Некоммерческое акционерное общество

АЛМАТИНСКИЙ УНИВЕРСИТЕТ ЭНЕРГЕТИКИ И СВЯЗИ

Кафедра иностранных языков

Foreign (professional) language

Methodological instructions for Master students of 6M0171600 – Instrumentation specialty. For practical study and development of reading and translating skills.

Алматы 2018

СОСТАВИТЕЛЬ: доцент, Серикбаева У.Б.Методические указания по чтению и переводу технических текстов для магистрантов специальности 6М071600 –Приборостроение– Алматы. АУЭС, 2018 - 30 с.

Методические указания предназначены для совершенствования навыков и умений профессионального общения студентов технических вузов на английском языке.

Цель методического указания – совершенствование навыков и умений говорения, а также чтения и перевода текстов по специальности Каждый текст сопровождается тематическим словарем и системой языковых упражнений.

Тематика текстов отвечает профилю вуза.

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Печатается по плану издания некоммерческого акционерного общества «Алматинский университет энергетики и связи» на 2018г.

Unit 1. Measurement techniques
Grammar: Participle, Perfect (Passive)

Exercise 1. Read and translate this text

Measurement techniques have been of immense importance ever since the start of human civilization, when measurements were first needed to regulate the transfer of goods in barter trade to ensure that exchanges were fair. The industrial revolution during the nineteenth century brought about a rapid development of new instruments and measurement techniques to satisfy the needs of industrialized production techniques. Since that time, there has been a large and rapid growth in new industrial technology. This has been particularly evident during the last part of the twentieth century, encouraged by developments in electronics in general and computers in particular. This, in turn, has required a parallel growth in new instruments and measurement techniques. The massive growth in the application of computers to industrial process control and monitoring tasks has spawned a parallel growth in the requirement for instruments to measure, record and control process variables. As modern production techniques dictate working to tighter and tighter accuracy limits, and as economic forces limiting production costs become more severe, so the requirement for instruments to be both accurate and cheap becomes ever harder to satisfy. This latter problem is at the focal point of the research and development efforts of all instrument manufacturers. In the past few years, the most cost-effective means of improving instrument accuracy has been found in many cases to be the inclusion of digital computing power within instruments themselves.

Vocabulary notes:
Translate into Russian and remind them

Measurement techniques
Regulate
Transfer
Ensure
Rapid development
Production
Rapid growth
Application
Spawn
Requirement
Tighter
Accuracy
Research
Improve
Include

To spawn
To encourage
Required a parallel growth
Accurate and cheap

Exercise 2. Discuss this text

1.About instruments.
2.The application of instruments.
3.The importance of instruments.

Exercise 3. Complete the following sentences using the text

1.When measurements were first needed to regulate the …… in barter trade to ensure that …… were fair.
2. This, in turn, has …… a parallel growth in new instruments and measurement techniques.
3. The massive growth in the …… of computers to industrial process control and monitoring tasks has …… a parallel growth in the requirement for instruments to ……., record and control process variables.
4. Modern production techniques dictate working to …… and tighter …… limits.
5.The most cost-effective means of …… instrument …… has been found in many cases.

Exercise 4. Translate into Russian

1.The reaction involves the following temperature changes.
2.Starting from the most elementary viewpoint
3.This substance is best suited as starting compound.
4.We obtained these values in terms of the following formula.
5.We have analyzed the following compounds.

Exercise 5. Translate into Russian (Perfect Tenses)

1.The product has been proved to affect the overall yield.
2.As yet no successful experiment has been described.
3.It is known that he has come.
4.A new glass works has been built in 1963.
5.When the reaction had been finished the temperature fell.

Exercise 6. Translate into Russian (Passive voice)

1.These materials are not found in their natural form.

2.The investigations will be carried on.
3.This is done by employing two gas channels and wires.
4.Water was removed from the reaction as fast as it was formed.
5.A discussion of this system has been given elsewhere.

Exercise 7. Translate these sentences with the word *affect*

1.The results were affected by the presence of impurities.
2.The insulation was affected by water vapors.
3.The rates and molecular weights are affected by lowering the temperature.
4.These factors are unaffected by temperature changes.
5.Very low and very high gas rates both adversely affect the efficiency of separation.

Unit 2. Measurement system
Grammar: Infinitive

Exercise 1. Read and translate this text

Measurement system applications today, the techniques of measurement are of immense importance in most facets of human civilization. Present-day applications of measuring instruments can be classified into three major areas. The first of these is their use in regulating trade, applying instruments that measure physical quantities such as length, volume and mass in terms of standard units. The particular instruments and transducers employed in such applications are included in the general description of instruments presented in Part 2 of this book. Measurement and Instrumentation Principles 7 The second application area of measuring instruments is in monitoring functions. These provide information that enables human beings to take some prescribed action accordingly. The gardener uses a thermometer to determine whether he should turn the heat on in his greenhouse or open the windows if it is too hot. Regular study of a barometer allows us to decide whether we should take our umbrellas if we are planning to go out for a few hours. Whilst there are thus many uses of instrumentation in our normal domestic lives, the majority of monitoring functions exist to provide the information necessary to allow a human being to control some industrial operation or process. In a chemical process for instance, the progress of chemical reactions is indicated by the measurement of temperatures and pressures at various points, and such measurements allow the operator to take correct decisions regarding the electrical supply to heaters, cooling water flows, valve positions etc.

Vocabulary
Translate these words from the text and mind them.

Measurement system
Applications
Regulating trade
Physical quantities
Volume
Employ
Monitoring functions
Provide information
Enables human
Determine
Heat
Allow
Whilst
Exist
Indicate
Electrical supply
Cooling
Valve positions

Exercise 2. Discuss this text

1.About the application of instruments.
2.About the function of instruments.
3.About the description of instruments.

Exercise 3. Underline the correct word or phrase in the following

1.He denied *telling/ to tell* lies.
2.He *denied / refused* that he had told lies.
3.They suggested to *postpone / postponing* the match to the following week.
4.The weather delayed that they *arrived / their arrival*.
5.I cannot bear *to see / see* children suffer.

Exercise 4. Complete the 2-d sentence so that it is as similar in meaning as possible to the first sentence, using the word given. Do not change this word.

1.I am sorry but we have decided not to accept your application.
Regret
I ………………………………………………………………….
We have decided to reject your application.
2.Funnily enough I'd prefer a pizza for a change.
Rather
Funnily enough ……………………………….

3.We were not allowed to drink too much Coke when we were children.
Let
Our parents ………………………………………………………………

4.I think it would be a good idea to take the train.
Suggest
I …………………………………………………………

5.She succeeded in persuading her parents to let her go.
Managed
She ……………………………………………………………

Exercise 5. Translate these sentences paying attention to Infinitive

1.The interval to be measured.

2.It was decided to remove the whole of the slag without dissolution of the uranium.

3.To work I must have all the necessary equipment.

4.Rotation spectra can be used to measure bond lengths.

5.This substance is oxidized by silver oxide to lose one hydrogen atom.

Exercise 6. Translate these sentences with *such as*

1.Other factors, such as rate of distillation (скорость дистиляции), reflux ratio (флегм вое число), and pressure drop will be considered later.

2.In our experiments we took account of the main variables such as heat, pressure, and specific weight.

3.This frequency occurs also in compounds such as thioacetic (тиоуксусная) acid.

4.Certain structural factors such as the size of the diphenyls (дифенилы) must be taken into consideration.

5.The apparatus must of course be also constructed, that parts, such as the column, which may have to be interchanged can be easily reached.

Unit 3. Elements of a measurement system
Grammar: Participle (Passive Voice)

Exercise 1. Read and translate this text

Elements of a measurement system. A measuring system exists to provide information about the physical value of some variable being measured. In simple cases, the system can consist of only a single unit that gives an output reading or signal according to the magnitude of the unknown variable applied to it. However, in more complex measurement situations, a measuring system consists of several separate elements. These components might be contained within one or more boxes, and the boxes holding individual measurement elements might be either close together or physically separate. The term measuring instrument is commonly used to describe a measurement system, whether it contains only one or many elements, and this term will be widely used throughout this text. The first element in any measuring system is the primary sensor: this gives an output that is a function of the measured (the input applied to it). For most but not all sensors, this function is at least approximately linear. Some examples of primary sensors are a liquid-in-glass thermometer, a thermocouple and a strain gauge. In the case of the mercury-in-glass thermometer, the output reading is given in terms of the level of the mercury, and so this particular primary sensor is also a complete measurement system in itself. However, in general, the primary sensor is only part of a measurement system. The types of primary sensors available for measuring a wide range of physical quantities are presented in Part 2 of this book. Variable conversion elements are needed where the output variable of a primary transducer is in an inconvenient form and has to be converted to a more convenient form. For instance, the displacement-measuring strain gauge has an output in the form of a varying resistance. The resistance change cannot be easily measured and so it is converted to a change in voltage by a bridge circuit, which is a typical example of a variable conversion element. In some cases, the primary sensor and variable conversion element are combined, and the combination is known as a transducer. Ł Signal processing elements exist to improve the quality of the output of a measurement system in some way. A very common type of signal processing element is the electronic amplifier, which amplifies the output of the primary transducer or variable conversion element, thus improving the sensitivity and resolution of measurement. This element of a measuring system is particularly important where the primary transducer has a low output. For example, thermocouples have a typical output of only a few millivolts. Other types of signal processing element are those that filter out induced noise and remove mean levels etc. In some devices, signal processing is incorporated into a transducer, which is then known as a transmitter. Ł In addition to these three components just mentioned, some measurement systems have one or two other components, firstly to transmit the signal to some remote point and secondly to display or record the signal if it is not fed automatically into a feedback control system. Signal transmission is needed when the observation or application point of the output of a measurement system is some distance away from the site of the primary transducer. Sometimes, this separation is made solely for purposes of convenience, but more often it follows from the physical inaccessibility or environmental unsuitability of the site of the primary transducer for mounting the signal Ł In some cases, the word 'sensor' is used generically to refer to both transducers and transmitters. Measurement and Instrumentation Principles 9 Measured variable (measured) Sensor Variable conversion element Signal processing Output measurement Output display/ recording Signal presentation or recording Use of measurement at remote point Signal transmission Fig. 1.2 Elements of a measuring instrument. presentation/recording unit. The signal transmission element has traditionally consisted of single or multi-cored cable, which is often screened to minimize signal corruption by induced electrical noise. However, fiber-optic cables are being used in ever increasing numbers in modern installations, in part because of their low transmission loss and imperviousness to the effects of electrical and magnetic fields. The final optional element in a measurement system is the point where the measured signal is utilized. In some cases, this element is omitted altogether because the measurement is used as part of an automatic control scheme, and the transmitted signal is fed directly into the control system. In other cases, this element in the measurement system takes the form either of a signal presentation unit or of a signal-recording unit. These take many forms according to the requirements of the particular measurement application, and the range of possible units is discussed more fully in Chapter 11. 1.4 Choosing appropriate measuring instruments. The P starting point in choosing the most suitable instrument to use for measurement of a particular quantity in a manufacturing plant or other system is the specification of the instrument characteristics required, especially parameters like the desired measurement accuracy, resolution, sensitivity and dynamic performance (see next chapter for definitions of these). It is also essential to know the environmental conditions that the instrument will be subjected to, as some conditions will immediately either eliminate the possibility of using certain types of instrument or else will create a requirement for expensive protection of the instrument. It should also be noted that protection reduces the performance of some instruments, especially in terms of their dynamic characteristics (for example, sheaths protecting thermocouples and resistance thermometers reduce their speed of response). Provision of this type of information usually requires the expert knowledge of personnel who are intimately acquainted with the operation of the manufacturing plant or system in question. Then, a skilled instrument engineer, having knowledge of all the instruments that are available for measuring the quantity in question, will be able to evaluate the possible list of instruments in terms of their accuracy, cost and suitability for the environmental conditions and thus choose the 10 Introduction to measurement most appropriate instrument. As far as possible, measurement systems and instruments should be chosen that are as insensitive as possible to the operating environment, although this requirement is often difficult to meet because of cost and other performance considerations. The extent to which the measured system will be disturbed during the measuring process is another important factor in instrument choice. For example, significant pressure loss can be caused to the measured system in some techniques of flow measurement. Published literature is of considerable help in the choice of a suitable instrument for a particular measurement situation. Many books are available that give valuable assistance in the necessary evaluation by providing lists and data about all the instruments available for measuring a range of physical quantities (e.g. Part 2 of this text). However, new techniques and instruments are being developed all the time, and therefore a good instrumentation engineer must keep abreast of the latest developments by reading the appropriate technical journals regularly. The instrument characteristics discussed in the next chapter are the features that form the technical basis for a comparison between the relative merits of different instruments. Generally, the better the characteristics, the higher the cost. However, in comparing the cost and relative suitability of different instruments for a particular measurement situation, considerations of durability, maintainability and constancy of performance are also very important because the instrument chosen will often have to be capable of operating for long periods without performance degradation and a requirement for costly maintenance. In consequence of this, the initial cost of an instrument often has a low weighting in the evaluation exercise. Cost is very strongly correlated with the performance of an instrument, as measured by its static characteristics. Increasing the accuracy or resolution of an instrument, for example, can only be done at a penalty of increasing its manufacturing cost. Instrument choice therefore proceeds by specifying the minimum characteristics required by a measurement situation and then searching manufacturers' catalogues to find an instrument whose characteristics match those required. To select an instrument with characteristics superior to those required would only mean paying more than necessary for a level of performance greater than that needed. As well as purchase cost, other important factors in the assessment exercise are instrument durability and the maintenance requirements. Assuming that one had £10 000 to spend, one would not spend £8000 on a new motor car whose projected life was five years if a car of equivalent specification with a projected life of ten years was available for £10 000. Likewise, durability is an important consideration in the choice of instruments. The projected life of instruments often depends on the conditions in which the instrument will have to operate. Maintenance requirements must also be taken into account, as they also have cost implications. As a general rule, a good assessment criterion is obtained if the total purchase cost and estimated maintenance costs of an instrument over its life are divided by the period of its expected life. The figure obtained is thus a cost per year. However, this rule becomes modified where instruments are being installed on a process whose life is expected to be limited, perhaps in the manufacture of a particular model of car. Then, the total costs can only be divided by the period of time that an instrument is expected to be used for, unless an alternative use for the instrument is envisaged at the end of this period. Measurement and Instrumentation Principles 11 To summarize therefore, instrument choice is a compromise between performance characteristics, ruggedness and durability, maintenance requirements and purchase cost. To carry out such an evaluation properly, the instrument engineer must have a wide knowledge of the range of instruments available for measuring particular physical quantities, and he/she must also have a deep understanding of how instrument characteristics are affected by particular measurement situations and operating conditions.

Exercise 2. Translate these words from the text and mind them

Physical value
Output

Magnitude
Contained
Primary sensor
Available
Physical quantities
Variable conversion
Resistance
Circuit
To exist to improve the quality
Electronic amplifier
Primary transducer
Induced noise
Remove mean levels
Dynamic performance
Evaluation
Environmental conditions
Cost implications
To carry out
Purchase cost

Exercise 3. Discuss the text

1.What is a measuring system?
2.What does a measuring system consist of?
3.What do signal processing elements exist for?
4.Speak about the instrument characteristics.

Exercise 4. Underline the correct word or phrase in the following

1.We really cannot afford *buying/ to buy* a new washing machine.
2.I look forward to *seeing / to see* you at the party.
3.Before *going* / that I *went* to the interview, I bought a new tie.
4.I'd rather *stay / to stay* at home tonight, if that's all right.
5.Isaw someone to *climb / climbing* through the window.

Exercise 5. Complete the second sentences so that it is as similar in meaning as possible to the first sentence, using the word given. Do not change this word.

1.It looks as if this door's locked after all.
Appears
This ………………………………………
2.One of things I hate is possible eating popcorn in the cinema.
Stand
One of the things I ………………………………………………

3.The singer arrived two hours late but I'm glad I waited for him.
Worth
The singer ………………………………………………………
4.Jack said he had to catch the early flight.
Insisted
Jack ……………………………………….
5.I can't wait to get your next letter.
Forward
I ……………………………………

Exercise 6. Translate these sentences. Pay attention to Passive Voice

1.The investigations will be carried on.
2.The pressure at one of these points can be chosen at will.
3.This is done by employing two gas channels and wires.
4.A six fold (шесть раз) decrease in yield (выхода) was observed.
5.Water was decomposed into oxygen and hydrogen.
6.Water was removed as fast as formed.

Unit 4. Instrument types and performance characteristics
Grammar: Modal Verbs

Exercise 1. Read and translate this text

Instrument types and performance characteristics. Instruments can be subdivided into separate classes according to several criteria. These sub classifications are useful in broadly establishing several attributes of particular instruments such as accuracy, cost, and general applicability to different applications. Active and passive instruments are divided into active or passive ones according to whether the instrument output is entirely produced by the quantity being measured or whether the quantity being measured simply modulates the magnitude of some external power source. This is illustrated by examples. An example of a passive instrument is the pressure-measuring device. The pressure of the fluid is translated into a movement of a pointer against a scale. The energy expended in moving the pointer is derived entirely from the change in pressure measured: there are no other energy inputs to the system. An example of an active instrument is a float-type petrol tank level indicator as sketched in Figure 2.2. Here, the change in petrol level moves a potentiometer arm, and the output signal consists of a proportion of the external voltage source applied across the two ends of the potentiometer. The energy in the output signal comes from the external power source: the primary transducer float system is merely modulating the value of the voltage from this external power source. In active instruments, the external power source is usually in electrical form, but in some cases, it can be other forms of energy such as a pneumatic or hydraulic one. One very important difference between active and passive instruments is the level of measurement resolution that can be obtained. With the simple pressure gauge shown, the amount of movement made by the pointer for a particular pressure change is closely defined by the nature of the instrument. Whilst it is possible to increase measurement resolution by making the pointer longer, such that the pointer tip moves through a longer arc, the scope for such improvement is clearly restricted by the practical limit of how long the pointer can conveniently be. In an active instrument, however, adjustment of the magnitude of the external energy input allows much greater control over Measurement and Instrumentation Principles 13. Spring Piston Fluid Pointer Scale. Passive pressure gauge. Petrol-tank level indicator. measurement resolution. Whilst the scope for improving measurement resolution is much greater incidentally, it is not infinite because of limitations placed on the magnitude of the external energy input, in consideration of heating effects and for safety reasons. In terms of cost, passive instruments are normally of a more simple construction than active ones and are therefore cheaper to manufacture. Therefore, choice between active and passive instruments for a particular application involves carefully balancing the measurement resolution requirements against cost.

Null-type and deflection-type instruments. The pressure gauge just mentioned is a good example of a deflection type of instrument, where the value of the quantity being measured. Instrument types and performance characteristics Weights Piston Datum level. An alternative type of pressure gauge is the deadweight gauge, which is a null-type instrument. Here, weights are put on top of the piston until the downward force balances the fluid pressure. Weights are added until the piston reaches a datum level, known as the null point. Pressure measurement is made in terms of the value of the weights needed to reach this null position. The accuracy of these two instruments depends on different things. For the first one it depends on the linearity and calibration of the spring, whilst for the second it relies on the calibration of the weights. As calibration of weights is much easier than careful choice and calibration of a linear-characteristic spring, this means that the second type of instrument will normally be the more accurate. This is in accordance with the general rule that null-type instruments are more accurate than deflection types. In terms of usage, the deflection type instrument is clearly more convenient. It is far simpler to read the position of a pointer against a scale than to add and subtract weights until a null point is reached. A deflection-type instrument is therefore the one that would normally be used in the workplace. However, for calibration duties, the null-type instrument is preferable because of its superior accuracy. The extra effort required to use such an instrument is perfectly acceptable in this case because of the infrequent nature of calibration operations. Analogue and digital instruments give an output that varies continuously as the quantity being measured changes. The output can have an infinite number of values within the range that the instrument is designed to measure. The deflection-type of pressure is a good example of an analogue instrument. As the input value changes, the pointer moves with a smooth continuous motion. Whilst the pointer can therefore be in an infinite number of positions within its range of movement, the number of different positions that the eye can discriminate between is strictly limited, this discrimination being dependent upon how large the scale is and how finely it is divided. A digital instrument has an output that varies in discrete steps and so can only have a finite number of values. The rev counter sketched is an example of Measurement and Instrumentation Principles 15.

Rev counter is a digital instrument. A cam is attached to the revolving body whose motion is being measured, and on each revolution the camp opens and closes a switch. The switching operations are counted by an electronic counter. This system can only count whole revolutions and cannot discriminate any motion that is less than a full revolution. The distinction between analogue and digital instruments has become particularly important with the rapid growth in the application of microcomputers to automatic control systems. Any digital computer system, of which the microcomputer is but one example, performs its computations in digital form. An instrument whose output is in digital form is therefore particularly advantageous in such applications, as it can be interfaced directly to the control computer. Analogue instruments must be interfaced to the microcomputer by an analogue-to-digital (A/D) converter, which converts the analogue output signal from the instrument into an equivalent digital quantity that can be read into the computer. This conversion has several disadvantages. Firstly, the A/D converter adds a significant cost to the system. Secondly, a finite time is involved in the process of converting an analogue signal to a digital quantity, and this time can be critical in the control of fast processes where the accuracy of control depends on the speed of the controlling computer. Degrading the speed of operation of the control computer by imposing a requirement for A/D conversion thus impairs the accuracy by which the process is controlled.

Indicating instruments and instruments with a signal output. The final way in which instruments can be divided is between those that merely give an audio or visual indication of the magnitude of the physical quantity measured and those that give an output in the form of a measurement signal whose magnitude is proportional to the measured quantity. The class of indicating instruments normally includes all null-type instruments and most passive ones. Indicators can also be further divided into those that have an analogue output and those that have a digital display. A common analogue indicator is the liquid-in-glass thermometer. Another common indicating device, which exists in both analogue and digital forms, is the bathroom scale. The older mechanical form of this is an analogue type of instrument that gives an output consisting of a rotating. Instrument types and performance characteristics pointer moving against a scale (or sometimes a rotating scale moving against a pointer). More recent electronic forms of bathroom scale have a digital output consisting of numbers presented on an electronic display. One major drawback with indicating devices is that human intervention is required to read and record a measurement. This process is particularly prone to error in the case of analogue output displays, although digital displays are not very prone to error unless the human reader is careless. Instruments that have a signal-type output are commonly used as part of automatic control systems. In other circumstances, they can also be found in measurement systems where the output measurement signal is recorded in some way for later use. This subject is covered in later chapters. Usually, the measurement signal involved is an electrical voltage, but it can take other forms in some systems such as an electrical current, an optical signal or a pneumatic signal.

Smart and non-smart instruments. The advent of the microprocessor has created a new division in instruments between those that do incorporate a microprocessor (smart) and those that don't.

Static characteristics of instruments. If we have a thermometer in a room and its reading shows a temperature of 20°C, then it does not really matter whether the true temperature of the room is 19.5°C or 20.5°C. Such small variations around 20°C are too small to affect whether we feel warm enough or not. Our bodies cannot discriminate between such close levels of temperature and therefore a thermometer with an inaccuracy of š0.5°C is perfectly adequate. If we had to measure the temperature of certain chemical processes, however, a variation of 0.5°C might have a significant effect on the rate of reaction or even the products of a process. A measurement inaccuracy much less than š0.5°C is therefore clearly required.

Accuracy of measurement is thus one consideration in the choice of instrument for a particular application. Other parameters such as sensitivity, linearity and the reaction to ambient temperature changes are further considerations. These attributes are collectively known as the static characteristics of instruments, and are given in the data sheet for a particular instrument. It is important to note that the values quoted for instrument characteristics in such a data sheet only apply when the instrument is used under specified standard calibration conditions. Due allowance must be made for variations in the characteristics when the instrument is used in other conditions. The various static characteristics are defined in the following paragraphs.

Accuracy and inaccuracy (measurement uncertainty). The accuracy of an instrument is a measure of how close the output reading of the instrument is to the correct value. In practice, it is more usual to quote the inaccuracy figure rather than the accuracy figure for an instrument. Inaccuracy is the extent to Measurement and Instrumentation Principles which a reading might be wrong, and is often quoted as a percentage of the full-scale (ft.'s.) reading of an instrument. If, for example, a pressure gauge of range 0–10 bar has a quoted inaccuracy of š1.0% ft.'s. (š1% of full-scale reading), then the maximum error to be expected in any reading is 0.1 bar. This means that when the instrument is reading 1.0 bar, the possible error is 10% of this value. For this reason, it is an important system design rule that instruments are chosen such that their range is appropriate to the spread of values being measured, in order that the best possible accuracy is maintained in instrument readings. Thus, if we were measuring pressures with expected values between 0 and 1 bar, we would not use an instrument with a range of 0–10 bar. The term measurement uncertainty is frequently used in place of inaccuracy. Precision is a term that describes an instrument's degree of freedom from random errors. If a large number of readings are taken of the same quantity by a high precision instrument, then the spread of readings will be very small. Precision is often, though incorrectly, confused with accuracy. High precision does not imply anything about measurement accuracy. A high precision instrument may have a low accuracy. Low accuracy measurements from a high precision instrument are normally caused by a bias in the measurements, which is removable by recalibration. The terms repeatability and reproducibility mean approximately the same but are applied in different contexts as given below. Repeatability describes the closeness of output readings when the same input is applied repetitively over a short period of time, with the same measurement conditions, same instrument and observer, same location and same conditions of use maintained throughout. Reproducibility describes the closeness of output readings for the same input when there are changes in the method of measurement, observer, measuring instrument, location, conditions of use and time of measurement. Both terms thus describe the spread of output readings for the same input. This spread is referred to as repeatability if the measurement conditions are constant and as reproducibility if the measurement conditions vary. The degree of repeatability or reproducibility in measurements from an instrument is an alternative way of expressing its precision. Figure 2.5 illustrates this more clearly. The figure shows the results of tests on three industrial robots that were programmed to place components at a particular point on a table. The target point was at the center of the concentric circles shown, and the black dots represent the points where each robot actually deposited components at each attempt. Both the accuracy and precision of Robot 1 are shown to be low in this trial. Robot 2 consistently puts the component down at approximately the same place but this is the wrong point. Therefore, it has high precision but low accuracy. Finally, Robot 3 has both high precision and high accuracy, because it consistently places the component at the correct target position.

Tolerance is a term that is closely related to accuracy and defines the maximum error that is to be expected in some value. Whilst it is not, strictly speaking, a static 18 Instrument types and performance characteristics (a) Low precision, low accuracy (b) High precision, low accuracy (c) High precision, high accuracy ROBOT 1 ROBOT 2 ROBOT 3. Comparison of accuracy and precision. characteristic of measuring instruments, it is mentioned here because the accuracy of some instruments is sometimes quoted as a tolerance figure. When used correctly, tolerance describes the maximum deviation of a manufactured component from some specified value. For instance, crankshafts are machined with a diameter tolerance quoted as so many microns (106 m), and electric circuit components such as resistors have tolerances of perhaps 5%. One resistor chosen at random from a batch having a nominal value 1000 W and tolerance 5% might have an actual value anywhere between 950 W and 1050 W.

Vocabulary
Translate and mind these words

Resistor
Tolerance
Low precision
High precision
Electric circuit
Concentric circles
Reproducibility
Repeatability
High precision instrument
Standard calibration conditions
The accuracy figure
Inaccuracy figure
The rate of reaction
To measure
Deflection type instrument
Smart and non-smart instruments
Rev counter
Adjustment of the magnitude
Recalibration.
Approximately
Optical signal
To apply
Measuring pressures
Actual value and nominal value

Exercise 2. Discuss this text

1.Speak about instrument types and performance characteristics.
2.Spear about active and passive instruments.
3. Speak about smart and non-smart instruments.

Exercise 3. Translate these sentences with modal verbs

1.He must have finished his experiments.
2.This must have given rise to the molecule changing its configuration.
3.The experiment must have been carried out.
4.The reaction may have been accompanied by tar (смола) formation.
5.This must have taken place as a result of the molecule having changed its conformation.

Exercise 4. Translate into Russian. Mind *provided that*

1.A circuit operates well provided that it does not have any trouble.
2.The bulb lights provided that the circuit is connected to the cell.
3.A cell supplies energy provided that its electrodes are of different materials.

Exercise 5. Complete these sentences using the words from the text

1.The energy ……. in moving the pointer is derived entirely from the change in ……… measured: there are no other energy inputs to the system.
2.The energy in the output signal comes from the …… power source.
3.One very important difference between …… and passive instruments is the level of………. resolution that can be obtained.
4.The ……. type instrument is clearly more convenient.
5.The distinction between analogue and digital instruments has become particularly important with the …… growth in the ………. of microcomputers to automatic control systems.

Exercise 6. Put questions in italics

1.Active and passive instruments are divided into active or passive ones according to whether the **instrument output** is entirely produced.
2.The primary transducer **float** system is merely modulating the value of the voltage from this external power source.
3.Instruments that have a **signal-type output** are commonly used as part of automatic control systems.
4.The accuracy of an instrument is **a measure** of how close the output reading of the instrument is to the correct value.
5.Low accuracy measurements from a high precision instrument are normally **caused** by a bias in the measurements, which is removable by recalibration.

Exercise 7. Form the words according to the model and translate them

Model: charge –overcharge – перегрузка, connect-disconnect- разъденить

Pressure-
Heat-
Stress-
Current-
Load –
Organize-
Place-
Stress-
Use-

Exercise 8. Read and translate into Russian. Mind *one*

1.One should take this catalyst, not the old one.
2.This procedure proved to be greatly improved over the previous one.
3.The new procedure is twice as effective as the old one.
4.This substance reacts three times as fast as the other one.
5.This substance reacts half as fast as the other one.

Exercise 9. Read and translate into Russian. Mind *procedure*

1.The paper presents a new procedure to prepare these compounds.
2.Besides being very involved this procedure is very costly.
3.This procedure is finding increasing use.
4.This procedure is applicable whether or not the product is pure.
5.The main advantage of this procedure lies in its simplicity.

Exercise 10. Read and translate into Russian. Mind *suitable*

1.Under the action of suitable reagents.
2.The concentration of the acid was followed by a suitable apparatus.
3.Tetrahydrofurfuryl (тетрагидрофурфуриловый) alcohol is said to be a suitable medium for reactions of this sort.
4.After a suitable time the amount of nitration (нитрования) products is determined.

Unit 5. Calibration of measuring sensors and instruments
Grammar: Infinitives after Verbs and Prepositions

Exercise 1. Read and translate the text

Calibration of measuring sensors and instruments. Calibration consists of comparing the output of the instrument or sensor under test against the output of an instrument of known accuracy when the same input (the measured quantity) is applied to both instruments. This procedure is carried out for a range of inputs covering the whole measurement range of the instrument or sensor. Calibration ensures that the measuring accuracy of all instruments and sensors used in a measurement system is known over the whole measurement range, provided that the calibrated instruments and sensors are used in environmental conditions that are the same as those under which they were calibrated. For use of instruments and sensors under different environmental conditions, appropriate correction has to be made for the ensuing modifying inputs. Whether applied to instruments or sensors, calibration procedures are identical, and hence only the term instrument will be used for the rest of this chapter, with the understanding that whatever is said for instruments applies equally well to single measurement sensors. Instruments used as a standard in calibration procedures are usually chosen to be of greater inherent accuracy than the process instruments that they are used to calibrate. Because such instruments are only used for calibration purposes, greater accuracy can often be achieved by specifying a type of instrument that would be unsuitable for normal process measurements. For instance, ruggedness is not a requirement, and freedom from this constraint opens up a much wider range of possible instruments. In practice, high-accuracy, null-type instruments are very commonly used for calibration duties, because the need for a human operator is not a problem in these circumstances. Instrument calibration has to be repeated at prescribed intervals because the characteristics of any instrument change over a period. Changes in instrument characteristics are brought about by such factors as mechanical wear, and the effects of dirt, dust, fumes, chemicals and temperature changes in the operating environment. To a great extent, the magnitude of the drift in characteristics depends on the amount of use an instrument receives and hence on the amount of wear and the length of time that it is subjected to the operating environment. However, some drift also occurs even in storage, as a result of ageing effects in components within the instrument.

Measurement and Instrumentation Principles. Determination of the frequency at which instruments should be calibrated is dependent upon several factors that require specialist knowledge. If an instrument is required to measure some quantity and an inaccuracy of š2% is acceptable, then a certain amount of performance degradation can be allowed if its inaccuracy immediately after recalibration is š1%. What is important is that the pattern of performance degradation be quantified, such that the instrument can be recalibrated before its accuracy has reduced to the limit defined by the application. Susceptibility to the various factors that can cause changes in instrument characteristics varies according to the type of instrument involved. Possession of an in-depth knowledge of the mechanical construction and other features involved in the instrument is necessary in order to be able to quantify the effect of these quantities on the accuracy and other characteristics of an instrument. The type of instrument, its frequency of use and the prevailing environmental conditions all strongly influence the calibration frequency necessary, and because so many factors are involved, it is difficult or even impossible to determine the required frequency of instrument recalibration from theoretical considerations. Instead, practical experimentation has to be applied to determine the rate of such changes. Once the maximum permissible measurement error has been defined, knowledge of the rate at which the characteristics of an instrument change allows a time interval to be calculated that represents the moment in time when an instrument will have reached the bounds of its acceptable performance level. The instrument must be recalibrated either at this time or earlier. This measurement error level that an instrument reaches just before recalibration is the error bound that must be quoted in the documented specifications for the instrument. A proper course of action must be defined that describes the procedures to be followed when an instrument is found to be out of calibration, i.e. when its output is different to that of the calibration instrument when the same input is applied. The required action depends very much upon the nature of the discrepancy and the type of instrument involved. In many cases, deviations in the form of a simple output bias can be corrected by a small adjustment to the instrument (following which the adjustment screws must be sealed to prevent tampering). In other cases, the output scale of the instrument may have to be redrawn, or scaling factors altered where the instrument output is part of some automatic control or inspection system. In extreme cases, where the calibration procedure shows up signs of instrument damage, it may be necessary to send the instrument for repair or even scrap it. Whatever system and frequency of calibration is established, it is important to review this from time to time to ensure that the system remains effective and efficient. It may happen that a cheaper (but equally effective) method of calibration becomes available with the passage of time, and such an alternative system must clearly be adopted in the interests of cost efficiency. However, the main item under scrutiny in this review is normally whether the calibration interval is still appropriate. Records of the calibration history of the instrument will be the primary basis on which this review is made. It may happen that an instrument starts to go out of calibration more quickly after a period of time, either because of ageing factors within the instrument or because of changes in the operating environment. The conditions or mode of usage of the instrument may also be subject to change. As the environmental and usage conditions of an instrument may change beneficially as well as adversely, there is the possibility that the recommended calibration interval may decrease as well as increase. 66 Calibration of measuring sensors and instruments 4.2 Control of calibration environment Any instrument that is used as a standard in calibration procedures must be kept solely for calibration duties and must never be used for other purposes. Most particularly, it must not be regarded as a spare instrument that can be used for process measurements if the instrument normally used for that purpose breaks down. Proper provision for process instrument failures must be made by keeping a spare set of process instruments. Standard calibration instruments must be totally separate. To ensure that these conditions are met, the calibration function must be managed and executed in a professional manner. This will normally mean setting aside a particular place within the instrumentation department of a company where all calibration operations take place and where all instruments used for calibration are kept. As far as possible this should take the form of a separate room, rather than a sectioned-off area in a room used for other purposes as well. This will enable better environmental control to be applied in the calibration area and will also offer better protection against unauthorized handling or use of the calibration instruments. The level of environmental control required during calibration should be considered carefully with due regard to what level of accuracy is required in the calibration procedure, but should not be over specified as this will lead to unnecessary expense. Full air conditioning is not normally required for calibration at this level, as it is very expensive, but sensible precautions should be taken to guard the area from extremes of heat or cold, and also good standards of cleanliness should be maintained. Useful guidance on the operation of standards facilities can be found elsewhere (British Standards Society, 1979). Whilst it is desirable that all calibration functions are performed in this carefully controlled environment, it is not always practical to achieve this. Sometimes, it is not convenient or possible to remove instruments from process plant, and in these cases, it is standard practice to calibrate them in situ. In these circumstances, appropriate corrections must be made for the deviation in the calibration environmental conditions away from those specified. This practice does not obviate the need to protect calibration instruments and maintain them in constant conditions in a calibration laboratory at all times other than when they are involved in such calibration duties on plant. As far as management of calibration procedures is concerned, it is important that the performance of all calibration operations is assigned as the clear responsibility of just one person. That person should have total control over the calibration function, and be able to limit access to the calibration laboratory to designated, approved personnel only. Only by giving this appointed person total control over the calibration function can the function be expected to operate efficiently and effectively. Lack of such definite management can only lead to unintentional neglect of the calibration system, resulting in the use of equipment in an out-of-date state of calibration and subsequent loss of traceability to reference standards. Professional management is essential so that the customer can be assured that an efficient calibration system is in operation and that the accuracy of measurements is guaranteed. Calibration procedures that relate in any way to measurements that are used for quality control functions are controlled by the international standard ISO 9000 (this subsumes the old British quality standard BS 5750). One of the clauses in ISO 9000 requires that all persons using calibration equipment be adequately trained. The manager in charge of the calibration function is clearly responsible for ensuring that Measurement and Instrumentation Principles 67 this condition is met. Training must be adequate and targeted at the particular needs of the calibration systems involved. People must understand what they need to know and especially why they must have this information. Successful completion of training courses should be marked by the award of qualification certificates. These attest to the proficiency of personnel involved in calibration duties and are a convenient way of demonstrating that the ISO 9000 training requirement has been satisfied.

Exercise 2. Verb + to- infinitive

Here are some examples of verbs that use this pattern:

1.I agreed to go with her.
2.He appears to be dead.
3.We cannot afford to go on holiday this year.

Here are more verbs in this group:

Expect, intend, manage, plan, promise, threaten, like, choose, fail, hope, mean, prepare, refuse, want, wish, decide, hesitate, learn, offer, pretend, seem.

We can also follow many of these verbs with a *that*-clause, a noun, an adjective or a prepositional phrase:

Examples:

1.I *agree that* it is difficult. (verb + *that* – clause)
2.She *failed the exam*. (verb + noun)
3.She *seems frightened*. They *appear happy*. (verb + adjective)
4.They *agreed on a course of action*. (verb + prepositional phrase)

Exercise 3. Verb +bare Infinitive

This is a small group. Here are examples of verbs that use this pattern:

1.*Let* me *give* you some advice. (= allow me to …)
2.I *would* rather *go* to Italy. (= prefer to …)
3.You *would* better *watch* what you are saying. (= I advise you to …)
4.They *made* us *get up* early. (= forced us to …)

Exercise 4. Complete these sentences using words from the text

1.This procedure is carried out for a range of inputs covering the whole ……… of the instrument or sensor.
2. Calibration ensures that the ………. of all instruments and sensors used in a measurement system.
3.Such instruments are only used for ………, greater accuracy can often be achieved by specifying a type of instrument that would be unsuitable for normal process measurements.
4.Determination of the ……. at which instruments should be calibrated is dependent upon several factors that …… specialist knowledge.
5.This measurement …… level that an instrument reaches just before recalibration is the error bound that must be …… in the documented specifications for the instrument.

Exercise 5. Put questions in italics

1.Calibration consists of comparing the **output of the instrument** or sensor under test against the output of an instrument of known accuracy when the same input (the measured quantity) is **applied** to both instruments.

2. Instruments used as **a standard in calibration procedures** are usually chosen to be of greater inherent accuracy than the process instruments that they are used to calibrate.

3. The magnitude of the drift in characteristics depends on the **amount of use an instrument** receives and hence on the amount of wear and the length of time that it is subjected to the operating environment.

4. As far as management of calibration procedures is concerned, it is important that **the performance of all calibration operations** is assigned as the clear responsibility of just one person.

Exercise 6. Translate these sentences into Russian. Mind *prepositions*

1.The investigations will be carried *on.*

2.Oxidation (окисление) was carried *out* for two hours.

3.The admixtures (примеси) remaining in the end product were distilled off.

4.The reaction may start *in* a week.

5.Steam entrain aniline (анилин) and carriers it *over* into the receiving flask (колба).

Exercise 7. Translate these sentences into Russian. Mind *to allow, to enable, to permit*

1.High temperatures allowed the reaction to be carried out in two hours.

2.The enhancement (увеличение) in the intensity of this band is sufficient to enable conjugation (сопряжение) to be recognized.

3.Hydrolysis (гидролиз) at high temperatures permitted the reaction to be carried out in 30 minutes.

4.If we raise the temperature the film(пленка) will expand, allowing more hydroxyl (гидроксил) groups to enter the water.

5.Reaction rate studies permit a decision to be made concerning the above isomerization (изомеризации).

Supplementary texts for reading

Unit 6. Electrical indicating and test instruments

Electrical indicating and test instruments. The magnitude of voltage signals can be measured by various electrical indicating and test instruments, such as meters (both analogue and digital), the cathode ray oscilloscope and the digital storage oscilloscope. As well as signal-level voltages, many of these instruments can also measure higher-magnitude voltages, and this is indicated where appropriate.

Digital meters. All types of digital meter are basically modified forms of the digital voltmeter (DVM), irrespective of the quantity that they are designed to measure. Digital meters designed to measure quantities other than voltage are in fact digital voltmeters that contain appropriate electrical circuits to convert current or resistance measurement signals into voltage signals. Digital mustimeters are also essentially digital voltmeters that contain several conversion circuits, thus allowing the measurement of voltage, current and resistance within one instrument. Digital meters have been developed to satisfy a need for higher measurement accuracies and a faster speed of response to voltage changes than can be achieved with analogue instruments. They are technically superior to analogue meters in almost every respect. However, they have a greater cost due to the higher manufacturing costs compared with analogue meters. The binary nature of the output reading from a digital instrument can be readily applied to a display that is in the form of discrete numerals. Where human operators are required to measure and record signal voltage levels, this form of output makes an important contribution to measurement reliability and accuracy, since the problem of analogue meter parallax error is eliminated and the possibility of gross error through misreading the meter output is greatly reduced. The availability in many instruments of a direct output in digital form is also very useful in the rapidly expanding range of computer control applications. Quoted inaccuracy figures are between š0.005% (measuring d.c. voltages) and š2%. Additional advantages of digital meters are their very high input impedance (10 M compared with 1–20 k for analogue meters), the ability to measure signals of frequency up to 1 MHz and the common inclusion of features such as automatic ranging, which prevents overload and reverse polarity connection etc. Measurement and Instrumentation Principles 103 The major part of a digital voltmeter is the circuitry that converts the analogue voltage being measured into a digital quantity. As the instrument only measures d.c. quantities in its basic mode, another necessary component within it is one that performs a.c.–d.c. conversion and thereby gives it the capacity to measure a.c. signals. After conversion, the voltage value is displayed by means of indicating tubes or a set of solid-state light-emitting diodes. Four-, five- or even six-figure output displays are commonly used, and although the instrument itself may not be inherently more accurate than some analogue types, this form of display enables measurements to be recorded with much greater accuracy than that obtainable by reading an analogue meter scale. Digital voltmeters differ mainly in the technique used to effect the analogue-to-digital conversion between the measured analogue voltage and the output digital reading. As a general rule, the more expensive and complicated conversion methods achieve a faster conversion speed. Some common types of DVM are discussed below.

Unit 7. Instrumentation and computer networks

Instrumentation and computer networks. The inclusion of computer processing power in intelligent instruments and intelligent actuators creates the possibility of building an instrumentation system where several intelligent devices collaborate together, transmit information to one another and execute process control functions. Such an arrangement is often known as a distributed control system. Additional computer processors can also be added to the system as necessary to provide the necessary computational power when the computation of complex control algorithms is required. Such an instrumentation system is far more fault tolerant and reliable than older control schemes where data from several discrete instruments is carried to a centralized computer controller via long instrumentation cables. This improved reliability arises from the fact that the presence of computer processors in every unit injects a degree of redundancy into the system. Therefore, measurement and control action can still continue, albeit in a degraded form, if one unit fails. In order to affect the necessary communication when two or more intelligent devices are to be connected together as nodes in a distributed system, some form of electronic highway must be provided between them that permits the exchange of information. Apart from data transfer, a certain amount of control information also has to be transferred. The main purpose of this control information is to make sure that the target device is ready to receive information before data transmission starts. This control information also prevents more than one device trying to send information at the same time. In modern installations, all communication and data transmission between processing nodes in a distributed instrumentation and control system is carried out digitally along some form of electronic highway, although analogue data transmission (mainly current loop) is still widely used to transmit data from field devices into the processing nodes. If analogue transmission is used for measurement data, an analogue-to-digital converter must be provided at the interfaces between the measurement signal transmission cables and the processing nodes. The electronic highway can either be a serial communication line, a parallel data bus, or a local area network. Serial data lines are very slow and are only used where a 188 Instrumentation/computer networks low data transmission speed is acceptable. Parallel data buses are limited to connecting a modest number of devices spread over a small geographical area, typically a single room, but provide reasonably fast data transmission. Local area networks are used to connect larger numbers of devices spread over larger geographical distances, typically a single building or site. They transmit data in digital format at high speed. Instrumentation networks that are geographically larger than a single building or site can also be built, but these generally require transmission systems that include telephone lines as well as local networks at particular sites within the large system. The input/output interface of an intelligent device provides the necessary connection between the device and the electronic highway. The interface can be either serial or parallel. A serial interface is used to connect a device onto a serial communication line. The connection is effected physically by a multi-pin plug that fits into a multi-pin socket on the casing of the device. The pins in this plug/socket match the signal lines used in the serial communication line exactly in number and function. Effectively, there is only one standard format for serial data transmission that enjoys international recognition. Whilst this is advantageous in avoiding compatibility problems when connecting together devices coming from different manufacturers, serial transmission is relatively slow. A parallel interface is used to connect devices onto parallel instrument buses and also into all other types of network systems. Like the serial interface, the parallel interface exists physically as a multi-pin plug that fits into a multi-pin socket on the casing of the device. The pins in the plug/socket are matched exactly in number and function with the data and control lines used by a particular parallel instrument bus. Unfortunately, there are a number of different parallel instrument buses in use and thus a corresponding number of different parallel interface protocols, with little compatibility between them. Hence, whilst parallel data transmission is much faster than serial transmission, there are serious compatibility problems to be overcome when connecting together devices coming from different manufacturers because of the different parallel interface protocols used.

Unit 8. Temperature measurement

Temperature measurement. Principles of temperature measurement. Temperature measurement is very important in all spheres of life and especially so in the process industries. However, it poses particular problems, since temperature measurement cannot be related to a fundamental standard of temperature in the same way that the measurement of other quantities can be related to the primary standards of mass, length and time. If two bodies of lengths l1 and l2 are connected together end to end, the result is a body of length l1 C l2. A similar relationship exists between separate masses and separate times. However, if two bodies at the same temperature are connected together, the joined body has the same temperature as each of the original bodies. This is a root cause of the fundamental difficulties that exist in establishing an absolute standard for temperature in the form of a relationship between it and other measurable quantities for which a primary standard unit exists. In the absence of such a relationship, it is necessary to establish fixed, reproducible reference points for temperature in the form of freezing and boiling points of substances where the transition between solid, liquid and gaseous states is sharply defined. The International Practical Temperature Scale (IPTS)Ł uses this philosophy and defines six primary fixed points for reference temperatures in terms of: ž the triple point of equilibrium hydrogen

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259.34°C ž the boiling point of oxygen

182.962°C ž the boiling point of water 100.0°C ž the freezing point of zinc 419.58°C ž the freezing point of silver 961.93°C ž the freezing point of gold 1064.43°C (all at standard atmospheric pressure) The freezing points of certain other metals are also used as secondary fixed points to provide additional reference points during calibration procedures. Ł The IPTS is subject to periodic review and improvement as research produces more precise fixed reference points. The latest version was published in 1990. 272 Temperature measurement Instruments to measure temperature can be divided into separate classes according to the physical principle on which they operate. The main principles used are: ž The thermoelectric effect ž Resistance change ž Sensitivity of semiconductor device ž Radiative heat emission ž Thermography ž Thermal expansion ž Resonant frequency change ž Sensitivity of fiber optic devices ž Acoustic thermometry ž Color change ž Change of state of material.

Unit 9. Intelligent temperature-measuring instruments

Intelligent temperature-measuring instruments. Intelligent temperature transmitters have now been introduced into the catalogues of most instrument manufacturers, and they bring about the usual benefits associated with intelligent instruments. Such transmitters are separate boxes designed for use with transducers that have either a d.c. voltage output in the mV range or an output in the form of a resistance change. They are therefore suitable for use in conjunction with thermocouples, thermopiles, resistance thermometers, thermistors and broad-band radiation pyrometers. All of the transmitters presently available have non-volatile memories where all constants used in correcting output values for modifying inputs etc. are stored, thus enabling the instrument to survive power failures without losing such information. Facilities in transmitters now available include adjustable damping, noise rejection, self-adjustment for zero and sensitivity drifts and expanded measurement range. These features allow an inaccuracy level of š0.05% of full scale to be specified. Mention must be made particularly of intelligent pyrometers, as some versions of these are able to measure the emissivity of the target body and automatically provide an emissivity-corrected output. This particular development provides an alternative to the two-color pyrometer when emissivity measurement and calibration for other types of pyrometer pose difficulty. Digital thermometers (see section 14.2) also exist in intelligent versions, where the inclusion of a microprocessor allows a number of alternative thermocouples and resistance thermometers to be offered as options for the primary sensor. The cost of intelligent temperature transducers is significantly more than their no intelligent counterparts, and justification purely on the grounds of their superior accuracy is hard to make. However, their expanded measurement range means immediate savings are made in terms of the reduction in the number of spare instruments needed to cover a number of measurement ranges. Their capability for self-diagnosis and self-adjustment means that they require attention much less frequently, giving additional savings in maintenance costs.

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Сводный план 2018г., поз.69

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АНГЛИЙСКИЙ ЯЗЫК

Методические указания по чтению и переводу технических текстов для магистрантов специальности 6М071600 – Приборостроение)

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Подписано в печать___________ Формат 60х84 1/16
Тираж 50 экз. Бумага типографская № 1
Объем____ уч. –изд. л. Заказ______. Цена_______.

Копировально-множительное бюро
Некоммерческого акционерного общества
«Алматинский университет энергетики и связи» 050013, Алматы,
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