LOGIC OF ARIZ[1]

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Abstract
Algorithm of inventive problem solving (ARIZ) is a part of theory of inventive problem solving (TRIZ) developed by G. Altshuller. ARIZ consists of a program (sequence of actions) for the exposure and solution of contradictions, i.e., the solution of problems. ARIZ includes: the program itself, information support supplied by the knowledge base, and methods for the control of psychological factors, which are a component part of the methods for developing a creative imagination. Furthermore, sections of ARIZ are predetermined for the selection of problems and the evaluation of the received solution. Last modification of the algorithm developed by G. Altshuller is an algorithm of 1985 - ARIZ-85-C. ARIZ-85-C is a step by step sequence. Thus it is possible to solve problems, but it is impossible to understand all functions of ARIZ. ARIZ is intended not only for the solving difficult (not standard) problems, but also for development inventive (creative, system) thinking. The inventive thinking is thinking through contradictions, which reveals original causes (roots) of a problem. In my opinion, this is the more important function. One can carry out this function only if one has studied the logic of ARIZ, which is presented in this paper.
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1. Introduction

ARIZ is a step-by-step program for the analysis and solution of inventive problems. The first modification appeared in 1959 (ARIZ-59). Other modifications are ARIZ-61, ARIZ-71, ARIZ-77, ARIZ-82, and ARIZ-85-C. The basic sequence for the solution of problems with ARIZ has already been examined. The final modification of ARIZ included three basis components: **program, information support** and **methods for the control of psychological factors.**

1. The **ARIZ program** consists of a sequence of operations for the following operations: exposure and solution of contradictions (see the basic sequence of ARIZ); analysis of the initial situation and selection of the problem to be solved; synthesis of the solution; analysis of the received solutions and selection of the best variant; development of received solutions; collection of the best solutions and summarization of this material for the improvement of methods for solving other problems. The structure of the program and the laws for its implementation are based on the laws and regularities of technological development.

2. Information support are supplied from the **knowledge base**, which includes a system of ***standards*** *for the solution of inventive problems*; ***engineering effects*** (physical, chemical, biological, mathematical, and particularly geometric – the most developed effect at the present day); *techniques for the elimination of contradictions* ***(inventive principles)***; *methods for the application of* ***resources*** of nature and technology.

3. Methods for the control of psychological factors are necessary as a result of the fact that the program ARIZ is not intended for computers and that problems are not solved automatically, but with the help of a human being. Therefore, the problem solver often exhibits psychological inertia, and it is necessary to control this. Furthermore, these methods allow one to develop the creative imagination necessary for the solution of complicated inventive problems.

2. Concept about contradictions

Different technological means were and are developed to satisfy the needs of man.

But needs grow significantly faster than our ability to satisfy them, and this in its own way serves as a source of technological progress.

The development of a new entity more often than not entails the improvement of some set of technological parameters of a system.

Complicated inventive problems (of unknown type) require a nontrivial approach because the improvement of one system parameter leads to the inadmissible deterioration of another. **Contradictions** arise.

The solution of problems with ARIZ constitutes a sequence for the exposure and solution of contradictions and the reasons that produce the given contradictions, as well as their elimination by use of the knowledge base. In this manner cause and effect relationships are determined – the essence of which is the intensification and aggravation of contradictions.

For this purpose, ARIZ considers three types of contradictions: **superficial, intensified** and **aggravated.** G. Altshuller named them respectively: ***administrative, technical*** and ***physical***.

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SUPERFICIAL CONTRADICTION (SC) – contradiction between the expressed need and ability to satisfy that need. This is sufficiently easy to determine. These contradictions are often produced by administrators or customers, and are expressed in the following manner: *"It must be completed immediately, but how is unknown", "Some kind of system parameter is faulty, so it must be fixed", "It is necessary to eliminate the shortcoming, but how we don't know", "There is spoilage in the production of wares, but the reason is unknown".*

In this manner SC is expressed in the form of a **harmful effect (HE)** - something negative, or the **necessity to create something new** by unknown means.

Example 1. In the late 50s the construction bureau of A.N.Tupolev was given the task of creating a new passenger aircraft with 170 seats and the capacity for prolonged flight. To achieve this, aircraft engines with a combined output of 50 ths. hsp. were necessary. The most powerful TV-2 engines in the USSR were only 6 ths. hsp. What can be done?

Example 2. It is necessary to increase the speed of a ship, but how is unknown.

INTENSIFIED CONTRADICTION (IC) – this is a contradiction between specific parts, qualities or parameters of a system. IC arises during the improvement of one part (quality or parameter) of a system at the expense of the inadmissible deterioration of another. It reveals the reason for the appearance of a superficial contradiction by intensifying it. More often than not, at the heart of superficial contradiction (SC) lies several intensified contradictions (IC).

As a rule, by improving certain characteristics of an entity, we dramatically worsen others. Usually it is necessary to search for a compromise, that is, to sacrifice something.

During the solution of technological problems, the technological characteristics of an entity are changed, therefore G. Altshuller named intensified contradictions **technical contradictions.**

A technical contradiction arises as a result of the disproportionate development of different system parts (parameters). When there are a significant number of changes to one of the system parts (parameters) and a sharp "lag" in development of another (other) of its parts, the situation arises in which quantitative changes from one side of the system acts in contradiction with others. Solution of this kind of contradiction often requires the qualitative change of the technological system. This is manifested in the law of transition from quantitative to qualitative changes.

Continuation of the above examples.

Example 1 (continuation). In order to achieve the required combined engine capacity it is necessary to use 8 engines. The farthest engines would have to be located at a distance of 25 m from the fuselage, but this would cause the wings to be lengthened to an unallowable degree. An intensified contradiction arises between the airplane's **POWER** and the inadmissible increase of the **LENGTH** of its wings.

We can formulate another intensified contradiction. If we turn to twin engines with a total output of 12,000 hsp., it is necessary to use a propeller with a diameter of 9 m. A diameter of 9 m. would necessitate lifting the airplane 5 m. above the ground. The intensified contradiction in this case is between the **POWER** of the engines and the great **HEIGTH** of the airplane.

These types of ICs in particular can be eliminated by the use of the technique "**transition to another measurement**."

A.N.Tupolev solved the described contradiction in the following manner. He suggested pairing engines in a single block and positioning two four-blade propellers that rotate in different directions directly on one shaft of the block. Only 4 blocks were needed (two per wing), and the diameter of the propeller consisted of 5.2 m. It was not necessary to greatly increase the height of the airplane. As a result, the TU-114 airplane was created with a rather high flight speed of 870 km/hr.

Example 2 (continuation). Increase of the weight-carrying capacity of a ship is connected with the reduction of its speed. In turn, increasing the speed of the ship leads to a growth in engine power and increased energy loss, which requires an increase in weight and the dimensions of the propulsion system and fuel stores. The excessive increase of these components may lead to a situation in which there is nowhere to place the payload. In the given example the following technical contradictions are exposed: **WEIGHT-CARRYING CAPACITY – SPEED, SPEED – POWER, POWER – ENERGY LOSS, ENERGY LOSS – WEIGHT**, etc.

Here are two more examples.

Example 3. Usually conductors in integral circuits are made of gold, which has the smallest resistivity to energy flow, but an inadmissibly poor adhesion with the backing material. What can be done?

An intensified contradiction between **ELECTROCONDUCTIVITY** and **ADHEISION** arises.

Example 4. "In the end constructors came to the conclusion that during the planing of a yacht's body it was necessary to attain a kind of optimal compromise in the observance of three basic pre-requisites:

1) minimal resistance of the body's form;
2) maximal stability;
3) minimal resistance from friction.

These requirements are contradictory. A long narrow yacht has little resistance of form, however, it is not very stable and can not carry a sufficiently large sail. An increase in stability by means of an increased ballast weight accompanies the simultaneous increase in draught and, as a result, increases the resistance caused by friction. Increasing the stability by means of increasing the width of the body results in increased resistance from the form of the body. The constructor's problem lies in the search for a 'golden median' in the application of three contradictory construction principles."

Before solving these problems, we will consider another type of contradiction incorporated in ARIZ.

AGGRAVATED CONTRADICTION (AC) – presentation of diametrically opposed qualities (for example, physical) in a certain part of a technological system. This is necessary to determine the reasons producing the intensified contradiction, i.e., aggravated contradictions constitute the further intensification of the contradiction. Amplification (intensification) of contradictions can be continued to an even greater degree for the exposure of the contradiction's initial cause. For someone unacquainted with ARIZ the formulation of AC sounds unaccustomed and even unorthodox – **some part of the TS should be located simultaneously in two mutually exclusive states**: to be *cold* and *hot*, *in motion* and *motionless*, *long* and *short*, *flexible* and *rigid*, *electrically conducive* and *non-conducive,* etc.

The study of reasons producing intensified (technical) contradictions in technological systems as a rule leads to the necessity of exposing contradictory **physical** qualities of a system. Therefore, G.Altshller gave them the name **physical contradictions**.

We continue the examination of example 4.3.

Example 3 (continuation). We will formulate the aggravated contradiction (AC). In order for the conductor in the IMS to have low resistivity, it should be made of gold, but in order for the conductor to have good adhesion with the backing material, it should be made out of another material. A more concise and more extreme AC can be formulated: the material of the conductor should be **GOLD** and **NON-GOLD**. A typical solution for this type of aggravated contradiction is the use of an **INTERMEDIARY**.

Remember this law. We will return to it again. It's clear you have already guessed the solution. First apply a **pre-coat** that has good adhension with both the backing material and with gold, and then spray gold on this base. As a pre-coat use nickel or titanium.

Example 5. For the power supply of most radio-technical equipment (RTE) a industrial network with an alternating current is used, although the majority of RTE blocks, for example, the amplifier, generator and others, need a constant power voltage. For this reason it is necessary to have an element on the outlet of the amplifier that has contradictory physical characteristics. It should be **CONDUCIVE** for the positive half wave of the sinasoid flow and **NONCONDUCIVE** for the negative one in order to supply the amplifier with a polarized supply voltage. The given aggravated contradiction (AC) is solved by means of a rectifier acting on the diodes that possesses the indicated physical qualities and transforms the alternating current into a constant one.

It is worth stressing again that contrary to intensified (technical) contradictions, which belong to the system as a whole, aggravated (physical) contradictions concern only a certain part of the system.

In this manner, the three types of contradictions we have examined form a chain: **superficial contradiction (SC) – intensified contradiction (IC) – aggravated contradiction (AC)**, which determines the cause and effect relationships in the technological system under examination.

SC $\longrightarrow$ **IC** $\longrightarrow$ **AC**

We will illustrate this chain with examples.

Example 4.6. The non-ideal qualities of a switch for powerful transistors and diodes constitute the reason for loss of electrical energy. This energy heats the semiconductor and negatively effects its heating regime.

We will formulate the **superficial contradiction (SC)**: ***"It is necessary to improve the heating regime of the transistor (diode) switch in the radio-electric apparatus in which it positioned."*** Or: ***"It is necessary to prevent the heating of the force transistor in the amplifier of the radio receiver."*** In the first formula the PP indicates which quality must be improved, and in the second it shows the **harmful effect (HE) –** ***heating of the transistor***.

Elimination of the indicated superficial contradiction can be realized by creating a new transistor or by the application of a radiator, which improves the heating regime of the transistor. However, the addition of a radiator increases the dimensions of the radio apparatus.

The **intensified contradiction (IC)** is between the ***TEMPERATURE*** and the ***DIMENSIONS*** or between the ***LOSS OF ENERGY (POWER)*** and the ***DIMENSIONS.***

Improvement of heat abstraction necessitates the increase of the area of the radiator, but the decrease of the dimensions of the radio apparatus requires the decrease of the area of the radiator.

We will describe the **aggravated contradiction (AC)**: ***area of the radiator should be LARGE to facilitate the removal of heat, and SMALL in order to preserve the small dimensions of the radio apparatus.***

It is possible to resolve this kind of contradiction by means of a change in structure. Ribs should be created in the radiator. The general area of the radiator remains the same as before, but the dimensions of the apparatus do not increase and can even be decreased.

Example 2 (continuation). We will examine the example in which the carrying capacity of a ship must be increased. It is possible to decrease energy loss by eliminating the underwater section of the ship's body. But this section is crucial for the boat's stability while afloat. And so the following aggravated contradiction arises: **the underwater section of the body should preserve buoyancy and should not cause a rise in energy loss during increased speed.**

Example 4 (continuation). The example about the body design of a yacht reveals several aggravated contradictions.

1. **In order for the yacht to travel with great speed (having little resistance in form), the body should be long and narrow, but in order to carry a large sail (to be stable), the body should be wide.**
2. The second aggravated contradiction is related to another part of the yacht – to the ballast (keel). **To increase the stability of the yacht, the ballast should be heavy, but in order for the boat to be more maneuverable, the ballast should be light.**

Example 6. The invention of the rifle was intended to improve the results of shooting. To this end threading was added to the smooth barrel of the musket, along which the bullet was firmly driven. As a consequence it took more time and became much more complicated to load the rifle. It became necessary to insert the bullet by means of a ramrod (before this the weapon was loaded from the muzzle).

An intensified (technical) contradiction arose between the accuracy of the shot (the advantage of the rifle's threading) and the velocity of the shot or the ease of loading (the advantage of a smooth-barreled weapon – the musket).

At the heart of this intensified contradiction lies several aggravated contradictions (physical). Here are a few of them:

1. **In order to increase the accuracy of firing, threading on the inner surface of the barrel is necessary, but in order to ensure the ease of loading (to increase the speed of firing), threading is unnecessary (the inner surface of the barrel should be smooth).**
2. **Or – in order to increase the speed of firing the bullet should not lie close to the inner surface of the barrel, but to increase the accuracy of firing, the bullet should lie close to the inner surface and even cut into the threading.**

Note that these aggravated contradictions are created for different parts of the system (rifle): 1 – for the barrel, 2 – for the bullet.

At that time the bullet turned by means of greased matter (plaster) and could be inserted into the barrel with a ramrod and without extra force.

It then became clear that to increase the accuracy and distance of the shot, the bullet must be given a rotating motion, which helps the bullet become steadier and maintain flight in the specified direction. Spiral threading began to be used on the inner surface of the barrel. The previous contradiction was aggravated to an even greater degree in connection with the fact that it became even more difficult to load the rifle.

The rifle to a significant degree surpassed the smooth-barreled musket in terms of accuracy. In addition, loading the rifle turned out to be sufficiently difficult. Ramming the bullet became an exhausting operation; powder and the bullet, wrapped in plaster, were placed in the barrel separately, and in the period of one minute it was possible to fire no more than one shot.

In this case an aggravated contradiction appears.

Threading should be spiral to increase the accuracy of firing and should not be spiral (should be straight) to increase the velocity of the shot.

Here is another situation characteristic for aggravated contradictions: An old-fashioned rifle needed to be short in order to ease the insertion of bullets – sufficiently short so that it could not be used as a shaft for a bayonet. **The barrel of the rifle should be short so it is easier to ram the bullets, but it should be long in order to serve as a shaft for a bayonet.**

Now, having examined different contradictions, it is pertinent to remark again that solving a complex technological system means improving the necessary indices of the system without sacrificing the effectiveness of others. This can be achieved by way of exposing intensified (technological) contradictions, determining the reasons that cause them, or even the primary reasons for these reasons (exposure of aggravated contradictions), and eliminating the reasons, i.e., the solution of aggravated (physical) contradictions.

The stage of exposing aggravated contradictions constitutes the exact formulation of the problem.

The exposure of an aggravated contradiction during the solution of technological problems requires a certain kind of directed search, which is possible only through knowledge of the answer. In an actual technological problem, the answer, of course, is unknown.

Finding the correct approach to the solution can be achieved by focusing on the laws of developing technological systems, and, above all, on the law of increasing the degree of "idealness" of technological systems.

3. The path to the ideal

The solution of mathematical problems and problems "by quick-wittedness" is often achieved by the method "reversing the process." The essence of this method lies in the fact that in order to solve a problem, you need to start with the end result. The answer is to determine the final result. Clarifying this, the road to the beginning, i.e., the solution of the problem, is "paved."

It would be misleading to undertake the solution of technological problems in the same way. But how can one find out the answer?

Truly, during the solution of technological problems, the end result is unknown, however, it is still possible to continue on ... It is possible to imagine the ideal of a developed construction – this ideal construction is the **ideal final result (IFR)**.

An **ideal technological system** is one that does not exist, although its function is fulfilled, i.e., the goal is achieved without the means. IFR is the beacon to which one should look during the solution of problems. The closeness of the received solution to the ideal determines the level and quality of the solution.

IKR is the solution we would like to see in our dreams, carried out by fantastic creatures or means (magic wand). For example, a road that exists only where it touches the wheels of transport vehicles.

Researchers of the ocean's depths also dream of ideal constructions: "of course, already for many years people have known that an **ideal** (author's stress) apparatus would be one that creates 'earth-like' conditions on the ocean floor."

Example 7. The ideal emergency device in water would be a boat that is unsinkable in any weather condition. "... ship building firms of a number of countries have developed an "unsinkable" emergency boat, fully hermetic and accommodating 35 people in the deck, who fasten themselves to the seats by means of emergency belts. The boast is constructed of durable light material and can catapult from a height of 25 m without any harm to its passengers. Even after submersion beneath water it returns to the surface, maintaining a normal position.

One of the basic traits of an "ideal construction" ("ideal machine") is that it should **appear only at the moment when it is necessary to complete the necessary action, and furthermore, at that time it should undertake 100% of the rated working load.** This trait has been long known to us in fairy tales - "Скатерть-самобранка," etc. Many examples can also be found in real life: retractable and folding objects. For example, folding and attachable furniture (tables, couches, beds, etc.), inflatable objects (boats, emergency vests, mattresses, pontoons, etc.)

Example 8. For the rescue of people during emergency aircraft landings in water, English engineers developed a safety device that constitutes pontoons which automatically inflate with compressed air.

The second trait of an "ideal machine" or an ideal construction is that it doesn't exist at all, but the task it should carry out takes place as if by itself (with the help of magic wand).

The ideal truck is a container transporting a load. All other parts of the truck are extraneous and are unnecessary for the simple achievement of this goal.

IKR of a means of transport is when it does not exist, but nonetheless the load is transported (the load "itself" travels in the necessary direction with the necessary speed).

Here are examples of the quality of "idealness:"

Example 9. "Automobile seat belts must be changed periodically. The concern has been expressed that the material may weaken. Belts have been invented that show by their appearance when they need changing."

Example 10. "A layer of colored paint is applied to the tread of a protector and the number of kilometers traveled by the automobile before attrition of the applied layer is recorded. This method for evaluating the wearability of the tire is simple and useful during testing of the longevity of new types and constructions. This method can be used during the inspection of tires for their replacement.

Example 11. Window glass needs cleaning. To undertake this operation on high, large shop windows is somewhat labor-intensive. If the shops are "glazed" with lavsan film, then during a gust of light wind the film **itself** clears dust from the window. This film is transparent, light, and unharmed by hydrofluoric acid fumes. For the "glazing" of windows with this type of film lightened frames can be used.

Example 12. The contact between трущихся surfaces made of steel leads to their wear, therefore points of contact are lubricated.

Polish specialists claim that any steel becomes **self-lubricating** (IKR), without loosing its best mechanical qualities when 0,3% lead is added to it. It is possible to increase cutting speed and extend the useful life of instruments.

Example 13. In order for the nut in bolt connections not to work itself free during use, a second (counter) nut should be screwed onto the bolt.

The ideal in the given situation would be a "nut that fastens (locks) itself." Now more than a few different varieties of self-locking nuts already exist. Here is one of them.

The nut is reliably held in place at the end of the prong by sharp edges, which are directed on a tangent to the threading hole and have an angle of 7-10°. This type of solution allows the self-locking nut to be used many times. Furthermore, the installation and de-installation time is reduced by 30%, the reliability of the connections is increased and the nomenclature range of the fasteners is reduced. This kind of nut is especially necessary for connections which experience different kinds of loads.

In bolt connections without nuts, the bolt ITSELF should lock "...on the face surface of the head (in this case, on the bolt, but it is also possible on the nut - authors), directed towards the connected part and carried out by concentric tapered ringed projections (with the filing] - authors) (see fig. 1).

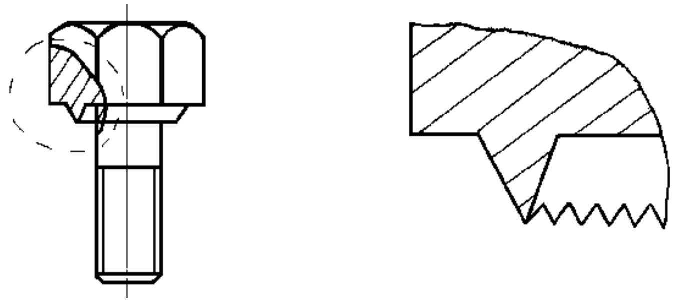
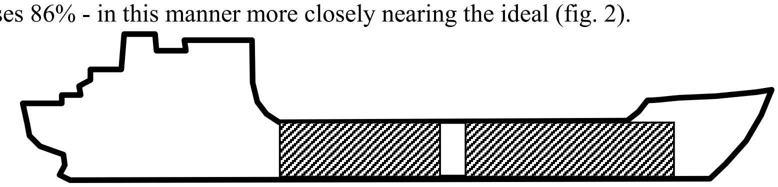


Fig. 1.

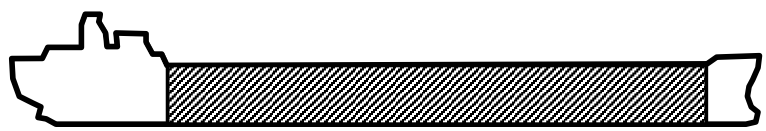
Striving for the ideal is the general tendency in the development of technological systems.

In means of transportation this tendency manifests itself particularly in the steady increase of the share of positive weight the transport vehicle uses. This explains the increase of displacement in ships, especially tankers.

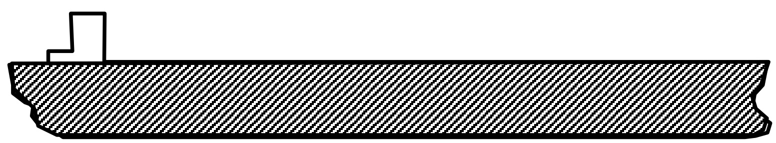
A tanker that displaces 3000 tons uses 57% of its displacement beneficially, whereas a tanker displacing greater than 200,000 tons uses 86% - in this manner more closely nearing the ideal (fig. 2).



a) A tanker that displaces 4760 tons



b) A tanker that displaces 102000 tons



c) Ideal tanker

Fig. 2.

Example 14. The processing of parts with abrasive wheels is accompanied by an increase of temperature at the contact zone. The heat negatively acts upon the surface layer of the part and increases the wear on the wheel itself.

IFR in the given case is when the wheel itself protects the part and itself from overheating.

In the Machine-building Institute grinding wheels were developed that consist of traditional components, but contain endothermic additives in their composition. During the high temperatures that occur during grinding they disintegrate with the absorption of heat and remove it from the grinding area.

It is interesting to mention that striving for an ideal is inherent not only in technological systems as a whole, but also in their individual parts and in the processes that take place in them.

Therefore, in an **ideal substance** the substance does not exist, but its function (durability, impermeability, etc.) remains. For exactly this reason there is the tendency to use increasingly lighter and more durable materials in modern ships, i.e., material with an increasingly greater proportionate durability and strength.

Example 6 (continued). We will determine the ideal final result.

IFR of a radiator (heat abstraction) – the radiator does not exist, but the full removal of heat from the transistor is preserved.

The radiator should not exist, but the heat should be removed by means of the transistor itself. The radiator should appear only when the transistor begins to overheat. The radiator should be removed from the boundaries of the given radio electrical apparatus (REA) or the role of the radiator should be performed by some other element. In this manner directives for the solution are determined.

In the first directive, it follows to create a means of transport without the loss of energy, so that the problem of heat removal does not arise. This directive is the most difficult and, as a rule, is not useful for the development of the REA.

The second directive is fully acceptable because it is possible to create a heat conductor with tabs of Ni-Ti - Nickel-titanium alloys (nitinol) – material possessing the quality “shape memory”. During normal temperatures the tabs are pressed to the transistor, but when temperatures increase beyond acceptable levels, the tabs unfold, increasing the area of the conductor.

Removal of the conductor from the REA – the third directive – is sufficiently easy to accomplish by means of positioning the radiator and transistor on the exterior wall of the block, as it is done in measuring devices: digital voltmeters and frequency meters. Or it is possible to use a heating pipe, which allows locally produced heat to be removed a significant distance away from its source.

The solution of the fourth directive – use of the elements in the block for the removal of heat – is similar to that of the radio electronics model. In addition to heat-releasing semiconductor devices, the model contains elements with heat-conducting bodies that perform this function, for example, electromagnetic relay. In order to reduce the dimensions of the model, relays are positioned in two rows. Between the rows are fitted heat-releasing elements that allow contact with the heat-conducting bodies of the relay.

Example 15. The ideal body of an underwater apparatus should have a minimal relative mass and, above all, preserve the quality of the material: small density and great proportionate strength and rigidity, providing the corresponding relationship between the limits of yield and model of elasticity to the density of the material.

Therefore the body of modern underwater apparatuses are created from titanium. This metal possesses high mechanical qualities, resists corrosion in sea water, and is not magnetic.

In some cases it is also possible to speak of the **ideal form**. The ideal form ensures the maximum positive effect, for example, durability with the minimum usage of material.

Example 16. In an underwater device the ideal form for a durable body is a sphere. It possesses high stability and not a great density. Spherical forms have a minimum relationship of surface area to volume.

The **ideal process** is the achievement of results without a process, that is, instantaneously. Shortening the process of preparing a product is the goal of any progressive technology.

Thus, the sectional method of assembling vessels was replaced by a more progressive one – the block method. In the sectional method, the body of the ship was first gathered on the building berth from separate sections (deck, sideboards, ship bottom, etc.), and then the equipment was installed. The block method of assembly brings entire blocks to the building berth, which consist of large voluminous parts of the ship with previously installed equipment. Blocks are created in the assembly shop from separate sections. It is here that the necessary equipment is installed. In this manner, all that remains is to join together the separate blocks on the building berth.

The constant battle to increase the transport speed of loads also characterizes the tendency to strive for an ideal process. Increase of the transport speed is achieved by steady growth of the speed of transport means and by shortening the time required for loading and unloading operations.

Example 17. The median speed of container ships from 1960 – 1975 grew from 15 to 25 knots. Reduction of the time needed for loading and unloading operations is enabled by means that are nearly ideal. This is a ship with a horizontal method of unloading of the type "ro-ro" (trailer), on which the weight "itself" drives onto the ship and off of it onto wheels; on lighters (barges) the weight "itself" swims to the ship and from the ship to the determined site (a kind of “wagon”).

The ideal solution, of course, is almost impossible to achieve. IFR is the standard for which we should strive. It is the closeness of the received solution to the IFR that determines the quality of the solution.

By comparing the real solution with the IFR, we determine contradictions. In this manner the IFR is an instrument, necessary for the exposure of contradictions and for the evaluation of the quality of the solution. Consequently, IFR serves as a kind of "guiding star" for the solution of technological systems.

4. The path to the idea of solution

Having examined the basic concepts of ARIZ – IFR, intensified and aggravated contradictions, – we can easily imagine the stages in the exact formula of a technical problem.

The definitive basic procedure for the solution of problems with ARIZ can be represented in the following manner:

$$\textbf{SC} \longrightarrow \textbf{IC} \longrightarrow \textbf{IFR} \longrightarrow \textbf{AC} \longrightarrow \textbf{SOLUTION} \qquad \textbf{(1)}$$

From the point of view of ARIZ, the problem is formulated exactly when SC, IC, IFR, and AC are revealed in accordance with the chain represented above (1). To formulate of all its links, first of all reveal that which does not suit the "poser" of the problem in the given situation (superficial contradiction - SC) and what is faulty in the system (undesirable effect). What kind of requirements are necessary to expect from the system?

Thus the intensified contradiction (IC) is determined. Then the system is expressed in such a way so that the undesired effect is absent from it, yet the positive qualities are preserved. The result of expressing the system in this manner constitutes the formulation of the ideal final result - IFR. After comparison of the actual situation and the IFR, obstacles to the achievement of the ideal result are revealed, reasons for the appearance of the obstacles are sought, and the contradictory qualities that appear in certain parts of the system (operative zones) and do not satisfy the requirements of the IFR are determined. In this manner the aggravated contradiction (AC) is formulated, which constitutes the exact formulation of the problem.

The sequence (1) is characteristic of the basic modification of ARIZ. The development of ARIZ aspires to formalize and detail the described sequence and to more fully use the laws of developing technological systems and the knowledge base. A modification of the algorithm for the solution of inventive problems, ARIZ-85-C.

Example 18. A powerful radar station (PRS) has a rather massive antenna with a large area. The antenna is fastened to a shaft, but turns on it very rarely, and therefore does not have a mechanism, but rotates manually. After rotating, the antenna is supported on the shaft with a fixative device and a bolt connection. The effort needed to support the massive antenna on the shaft is significant, and therefore it is necessary to tighten the bolts rather strongly. However, the shaft deforms under the pressure of the strong tie-beams and it becomes practically impossible to turn it the next time. What can be done?

The **superficial contradiction (SC)** is practically formulated already in the described initial situation: a fixative element is needed that does not cause deformation of the antenna shaft. **Harmful effect (HE)** – ***deformation*** of the shaft.

Intensified contradiction (IC) - ***fixation*** of the shaft leads to its ***deformation***.

Ideal final result (IFR) – the shaft should be ***fixed***, but ***without deformation***.

Aggravated contradiction (AC) – the fixative element should be ***hard***, in order to support the shaft, and ***soft*** in order not to deform it.

Solution – the shaft is supported by a substance that melts during rotation. In the process of invention, it was finally determined that the shaft should float. In a melted state, liquid will support the antenna and more easily position it in a new direction.

Example 19. Finding a person buried beneath an avalanche in the mountains is very difficult. Many activation devices have been created for this purpose, like a transmitter that emits a signal in the area where the buried person lies. But all of these devices are not capable of working in the actual conditions of an avalanche. First of all, few tourists will agree to carry a transmitter "just in case." Secondly, the batteries that power the transmitter quickly lose their charge, and even if the emergency signaling device can be turned on only at the necessary moment, this is usually impossible when buried in snow. What can be done?

SC – it is necessary to minimize the mass of the device for detecting snow-covered victims and to make it capable of operating for a long period of time. But reduction of the dimensions of the transmitter is accompanied by the reduction of its energy capacity and operating period – this is the undesired effect.

IC – reduction of the mass and dimensions of the transmitter is achieved at the expense of decreasing the mass of the energy source, i.e., at the expense of shortening the time of uninterrupted work.

IFR – the transmitter works without an energy source for any length of time.

AC – the energy source should be large in order to preserve a long operating period for the transmitter, and small (zero), in order not to increase the dimensions and mass of the transmitter. Or – the energy source should exist and not exist.

Solution – The Swiss firm "Sulab" created a device that consists of a metal bracelet, which is given to everyone who goes into the mountains. The bracelet consists of a passive receiver device with an antenna of metallic foil, but no energy source or transmitter. The foil antenna receives the signal of the rescuers, which has a powerful transmitter. Its power is sufficient to excite a current in the bracelet, as it is done in crystal detector receivers. The current is fed by a nonlinear circuit, which doubles or halves the frequency of the signal and transmits it by means of the very same foil antenna. The rescuers listen to the reflected signal on a doubled or halved frequency and, using a directional antenna, can determine from where the signal is being emitted. The system works constantly, even if the person buried in an avalanche is unconcious, and the period of time the system can work is unlimited by a battery that could fail, because it doesn't exist.

5. Logic of ARIZ

The logic of solving problems with ARIZ shows the interconnections between elements in the basic sequence (1):

SC ⟶ IC ⟶ IFR ⟶ AC ⟶ SOLUTION (1)

The **superficial contradiction** (**SC**) is described either as a need for the appearance of a *new quality* or *action* "**A**" (**positive effect**), or in the form of a **harmful effect** (**anti-B**), which it is necessary to eliminate.

A **superficial contradiction** (**SC**) more often than not is expressed in the form of a **harmful effect** (**HE**), i.e. a parameter or requirement "**B**" in an undesirable, harmful or insufficient condition that we label "**anti B.**" It is represented in a diagram like this:

SC (HE): anti-B.

For the determination of **intensified contradictions** (**IC**), we expose two contradictory requirements of the system. We represent these requirements with the letters "**A**" and "**B.**" The intensified contradiction can be presented as a need for the improvement of characteristics satisfying requirement "**A,**" which leads to the unacceptable deterioration of characteristics satisfying requirement "**B**" (expressed as requirement **anti-B**). The undesired effect consists of requirement "**B.**" Or the contradiction can be formulated in reverse – the improvement of "**B**" at the cost of the deterioration of **A** (expressed as "**anti-A**").

IC: A – anti-B or **anti-A – B**

The formula of the **ideal final result** (**IFR**) should aim to eliminate the harmful effect (**anti-B**), while preserving the positive requirement "**A,**" that is:

IFR: A, B.

The **aggravated contradiction** (**AC**) is determined by exposing contradictory properties "**P**" and "**anti-P**" (for example, physical), which should be possessed by the element of the system that does not correspond with the requirements of IFR. For this it is necessary to determine what property "**P**" the element should possess in order to preserve requirement **B**, i.e., in order to eliminate the undesired effect. Simultaneously, the same element should possess the contradictory property (**anti-P**) in order to preserve the positive effect **A**. In this manner, the element should possess the property "**P**" in order to satisfy the requirement **B** (expressed as **P→B**), and quality "**anti-P,**" in order to preserve the requirement **A** (expressed as **anti-P→A**).

$$\textbf{AC:}\quad \textbf{P} \longrightarrow \textbf{B},\ \ \textbf{anti-P} \longrightarrow \textbf{A}$$

Further intensification of the contradiction takes place by means of exposing more deep (latent) properties "$\mathbf{P_1}$," which are necessary for the creation (preservation) of the earlier exposed property "**P.**"

$$\mathbf{P_1} \longrightarrow \mathbf{P}$$

In some cases during the solution of complicated inventive problems, it is necessary to expose even deeper cause and effect relationships in the system. For this it is necessary to expose even more latent properties $\mathbf{P_2, P_2, \ldots P_n}$. The next quality in the progression determines the reason for the emergence of the previous quality, i.e., that which is necessary for the fulfillment of the quality.

$$\begin{aligned} &\mathbf{P_2} \longrightarrow \mathbf{P_1}\\ &\mathbf{P_3} \longrightarrow \mathbf{P_2}\\ &\ldots\ldots\ldots\ldots\ldots\ldots\\ &\mathbf{P_n} \longrightarrow \mathbf{P_{n-1}} \end{aligned}$$

In these cases several aggravated contradictions are exposed ($\mathbf{AC_1, AC_2, AC_3 \ldots AC_n}$). This can be represented in a diagram:

$$\begin{array}{llll} \mathbf{AC_1:} & \mathbf{P_1} \longrightarrow \mathbf{P}; & \mathbf{anti\text{-}P_1} & \longrightarrow \mathbf{anti\text{-}P.} \\ \mathbf{AC_2:} & \mathbf{P_2} \longrightarrow \mathbf{P_1}; & \mathbf{anti\text{-}P_2} & \longrightarrow \mathbf{anti\text{-}P_1.} \\ \mathbf{AC_3:} & \mathbf{P_3} \longrightarrow \mathbf{P_2}; & \mathbf{anti\text{-}P_3} & \longrightarrow \mathbf{anti\text{-}P_2.} \\ \cdots & \cdots\cdots & \cdots\cdots & \cdots\cdots \\ \mathbf{AC_n:} & \mathbf{P_n} \longrightarrow \mathbf{P_{n-1}}; & \mathbf{anti\text{-}P_n} & \longrightarrow \mathbf{anti\text{-}P_{n-1}.} \end{array}$$

Solution of the problem (SP) consists of the solution of the aggravated contradiction, for example, by means of separation of the contradictory properties $\mathbf{P \ldots P_n}$.

$$\begin{array}{rr|l} \textbf{SP:} & \mathbf{P} & \textbf{anti P} \\ & \mathbf{P_1} & \textbf{anti } \mathbf{P_1} \\ & & \ldots\ldots \\ & \mathbf{P_n} & \textbf{anti } \mathbf{P_n} \end{array}$$

Typical methods of separating contradictory qualities are indicated in the textbook on ARIZ.

The logical diagram for the solution of problems with ARIZ is shown fully in fig. 3.

LOGICAL DIAGRAM OF ARIZ

$$\begin{array}{ll} \textbf{SC (HE):} & \textbf{anti-B} \\ \downarrow & \\ \textbf{IC:} & \textbf{A – anti-B} \\ \downarrow & \\ \textbf{IFR:} & \textbf{A, B} \\ \downarrow & \\ \textbf{AC:} & \textbf{P} \longrightarrow \textbf{B},\ \ \textbf{anti-P} \longrightarrow \textbf{A,} \\ \downarrow & \\ \textbf{SP:} & \textbf{P} \mid \textbf{anti-P} \end{array}$$

Fig. 3.

Problem 1

It is necessary to transfer all of the gas from a transport cylinder to two empty (working) cylinders. The capacity of each of the working cylinders is equal to one half of the capacity of the transport cylinder.

Two methods for transferring gas are known (fig. 4).

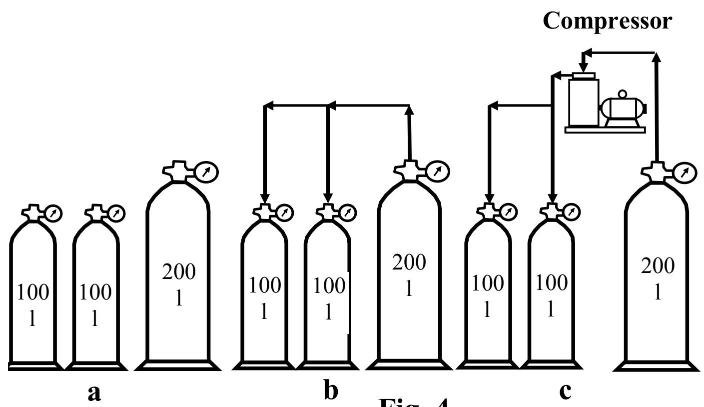


Fig. 4.

a) initial situation; b) direct connection of the transport cylinder with the working cylinder; c) connection by means of a compressor.

In the first method (fig. 4 b) the transport cylinder connects directly with the working cylinder. In this case, an equal pressure is fixed in all the cylinders, and one half of the gas will remain in the transport cylinder. The second method (fig. 4 c) is much more complicated: gas is pumped from the large cylinder into two others by means of a compressor. In this manner it is possible to transfer all of the gas, but it is necessary to use special equipment – a high-pressure compressor.

The problem consists of finding a method to fully transfer the gas from the transport cylinder to the working cylinder without the use of additional equipment (compressor).

This kind of problem is encountered during the "loading" of cylinders in deep-diving apparatuses at seaports. Compressed air is used for purging the cistern during surfacing of the apparatus.

Solution of the problem

1. **Short formulation of the problem**
   Find a simple method of transferring all of the gas from one cylinder to two others.
2. **Formulation of the superficial contradiction (SC)**

   SC: anti-B

   Part of the gas remains in the cylinder.
   (Harmful Effect): **INCOMPLETE** (**anti-B**) transfer of gas.
3. **Determination of the aggravated contradiction (AC)**
   In the given example, the transfer of gas is possible with and without the use of a compressor:
   - **with compressor**

   AC_1: B – anti-A

   The gas transfers **completely** (**B**), but as a result the system is **complicated** (**anti-A**).
   AC_1: Complete transfer of gas - **Complication.**
   All of the gas can be transferred from the transport cylinder to the working cylinder using a compressor, which **complicates** the system.
   - **without compressor**

   AC_2: A – anti-B

   The system is **not complicated** (**A**), but the gas transfers **incompletely** (**anti-B**).
   AC_2: Simplicity - Loss of gas.
   The **simple** method (direct connection) is used, but as a result one half of the gas is **lost**.
4. **Selection of AC.** We select **AC_2**, because this formula is based on the use of a **simple method.**
   Note: Within this step we selected a method of transferring gas only through the direct connection of one cylinder with another.
5. **Formulation of IFR**

   IFR: A, B

   The gas "itself" **fully** - (**B)** (with the same pressure and in the same quantity) transfers from one cylinder into two others, **without the use** (**A**) of additional equipment (**compressor**).
   IFR: Simplicity – Loss of gas.
6. **Formulation of the aggravated contradiction (AC).**

   AC: P→A, anti-P→B

   In order not to complicate the system, it is necessary to directly connect the cylinder with gas to an empty (working) cylinder, but this increases the general capacity in which the gas is located (decreasing its pressure), therefore not allowing the gas to be fully transferred. In this manner the "extra" **capacity** (quality

"**C**") should exist, so that the system remains **simple** "**A**," and should not exist (quality **anti-C**), so that the gas transfers **completely** "**B**."

Note: Remember that the basic characteristic of gas is to **occupy the entire available volume**. Therefore, during connection of the working cylinders, gas expands and occupies the entire capacity of the cylinders, while the pressure decreases.

7. **Formulation of aggravated contradiction 1 (AC_1).**

$$\mathbf{AC_1: P \to P_1, anti\text{-}P \to anti\text{-}P_1}$$

So that there is not an **excess capacity** "**P,**" the working cylinder should not be empty (it should be **filled**) "**C_1**," but to provide space for the **transfer of gas,** "**anti-P,**" the capacity of the working cylinder should be **empty** "**anti-P_1**."

The connected **cylinders should be filled** to prevent the gas from expanding, but **should not be filled** (should be empty) so that they can be filled with the required gas.

Note: In this step we determined the exact formulation of the problem.

8. **Solution of the problem** (solution of the AC)**.**

The separation of contradictory qualities can take place:

- **in space,**
- **in time,**
- by changing the **system's structure,** specifically, changing the ***aggregate condition***.

Therefore, the contradictory qualities are: the working cylinder should be **FULL** and **EMPTY** (filled and unfilled).

In space this contradiction ***is unsolvable***.

Separation of the indicated contradictory qualities **in time** requires that the ***substance*** filling the working cylinder ***gradually free space for the gas*** entering from the transport cylinder and fill the freed space in the transport cylinder.

It only remains to explain what kind of substance should fill the working cylinder. For this, **structural changes of the substance** are used, changing the **aggregate condition** of the gas.

The substance inside the working cylinder is located in a gaseous state, which does not satisfy our conditions. That means it should be made **solid** or **liquid**.

Should the cylinder be filled with a solid substance? A solid monolithic substance does not possess the necessary qualities. In this manner we could ruin the cylinders. Of course it is possible to fill the cylinders with sand or ice. That condition might solve the problem in principle, but it is not sufficiently effective. It remains to use liquid.

If the working cylinders are filled with a liquid excluding gas, placed above the transport cylinder, and connected by means of pipes, than the gas (fully and without a compressor) will transfer from the transport cylinder to the working one (fig. 5).

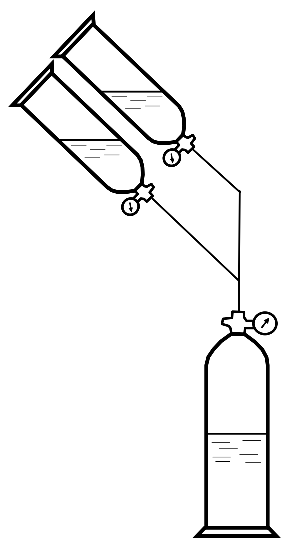


Fig. 5.

The idea of invention has been found.

4. Conclusion

The solution of problems with ARIZ constitutes a sequence for the exposure and solution of contradictions and the reasons that produce the given contradictions, as well as their elimination by use of the knowledge base. In this manner cause and effect relationships are determined – the essence of which is the intensification and aggravation of contradictions.

Use of the basic line of ARIZ and logic of ARIZ allows revealing original causes of a problem and relationships of cause and effect. Regular use of logic ARIZ allows developing the inventive thinking revealing and resolving the contradictions.