. When the number of parts is large, it is necessary to machine the details very accurately (minimizing the tolerance), which is not always possible and it is economically feasible.

Partial Interchangeability method - in this method, during assembly, not all parts, but parts of the parts are assembled without selection or resizing. In this method of assembly, some parts do not meet the specified accuracy and have to be divided and assembled again. In such cases, additional costs will be incurred in connection with the inspection and disassembly of all parts. The cost of processing details with a narrow tolerance of their dimensions is much lower, and it ensures the assembly of items (parts) with the required accuracy.
In this way, the af of collection
3. The third group of details includes the main (40-45%) part. They can be reused only after repair. This group includes more expensive and complex ground parts, such as the cylinder block, crankshaft, gearbox housing, rear axle, distribution shaft. The cost of restoring these details does not exceed 10-50% of the cost of their preparation.
The efficiency and quality of detail recovery depends on the chosen method. The following methods of detail recovery are widely used:
mechanical processing,
welding and thin coating,
spray coating,
galvanic and chemical treatment,
pressure treatment,
use of synthetic materials.
In the technological process of repairing machines and equipment, their details are cleaned, sorted into usable and unusable, and general repair work such as diagnosis is performed, as well as in some cases appropriate tests are carried out.
Technological impact works related to changing the geometric shape of the detail or the internal state of the object are included in the restoration works. For this purpose, the following technological processes are carried out: plastic deformation to redistribute the material in order to fill and cover the eaten surface of the detail, to restore the flexible deformed areas during operation or to restore the dimensions of the eaten areas, to

replace a part of the detail and to install additional elements , to treat the surfaces of details in some way, to remove a part of the metal.

Galvanic coating is based on the separation of metals from the solution of metal salts under the influence of electric current. When the detail is connected to the cathode of the negative pole of the current source, metal sits on its eaten surface. An anode connected to the positive pole of the current source serves as the second electrode. Both electrodes are placed in a solution of dissociable metal salts.
Galvanic and chemical coatings are applied to fill the corroded area of the part, and they are also used as rust prevention or topcoat. Chrome plating, plating, nickel plating, zinc plating and copper plating are widely used as galvanic coating methods, and oxidation and phosphating are widely used.

The process of depositing chromium on corroded surfaces is used to restore corroded details of up to 0.25-0.3 μm, as well as to protect against rusting. Shafts, working surfaces of axles, rolling bearing surfaces and other details are restored by chrome plating. Chrome plating is bluish-white in color. The hardness of the chromium applied to the parts is NV 800-1000, and the resistance to corrosion and corrosion is high. The service life of parts restored with chrome increases 4-10 times depending on the working conditions. Chrome plating can be applied to raw and hardened steels.

During mechanical processing, the thickness of the layer obtained from each side should not exceed 0.25 mm. The non-chroming parts of the part are covered with soap varnish, celluloid, tape, etc., and the holes are closed with lead plugs. The part prepared for chrome plating is mounted on suspensions and is electrolytically degreased on the wheel. The composition of the electrolyte consists of 50 g of caustic sodium, 1 l of water; degreasing composition: current density 5 A□dm2, electrolyte temperature 15-20°C, holding time in electrolyte 1-2 min. The quality of degreasing depends on the surface finish. The oxide film prevents the chrome from adhering firmly to the main part. The oxide film is removed in a 5% solution of $N_2O_4$ or in an electrolyte containing 100 g of chromic anhydride, 2-3 g of sulfuric acid, and 1 l of water.
An electric welding arc consists of a stable electric discharge formed when a strong current passes between solid or liquid electrodes in a gaseous environment. When such a discharge occurs, a lot of heat is released. The arc temperature depends on the current strength per unit area of the electrode cross-section. This quantity is called current density. The higher the current density, the higher the arc temperature. In manual electric arc welding using a soluble electrode, the current density is 10-20 A|mm2, the voltage is 18-20 V.

Welding wire and electrodes are used to fill the weld. For this purpose, a metal spike or wire is inserted into the arc zone. in manual electric arc welding, a plastered metal spike or rod is used as a liquid electrode.
Welding electrodes are marked with the letter "E" and numbers indicating the breaking strength of the welded joint. For example, the symbol E42 indicates that the tensile strength of the weld is 4.2 Mpa. Each category of electrode usually includes several brands of electrodes. For example, the E42 category includes OZS-1 and OM OMM-5 brand electrodes, the E42A category includes the SM-8 electrode, and so on.

Welding and coating of steel details. manual electric arc welding is widely used for repairing cracks and cracks in structures and body parts, joining broken parts of parts, and covering the spread surfaces of parts with metal dilution. The quality of welding and thin coating of steel parts depends on the chemical composition of the metal, its content and the amount of alloying compounds, the welding method and the brand of the electrode, and the quality of the surface treatment of the metal in preparation for thin coating.
Before liquid coating, the corroded surfaces of parts are cleaned with sandblasting devices or a metal brush, they are heated to 250-300°C, they are cleaned of oil product residues, the old liquid coating layer and spread grooves are removed.

Welding and coating of cast iron details. Due to the chemical composition and specific physical and chemical properties of cast iron, cast iron details are welded with great difficulty. Rapid cooling of metal causes it to harden, crack, and increase internal stress. In order to avoid this situation, various technological methods of welding and special electrodes are used. Cracked and broken cast iron parts are welded hot and cold.
Gas welding is used for hot welding. In this case, large cast-iron parts are heated to 600-650°C, small parts to 150-200°C, and after welding, they are slowly cooled. Joints in cast iron parts are prepared for welding like steel parts**.**
Cold welding. Cast iron parts are not preheated for cold welding. In this method, it is necessary to use electrodes and coating materials that do not allow the graying of cast iron, hardening of the weld seam, and the appearance of internal stresses. It is recommended to use a constant current with a reverse polarity and electrodes with a small (3-4 mm) diameter during cold electric welding of cast iron.
Machine repair methods are a set of technological and organizational rules for performing repair operations. In the experience of repairing machines, the following methods are used: without owner, owner and potok, aggregate and node methods. Many factors lead to the use of one or another method of machines. For this reason, the methods of repair of objects accepted at the project enterprise are selected according to the nature and size of the production program, the number of workers employed in the

main production process and in the sample production. The following factors should be taken into account.

## 12.2. Classification of repair methods

Year-round, seasonal according to the periodicity of maintenance.

According to the nature of the enterprise's provision of spare parts

According to the degree of ownership of the constructive elements of the objects to be repaired

According to the location of the objects to be repaired

The objects covered by the repair are based on their size

According to the classification of the production process, it is ready

enterprises. In this case, the restored component parts do not belong to a specific copy of the product, that is, the machine is divided into units and details, and the components and units other than restored and new parts are assembled without an owner.

In the proprietary repair method, on the contrary, the identity of the restored constituent parts to a specific copy of the item is preserved. The advantages of this method are that the joints that do not exceed the permissible dimensions are preserved, and the details are replaced only in the joints that exceed the permissible dimensions. As a result, the assembly, nodes and the whole machine in general will not be possessed. If you need to repair the uninterrupted operation of the machine during seasonal work and on a small work piece, such a repair method will be a cost-effective method.

But in practice, the owner-less repair method is often used, and it is economically justified only in cases where the machine is disassembled and assembled in a workshop.

Repair works by the Potok method are carried out in a certain technological sequence at specialized workplaces. Units, units and machines are repaired and assembled on assembly lines. Jobs are located along these lines. The object is assembled from ready-made, tested and tested aggregates and nodes. Lines for repair, assembly and testing of separate units, general assembly line of goods (machines, aggregates) in technological sequenceThe pipeline method is used when there are a lot of requests for service in a certain sequence and at the same time using specialized workstations for the same type of machines. Typically, this method is used to service trucks and passenger cars, complex machines such as powerful K-701 and T-150K tractors, which have the ability to move from farms to maintenance stations in a short period of time for scheduled service. is used more in showing.

Centralized service delivery is characterized by the provision of technical service through the employees and means of one department of the organization or enterprise.

Decentralized service is the service of machines with the personnel and equipment of several departments.

There are three main strategies for machine maintenance and repair:
1) upon request after stopping:
2) fixed depending on the amount of work performed (calendar time);
3) according to the status according to periodic control.
To evaluate the quality of technical service and repair, as well as the use of the car before and after repair, indicators are used:
1. The resource recovered during the overhaul of the machine and its constituent parts.
2. The readiness coefficient of the machine.
3. Technical utilization coefficient.
4. The level of maintenance and repair costs per unit of the volume of work performed in a shift and year, fuel consumption, and the volume of work performed in the post-repair period.
Repair and service units and enterprises are divided into three levels according to the territorial character and the nature of the work performed:
1. Production of repair service units and agricultural enterprises and their divisions, cooperative farms.
2. Production of repair and service units and service enterprises whose field of activity covers the administrative district.
3. Specialized repair enterprises and factories whose field of activity covers the region, the country and the republic.

Technical service or repair quality means a set of properties that describe the technical service or repair process and its results in accordance with the established requirements. The most important result of the high-quality work of repair and service enterprises is to ensure the given level of technical preparation of the equipment at a very low relative cost for its maintenance and repair.
For quantitative description, the following indicators can be used as appropriate goal achievement measures:
1) level of preparation of the park for the given period (beginning of seasonal work). This level is determined by the ratio of finished cars to the entire car park and is specified in percentages; coefficient of technical preparation or coefficient of technical use of machines;
1) the comparative cost of monetary means for the unit of work in technical service and repair (motor-hour, conditional reference hectare, kilometer, harvested crops, kilogram, etc.).
For repair factories and workshops, the following can serve as quality indicators:
1) average inter-repair resource (volume of work performed) and volumes of work performed in the units of the volume of work performed by brands of machines or in the period before repair;

2) the average duration of equipment repair (by type of machines and types of repair);
3) the repaired machines received by the user without reprimand (or the average evaluation of the quality in terms of points based on the results of acceptance; it is determined taking into account the amount and importance of the defects);
4) the size of the warranty period (volume of work to be performed) and machines that have not passed the warranty.
The following can serve as an indicator for evaluating the quality of work performed at technical service stations and points:
1) the average duration of maintenance and repair of equipment (by type of machines and types of maintenance);
2) machines received by the user free of maintenance and current repair (in percentage or points);
3) the average amount of equipment downtime during operation (in terms of one machine or a unit of mechanized work volume), the average labor cost (price) or technical maintenance to eliminate the consequences of downtime, or the current period of downtime due to elimination of downtime due to poor repair.
In a comprehensive approach to the problem of improving the quality of repair, the following should be included among the main factors affecting the quality indicators of repaired machines: repair fund, technological equipment, equipment, tools, measuring and control tools, condition of testing equipment ; quality of spare parts, components and materials; personnel qualifications; organization of technological processes of cleaning, disassembly, sorting (defecting), restoration of details, assembly, assembly, testing, testing and painting.
Among the conditions that help to show the factors that increase the quality of repair of machines are the following: material and psychological incentives of workers for the quality of work, correlation between the cost of repair and the quality of repaired items, economic organization of accounting, scientific organization of work, level of social development of the collective, residential and household conditions, entertainment, organization of rest, etc.One of the most important and complex issues of repair quality management is that it is necessary to combine the factors and conditions of production activities in the development of quality improvement measures.
Actions that increase the quality of repair are understood as effects or a set of effects that change a factor or condition. As a result of their use, the indicators of product quality change. Measures can be divided into three types according to their nature. The first type includes measures that affect only factors of product quality improvement, the second - measures that affect only conditions, and the third - measures that affect factors and conditions in one way.
The following preliminary materials are prepared for the design of the enterprise.

Feasibility study of the assignment for design; production program; type, brand, dimensions and mass of the object, the cost of the object new and after repair and new or reconstructed.
Design assignments should be relevant to existing students and guidelines, and baseline data should be appropriate to existing students and guidelines. The initial data for the design of enterprises of different levels will be different. For example, for enterprises at the intra-farm level: the brand and quantity of equipment to be serviced and repaired, the planned annual volume of work of cars and the average distance traveled by cars in a year in the farm seasonality of performed repair and maintenance works and the volume of works given to foreign enterprises; the composition and description of the auxiliary objects intended for production and repair-service works operating in the farm; It should be taken into account that production sites can be combined with the same type of technological processes in existing and planned objects. The above should be reflected in the design assignments of central repair workshops and technical service points. The decision of the dependent organization is not required for the design of such small objects.
In large enterprises, the number and date of the decision of higher organizations, construction district or place, product description and production capacity of the enterprise, sources of maintenance funds, sources of water, fuel, gas and electricity supply , periods of demolition or reconstruction, as well as queues for launching the company's shops, prospects for its expansion, the estimated amount of capital funds, the cost of a product unit, and indicators of labor productivity that should be achieved in the design are shown.
12.3. Content of the project and its development procedure.
The project covers the entire complex of issues related to the new construction or reconstruction of the enterprise and consists of the following parts: technological, plumbing, energy, construction and economic. All parts are interconnected, and the technological part is the leading part.
The working drawings of the technological part of the project also include the plans of the production buildings where the equipment is placed. In them, construction structures should be connected with all types of equipment and communications, sanitary-technical, energy and other devices.
The technological work project is developed in cases where it is not required to carry out preliminary design and research work to solve the issue of choosing a route for the construction site or line facilities, choosing sources and supply methods, as well as choosing the main technical solutions. The resolution of these issues is determined in advance by local construction conditions, experience in the design of similar objects, and the availability of suitable exemplary or individual projects that are recommended for repeated use.

To carry out such an improvement project, it is necessary to have the following:
proposal of the head of the repair enterprise on the improvement project (purpose of improvement)
bulletins showing the consumption level (physical and spiritual) of technological and lifting-carrying equipment, its availability, power and balance of electrical equipment.
The following should also be taken into account:
1) drawing up a plan of the site where the equipment is placed. In this case, the plot to be reconstructed must have an area that can be expanded (if it is necessary during the design);
2) the time norms in force at the enterprise for the product unit by types of work (units, disassembling and assembling cars, repairing cabins, covering details by liquefying metals, etc.) and exceeding the norms of the volume of work to be performed do with 'i;
3) operation procedure of the site;
4) consumption of materials;
5) description of the industrial building (type of columns, closed view; name of the floor, project of curtain walls, etc.);
6) consumption of water, steam and compressed air;
7) classification and status of the ventilation project;
8) the number of workers specified in the list;
9) plan and report calculation of product cost.
All this information is obtained as a result of the inspection of the object to be rebuilt and is used in the calculations of the project.

Control questions

1. Give an understanding of the repair technology of technological machines and equipment?
2. Classification of repair methods?
3. What is the content of the project and the procedure for its development?
4. How is a design assignment made in large enterprises?
5 Problems of improving the quality of repair?

**MINISTRY OF HIGHER AND SECONDARY SPECIAL EDUCATION OF THE REPUBLIC OF UZBEKISTAN**

**MINISTRY OF HIGHER AND SECONDARY SPECIAL EDUCATION OF THE REPUBLIC OF UZBEKISTAN**

**INSTITUTE OF ENGINEERING AND ECONOMICS**
**Faculty of "Oil and Gas".**
**"Technological machines and equipment" department**

# RELIABILITY OF TECHNOLOGICAL MACHINES AND EQUIPMENT

**from science**

## METHODICAL GUIDE FOR PERFORMING PRACTICAL EXERCISES

**(For bachelors of 5320300 "Technological machinery and equipment (oil and gas industry)" course)**

Karshi - 2022 y

This methodological instruction was considered in the minutes of the "Technological machines and equipment" department No. _____20__ of the year No. ___, of the meeting of the methodological commission of the "Oil and Gas" faculty No. _____.20__ of the year. It was approved and published in the report No. ____ of QarMII Methodical Council of _____20___.

Procedural instruction 5320300- "Technological machines and equipment" for students of the bachelor's field of education with practical training borish uchun mo‘ljallangan.


Reviewers:

Kh.B. Rakhmatov - associate professor of the department "Oil and gas processing technology" of QarMII, Ph.D.

O. Murtozayev - Head of the Ethylene Production Department of "Shortan Gas Chemical Complex" LLC.

# INTRODUCTION

The main direction of industrial development is its further mechanization, electrification and automation.

The basis of this direction is the system of technological machinery. To fulfill this task, it is necessary to improve the accuracy of machinery, provide it, provide service, and create a storage base.

Improving the accuracy of the technique is of great economic importance. The fact is that the costs of repairing, maintaining and maintaining cars are currently much higher than their initial cost. Therefore, solving the problem of reliability allows you to save a lot of money.

The main task of the science of reliability of machines is to develop measures aimed at ensuring that machines perform their assigned tasks as a result of studying the laws of failure, while spending as little as possible. Taking into account the requirements of the state standards for the training of specialists, the main concepts and rules of the theory of reliability are studied in the science, the natural and mathematical foundations of reliability, the characteristics of quantitative indicators, testing machines for reliability, methods of preliminary determination of reliability indicators and the main directions of increasing reliability are considered.

This methodological instruction is intended for practical work of students studying in the field of 5320300 "Technological machines and equipment" in the science of machine accuracy, and its main goal is to strengthen the theoretical knowledge obtained on the reliability of machines.

Before starting practical work, the student should familiarize himself with the theoretical part, learn the construction of devices and equipment and learn the procedure. Registration and submission of practical work is carried out within the hours allocated in the curriculum.

**1 -**

## Topic: Fundamentals of analytical apparatus in the theory of reliability

Usually, the quality of products, including machines, is evaluated by various indicators: accuracy, technology, economy, level of integration, convenience, compliance with patent requirements, competitiveness and other indicators. Accuracy is one of the characteristics of the machine, which determines its quality in many ways.
Issue-1. Figure 1 shows the scheme of a densely packed reactor. As can be seen from this scheme, the failure of any element stops the operation of the entire system. In this case, if we consider these elements (nodes) to be damaged independently, the probability of failure of the reactor is equal to the following**:**

$$Pc(t)=P1(t)*P2(t)*P3(t)$$

To determine the type of connection, it is necessary to count the elements of the system one by one and ask this question: if this element stops, will the whole system also stop? If the system hangs, then this element is connected in series; if the system does not hang, this connection is of a different type.
In order to better understand the serial connection of elements in the system, we turn to theoretical-multiplicative concepts. Multipliers P1, P2, P3 presented in Fig. 2 show the activity of specific elements presented in Fig. 1, i.e. if the probability of non-destruction (reliability) of the process is that the point falls on the field P1, the probability of reliability of the mixing equipment is that it falls on the point P2, the case if the reliability falls to the point P3, the state of serviceability of the entire system corresponds to the intersection of multipliers
P1, P2, P3.

Then for system reliability we can write:$Ps=P_1*P_2*P_3$

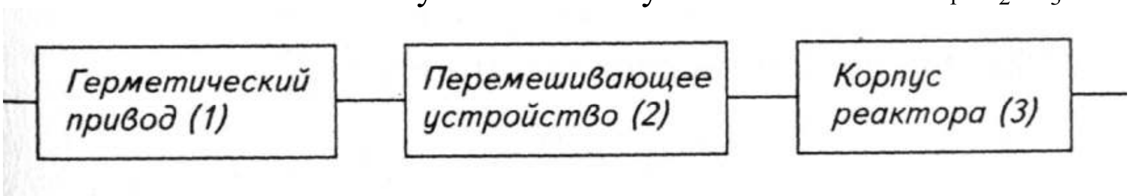



Figure 1. Scheme of a dense reactor
Reliability, serviceability, more precisely, since the reliability indicator depends on time, (8) can be written as follows:$Ps= P1*P2*Pn= I$

That is, we have expression (4).

This expression serves as a calculation that determines the index of system elements connected in series.

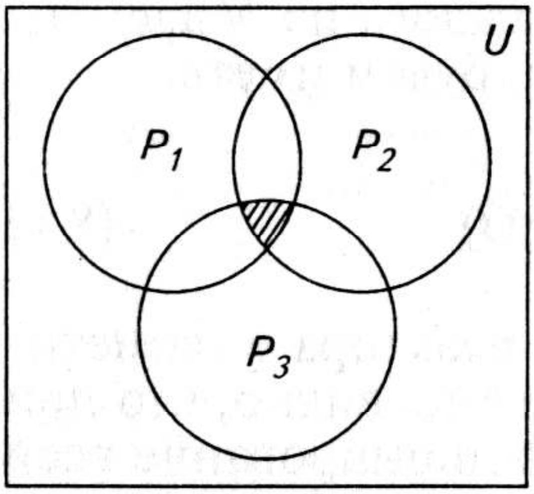



Figure 2. Theoretical-composite image of serial connection of elements in the system.

The following conclusions can be drawn from this formula:
1) System reliability of elements connected in series is always less than the reliability of the most unreliable element of the system, i.e.
Ps‹Pi min
2) The more complex the system of elements connected in series, the less reliable it is; as the system becomes more complex, its reliability decreases.
3) If all elements of the system have an exponential law of distribution of reliability when connected in series, then based on expression (9) we have the following:
Ps(t)= * = q c=q1+ q 2+…+ q n= I,
Here q1, q2,…. qn is the rate of deterioration of system elements.
In particular, if the system with elements connected in series consists of the same elements, expression (9) will have the following form:
Pc(t)=[P(t)]n
and if the exponential law of distribution also holds, i.e
P(t)=e-lt
(11) the system will have the following appearance:

Pc(t)=e-nlt=e- qct; q s=nq

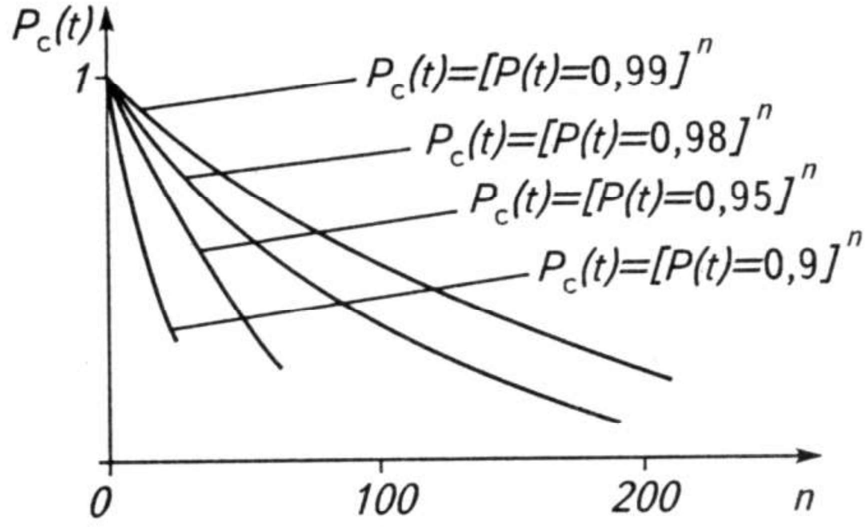


Figure 3. Variation of system reliability depending on the value and reliability of elements.

But for the exponential law

q = 1/four

then Four=four/n

here, the average time of failure of the four-system, that is, the reliability indicator of the serial connection of the system consisting of the same elements is n times less than the reliability of the element.

Figure 3 shows the graph of the change of the reliability of the system with the same element connected in series, the number of elements n, and the reliability index P(t) of the individual elements with different values. As you can see from the picture, the reliability of the system depends a lot on the value of the elements in the system.

To simplify the pumping station from the parallel connected pumps, the present time is the same reliability indicators

P1(t) = P2(t) = P3(t) = P(t)

We find reliability indicators of systems. (i.e. pumping station) we put the data in the table according to the Pc(t) formula.

n P(t)

0.9 0.99 0.999

2 0.99 0.9999 0.96

3 0.999 0.96 0.99

Note: 0.96 means 0.999999

To explain this, we do the following: the reliability of a system whose elements are connected in parallel increases the reliability of each element and the reliability of the standard. As the number of elements increases, this law can be used to create very reliable systems from less reliable elements. This principle has been used for a long time. This is called the principle of redundancy, or in other words, when n = 2, these

elements repeat each other (dublirovanie). The method is not always suitable for the purpose, but if it is, it is still widely used. In technology and in the animal world, which is in the living process of evolution. It can be seen in the reinforcement and reserve of organisms in existence. These are eyes, lungs, kidneys, ears, etc.
In the method of increasing system reliability, redundancy is generally increased as a result of exceeding the reliability limit. We evaluate the effect on the book by calculating the accuracy of the detection.

dPc(t) =n [ 1- P(t)n-1d P(t) ]

We put some data of P(t) in a table of 3 or 2 elements. It can be seen from here that the error of the calculation book Pc(t) is much smaller than the product of P(t).

Control questions.

1. What is the connection of parallel connection of systems?
2. How are elements connected in series in the system?
3. Why is it necessary to study the connections between indicators?

**2 - Practical training.**

Topic: Statistical development of information about the reliability of objects

As a result of observations, we will see the issue of using the breakdown time of the hot acid drive pump to determine the random quantities q of the digital characteristics and the appearance of the distribution law.
As a result of the observations, 100 random values of the pump breakdown time (t) were obtained and are given below:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14 | | 7 | 33 | 5 | 1 | 8 | 2 | 5 | 69 |
| 49 | 16 | 6 | 7 | 67 | 8 | 8 | 2 | 4 | 9 |
| 45 | | 5 | 9 | 24 | | 7 | 0 | 6 | 05 |
| 07 | 6 | 2 | 5 | 28 | 08 | | 25 | | 8 |
| 5 | | 07 | 9 | 06 | 7 | | 44 | 2 | 01 |
| 6 | | 25 | 8 | 46 | 3 | 09 | 5 | 0 | 8 |
| 4 | 9 | 6 | 4 | 9 | 8 | 6 | | 87 | 5 |
| 2 | 65 | 8 | 94 | 7 | 1 | | 4 | 8 | 7 |
| 7 | | 2 | 1 | 1 | | 8 | 4 | 54 | |
| | 70 | | 1 | 3 | 8 | 49 | 68 | 89 | 5 |

It is appropriate to present the experimental statistical material in the form of a statistical series in order to give it a look and brevity.
In most data, the minimum value of the series is 1 hour and the maximum value is 370 hours.
Row shaking is equal to:

tmax-tmin=370-1=369

The range of total values of the random variable t (n=100) is divided into intervals. For the convenience of calculations, it is appropriate to take them as equal. Its amount is taken from 7-15. A large number of intervals is acceptable for extensive and homogeneous statistical material.
The approximate size of the interval dt is determined by the following formula:

dt=(tmax-tmin)/1+2.31 lg n (2.1)

If the number of values of the random variable in equal intervals accepted according to formula 1.1 is less than 10, then intervals of different lengths are accepted.
we calculate for each interval and present it in the table below.Statistikqatorgaishlovberish

| № | нтервал | азмах | | $=n_i/n$ | | $t_i$ | $(n_i/n)$ | $_i/n\Delta t$ | $[(t_i-M(t)]^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 0 |
| | -10 | 0 | 5 | .15 | | .75 | .15 | .015 | 35 |
| | 0-20 | 0 | 4 | .14 | 5 | .1 | .29 | .014 | 04 |
| | 0-30 | 0 | 1 | .11 | 5 | .75 | .40 | .011 | 75 |
| | 0-50 | 0 | 5 | .15 | 0 | 0 | .55 | .0075 | 83.75 |
| | 0-80 | 0 | 4 | .14 | 5 | .1 | .69 | .0047 | 4 |
| | 0-110 | 0 | | .07 | 5 | .65 | .76 | .0023 | 8 |
| | 10-150 | 0 | | .08 | 30 | 0.4 | .84 | .0020 | 42 |
| | 50-190 | 0 | | .05 | 70 | .5 | .89 | .0013 | 51.25 |
| | 90-250 | 0 | | .06 | 20 | 3.2 | .95 | .0010 | 261.5 |
| 0 | 50-350 | 20 | | .05 | 10 | 5.5 | .0 | .0004 | 761.25 |
| | | | 00 | 0 | | I(t)=7 soat | | | (t)= 456soat |

The 1st line shows the discharge numbers of the division of the change interval;
In line 2, the boundary of each interval in which the previous interval has an end point, and the end point does not have a start point;
In the 3rd row, the digital indicator of interval shaking;
In the 4th line, the amount of values of the random variable falling into the interval, that is, the absolute frequency;
In line 5, relative frequency or empirical probability:

Pi=ni/n (2.2)

where n=100; the dropped frequency for all intervals should be equal to 1, this condition serves as a check of the correctness of the frequency calculation for each interval;
In line 6, the coordinates of ti between each interval are specified;
The 7th line contains the Peaty multiplier, which when collapsing gives the coordinates of the center of division, that is, the average statistic:

q(Piti)=M(t)=75 (hours)

In line 8, the falling frequency is q(ni/n) or F*(t);
In the 9th line, the empirical density of the probability;
Line 10 contains the product Pi(ti-M(t))2, which serves to determine the statistical variance D(t):

q(t)=qD(t)=q6456=80 (hours) (2.3)

Coefficient of change

V(t)= q (t)/M(t)=80/75=1.07 ( 2.4)

The following characteristics are often used in statistical observations: determination of the root mean square error of the arithmetic mean (mathematical expectation)

dM(t)=q(t)/qn=80/q100=8 (h) (2.5)

and root mean square error of root mean square deviation

q(t)= q(t)/q2n=80/q200=5.7 (h) (2.6)

Then we estimate the values:

M(t)=75±8 (hours)

To construct a histogram (Fig. 1.1), the intervals dti flow along the abscissa axis t (table 1.1, line 2) are constructed with a random variable ti and a rectangular surface in each interval, which is in the given interval random variable is equal to the frequency of occurrence. The heights of the rectangles are proportional to the corresponding frequencies and the empirical probability density ni/(ndt) for each interval (data in row 9 of table 1.1).
Figure 2 shows the distribution histogram of the statistical probability value laid out from the middle of each interval. Based on the properties of the histogram, it can be assumed that the observed random variable is distributed according to the exponential law. The fact that the mathematical expectation M(t)=75 hours and the root mean square flow q(t)=80 hours coincide with the random variable t gives information about it (variation coefficient Vq1).
As a mathematical waiting period, it can be written as the following, taking it as a violation estimate (statistical average) M(t)=75 hours:
f(t)= qeti or f(t)= q exp(- qti) (2.7)
Given that q=1/M(t)=const in the exponential law of distribution, then
f (t)= q exp(- t)=0.013e-0.013t (2.8)
Using the table of the e-x function (see Appendix I.3), it is possible to calculate the value of the probability density at the limit of the intervals. (Table 1.2, line 5).
The smoothing curve of the distribution representing the graph of the function f(t) without the random errors of the histogram path, preserving the exact properties of the

statistical distribution, is presented in the histogram in Fig. 2.

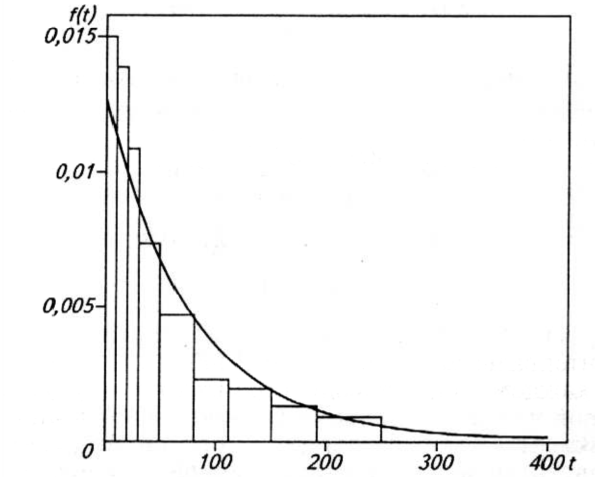



Figure 2.1. The histogram is the duration of the breakdown and the smoothing curve.

When choosing a theoretical distribution curve, one cannot ignore some differences between it and statistical distribution. It is important to know whether these differences are explained by chance alone, due to the limited number of experimental data, or whether this particular and selected curve misfits the given distribution.

This can be determined by a measure called Pearson's agreement criterion:

X2=q[ni-nP'(ti)/nP'(ti) (2.9)

Here: the number of intervals of K-statistical distribution, in our example K=10; ni-the number of values of random variables in each interval (see table, line 4); The total number of observed values of n-random variable, in our example n=100; P'(ti) is the theoretical probability of a random variable falling into the i-th interval.

The value of the probability of random variables falling into the i-th interval is presented in row 5 of Table 2. They are equal to the half-growth function of the interval distribution**.**

P'(ti‹t‹ti+1)=F(ti+1)-F(ti) (2.10)

2 Jadval. Ehtimolliklarningnazariyqiymatlari

| | | $t_i$ | 0.013ti | $(t_i)$ | $P(t_i)$ | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | 0 | .13 | .878 | .122 | 2.2 | .643 |
| | 0 | .26 | .770 | .108 | 0.8 | .948 |
| | 0 | .39 | .677 | .093 | .3 | .311 |
| | 0 | .65 | .522 | .155 | 5.5 | .016 |
| | 0 | .04 | .353 | .169 | 6.9 | .500 |
| | 10 | .43 | .239 | .114 | 1.4 | .70 |
| | 50 | .95 | .142 | .097 | .7 | .298 |
| | 90 | .47 | .085 | .037 | .7 | .457 |
| 0 | 50 | .25 | .039 | .046 | .6 | .426 |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 70 | 81 | 008 | 031 | 1 | 16 |

The distribution of X2 depends on the parameters R, which are called the number of degrees of freedom. The number of degrees of freedom is equal to the difference K of independent conditions (relationships) placed on ni/n frequencies:

R=K-S (2.11)

The exponential law of random size distribution is the number of connections S=2, for normal S=3.

There is a special table for the distribution of q2 (see appendix I.4), using it, it is possible to find the probability that the quantity X2 distributed according to the law will exceed this amount for the exact amount of the obtained amount of X2 and the degree of freedom R. At the same time, if the obtained probability is greater than 0.3-0.4, it is recognized that the data obtained from the experiment do not contradict the accepted theoretical law of the distribution of random variables.

In our example, X2=6.463 and the number of degrees of freedom is R=10-2=8. according to the table of values, we determine P=0.6 from X2=6.463 and R=8.

Along with the "chi-square" criterion, the most commonly used criteria include the Kolmogarov criterion.

As a measure of separation between theoretical and statistical distributions, Kolmogarov considers the maximum amount of the difference modulus between the statistical function F*(t) of the distribution and the theoretical function F(t) of the characteristic distribution:

D=maxqF*(t)-F(t)q (2.12)

The quantity D is determined from the graphs F*(t) and F(t). Figure 2.3 shows the statistical and theoretical (exponential) functions of the distribution.

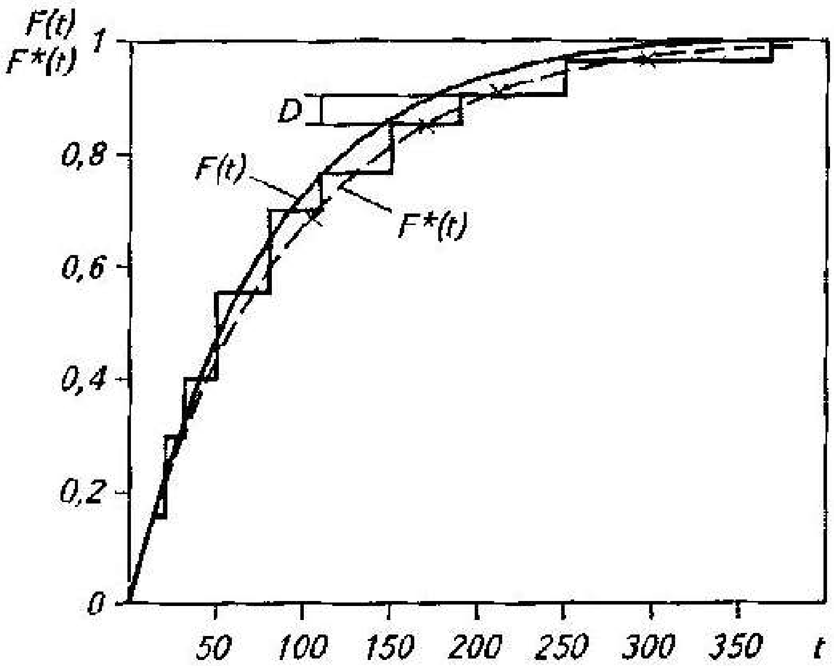



Figure 2.3. Graph of distribution of statistical F*(t) and theoretical F(t) functions.

The collapsed frequency qni/n (see Table 1.1, line 8) is used to construct the statistical integral function F*(t) of the distribution. The value used in the construction of the theoretical (exponential) function of the distribution:
F(t)=1-e-qt =1-e-0.013t
and row 4, we use the data of Table 1.2.
As can be seen from Figure 4, the maximum D=0.06
Then q*=Dqn quantity and P(q*)=0.864 from Appendix I.5
The probability P(q*) is not small, so the hypothesis about the exponential law of the distribution of the pump failure time is also confirmed by the Kolmogarov criterion.

Control questions.

1. Histogram breakdown period and smoothing curve?
2. Random errors of the histogram path?
3. Explain the statistical integral function of the distribution

**3-4 – Practical training.**

Topic: Calculation of reliability characteristics of the system in the distribution of disturbances with the exponential law.

The law of exponential distribution is complex and used in machines that work in severe conditions. The exponential distribution law is often used in sudden crashes.
Probability density (differential function) between two failures:
Here: * - speed of disturbances;

t is the maximum time of non-destruction;

e = 2.7183 is the amount of the natural logarithm.

$$(t) = e^{-\int_0^t \lambda(t)\,dt}$$

It is built from the equation - the probability of non-destructive operation decreases according to the exponential law. Therefore R(t)=exp(-*t) is said to be exponential law precision.

The extremo of disturbances is found from the following equation:

$$\lambda(t) = f(t)/P(t) = \lambda e^{-\lambda t} / e^{-\lambda t} = \lambda = consi$$

Exponential distribution according to the law *(t), P(t), F(t) and f(t) are shown in the graph.

For example: Find the accuracy of the column apparatus, if t=10 hours, T=62 hours.

Non-destructive operation time

$$(10) = 1 - e^{-10/62} = 1 - e^{-0,161} = 1 - 0,85 = 0,15$$

$$= 1/T_{CP} = 1/62 = 0,016 coam^{-1}$$

Veybullataqsimlashqonuniasosanmashinanimustaxkamliginianiqlashdaishlatiladi.

The differential function (probability density) is written:

$$(t) = a/T_{CP}(t/T_{CP})^{a-1} e^{-(t/T_{CP})^a}$$

IntegralfunksiyasiVeybullabuyicha:

$$'(t) = 1 - e^{-(t/T_{CP})^a}$$

Buzilmayishlashextimoli formula buyichayechiladi:

$$(t) = 1 - F(t) = e^{-(t/T_{CP})^a}$$

$$(t) = f(t) = P(t) = a/T_{CP}(t/T_{CP})^{a-1}$$

Natijadabuzulishlarjadalligi:

Differensialva integral funksiyaVeybulltaksimlashqonunbuyichagrafikdakursatilgan.

a=1 bulgandaVeybullaqonunieksponensialqonunigautadi, agar a=2 undaReleyaqonunigautadi.

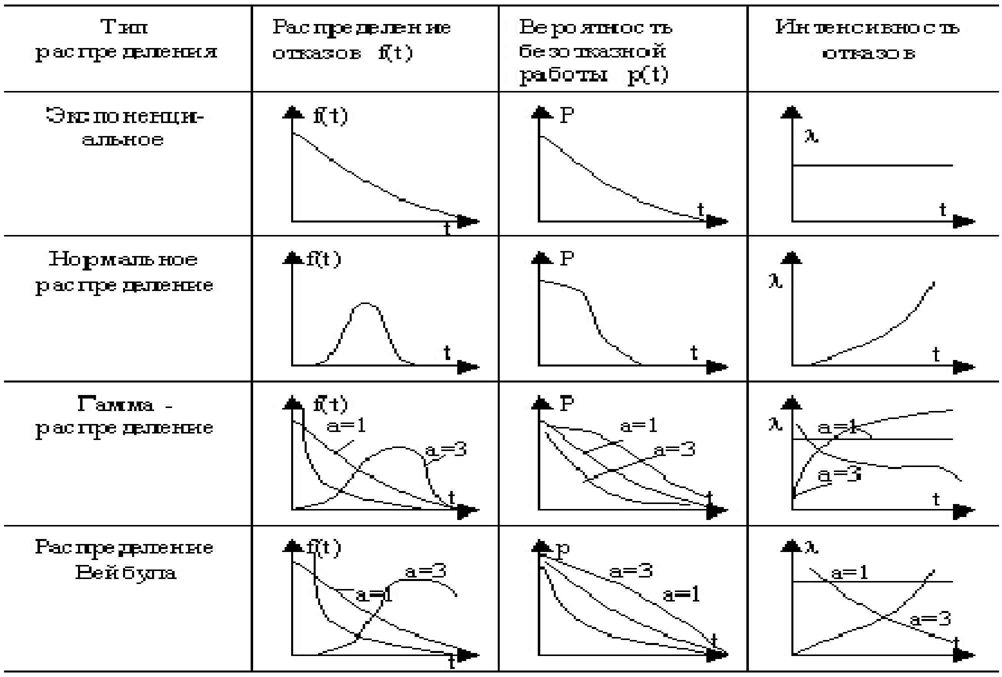



Рис. 1.6

: Ma’lum, kutilmaganmikdor – Veybullaqonunigabuysunadivaparametri $T_{SR}$=500 soat, a=3. Buzulmayishlashextimolinitopish, agar t=100 soat, vataksimlashzichligivabuzulishlarjadalligit$_{nuktada}$=100 soat.

Topamiz $t/T_{CP}$=100/500=0,5.   0,5da a=3

Yani   R(100)=0,8825.

Topamiz $t/T_{CP}$=100/500=0,5.  0,5da a=3

Unda: $T \cdot f(t)$=0,6619  shu bilan f(100)=0,6619/500=0,0013

Topamiz $t/T_{CP}$=100/500=0,5.

$T\lambda(t)$=0,7500

Yani$\lambda(100)$=0,7500/500=0,0015 soat$^{-1}$

3 - жадвал. $e^{-\lambda t}$ нинг қийматлари.

| t | $e^{-\lambda t}$ | t | $e^{-\lambda t}$ | t | $e^{-\lambda t}$ | t | $e^{-\lambda t}$ |
|---|---|---|---|---|---|---|---|
| 0,01 | 0,990 | 0,37 | 0,691 | 0,73 | 0,482 | 1,09 | 0,336 |
| 0,02 | 0,980 | 0,38 | 0,684 | 0,74 | 0,477 | 1,10 | 0,333 |
| 0,03 | 0,970 | 0,39 | 0,677 | 0,75 | 0,472 | 1,11 | 0,330 |
| 0,04 | 0,961 | 0,40 | 0,670 | 0,76 | 0,468 | 1,12 | 0,326 |
| 0,05 | 0,951 | 0,41 | 0,664 | 0,77 | 0,463 | 1,13 | 0,323 |
| 0,06 | 0,942 | 0,42 | 0,657 | 0,78 | 0,458 | 1,14 | 0,320 |
| 0,07 | 0,932 | 0,43 | 0,651 | 0,79 | 0,454 | 1,15 | 0,317 |
| 0,08 | 0,923 | 0,44 | 0,644 | 0,80 | 0,449 | 1,16 | 0,313 |
| 0,09 | 0,914 | 0,45 | 0,638 | 0,81 | 0,445 | 1,17 | 0,310 |
| 0,10 | 0,905 | 0,46 | 0,631 | 0,82 | 0,440 | 1,18 | 0,307 |
| 0,11 | 0,896 | 0,47 | 0,625 | 0,83 | 0,436 | 1,19 | 0,304 |
| 0,12 | 0,887 | 0,48 | 0,619 | 0,84 | 0,432 | 1,21 | 0,301 |
| 0,13 | 0,878 | 0,49 | 0,613 | 0,85 | 0,427 | 1,22 | 0,295 |
| 0,14 | 0,869 | 0,50 | 0,607 | 0,86 | 0,423 | 1,23 | 0,292 |
| 0,15 | 0,861 | 0,51 | 0,600 | 0,87 | 0,419 | 1,24 | 0,289 |
| 0,16 | 0,852 | 0,52 | 0,595 | 0,88 | 0,415 | 1,25 | 0,286 |
| 0,17 | 0,844 | 0,53 | 0,589 | 0,89 | 0,411 | 1,25 | 0,286 |
| 0,18 | 0,835 | 0,54 | 0,583 | 0,90 | 0,407 | 1,26 | 0,284 |
| 0,19 | 0,827 | 0,55 | 0,577 | 0,91 | 0,403 | 1,27 | 0,281 |
| 0,20 | 0,819 | 0,56 | 0,571 | 0,92 | 0,399 | 1,28 | 0,278 |
| 0,21 | 0,811 | 0,57 | 0,566 | 0,93 | 0,395 | 1,29 | 0,275 |
| 0,22 | 0,803 | 0,58 | 0,560 | 0,94 | 0,391 | 1,30 | 0,273 |
| 0,23 | 0,795 | 0,59 | 0,554 | 0,95 | 0,387 | 1,35 | 0,269 |
| 0,24 | 0,787 | 0,60 | 0,549 | 0,96 | 0,383 | 1,40 | 0,247 |
| 0,25 | 0,779 | 0,61 | 0,543 | 0,97 | 0,379 | 1,45 | 0,237 |
| 0,26 | 0,771 | 0,62 | 0,538 | 0,98 | 0,375 | 1,50 | 0,223 |
| 0,27 | 0,763 | 0,63 | 0,533 | 0,99 | 0,372 | 1,55 | 0,212 |
| 0,28 | 0,756 | 0,64 | 0,527 | 1,00 | 0,368 | 1,60 | 0,202 |
| 0,29 | 0,748 | 0,65 | 0,522 | 1,01 | 0,364 | 1,65 | 0,192 |
| 0,30 | 0,741 | 0,66 | 0,517 | 1,02 | 0,361 | 1,70 | 0,183 |
| 0,31 | 0,733 | 0,67 | 0,512 | 1,03 | 0,357 | 1,75 | 0,174 |
| 0,32 | 0,726 | 0,68 | 0,507 | 1,04 | 0,353 | 1,80 | 0,175 |
| 0,33 | 0,719 | 0,69 | 0,502 | 1,05 | 0,350 | 1,85 | 0,157 |
| 0,34 | 0,712 | 0,70 | 0,497 | 1,06 | 0,346 | 1,90 | 0,150 |
| 0,35 | 0,705 | 0,71 | 0,492 | 1,07 | 0,343 | 1,95 | 0,142 |
| 0,36 | 0,698 | 0,72 | 0,487 | 1,08 | 0,340 | 2,00 | 0,135 |

**Carrying out practical training (according to the option).**

| № | t | T |
|---|---|---|
| 1 | 12 | 68 |
| 2 | 14 | 74 |
| 3 | 8 | 56 |
| 4 | 16 | 80 |
| 5 | 18 | 82 |
| 6 | 12 | 88 |
| 7 | 15 | 75 |
| 8 | 14 | 72 |
| 9 | 16 | 74 |
| 10 | 12 | 76 |
| 11 | 10 | 68 |
| 12 | 18 | 66 |
| 13 | 12 | 64 |
| 14 | 17 | 65 |
| 15 | 16 | 78 |
| 16 | 12 | 72 |
| 17 | 14 | 74 |
| 18 | 15 | 85 |
| 19 | 13 | 83 |
| 20 | 20 | 90 |
| 21 | 21 | 92 |
| 22 | 22 | 93 |
| 23 | 18 | 88 |
| 24 | 17 | 87 |
| 25 | 19 | 90 |
| 26 | 12 | 74 |
| 27 | 18 | 82 |
| 28 | 17 | 67 |
| 29 | 23 | 72 |
| 30 | 13 | 64 |

Control questions.

1. Explain the law of exponential distribution?
2. Explain Weibull distribution law?
3. Explain the relay distribution law?
4. Explain the law of normal distribution?

**5-6 – Practical training.**

Topic: Calculation formulas using nomograms and graphs, approximate calculation methods using correcting (correcting) coefficients.
The tests are divided by the venue as follows:
1. Tests under bench conditions - provide information about the loss of machine or aggregate performance, that is, about their reliability characteristics. When developing test methods, it is necessary to take into account the compatibility of test conditions and procedures with operating conditions. Bench tests are usually continued until a failure occurs or until the item has run for a specified period of time.
2. Operational and polygon tests are used for experimental and serial samples. Experimental samples of technological machines and equipment are tested in harsh operating conditions on specially selected and artificially created fields and in various climatic conditions. Such tests have the following disadvantages:
a) the duration of the experiments is not always sufficient, similar to the actual operating conditions;
b) the test result determining the object's reliability parameters cannot provide information about at least the average value of the service life of technological machines and equipment. Therefore, accelerated tests are used, in which reliability information is obtained in a very short time.
When conducting control tests, items are individually tested for their integrity, durability, repairability, and maintainability.

5.3. Reliability test object
The object of reliability tests can be:
1. Samples - if the characteristics of products or materials that determine their durability are tested (fatigue strength, anti-erosion and corrosion properties, etc.);
2. Details (joints, kinematic pairs) - if construction and technology
if there is a need to take into account the influence of biological factors on the service life of this part (bearings, gears, guides, hinges, etc.);
3. Machine, assembly and units - if it is necessary to take into account the interaction of some mechanisms and structural elements and their influence on performance indicators (gearbox, reducers, engines, control systems, etc.);
4. Machine - testing the interaction of all aggregates, nodes and mechanisms in the machine in operating conditions and work procedures (vehicles);
5. Machine system - if the interaction of some machines that make up one production complex is evaluated through reliability indicators (automotive enterprise).

5.4. Characteristics evaluated in reliability testing
They are mainly divided into two groups:
1. Characteristics of wear (deterioration) processes and degree of deterioration of items. In the tests, the passage of corrosion processes, corrosion, shape changes, fatigue disorders, etc. are studied. These factors are the main reasons for the loss of machine performance.

2. Characteristics of changes in output parameters of the device over time (accuracy, efficiency, load capacity, etc.). Exceeding the allowed limits of these characteristics leads to violations.

The more complex the test object, the more output parameters will have to be evaluated for a large number of tests.

5.5. Testing of experimental and serial samples

When conducting reliability tests, it is necessary to divide their volume between experimental and serial production in such a way that the necessary information can be obtained as a result of it, and appropriate changes can be made to the design of the product as soon as possible. However, many issues cannot be solved in experimental production, only serial samples can give the desired results. In addition, when testing serial samples for reliability, the following should be taken into account:

a) experimental verification of whether the necessary structural changes have been made to the machine as a result of bringing the layout up to standard;

b) expansion of work procedures and other studies of items in actual operating conditions;

v) to determine the causes of damage of items during the operation of the first serial samples.

When testing prototypes, only a small number of items (maybe even a single item) are placed because these items are made in small quantities. But these tests are not enough, because the reliability indicators obtained from a small number of items and based on insufficient information do not reflect the actual condition of the items.

## 7-8- Practical training.

## Topic: Selection of normalized indicators of reliability for chemical production facilities

Basic requirements for information collection methods

a) Collection of information on reliability operational and maintenance

should be conducted by the organization that conducts information collection in enterprises;

b) Collecting information and transferring it to the collecting organization centrally,

should be done by inspection and questionnaire;

d) Initial data collection base point or operational and should be carried out by repair companies;

g) The investigation is conducted by the organization that collects the information. In this case, of the item

the technical condition is studied in operating conditions, the forms of initial information recording (operation and repair documents, accident inspections, protest documents, etc.) are analyzed, and its results are reflected in data collectors;

d) Questionnaire is a special request of the organization that collects information

implements by sending leaflets to operational and repair enterprises;

f) Selection of base enterprises should provide information for operational conditions in the brochure.

7.5. Requirements for information analysis and processing

Informationprocessingincludes:

- coding and classification of primary data;

- accuracy, completeness and uniformity of information about product reliability

ensurecompliancewithrequirements;

- ensuring that all information undergoes qualitative and quantitative analysis; Qualitative and quantitative analysis includes:

- exclusionofunclearinformation;

- checking that the information is different;

- statistical processing of information and assessment of reliability indicators;

- measures to improve reliability based on the results of reliability analysis development.

During the analysis of the causes of the breakdown and the last state, the following is

carriedout:

- signs of receiving primary data (operational conditions, systematization by duration, types of breakdowns, etc.);

- identification of details limiting the reliability of the item;

- determining the causes of the violation;

- effectiveness of construction-technological and organizational measures

assessmet;
(Appendix 1);

- a journal of maintenance and current repair of the product.

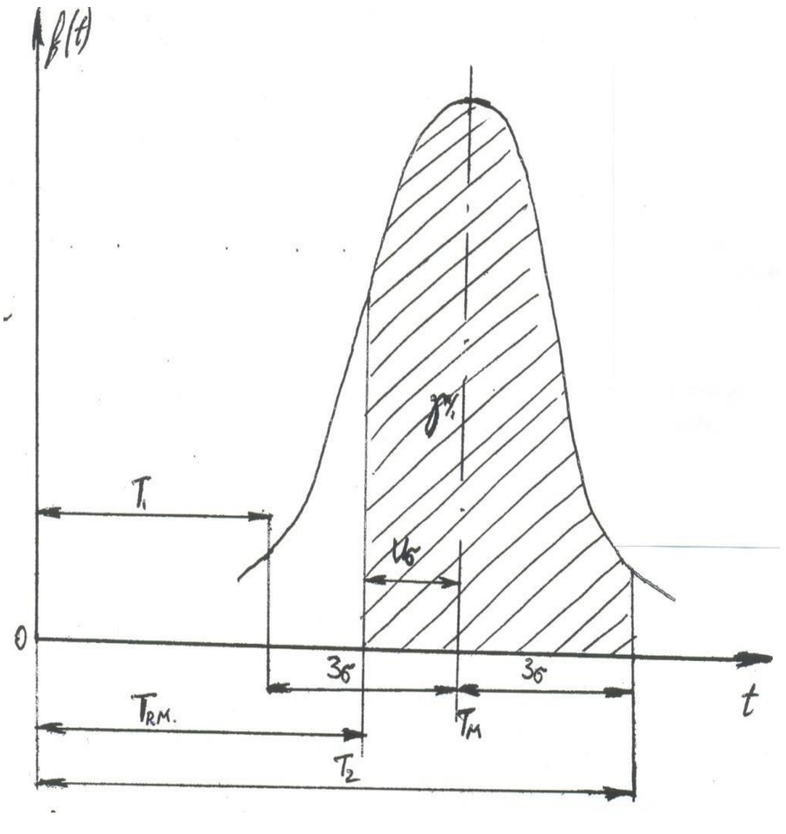
The log contains the item's passport information, company name, name of the damaged part, type and frequency of maintenance, method of eliminating the damage, maintenance and current repair costs, taking into account the value of the replaced parts. should be;

- one-time documents for the operation of goods (waybill, aggregate repair sheet (Appendix 2), information on product failure, spare part application (Appendix 3), etc.).

Collector-forms are designed to record the information entered into a system and are filled out with the help of specially trained personnel and on the basis of preliminary documents or in the process of operational observations. Basicforms:

- a map-collector of violations (information map Appendix 4)

- on maintenance and current repair of the product information mapper.



Forms for recording the results of product reliability analysis are designed to record quantity and quality results, work procedures, spare parts consumption, reasons for failures, and a list of details that limit the reliability of the product

**Control questions.**

1. How are P(t) and t related to each other?
2. What is the relationship between f(t), P(t), $\lambda(t)$?
3. Why is it necessary to study the connections between indicators?

## 9-10 – Practical training

### Topic: Determining reliability indicators according to the law of distribution.

The device is divided into 9 major compounds (1-9) to indicate the location of the failure, and other compounds (external sources) are marked with the number "0". Each large compound is divided into 9 small compounds (number 2), which in turn are divided into 9 main details (number 3).

Depending on the nature of the failures, they are divided into the following: mechanical (1-10 for details, 11-20 for connections); physical and chemical (21-40); quantitative change of components in the system (41-60); electricity (61-80); in external supply sources (81-90).

External symptoms of failure (number 6 of the code) include the stop of KM, high temperature in the object, increase in electricity consumption and power consumption, knocking, etc.

The reason for failure (7th number of the code) may be structural, technological installation. These reasons are not always detected when examining the crash (the number "0" is assigned to the code).

The percentage relationship between major, medium and minor failures, that is, the amount of work required to eliminate the failure (8th digit of the code), is characterized by repairability.

Depending on their nature, layoffs can be simple and unexpected. Normal failure can be detected and eliminated during the next inspection of the device. Unexpected failures are usually determined by emergency situations during operation.

From the point of view of the age of the machine and the statistical distribution of the frequency of breakdowns, they are divided into three types:

Start-up failures - occur during the initial period of machine operation, mainly due to insufficient inspection at the manufacturing plant. It will have a high rate in the first-second month of operation and will completely disappear in the following months.

Random failures are caused by various hidden defects, which cannot be eliminated by the existing inspection methods. These outages will have a small but constant intensity throughout the operation period.
Corrosion-induced failures usually begin to occur after several years of operation. At the end of operation, the intensity of these failures increases suddenly and quickly reaches 100%. The occurrence of such failures is different for different cooling machines: from 2-3 years to 15-20 years.

3.2. Distribution of random variables

When solving engineering tasks, for example, determining the demand for replacement of parts and units of machines and equipment, or planning the production of spare parts, it is necessary to know the average service life (resource) of items and how certain resources are grouped around this average amount. Therefore, it is important to know the distribution laws of random variables

$$p = \frac{m}{N} \qquad (3.1.)$$

where:

- p is the percentage of relative violations;
- m is the number of violations in the interval; N is the number of items under observation.

The distribution laws of random variables depend on the causes of disturbances.

3.3. Breakdowns and malfunctions

A key concept in reliability theory is distortion.
Disruption is defined as complete or partial loss of machine and equipment (aggregate, node or system) functionality. In this case, machines and equipment cannot perform their tasks at the level of the requirements of the parameters specified in the regulatory and technical documents.
Malfunction is defined as the deviation of at least one of the parameters characterizing the technical condition of the machine and equipment (aggregate, unit or system) from the permissible limits.
Classification of disorders
When analyzing the reliability of machines and equipment and aggregates, the classification of violations is always carried out. Violations are classified as follows.
During the operation of machinery and equipment, its technical condition gradually deteriorates, the rate of wear and tear, maintenance and current repair work increases, ease of management and reliability decreases, etc. k.
Attrition. During operation, the parameters of the technical condition of the machine and equipment change under the influence of the external environment. For example, rubber-technical products lose their strength and elasticity due to oxidation, hot or cold temperatures, moisture, solar radiation, and the chemical effects of oil, fuel, or liquids. Oil-oil materials are contaminated with corrosion products, the viscosity characteristics deteriorate, the strength of the additives in it is lost, etc.

## 11-Practical training

**Topic: Clarifying the level of reliability indicators**

Maintenance periodicity is the periodicity of standard operation between successive executions of the same preventive actions on the vehicle.

Methods of determining the periodicity of technical service:

- The simplest way. According to this method, the periodicity of the vehicle's fuel consumption is considered the same as the periodicity of similar vehicles.
- Analytical method. This method is based on the processes of technical operation of vehicles, the results of observation and the laws of technical condition change.
- Imitation (imitation) modeling method. This method is based on simulating real and random maintenance processes (imitation, modeling).

Analytical methods:

1) The method of determining the periodicity of technical service according to the level of permitted integrity. This method □8□ is based on choosing an optimal periodicity that corresponds to the time when the element failure probability F does not exceed the previously given amount (steady state).

Probability of fail-safe operation: $R_{р.э.}(x_i \geq l_o) \geq R_{р.э} = \gamma$, i.e

where: Rr.e is the probability of operation without admissible damage;

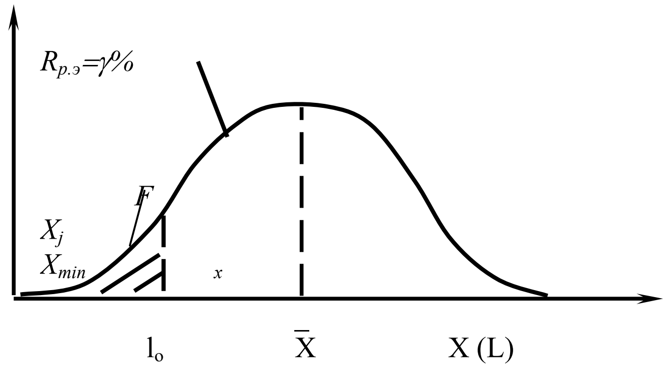
xi - i-th service life until failure;

F □ (1 – Rr.e.),

F - unstable state;

lo - periodic maintenance;

f(L




Such uneven progress is partly explained by technical and organisational difficulties in applying results management approaches. As this review shows, results systems can be difficult to implement in institutions that are not designed for learning and with weak accountability feedback mechanisms. Staff need the skill to develop a suitable number of quality indicators to track results, and, more importantly, to use results information effectively. Many international discussions on development results have become mired in 1. INTRODUCTION 16 the technical aspects of the process such as defining results terminology, appropriate indicators, or developing frameworks. They have consequently neglected the critical issues of incentives, complexity, politics and institutional change. Moreover, donor agencies operate in many different country contexts, across numerous sectors, with a wide variety of stakeholders on issues that are often difficult to measure.

They also rely to a large extent on partner governments' data and results systems, which can vary greatly. The purpose of this review is to identify the main challenges in measuring and managing for results in development co-operation, and to present examples of DAC members' experience

. Throughout the review, the term “results” refers to the DAC definition: “output, outcome or impact (intended or unintended, positive and/or negative) of a development intervention”. The main sources of information were a 2013 online survey on DAC members' results measurement and management (OECD 2013b); an extensive literature review including peer reviews and online research on grey literature; a review of corporate evaluations of results systems from major bilateral and multilateral donors; ongoing discussions on results-based management and results-based funding approaches in the development community; and two workshops organised by the Development Co-operation Directorate (DCD) on the results agenda and results-based funding. Each chapter presents challenges identified in the literature, findings from the survey on how donors perceive and face these challenges and a selection of practical examples. One of the difficulties encountered when conducting the review was that many DAC members are in the process of reforming or creating a new approach to results measurement and management. Therefore, few evaluations or in-depth analyses of the systems in place were available.

$$\beta = \frac{l_O}{L}$$

## Control questions

1. Explain the "shape index" of the Weibull-Gnedenko distribution law?
2. Tell me how to determine the periodicity of technical service?
3. Write down the formula for the exponential distribution law?
4. Tell me how to determine the periodicity of technical service?

## 12-Practical training.

**Topic: Engineer's technological analysis of object**
damageSinashdavomiyliginingxajminivabuzilganmashinalarsoninistudy methods of identification.

Test planning determines test duration, size, and number of failed machines.
Consider test size, duration, and methods for identifying failed machines for the following test plan options.
a) The number of monitoring machines "N" is /N V, N/. define for option.
b) Determining the number of interchangeable machines "R" for the option /N,V,R/.
v) Test duration "T" /N,V,T/. define for option.
1. /N,V,N/ scheduling option.
To determine the number of tracked cars, the following values must be given.
□-relative error in evaluating the checked indicator of accuracy;
□- probability of reliability in assessing the checked indicator of thoroughness;
V is the recommended coefficient of variation. (What is meant by variation? Variation means variability between events. In other words, variation means variability between units (variants) of a statistical set, i.e. differences from one another.)

V=G/X
Here, G-dispersion; The main characteristic of X-Test;
The relative error in the assessment of the checked indicator of accuracy "b" is determined according to the following decision; 0.05; 0.1; 0.15; 0.2;
The probability of reliability in assessing the tested indicator of accuracy "□" is determined from the following decision: 0.8; 0.9; 0.95; 0.99.
The minimum number of monitored machines "N" is determined by the formula below. (according to the law of normal distribution).
N=f(t)+af
Here, t-test time, hours; parameter of the distribution law of the values of the tested indicator of accuracy.
From equation (1), here, t□,N-1¬ is a standard quantile with N-1 degrees of freedom corresponding to one-sided reliability probability "□";
The values of expression (1) are tabulated, and the number of monitored cars is determined according to table 10.

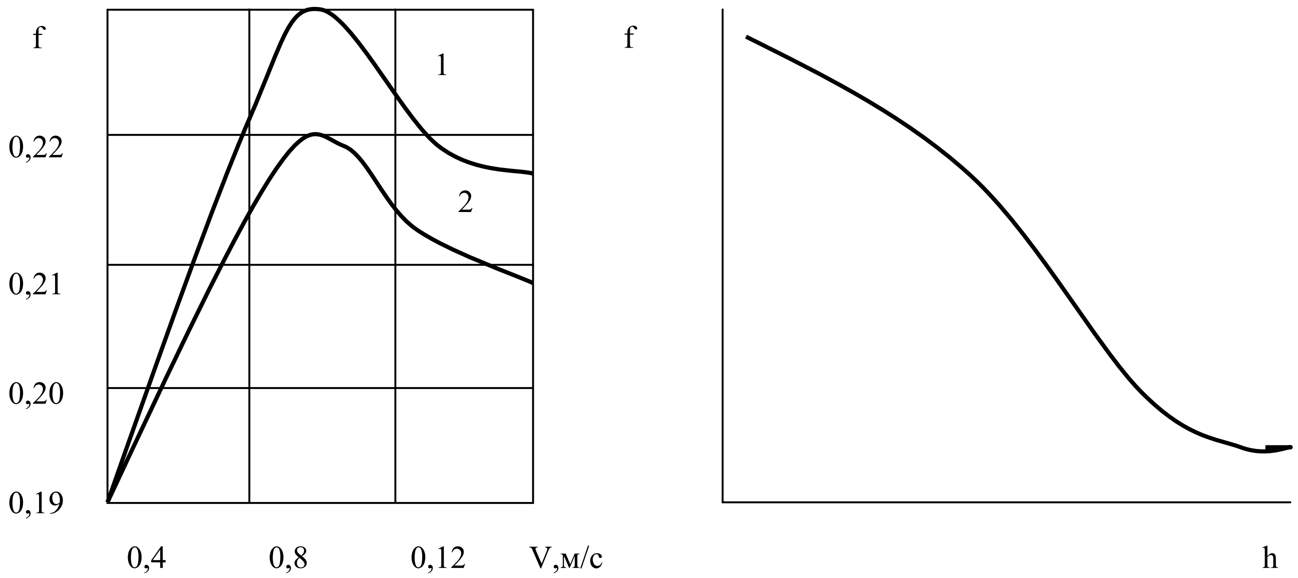
10-picture

| δ | β | /N,V,N/ | | | | |
|---|---|---|---|---|---|---|
| | | 00,10 | 0,5 | 0,20 | 0,25 | 0,30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0,05 | 0,80 | | | | | |
| | 0,90 | 4 | 6 | 13 | 20 | 25 |
| | 0,95 | 8 | 15 | 25 | 40 | 65 |
| | 0,99 | 13 | 25 | 40 | 65 | 100 |
| | | 25 | 30 | 100 | 150 | 200 |
| 0,10 | 0,80 | | | | | |
| | 0,90 | | | | | |
| | 0,95 | - | 3 | 5 | 8 | 10 |
| 0,15 | 0,80 | - | - | | 3 | 4 |
| | 0,90 | 5 | | | | |
| | 0,95 | - | 3 | | 4 | 6 |
| | 0,99 | 8 | | | | |
| | | 3 | 5 | | 6 | 10 |
| | | 13 | | | | |
| | | 5 | 8 | | 13 | 15 |
| | 0,80 | 25 | | | | |
| 0,20 | 0,90 | | | | | |

thanks to the braking system, he made it possible to stop a fast-moving train and car in a short time, speed up a chemical reaction thousands of times, record the human voice on a record, hear the sounds of musical instruments, and many other things.

Friction is a process that occurs when almost any mechanism works. Technically, it has two meanings. Friction in bearings, gears, and piston systems leads to wear of surfaces and loss of power. Therefore, friction in this place is a harmful factor. Brakes and clutches also benefit from friction, so wear is allowed here.




б)

Figure 1.1. a) Dependence of the friction coefficient of steel on pressure and speed of movement in a cast iron sample b) Dependence of the change of the friction coefficient on the thickness of the oxidized (copper-copper) layer.

Types of friction. According to the kinematic signs of the relative movement of bodies, the following types of friction are more common.

Friction at rest is friction in micromovements before two bodies move relative to each other.

Friction in motion is friction between two bodies in relative motion.

Friction without friction is the friction of two bodies when no friction material is applied to the rubbing surface (Fig. 2). During the use of machines and mechanisms, the destruction of details in them is not always uniform. Rapid decay is observed during the initial period of operation. The duration of this condition depends on the quality of the rubbing surfaces and the mode of operation of the mechanisms.

If the hardness of the rubbing parts and the material used are selected correctly, it will go to uniform wear at speed. This situation continues until the size of the rubbing parts changes and the mode of operation changes.

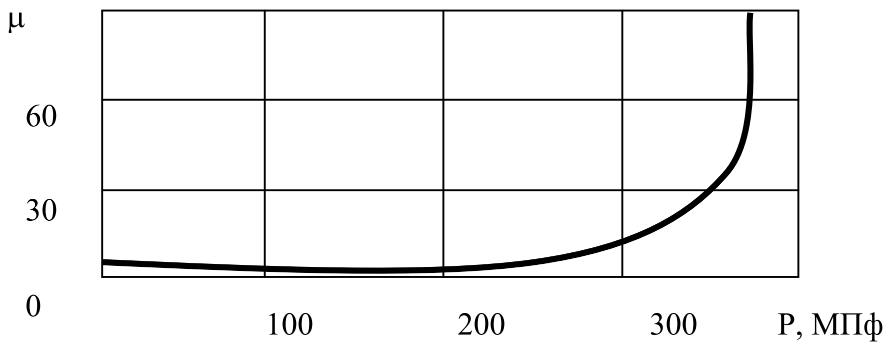
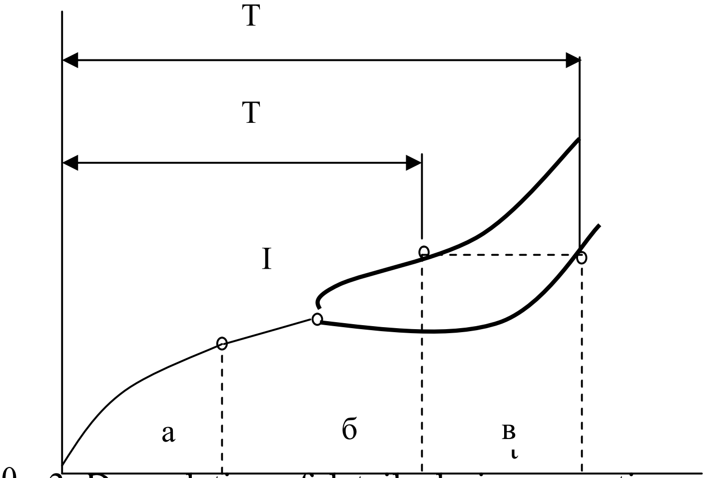



Figure 1.2. Friction of parts during operation without lubricating oil.




Figu .3. Degradation of details during operation.

As a result, the period of progressive degradation may begin and lead to an emergency situation.

Currently, there are several hypotheses for studying the nature of the decay phenomenon. According to the nature of the most influencing factors, the following types of decay can be seen: mechanical, molecular-mechanical, corrosion-mechanical.

Abrasive erosion. One of the main factors of the intensive course of erosion is caused by the falling of abrasive particles on the rubbing surface. As a result of these particles being harder than metal and falling on the surfaces of the parts, the phenomenon of decay occurs. Such decays can often be observed in open working bodies of machines, open rolling bearings, open moving parts, etc.

The most dangerous type of corrosion is called sticking, which is said to stick the rubbing surfaces together through friction. In this case, metal fragments move from one surface to another and adhere to a harder surface, and as a result, zasdaniye occurs.

The reasons for such interconnection of metals arise from the characteristics of interconnected surfaces.

Seizure occurs mainly due to the friction of non-lubricated surfaces.

In order to prevent malfunctions in technological machines and equipment, it is necessary to eliminate the condition of jamming as much as possible. The only way to do this is to choose the right oil raw materials and lubricate at the right place and at the right time.

Fatigue decay. The reason for this situation is the metal decay due to fatigue, and as a result of the appearance of cracks on the working surfaces of the details, rubbing

**Control questions**

1. Explain test planning?
2. Explain the coefficient of variation?
3. Tell the formula of the law of distribution of random values?

## 13 - Practical training.

### Topic: Determining reliability indicators of technological systems in slow-gradual breakdowns.

During operation and storage, any machine is exposed to various internal and external influences. As a result, its main parameters and characteristics are violated. The main reasons for the violation of the initial characteristics of the machine are the violation of its working conditions, lack of timely maintenance, low quality of repair, etc.

Usually, damage to parts occurs as a result of violation of the rules of use and maintenance of machines, and only in some cases due to exhaustion of metal or hidden defects in it (cracks, voids). When the rules of operation are followed, the consumption of adjacent parts increases gradually depending on the time of their operation. More than 80% of machine parts fail due to corrosion.

The accuracy of the machines depends to a large extent on the vibrations of the machines when the crankshafts, flywheels, and pulleys work. During the repair and replacement of some parts, their balance is disturbed, which causes the frame of the car to vibrate. The vibration that occurs during the operation of fast-rotating parts creates additional loads on various parts and bearings.

There are several reasons why the parts are not balanced: they may be due to incorrect dimensions, uneven density of the material, errors during assembly. As a result of a violation of ball bearing, the load on the bearings of the shafts increases sharply, which leads to a decrease in the useful work coefficient of the details and their excessive wear.

13.1. Corrosion, wear and tear of materials.

During the operation of the machines, due to the eating of adjacent parts, gaps of impermissible size appear between them, which disrupt the normal operation of the machines.

The rate of consumption is the ratio of the amount of consumption to the time taken for this consumption.

The rate of erosion is the ratio of the amount of erosion to the path along which this erosion occurred or the amount of work performed.

In the process of operation of technological machines and equipment, their working bodies are affected by different physical and chemical properties. As a result, machine parts gradually wear out, as a result of which the working ability of working bodies decreases. One of the main factors that lead to a decrease in performance is friction and wear.

Friction is a wonderful phenomenon of nature. He gave mankind heat and fire, thanks to the braking system, he made it possible to stop a fast-moving train and car in a short time, speed up a chemical reaction thousands of times, record the human voice on a record, hear the sounds of musical instruments, and many other things.

Friction is a process that occurs when almost any mechanism works. Technically, it has two meanings. Friction in bearings, gears, and piston systems leads to wear of surfaces and loss of power. Therefore, friction in this place is a harmful factor. In the case of brakes and clutches, friction is useful, so it tries to increase it to a certain value without going beyond the permissible limits of **wear.**

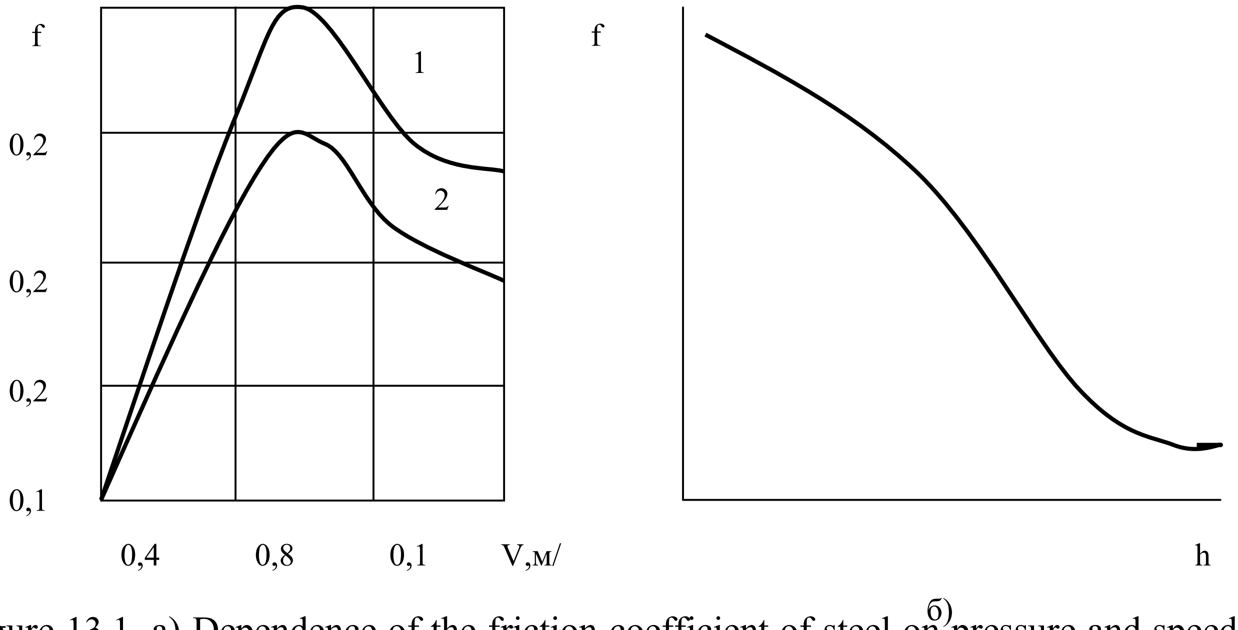



Figure 13.1. a) Dependence of the friction coefficient of steel on pressure and speed of movement in a cast iron sample b) Dependence of the change of the friction coefficient on the thickness of the oxidized (copper-copper) layer.

Types of friction. According to the kinematic signs of the relative movement of bodies, the following types of friction are more common.

Friction at rest is friction in micromovements before two bodies move relative to each other.

Friction in motion is friction between two bodies in relative motion.

Friction without friction is the friction of two bodies when no friction material is applied to the rubbing surface (Fig. 13.1). During the use of machines and mechanisms, the destruction of details in them is not always uniform. Rapid decay is observed during the initial period of operation. The duration of this condition depends on the quality of the rubbing surfaces and the mode of operation of the mechanisms.

If the hardness of the rubbing parts and the material used are selected correctly, it will go to uniform wear at speed. This situation continues until the size of the rubbing parts changes and the mode of operation changes.

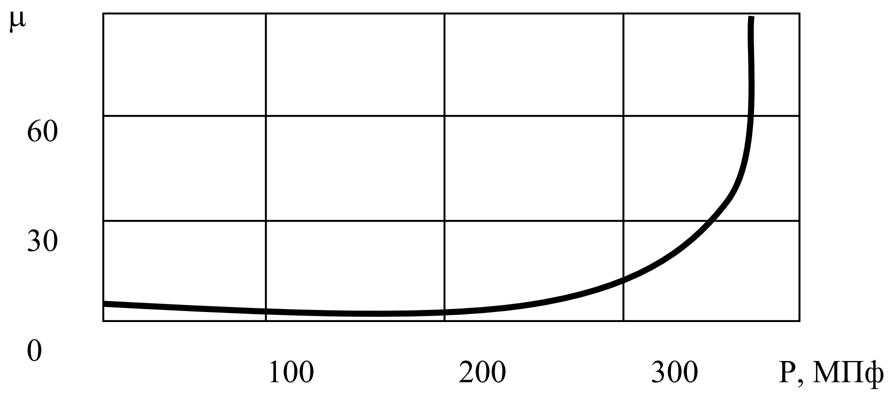


**Figure 13.2. Friction of parts during operation without lubricating oil.**

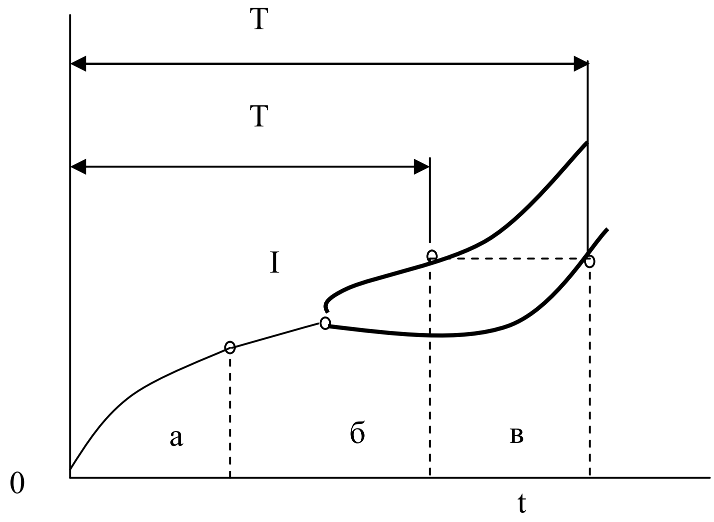



**Figure 13.3. Degradation of details during operation.**

As a result, the period of progressive degradation may begin and lead to an emergency situation.

Currently, there are several hypotheses for studying the nature of the decay phenomenon. According to the nature of the most influencing factors, the following types of decay can be seen: mechanical, molecular-mechanical, corrosion-mechanical.

Abrasive erosion. One of the main factors of the intensive course of erosion is caused by the falling of abrasive particles on the rubbing surface. As a result of these particles being harder than metal and falling on the surfaces of the parts, the phenomenon of decay occurs. Such decays can often be observed in open working bodies of machines, open rolling bearings, open moving parts, etc.

The most dangerous type of corrosion is called sticking, which is said to stick the rubbing surfaces together through friction. In this case, metal fragments move from one surface to another and adhere to a harder surface, and as a result, zasdaniye occurs.

The reasons for such interconnection of metals arise from the characteristics of interconnected surfaces.

Seizure occurs mainly due to the friction of non-lubricated surfaces.

In order to prevent malfunctions in technological machines and equipment, it is necessary to eliminate the condition of jamming as much as possible. The only way to do this is to choose the right oil raw materials and lubricate at the right place and at the right time.

Fatigue decay. The reason for this situation is the metal decay due to fatigue, and as a result of the appearance of cracks on the working surfaces of the details, rubbing occurs.

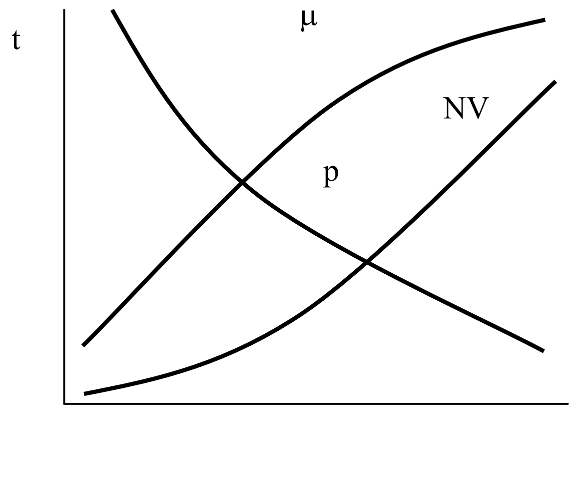



Figure 13.4. The influence character of the hardness of the parts materials NV, the loading t in operation, and the viscosity of the oil m before the appearance of fatigue decay.

Fatigue fatigue occurs mainly on lubricated surfaces that work under high stress, such as gears, rolling bearings.
The intensive process of fatigue wear takes place in the following order: first, a crack appears on the rubbing surfaces due to fatigue, and the lubricant falls into this crack, gradually forming a powder, and as a result, small particles appear on the surface of the rubbing part.
The main reason for the development of fatigue wear depends on the friction conditions (temperature and stress), the properties of the materials of the friction parts (physical-mechanical properties) and the lubricants.
Residual crushing in details. Residual crushing in parts occurs in the following cases:
1. Under the influence of high volume falling on the surface;
2. When the stress induced by a large load is at or near the limit of the part material.

In the first case, there is crushing on the surface, and in the second case, twisting and bending occurs.
The appearance of crushing on the surface of the parts occurs mainly in the parts that work with impact. Examples include crushing of teeth on gears, crushing of keys and splines.
Plastic crushing of the surfaces occurs gradually, first of all, due to the increase in the density of the working surfaces, intermediate cracks appear, as a result of which the dynamic load on the teeth increases, cracks and pitting are formed.
Twists and bends are mainly caused by high stresses in the material. Such situations are mainly observed in elastic elements, for example: springs, springs.

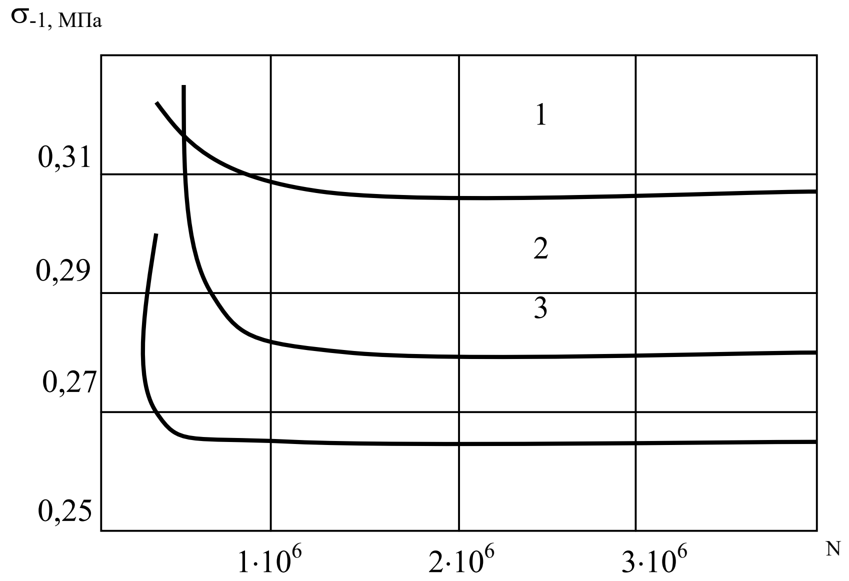



Figure 13.5. The influence of the number of loading cycles on the fatigue strength of the material (steel 45): 1- in the oscillating friction in an acidic environment; 2- in vibrational friction with the participation of lubricant; 3. In the absence of friction.
Fatigue of materials is defined as the gradual appearance of cracks in metals due to the stresses that appear under the influence of variable forces or high loads. Examples of this include torsions (body parts, frames), springs, crankshafts, etc.
Fatigue strength of materials refers to the resistance of materials to failure through fatigue. It is determined by the strength limit. The durability limit depends on the quality of the surface of the working part and the factor of working conditions: corrosion (rust), corrosion (wear), mechanical damage. The highest fatigue strength is observed in rolling friction surfaces operating in an active environment.
Thus, the fatigue strength and durability depend not only on the constructional structure and manufacturing technology of the details working under cyclic loading conditions,

but also on the working conditions and character. For example, oil-free operation and corrosion of parts, scratches on parts, and damage on surfaces have a great impact on the working resource of parts.

Changes in the mechanical properties of materials lead to wear and tear, in addition to fatigue.

Due to changes in the physical and chemical properties of materials under the influence of the environment (light, oxygen, low temperature), products wear out. As a result, the flexibility and strength properties of the details decrease, and cracks appear. The state of wear and tear leads to a sharp decrease in the service life of machines and mechanisms.

In order to assess and predict the technical condition of machines and mechanisms, it is necessary to determine the wear of friction parts. Currently, the methods of determining the level of consumption are divided into two groups:

1. Method of periodic measurement of consumption;
2. Constantly measure the level of wear during the operation of machines.

Periodic measurement method. In order to assess the accuracy of the machine elements, periodically (periodic) measurement works are carried out to determine the level of corrosion.

The method of periodic measurement of wear includes the following methods: the method of measuring with a micrometer; artificial base method; the method of losing mass due to eating; a method of measuring the particles of detail consumed in the composition of lubricants.

Micrometer measurement is carried out by controlling some parameters of details. These works are carried out with the help of a micrometer, barbell circle, nutrometer, microscope and other tools.

The measurement accuracy is 0.01-0.001mm depending on the type of tools used.

The method of measuring by creating an artificial base, a geometric shape is drawn on the working surface of the detail at a certain depth, and the degree of spreading is determined through this depth, these works are determined using optical measuring devices.

In the method of weighing the mass of the food, the rubbing parts are periodically weighed with the help of scales and measured by the volume of lost mass. PR-500 accessory scales, VLA-200 analytical scales, ATV-200 and other scales are used as measuring instruments.

In the method of lubricants, it is determined by the amount of metal particles in the used oils. This amount is determined using the detailing mechanism.

A method of continuous measurement of food intake. Continuous measurement of wear during the operation of machines and mechanisms is carried out by various methods:

· measure the working environment by consumption;

by changing the pressure in the working environment;

· through radioactive isotopes;•

In the method of measuring the consumption by the consumption of the working medium, the machines are equipped with special devices, and with their help, the consumed liquid (lubricant) is transferred to the rubbing surfaces through a special slot, and the amount of consumption is measured. An increase in the consumption of lubricants indicates an increase in the gap, which means that the wear surfaces of the parts have increased.

The difference between the method of determining wear by operating pressure and the previous method is that the decrease in operating pressure indicates the increase of cracks on the rubbing surfaces. This happens due to the corrosion of the rubbing surfaces.

In the method of measurement using radioactive isotopes, a radioactive substance is firmly placed on the surface of the rubbing parts at a certain depth. The material of the radioactive substance should not be too different from the material of the detail. This material is cylindrical in shape, the diameter should not exceed 0.7-1.0 mm, 1.0-1.5 mm.

With the help of this method, it is determined not only the intensive course of corrosion, but also which part of the rubbing surface is eroded more.

Control questions

1. The reasons for the wear of adjacent parts during the operation of machines explain?
2. In what cases does residual crushing occur in details?
3. Describe the types of friction?
4. Describe the mechanical properties of materials?

## 14 - Practical training.

**Topic: Determining the reliability indicators of non-renewable technological systems.**

Special reliability tests:
1. Research tests - tests conducted to study the factors affecting the reliability of the product.
2. Control tests - tests conducted to assess the level of reliability of a specific item.
The tests are divided by the venue as follows:
1. Tests under bench conditions - provide information about the loss of machine or aggregate performance, that is, about their reliability characteristics. When developing test methods, it is necessary to take into account the compatibility of test conditions and procedures with operating conditions. Bench tests are usually continued until a failure occurs or until the item has run for a specified period of time.
2. Operational and polygon tests are used for experimental and serial samples. Experimental samples of technological machines and equipment are tested in harsh operating conditions on specially selected and artificially created fields and in various climatic conditions. Such tests have the following disadvantages:
a) the duration of the experiments is not always sufficient, similar to the actual operating conditions;
b) the test result determining the object's reliability parameters cannot provide information about at least the average value of the service life of technological machines and equipment. Therefore, accelerated tests are used, in which reliability information is obtained in a very short time.
When conducting control tests, items are individually tested for their integrity, durability, repairability, and maintainability.

14.1. Reliability test object
The object of reliability tests can be:
1. Samples - if the characteristics of products or materials that determine their durability are tested (fatigue strength, anti-erosion and corrosion properties, etc.);
2. Details (joints, kinematic pairs) - if there is a need to take into account the effect of construction and technological factors on the service life of this part (bearings, gears, guides, hinges, etc.);
3. Machine, assembly and units - if it is necessary to take into account the interaction of some mechanisms and structural elements and their influence on performance indicators (gearbox, reducers, engines, control systems, etc.);

4. Machine - testing the interaction of all aggregates, nodes and mechanisms in the machine in operating conditions and work procedures (vehicles);
5. Machine system - if the interaction of some machines that make up one production complex is evaluated through reliability indicators (automotive enterprise).

14.2. Characteristics evaluated in reliability testing

They are mainly divided into two groups:
1. Characteristics of wear (deterioration) processes and degree of deterioration of items. In the tests, the passage of corrosion processes, corrosion, shape changes, fatigue disorders, etc. are studied. These factors are the main reasons for the loss of machine performance.
2. Characteristics of changes in output parameters of the device over time (accuracy, efficiency, load capacity, etc.). Exceeding the allowed limits of these characteristics leads to violations.

The more complex the test object, the more output parameters will have to be evaluated for a large number of tests.

14.3. Testing of experimental and serial samples

When conducting reliability tests, it is necessary to divide their volume between experimental and serial production in such a way that the necessary information can be obtained as a result of it, and appropriate changes can be made to the design of the product as soon as possible. However, many issues cannot be solved in experimental production, only serial samples can give the desired results. In addition, when testing serial samples for reliability, the following should be taken into account:
a) experimental verification of whether the necessary structural changes have been made to the machine as a result of bringing the layout up to standard;
b) expansion of work procedures and other studies of items in actual operating conditions;
v) to determine the causes of damage of items during the operation of the first serial samples.

When testing prototypes, only a small number of items (maybe even a single item) are placed because these items are made in small quantities. But these tests are not enough, because the reliability indicators obtained from a small number of items and based on insufficient information do not reflect the actual condition of the items.

14.4. Reliability testing methods

In order to determine the reliability characteristics of technological machines and equipment during operation, a test (control) is carried out by taking certain quantities of them. There are two ways to test the reliability of the transmission period:
- completed tests;

- accelerated (cross-sectional) tests.

Evaluation of reliability parameters in completed tests is carried out after failure of all items put to the test.

In accelerated (cross-sectional) tests, the evaluation of reliability parameters is carried out without waiting for the failure of all items, since the tests are carried out during operation, and their duration can be extended for several years. Regarding the accelerated tests, it should be noted that if the resource of the items is small, then the reliability parameters should be evaluated in the same way as the completed tests, since all these items will fail during the test period. There are special methods of processing the results of accelerated tests [8].

14.5. Methods of determining the number of items to be tracked

A fully completed [NUN] test must have a sufficient number of items to be monitored and provide the required accuracy.

When determining the number of items to be monitored, the following information is provided in advance: permissible error value d=0.05; 0.10; 0.15; By 0.20, confidence probability a=0.8; 0.9; 0.95; 0.975; equal to 0.99, and in some cases the distribution law of distortions can be given.

The fixed relative error is determined by the following expression:

$$\delta = \frac{L_{юч} - \overline{L}}{\overline{L}}, \qquad (14.1)$$

here: Luch is the upper limit of the one-sided confidence probability of the arithmetic value, thousand km;

- average arithmetic value, thousand km.

The minimum number of items to be monitored can be determined by the following methods.

- non-parametric method - in cases where the distribution laws of disturbances are not clear;
- parametric method - in cases where the distribution laws of disturbances are clear.

Nonparametric method. This method is considered a method of determining the minimum number of items under observation, and is used to determine the probability of items working without damage during a certain period of time, and when the laws of damage are unclear. The minimum number of items in the tracking is determined by the following formula:

$$N = \frac{\ln(1-\alpha)}{\ln R(L)}, \qquad (14.2)$$

$$\mathrm{N} = \frac{\ln(1-0{,}95)}{\ln(0{,}95)} = 45$$

## 14.6. Random quantities

The processes occurring in nature and technology can be divided into two large groups:

1. Processes determined by functional connection;
2. Random or probabilistic processes.

Processes determined by functional connection

If two values (X and Y) are related to each other by a certain expression such that for each value of X there is exactly one value of Y, then the value of Y is a function of the value of X , that is, X is called an independent independent variable value or argument. Example: dependence of fuel consumption on the traveled distance yqf(x).

Probabilistic processes arise under the influence of many variables, and their quantities are often unknown. Therefore, the results of probabilistic processes have different numerical values and are called random variables. For example, the amount of travel per failure, the initial and assembly quality of the part, the accuracy of the treatment given to it, the skills of the workers, the maintenance, the quality of the current maintenance and operational materials, the operation conditions etc. are random variables and depend on many factors. Among the random variables, the volume of work to eliminate a malfunction, the consumption of materials, the amount of technical condition parameters at certain times, etc. also includes

In order to carry out high-quality operation of machines and equipment, it is necessary to know the following laws of changes in their technical condition: the change in the technical condition of the vehicle unit and its parts according to the route; the extent of deterioration of technical condition parameters; the number of breakdowns of vehicles during the entire service life, etc.

## 14.7. Distribution of random variables

When solving engineering tasks, for example, determining the demand for replacement of vehicle parts, units and assemblies, or planning the production of spare parts, it is necessary to know the average lifetime (resource) of items and how certain resources are grouped around this average amount. Therefore, it is important to know the distribution laws of random variables.

$$p=\frac{m}{N}, \qquad (14.10)$$

where: r is the percentage of relative disturbances;

m is the number of violations in the interval;

N is the number of items under observation.

The distribution laws of random variables depend on the causes of disturbances.

## Control questions

**1. Explain the processes defined by functional binding?**
2. Explain random or probabilistic processes?
3. Tell me the methods of reliability testing?
4. Describe experimental and serial sample testing?
5. Describe the characteristics evaluated in reliability testing?

## List of references

1. Nurmuhammedov H.S., Jumaniozov M.J., Abdullayev A.Sh., Babayev Z.K., Karimov K.F. Repair and installation of chemical and oil industry equipment. - Tashkent: Science and technology, 2012. - 204 p.
2. Pronikov A.S. Parametricheskaya nadyojnost machine. Moscow. 2002. - 561 p.
3. "Manual for installers" Danfoss. M. 2005.
4. "Pravila ustroystva i bezopasnoy ekspulatasii holodilnih ustanovok", M.: 1991 g.
5. Lutkovsky V.V. Povisheniye nadyojnosti raboti kholodilnikh ustanovok., L.:1988 g.
6. Virtual materials: internal structure of piston compressors.

**Electronic resources**

1. http://www.ziyo.net
2. www.ABOK.ru "AVOK" jurnaliningelektronversiyasi.
3. **http://www**. Khimprom.cjb.net.
4. **www.danfoss.ru**