ALGORITHM OF INVENTIVE PROBLEM SOLVING

WARNING!

ARIZ is a complicated tool. Do not apply it to solve new practical problems without at least 80 academic hours of preliminary study.

ARIZ is a tool for thinking, but not a replacement for thinking. Do not hurry! Consider each step carefully. Also, it is necessary to note all considerations (in the margins) which occur during the problem solving process.

ARIZ is a tool for solving non-typical problems. Let's check: may your problem be solved using the System of Standard Solutions for Inventive Problems (Inventive Standards)?

PART 1. ANALYZING THE PROBLEM

1.1. formulate the mini-problem
1.2. define the conflicting elements
1.3. describe graphic models for technical contradictions
1.4. select a graphic model for further analysis
1.5. intensify the conflict
1.6. describe the problem model
1.7. apply the inventive standards

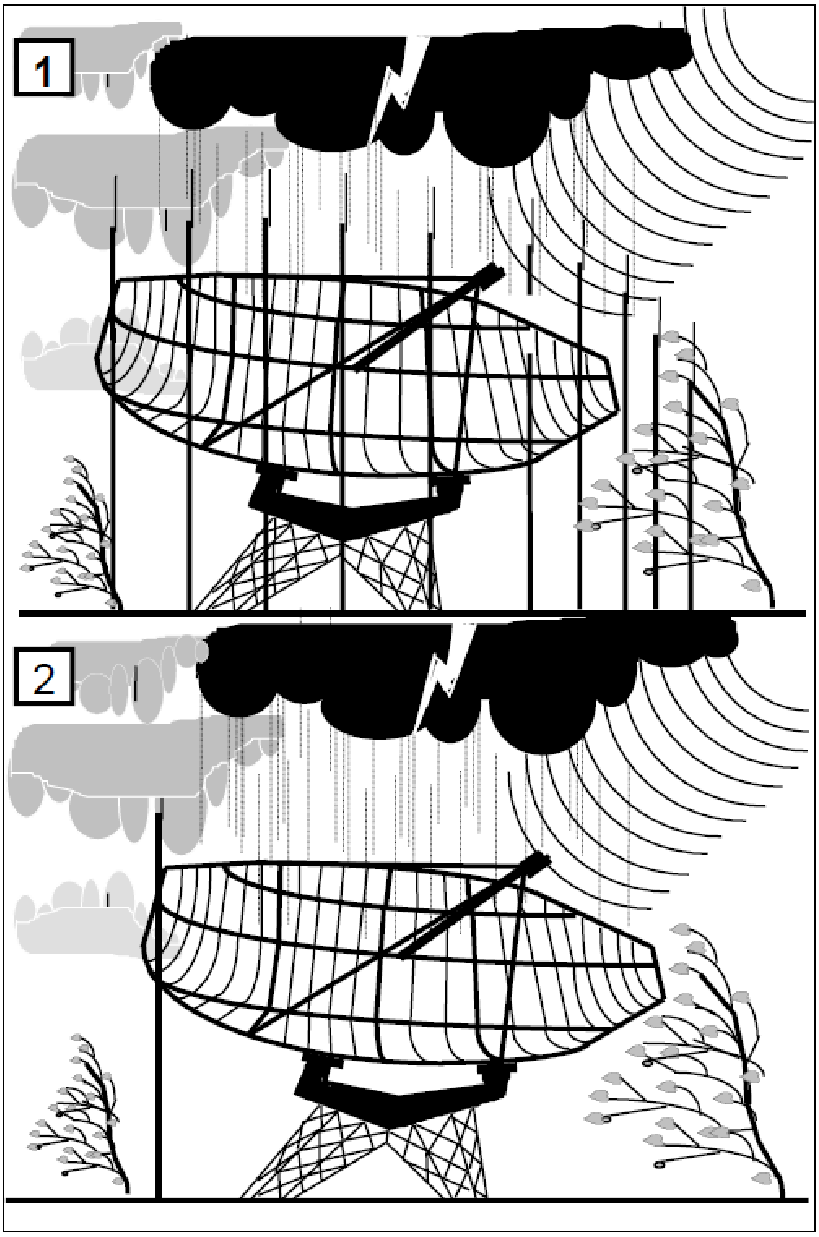
The main purpose of Part 1 is the transition from an indefinite initial problem situation to the clearly formulated and extremely simplified description (model) – Problem Model.

1.1. formulate the mini-problem

Formulate the "mini-problem" conditions (without special terms) according to the following pattern:

A technical system for <state the purpose of the system> includes <list the main parts of the system>.
Technical contradiction 1 (TC-1): (identify).
Technical contradiction 2 (TC-2): (identify).
It is necessary, with minimum changes to the system, to <state the required result>.

> *Example:*
>
> *The technical system <for receiving radio waves> includes <radio telescope's antenna, radio waves, lightning, and lightning rods>.*
>
> *TC-1: if there are many lightning rods, then they reliably protect the antenna from lightning, but absorb radio waves.*
>
> *TC-2: if there are few lightning rods, then there is no remarkable absorption of radio waves, but the antenna is not protected from lightning.*
>
> *It is necessary with minimum changes to the system, to <protect the antenna from lightning without absorbing radio waves >.*
>
> *(For this definition the special term "lightning rod" should be replaced with "conducting rod", "conducting column" or simply "conductor").*



Comments:

1. The mini-problem is obtained from the initial problem situation by introducing restrictions: "Everything in the system remains unchanged or is simplified, while the required action (or property) appears or a harmful action (or property) disappears. The transition from the problem situation to the mini-problem does not mean imply solving a small problem. Quite the contrary, introducing additional requirements (the result has to be achieved "without nothing") leads to an intensification of the conflict, and cuts off paths to compromise solutions.

2. While formulating step 1.1, one should indicate not only the technical parts of the system but also the natural ones that interact with the system. In the problem of protecting the telescope antenna the natural parts of the system are lightning and received radio waves (if they are emitted by natural cosmic objects).

3. **The Technical contradictions (TC)** denote the interaction in the technical system when the useful actions create the harmful ones. In other words, introduction (or improvement) of a useful action, or elimination (or reduction) of a harmful action, causes degradation (in particular, complication) of either all or part of the system.
   Technical contradictions are formulated by identifying (writing down) one state of a

system element with explanation of both the good and bad results of this state. Then the opposite state of the system element is identified, along with its associated explanation. Sometimes one simply gives the *product* as the problem situation. In this case there is no technical system (a *tool*) and therefore there is no clear technical contradiction (TC). Here the TC can be identified by considering two states of the *product*, even if one of the states is impossible to achieve.

> *For example a problem is stated: "How does one observe the micro-particles in a sample of an optically clean liquid with the naked eye? The particles are so small, that the light flows around them?"*
>
> *TC-1: if the particles are small, then the liquid is optically clean, but it is impossible to observe the particles with the naked eye.*
>
> *TC-2: if the particles are big, then they are easily observed, but the liquid is not optically clean. This is an unacceptable consequence.*
>
> *It seems that the problem definition excludes considering TC-2: changing the* product *is forbidden! In fact we will consider only TC-1 for this problem, but TC-2 will give us additional requirements for the* product*: small particles have to be small and have to also become large.*

4. To reduce mental inertia special terms associated with the *tool* and environment should be replaced with easy words, because special terms:

   - impose old concepts about working principles of the tool: for example, "the icebreaker breaks ice", when it is possible to move through the ice without breaking it;
   - can hide certain properties of the elements described in the problem situation: "mould" (to form concrete) this is not a plain "wall", but an "iron wall";
   - narrow the range of possible states of a substance: the term "paint" implies liquid or solid paint, although paint may be gaseous.

1.2. define the conflicting elements

Identify and write down the conflicting pair: a ***product*** and a ***tool***.

Rule 1.

If the tool, according to the problem situation conditions, can be in two states, it is necessary to indicate both of these states.

Rule 2.

If the problem situation includes several similar pairs of interacting elements, it is enough to consider only one pair.

> *Example:*
>
> **Product:** *lightning and radio waves.*
>
> **Tool:** *conducting rods (many rods or a few rods).*

Comments:

5. **The product** is the element that needs to be processed (manufactured, moved, changed, improved, protected from a harmful influence, revealed, measured etc.) according to the problem conditions. For problems concerned with detection and measurement some elements considered as *tools* (according to its base function), can be considered as *products* (e.g., grinding wheel).

6. **The tool** is the element that directly interacts with the *product* (e.g., mill rather than a milling machine; fire rather than a burner). In particular, a part of the environment can be considered as a *tool*. The standard parts from which the product is assembled can be considered as a *tool* too (e.g., meccano this is a tool for creating various "products").

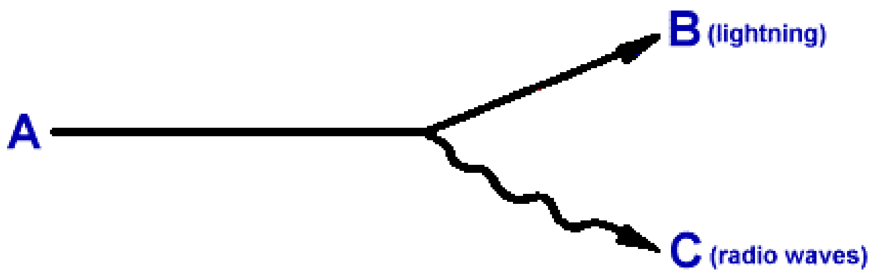
7. One of the elements in the conflicting pair can be doubled. For instance, two different *tools* are given, and they have to act on the *product* simultaneously, where one *tool* interferes with the other. Or two *products* are given, and they have to be processed with the same *tool*, where one *product* interferes with another.

1.3. describe graphic models for technical contradictions

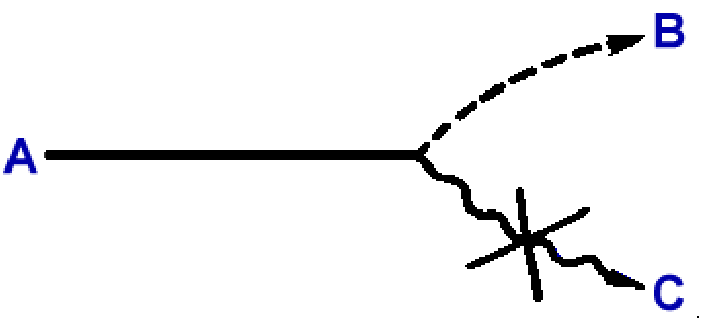
Build graphic models for conflicts TC-1 and TC-2 using Table 1. Typical Graphic Models of Technical Contradictions.

Example:

TC-1: Many conducting rods



TC-2: A few conducting rods

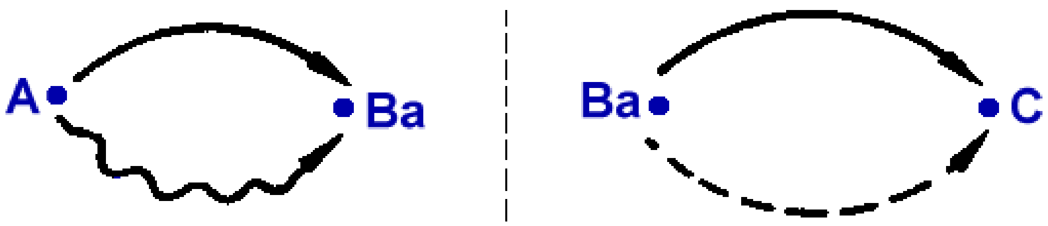


Comments:

8. Table 1 contains graphic models of typical conflicts. It is acceptable to use original (atypical) graphic models if they describe the meaning of conflict clearly.

9. Some problems can be described by multi-linked graphic models, for example:

Such models can be converted as two one-linked graphic models:



If B is considered as a *modified product* or if the basic property (or state) of A is transferred to B.

10. The conflict can be considered *in time* as well as *in space*.

11. Steps 1.2 and 1.3 specify the general problem situation description. Therefore it is necessary to return to step 1.1 after step 1.3 and to check if there is any discordance in the sequence 1.1 - 1.2 - 1.3. If a discordance exists, it is necessary to remove it and set up the sequence.

1.4. select a graphic model for further analysis

From the two graphic models of conflict it is necessary to choose the one which provides the best performance for the Main Manufacturing Process (i.e., the main function of the technical system as indicated in the problem description). Indicate what the Main Manufacturing Process (MMP) is.

> *Example:*
>
> *In the problem of protecting the radio telescope antenna the Main Manufacturing Process is receiving radio waves. Therefore TC-2 should be chosen: in this case the conducting rods do not absorb the radio waves.*

Comments:

12. By choosing one of the two graphic models of the conflict, one state of the *tool* is chosen above its two opposite states. Further problem solving efforts should be related to this state. It is prohibited to replace *few conductors* by some *optimal number of conductors. ARIZ requires intensifying the conflict rather than smoothing it over.*

    Keeping in mind one state of the tool, it will be necessary to achieve the required positive property of this tool while it is in this state. The needed property is inherent in another state of the tool.

    > *There are few conductors and we will not increase their number, but as a result of solving the problem the lightning has to be eliminated in the same manner as if there were many conductors.*

13. From time to time, it is difficult to define the MMP for measurement problems. Ultimately, measurements are almost always performed for modification purposes, i.e. to process a product, to produce something, etc. Therefore the MMP for measurement problems is the MMP of the whole system, not just its measuring part.

    > *For instance, it is necessary to measure gas pressure inside electric bulbs. MMP - to produce electric bulbs rather than to measure gas pressure.*

    However, some problems of measurement for scientific purposes can be considered as an exception.

1.5. intensify the conflict

Intensify the conflict by indicating the extreme state (action) of the elements.

Rule 3.

Most problems contain the following types of conflicts: "many elements" versus "few elements" ("strong element" versus "weak element" etc.). The conflict of "few elements" should be converted into the form "no elements" ("absent element") only.

> *Example:*
>
> *Let's consider that instead of "few conductors" there are "no conductors" in TC-2.*

1.6. describe the problem model

Formulate the Problem Model to indicate the following:
1) the conflicting pair;
2) the intensified conflict definition;
3) what the introduced X-element has to do to solve the problem (what the X-element should keep, eliminate, improve, provide, etc.).

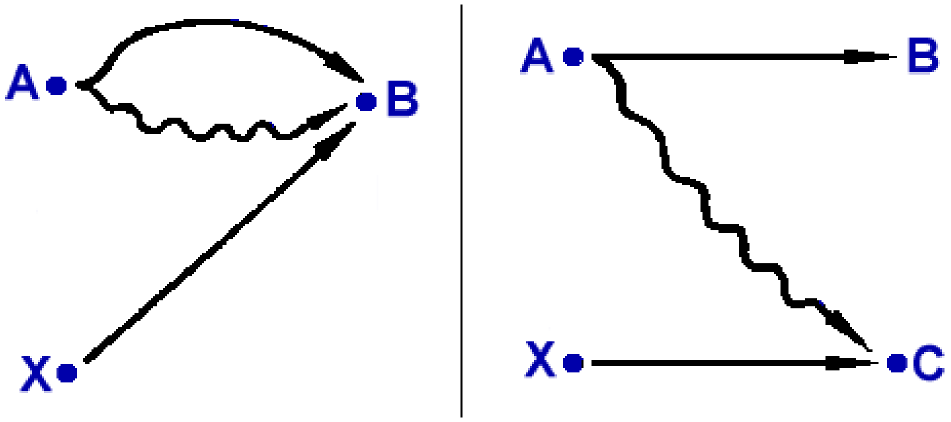
> *Example:*
>
> There are no conductors and there is lightning. The absent conductors do not cause interference (when the antenna receives the radio waves) and do not provide protection from lightning.
>
> One must find an X-element that will keep the ability of the absent conductors to avoid interference (with the antenna) and that will provide protection from lightning.

Comments:

14. The Problem Model is a type of abstraction where only some of the elements of the technical system are artificially selected. Other elements are implied only.

    > *For instance, in the Problem Model of antenna protection only two of the four elements (the antenna, radio waves, the conductor and lightning) are selected. Another two elements are just implied - they could be completely ignored.*

15. After step 1.6 one must return to step 1.1 and check the logic behind the creation of the Problem Model. Generally it is possible to define the chosen graphic conflict model more precisely by indicating the action of the X-element, for instance:



16. The X-element is not necessarily the new material part of the system. The X-element is some modification of the system, something basically unknown - X. For instance, it may be a temperature change or phase state changes for some part of the system or the environment.

1.7. apply the inventive standards

Check the possibility of applying the System of Standard Solutions for Inventive Problems for solving the Problem Model. If the problem has not been solved, go to Part 2 of ARIZ (i.e., steps 2.1 - 2.3). If the problem has been solved, go to Part 7 of ARIZ. Although in this case, it is recommended to continue the analysis through Part 2.

Comment:

17. The analysis performed in Part 1 of ARIZ and the development of a Problem Model clarifies the problem and in many cases allows the identification of standard (typical) properties of non-typical problems. It gives the possibility of using the Inventive Standards more effectively than for the initial problem situation description.

PART 2. ANALYZING THE PROBLEM MODEL

2.1. define the Operational Zone (OZ)
2.2. define the Operational Time (OT)
2.3. define the Substance-Field resources (SFR)

The main purpose of Part 2 is to identify available resources (space, time, substances, and fields) that may be useful for solving the problem.

2.1. define the Operational Zone (OZ)

Analyze and describe the Operational Zone (OZ).

Comment:

18. In the simplest case the Operational Zone is the space where the conflict indicated in the Problem Model appears.

> *Example:*
> *In the antenna protection problem the OZ is the space previously occupied by the lightning conductor, i.e., mentally defined as the "empty" rod, or "empty" column.*

2.2. define the Operational Time (OT)

Analyze and describe the Operational Time (OT).

Comment:

19. The operational time is when there are available resources of time: the time when conflict occurs (T_1) and the time before the conflict (T_2). A conflict (especially high-velocity, short-term) can usually be eliminated (prevented) during T_2.

> *Example:*
> *In the antenna protection problem the Operational Time consists of the time (T_1') during lightning discharge and the time before the next lightning discharge (T_1''). T_2 is not considered here.*

2.3. define the Substance-Field Resources (SFR)

Define the Substance and Field Resources (SFR) of the analyzed system, the environment, and the product. Compose a list of SFR.

Comments:

20. Substance and Field Resources (SFR) are substances and fields that already exist or may be easily obtained according to the problem conditions. There are three types of SFR:

    1. System (internal) resources:
    a) SFR of the tool;
    b) SFR of the product.

    2. Available (external) resources:

a) SFRs of the environment for the particular problem conditions, for instance, for the problem about small particles in optically clean liquid, water is a SFR;
b) SFRs which are common to all environments, including "background" fields, for instance gravity and the magnetic field of the Earth.

3. SFRs of the super-system:
a) waste materials of some outside systems (if available according to the problem conditions);
b) very cheap outside resources, where the cost may be ignored.

When solving a Mini-Problem it is necessary to achieve the needed result with the minimum expenditure of SFRs. Therefore, the utilization of internal (system) SFRs should first be considered. However, when it is necessary to develop solution concepts and/or solve forecasting problems (i.e., Maxi-Problems) the maximum amount of various SFRs should be considered.

21. It is known that the product is the unchangeable element - so what kind of resources might it have? Indeed the product can not be changed, i.e. it is unsuitable to change the product while solving the Mini-Problem. However, sometimes the product can:
    a) change itself;
    b) allow partial consumption (i.e. modification), when the product is unlimited (for instance, wind etc.);
    c) allow transition to the super-system (for instance, the brick has not changed, but the house has changed);
    d) allow application of micro-level structures;
    e) be combined with "nothing", i.e. with voids;
    f) allow temporary modification.

    Therefore, the product can be considered as an SFR only in rare cases where the product can be easily modified "without modification".

22. The SFRs are available resources and thus they should be utilized first. If there are not enough available resources other substances and fields can be considered. The analysis of SFRs in step 2.3 is preliminary.

> *Example:*
>
> *In the antenna protection problem the "absent lightning conductor" is considered. Therefore the SFRs contain only substances and fields from the environment. In this case an SFR is the air.*

PART 3. DEFINING THE IDEAL FINAL RESULT (IFR) AND PHYSICAL CONTRADICTION (PhC)

3.1. formulate IFR-1
3.2. intensify the definition of IFR-1
3.3. identify the Physical contradiction for the Macro-level
3.4. identify the Physical contradiction for the Micro-level
3.5. formulate IFR-2
3.6. apply the Inventive Standards to resolve the Physical contradiction

As result of applying Part 3 the image of the Ideal Final Result (IFR) should be formulated. The Physical Contradiction (PhC) that prevents the achievement of the IFR should be identified too. The ideal solution is not always achievable, but the IFR indicates the direction of the most powerful solution.

3.1. formulate IFR-1

Formulate and describe IFR-1 using the following pattern:

The X-element, without complication of the system and without harmful side effects, eliminates
<indicate the harmful action>
during the <Operational Time>
inside the <Operational Zone>,
and keeps the tool's ability to provide
<indicate the useful action>.

> *Example:*
>
> *The X-element without complication of the system and without harmful side effects, eliminates*
>
> *<the "non-attraction" of lightning by the absent conducting rod>*
>
> *during the <Operational Time>*
>
> *inside the <Operational Zone>,*
>
> *and keeps the tool's ability to provide*
>
> *<"non-hinderance" of the antenna's reception>.*

Comment:

23. There are other conflicts besides the conflict "a harmful action is associated with a useful one", for instance "introducing a new useful action results in complicating the system" or "one useful action is incompatible with another one". Therefore the formulation of the IFR, identified in step 3.1, is just a pattern for writing down the IFR.

    A basic definition of the IFR is the following: a useful feature should be obtained (or a harmful feature eliminated) without deteriorating other features (or producing harmful features).

3.2. intensify the definition of IFR-1

Intensify the formulation of IFR-1 by introducing additional requirements:
the introduction of new substances and fields into the system is prohibited, it is necessary to use the SFRs only.

> *Example:*

> *There is no tool in the antenna protection Problem Model ("absent lightning conductor"). According to Comment 24 the environment should be introduced into the definition of IFR-1, i.e. it is necessary to replace an X-element with the word "air" (or, more exactly: "the air column where the absent lightning conductor was").*

Comment:

24. According to Comments 20 and 21, SFRs should be considered in the following order during the problem solving process:
    - SFR of the tool (system/internal resources);
    - SFR of the environment (available/external) resources);
    - SFR of super-system;
    - SFR of product (if it is not prohibited by Comment 21).

    The above types of resources (SFR) determine four directions of further analysis. In practice, the problem conditions cut off some directions. When solving the Mini-Problem, it is enough to develop analysis up to the point where a solution concept is obtained; for instance, if a concept was obtained on the "tool line" (first line, above), then the other directions need not be considered. When solving the Maxi-Problem, it is necessary to consider all available directions. Thus, if you have found a concept on the "tool line", one should still consider the directions for environment SFRs, for super-system SFRs, and for product SFRs.

    When mastering ARIZ, a sequential, linear analysis is gradually being replaced by parallel analysis: the ability to transfer the solution concept from one "line" to another. This kind of ability is called "multi-screen thinking": the possibility to analyze the changes for a super-system, a system, and subsystems simultaneously.

WARNING!
Problem solving is accompanied by the break-down of old conceptions. New concepts appear which often can not be adequately described in words. For instance, how does one describe the property of paint to dissolve, without dissolving (to paint, without painting)?..
When applying ARIZ it is necessary to describe the analysis using simple, non-technical, even "childish" words, avoiding special terms (since they increase mental inertia).

3.3. identify the Physical contradiction for the Macro-level

Identify and describe the Physical contradiction at **Macro-level** using the following pattern:

the <Operational zone>,
during the <Operational time>,
has to… <indicate physical macro-state, for example "hot">
in order to perform <indicate one of the conflicting actions> and
has to… <indicate the opposite physical macro-state, for example "cold">
to perform <indicate another conflicting action or requirement>.

Comments:

25. The **Physical contradiction** is the opposing requirements from the physical state of the Operational Zone.

26. If it is difficult to give a complete definition of the Physical Contradiction, it is acceptable to define the *brief* PhC according to the following pattern:
    The element (or a part of it in the operational zone)
    Has to be <feature> to perform <indicate> and
    Does not have to be <feature> to perform <indicate>.

> *Example:*
>
> *The <air column>, during the Operational Time*
> *has to be <conducting> to <remove the lightning> and*
> *does not have to be <conducting> to <prevent absorption of the radio waves>.*
>
> *This definition suggests the answer: the air column has to be electrically conductive when there is a lightning discharge and should not be conductive all the rest of the time. Lightning discharge occurs relatively seldom and it acts quickly. The Law of Harmonization: the periodicity of the appearance of the lightning conductor has to be the same as the periodicity of lightning strikes.*
>
> *Obviously, this is not a complete solution concept. For instance: How can the air column be transformed into a conductor when lightning strikes? How can the conductor be made to disappear immediately after the lightening has struck?*

WARNING!
When solving a problem using ARIZ, the solution concept develops slowly (gradually).
It is risky to interrupt the problem solving process when an idea first appears or you may later find yourself fixing a half-developed idea. Follow through the solving process to the end of ARIZ!

3.4. identify the Physical contradiction for the Micro-level

Identify and describe the Physical contradiction at **Micro-level** using the following pattern:

There should be particles of a substance <indicate their physical state or action> in the Operational Zone
in order to provide <indicate the macro-state according to step 3.3>
and there should not be the particles (or particles should have the opposite state or action)
in order to provide <indicate another macro-state according to step 3.3>

> *Example:*
>
> *There should be <free charges> in the Air Column (when lightning strikes)*
> *to provide <electrical conductivity to "remove" the lightning>*
> *and there should not be <free charges> (the rest of the time)*
> *to provide <prevention of the absorption of the radio waves>.*

Comments:

27. It is not necessary in step 3.4 to precisely define the term "particles". For instance, the domains, molecules, ions etc. can all be considered as particles.

28. The particles may be:
    a) particles of a substance;
    b) a combination of particles and fields, or
    c) "particles of a field" (seldom).

29. If the problem has a solution only on the Macro-Level, there may be difficulties formulating step 3.4 because the definition of the PhC on the micro-level provides additional information: the problem is solved on the macro-level. In other words, attempting to formulate the Physical Contradiction for the micro-level can prove beneficial, if only because it provides us with the additional information that the problem has to be solved at the macro-level.

WARNING!
The first three parts of ARIZ essentially change the initial problem. Step 3.5 summarized this change. By formulating Ideal Final Result (IFR-2), we obtain an entirely new problem, a physical one. From this point we have to focus on this new problem!

3.5. formulate IFR-2

Identify and describe the Ideal Final Result (IFR-2) using the following pattern:

The Operational Zone <indicate>
has to provide <indicate the opposite macro- or micro-states>
itself during the Operational Time <indicate it>.

> *Example:*
>
> *The <neutral molecules in the air column> have to <transform themselves into free charges> during <lightning strikes>, and <the free charges> have to <transform themselves into neutral molecules> <after the lightning strikes>.*
>
> *The meaning of this new problem is as follows: for the duration of the lightning discharge the free charges should appear on their own inside the air column; in this case the column of ionized air acts as the lightning-conductor and "attracts" the lightning. Immediately after discharge the free charges in the air column should, on their own, become neutral molecules again. To solve this problem a knowledge of middle-school physics is needed.*

3.6. apply the inventive standards to resolve the physical contradiction

Check the possibility of applying the Inventive Standards to solve the new Physical Problem that was formulated as IFR-2. If after doing this, the problem is still unsolved, go to Part 4. If the problem is solved using the Inventive Standards it is possible to go to Part 7, however it is recommended to continue the analysis through Part 4 anyway.

PART 4. MOBILIZING AND USING SUBSTANCE-FIELD RESOURCES (SFR)

4.1. simulation with little creatures
4.2. take a "step back" from the IFR
4.3. using a combination of substance resources
4.4. using "voids"
4.5. using derived resources
4.6. using an electrical field
4.7. using a field and field-sensitive substance

At step 2.3, the available resources, which can be used "free of charge", were identified. Part 4 of ARIZ includes systematic procedures to increase the availability of resources. One considers the derivative SFRs that can be obtained almost free of charge through slight modification of the already available resources. Steps 3.3-3.5 began the transition from the problem to the solution based on the application of physics; Part 4 continues in this direction.

Rule 4.

Particles of any kind that are in one state have to perform one function only. In other words, rather than using "A" particles to perform functions 1 and 2, they have to perform function 1, and "B" particles have to be introduced for the purpose of performing function 2.

Rule 5.

Introduced "B" particles may be divided into two groups: B-1 and B-2. This provides the possibility of performing a new function (3) "free of charge" by arranging an interaction between the two groups of "B" particles.

Rule 6.

If the system must include only "A" particles, these can be divided into two groups as well: one group of particles remains in the previous state; the main parameter of the other particles are changed according to the problem.

Rule 7.

Groups of particles that are divided or introduced have to become identical to each other, or to previously existing particles, after carrying out their functions.

Comment:

30. Rules 4 through 7 apply to all of Part 4 of ARIZ.

4.1. simulation with Little Creatures

Method of Simulation with Little Creatures

a) describe a graphic model of conflict using the Simulation with Little Creatures (SLC);
b) modify this graphic model so that the "Little Creatures" act without conflict;
c) transit to a technical description.

Comments:

31. Simulation with Little Creatures includes representing the conflicting requirements as a drawing that describes how the Little Creatures operate (in a group, several groups, a crowd, etc.). The model can include one or a series of figures. The Little Creatures have to represent changeable elements of the Problem Model (the tool and/or the X-element).

"The conflicting requirements" describe the conflict in the Problem Model or the opposite physical states indicated in step 3.5. The latter is perhaps the best, but there are no exact rules for the transition from the physical problem (step 3.5) to the Little Creatures model. To describe the Problem Model conflict is usually easier.

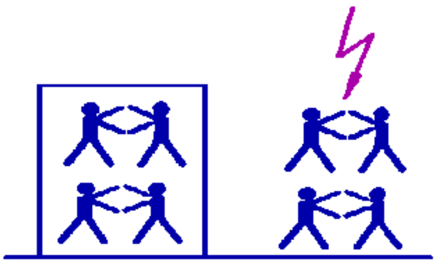
Sometimes it is preferable to modify the graphic model (step 4.1b) of the conflict by combining two figures in one drawing: the "bad action" and the "good action". If the events evolve in time, making several consequent drawings is appropriate.

WARNING!
The most common mistake in this step is to make a careless drawing. Good figures meet the following properties: a) they are expressive and understandable without words; b) they provide additional information about the Physical Contradiction and indicate general ways in which it can be resolved.

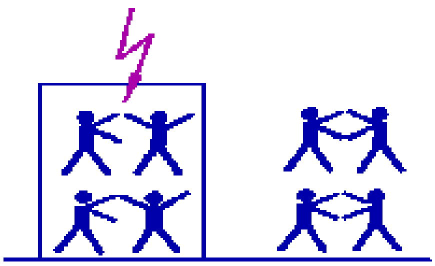
32. Step 4.1 is an auxiliary step. Its function is to visualize before mobilizing SFRs the needed actions of the particles in the Operational Zone and around the OZ. Simulation with Little Creatures clarifies the ideal action ("what should be done") without the physics ("how it should be done"). It also decreases mental inertia and improves the imagination. Thus, the SLC is a psychological method. However, simulation with the help of "Little Creatures " is realized according to the Laws of Evolution of Technical Systems. Therefore the SLC often leads to solution concepts. It is not recommended to stop the solving process here. The mobilization of the SFRs has to be performed.

Example:

A. The Little Creatures inside the mentally selected air column are the same as the air Little Creatures outside the column. Both groups are neutral (by convention, the Little Creatures hold each other hand-in-hand; their hands are busy, and thus they can not "catch" the lightning).



B. According to rule 6, it is necessary to divide the Little Creatures into two groups: the Little Creatures outside the column remain unchanged (neutral); Creatures inside the column remain in pairs (i.e. remaining neutral), but each Little Creature releases one hand, suggesting its desire to catch the lightning.



> *(Other graphic models are possible as well. In any case however, it is clearly necessary to divide the Little Creatures into two groups and change the state of the group inside the air column).*
>
> *C. The neutral state of the molecules inside the column should be favorable to ionization, to decomposition. The simplest way to achieve this is to reduce the air pressure inside the column.*

WARNING!
The purpose of mobilizing resources for the Mini-Problem solving process is not to apply all resources. The purpose, on the contrary, is to achieve the solution concept with a minimum expenditure of resources.

4.2. take a "step back" from the IFR

If it is known what the desired system should be (from the description of the problem conditions) and solving the problem is finding a way to achieve this system, it might be helpful to "step back" from the Ideal Final Result. The desired system is described, after which some minimum disassembling change is applied.

> *For instance, if according to the IFR two elements have to contact each other, the "step back from the IFR" would propose a gap between them. A new micro-problem then appears: How to eliminate this defect?*

This problem is usually easy to solve, and the problem solution concept provides a hint for solving the main problem.

4.3. using a combination of substance resources

Consider the possibility of using a mixture of the substance resources.

Comments:

33. If it was possible to solve the problem using available substance resources, the problem would never have appeared or would have been solved "automatically". Usually it is necessary to introduce new substances, but introducing new substances results in a more complicated system, the occurrence of harmful side effects etc. The subject of SFR analysis in Part 4 is to resolve this contradiction – to introduce substances without introducing them.

34. Step 4.3 recommends (in the simplest case) a transition from two mono-substances to a *heterogeneous* (not uniform) bi-substance.

    The question then arises: is it possible to transit from mono-substances to a heterogeneous bi-substance or poly-substance? System transitions analogous to homogeneous bi- and poly-systems are widely used and described in Inventive Standard 3.1.1. However this Standard deals with a combination of systems rather than substances, which are needed for step 4.3. The result of integrating two systems is a new system. The result of integrating two substances - two "pieces" of a system - is one piece and an increased volume of substance.

    One of the techniques for creating a new system by integrating similar systems is to keep the borders of the integrated systems in the new system. For instance, a single page of paper is a mono-system, a notebook is a poly-system, but a thick page of paper is not a poly-system. Therefore, keeping boundaries requires the introduction of a second substance – a "border" substance – even if this substance is empty space.

Thus step 4.4 represents the creation of a heterogeneous quasi-poly-system, with empty space as a second border substance. However, the empty space (void) is an unusual substance. When a substance and empty space are mixed, the borders are not always clearly recognized – but a new feature appears that is the required result.

4.4. using "voids"

Consider the possibility of solving the problem by replacing the existing substance resources with an empty space or a mixture of substance resources and empty space.

> *Example:*
>
> *The mixture of air and empty space is rarefied air. It is well known from physics that reducing the pressure of gas results in a reduction of the voltage required for discharge. Thus, the solution concept for the antenna problem is completely obtained.*
>
> *"It is proposed to make a radio-transparent lightning conductor from a dielectric hermetically-sealed tube, with the air pressure inside the tube chosen so as to provide the minimum gas-discharge gradient created by the lightning's electrical field". [A.c.177497]*
>
> *During a storm, the rarefied gas inside the dielectric rod becomes ionized. The ionized air inside the tube will conduct the lightning currents to the ground. After the storm the ions recombine, gas returns to a neutral state. In this case the lightning conductor does not distort the radio waves.*

Comment:

35. Empty space is an extremely important type of substance resource. It is always available in unlimited quantities, is very cheap, and easily mixed with the available substances to create hollow or porous structures, foam, bubbles, etc.

Empty space is not necessarily a vacuum. If the substance is solid the empty space inside it may be filled with liquid or gas. If the substance is liquid the empty space inside it may be a gas bubble. For substance structures of a particular level, lower-level structures may serve as empty space (see Comment 37). For instance, separated molecules can be considered as empty space for crystal lattice; atoms can be considered as empty space for molecules, etc.

4.5. using derived resources

Consider the possibility of solving the problem using derived substance resources or a mixture of derived substances with empty space.

Comment:

36. Derived substance resources can be obtained by changing the phase state of existing substance resources. For instance, if there is liquid as a substance resource, the derived resources can be considered as ice and vapor. On the other hand, the products of decomposing the substance resources can be considered as derived resources as well. For instance, hydrogen and oxygen are derived resources for water. The components are derived resources for multi-component substances. Substances obtained as a result of the decomposition or combustion of substance resources are derived resources too.

Rule 8.

If it is required to obtain substance particles (e.g., ions) but it is impossible to obtain them directly according to the problem conditions, they should be obtained by decomposing a substance of a higher structural level (e.g., molecules).

Rule 9.

If it is required to obtain substance particles (e.g., molecules) but it is impossible to obtain them directly or by using Rule 8, they should be obtained by building up or integrating the particles of a lower structural level (e.g., ions).

Rule 10.

The easiest way to apply Rule 8 is by decomposing the nearest higher "complete" or "excessive" structural level (e.g., negative ions); the easiest way to apply Rule 9 is by completing the nearest lower "incomplete" structural level.

Comment:

37. The substance can be regarded as a multi-layer hierarchical system. With sufficient accuracy for practical application, it is possible to consider the following hierarchy:

- minimally-processed substance (a simple material, for instance, wire);
- "super-molecules", such as crystal lattices, polymers, associations of molecules, etc.;
- complex molecules;
- molecules;
- parts of molecules, groups of atoms;
- atoms;
- parts of atoms;
- fundamental particles;
- fields.

The core of rule 8: the new substance can be obtained through a bypass (indirect) method of decomposing large structures of either substance resources or substances that can be introduced into the system.

The core of rule 9: it is available in another way by completing smaller structures.

The core of rule 10: it is recommended to decompose "complete" particles (such as molecules or atoms), because incomplete particles (e.g., positive ions) are already partially decomposed and thus resist further destruction; conversely, the building up of "incomplete" particles is recommended, because these tend to be more easily restored.

Rules 8-10 indicate effective directions for obtaining derived substance resources from the "depths" of existing or easily-implemented substances. These Rules point to the required physical effects for particular conditions.

4.6. using an electrical field

Consider the possibility of solving the problem by introducing an electrical field or two interacting electrical fields instead of a substance.

> *Example:*
>
> *A well-known method of testing the strength of a pipe is to twist it until it breaks. [A.c.182627].This method requires that the pipe be mechanically clamped, but clamping deforms the pipe.*
>
> *It is proposed to produce twisting torque by electrodynamic forces inside the pipe. [A.c.342759]*

Comment:

38. If the conditions of the problem situation restrict the use of available and derived substance resources, electrons (electrical current) can be applied. Electrons are

"substances" that exist inside any object. Moreover, electrons are associated with a field that is easily controlled.

4.7. using a field and field-sensitive substance

Consider the possibility of solving the problem using the pair: "field + substance additive that is responsive to this field".

> *For instance: "magnetic field + ferromagnetic substance", "ultraviolet radiation + phosphor", "heat + shape-memorizing metal", etc.*

Comment:

39. In step 2.3. available SFRs were explored. Steps 4.3-4.5 dealt with derived resources (from available SFRs). Step 4.6 is a partial deflection from available and derived SFRs: it introduces "foreign" fields. Step 4.7 is the next partial deviation: it introduces "foreign" substances and fields.

    The fewer the resources (SFRs) consumed, the more ideal the solution concept is likely to be. However, it is not always the case that a problem can be solved with small expenditure of resources. Sometimes it is necessary to step back and consider the introduction of "foreign" substances and fields. This should be done only when absolutely necessary, if it is impossible to apply available SFRs.

PART 5. APPLYING THE KNOWLEDGE BASE

5.1. applying the System of Standard solutions for Inventive problems
5.2. applying the problems-analogue
5.3. applying Principles for Eliminating Physical Contradictions
5.4. applying the Pointer to Physical Effects and Phenomena

In many cases, Part 4 of ARIZ helps to achieve a solution concept, so it is possible to go to Part 7 of ARIZ. If no solution is achieved after step 4.7, Part 5 is recommended.

The purpose of Part 5 of ARIZ is to mobilize all experience accumulated in the TRIZ knowledge base. The problem is significantly clearer at this point so it is very likely that direct utilization of the knowledge base will be successful.

5.1. applying the System of Standard solutions for Inventive problems

Consider the possibility of solving the problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying Inventive Standards.

Comment:

40. Actually, a return to the Inventive Standards takes place in steps 4.6 and 4.7. Before these steps the main idea was to utilize available SFRs, without the introduction of new substances and fields wherever possible. If it is impossible to solve the problem utilizing available and derived SFRs only, it is necessary to introduce new substances and fields. Most of the Inventive Standards introduce techniques for introducing the additives.

5.2. applying the problems-analogue

Consider the possibility of solving the problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying solution concepts for non-standard problems that have already been solved using ARIZ.

Comment:

41. Although there are an infinite number of inventive problems, there are comparatively few Physical Contradictions associated with them.
    Therefore drawing an analogy from a problem that contains an analogous contradiction can solve many problems. The problems might appear to be different, and therefore the appropriate analogy can be discovered only as the result of analysis on the level of the Physical Contradiction.

5.3. applying Principles for Eliminating Physical Contradictions

Consider the possibility of resolving the Physical contradiction using typical transformations (see Table 2. Principles for Eliminating Physical Contradictions)

Rule 11.

Only solution concepts that completely match the IFR or come close to it are acceptable.

5.4. applying the Pointer to Physical Effects and Phenomena

Consider the possibility of resolving the Physical contradiction using the Pointer to Physical Effects and Phenomena.

Comment:

42. Parts of the Pointer to Physical Effects and Phenomena was published in the journal "Technika i nauka" (1981-1983), books:
    - *DARING FORMULAS OF CREATIVITY*, Karelia, Petrozavodsk/ Selutsky A. B., ed.: 1987;
    - *A THREAD IN THE LABYRINTH*, Karelia, Petrozavodsk/ Selutsky A. B., ed.: 1988.;
    - *RULES OF A GAME WITHOUT RULES*, Karelia, Petrozavodsk/ Selutsky A. B., ed.: 1989.

PART 6. CHANGING OR SUBSTITUTING THE PROBLEM

Simple (typical) problems can be solved through direct elimination of the Physical Contradiction, for instance, by separating conflicting properties in space or in time. Solving complex (non-typical) problems is usually associated with changing the problem statement, that is, with removing the initial restrictions created by mental inertia – those that seem obvious from the beginning.

For instance, to resolve a problem about increasing the speed of an "icebreaker" it is necessary to transit to an "iceNObreaker".
Infinity "paint" can be obtained by the transition to "NOpaint" - electrolysis, gas bubbles were created. The bubbles themselves provide an adequate marker. Mental inertia had dictated that "painting" the model's trail is improved with the use of actual paint rather than another type of marker.

To correctly understand a problem it has to be solved; inventive problems cannot be precisely formulated at the outset. The process of problem solving is the process of correcting (reformulating) the problem statement.

6.1. transition to the technical solution

If the problem is solved, transfer the physical solution concept into a technical one: formulate the principle of action and develop a schematic diagram of a device that implements this principle.

6.2. checking the problem formulation for a combination of several problems

If the problem is not solved, check to see whether the description in Step 1.1 represents a combination of several problems. In this case, it is necessary to reformulate the step 1.1, by extracting separate problems. Those problems have to be solved one after another (often it is enough to solve just a main problem).

> *Example:*
>
> *It is necessary to solder sections of very thin gold chains. One meter of a chain of this type weighs only a gram. A method is needed by which hundreds of meters of a chain can be soldered per day.*
>
> *This problem can be decomposed into the following sub-problems:*
>
> *a) How to introduce the micro-doses of solder into the gaps of the links?*
>
> *b) How to heat the introduced micro-doses of solder without harming the chain?*
>
> *c) How to remove excessive solder, if any?*
>
> *The main problem is to introduce the micro-doses of solder into the gaps.*

6.3. changing the problem

If the problem is not solved, change the problem by selecting another Technical Contradiction in step 1.4.

> *Example:*
>
> *If a problem of measurement and/or detection is solved, to choose another TC often means that it is necessary to discard improvement of the measurement part and try to*

change the entire system so that the need for measurement disappears (Standard 4.1.1)

For instance, it is necessary to transport different types of oils through the same pipeline. If a liquid separator is used, or direct transportation (without separator), the problem is "How to increase the precision of measurement for the 'joint' section of oil?"

This "measurement" problem was changed into a "modification" problem: "How to eliminate mixing oils and the liquid separator?"

Solution: the liquid separator can mix freely with oils, but the liquid separator has to be transformed into gas and to be eliminated from the container itself, when necessary.

Required properties of the liquid separator:

- *it does not dissolve in oils;*
- *it is neutral to hydrocarbon substances;*
- *its density is equal to the density of transported oils;*
- *it does not freeze up to –50°C;*
- *it is cheap and safe.*

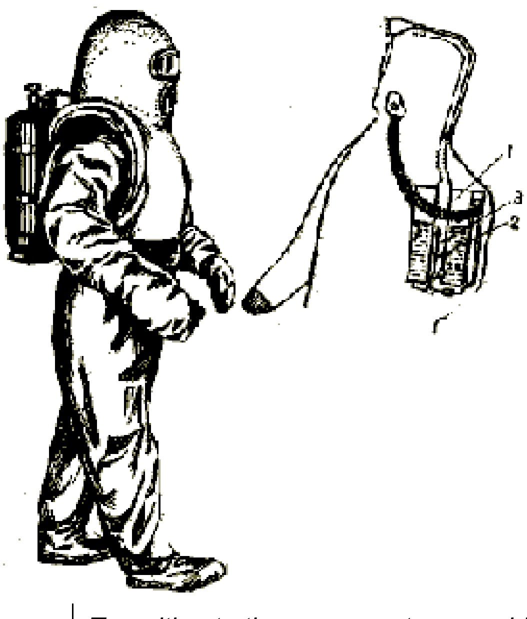
Ammonia was found through reference books.

[see: G.S.Altshuller: 1973, ALGORITHM OF INVENTION*, Moscowskiy Rabochy, Moscow, p.207-209; 270-271]*

6.4. reformulation of the mini-problem

If the problem is not solved, return to step 1.1 and reformulate the Mini-Problem with respect to the super-system. If necessary, repeat this reformulation process with the next several successive super-systems.

Example:



A typical example of this step is the solution concept for a gas-heat-reflecting suit (rescue suit). [see: G.S.Altshuller: 1973, ALGORITHM OF INVENTION, Moscowskiy Rabochy, Moscow, p.105-110].
Originally, this problem was formulated during the development of a refrigerating suit. However, to provide the required refrigerating power for the fixed weight of the suit was impossible according to physical principles. This problem was resolved by transiting to the super-system. It was proposed to make a gas-heat-reflecting suit by providing simultaneously the functions of a cooling system and respiratory system. The rescue suit works using liquefied oxygen. The liquefied oxygen is evaporated at first and works as a cooler. After transforming into a gas the oxygen is used in the respiratory system. [A.c.111144]

Transition to the super-system provides the possibility of enlarging the weight limits by 2-3 times.

PART 7. ANALYZING THE METHOD OF RESOLVING THE PHYSICAL CONTRADICTION

The main purpose of Part 7 of ARIZ is to check the quality of the obtained solution concept. The Physical Contradiction should be resolved almost ideally, "without nothing". It is better to spend an additional two or three hours to obtain a new, more powerful solution concept than to fight half a lifetime with a weak, difficult to implement idea.

7.1. checking the solution concept

Check the solution concept. Consider each introduced substance and field. Is it possible to apply available or derived SFRs instead of introducing the substances/fields? Can self-controlled substances be applied? Correct obtained technical solution accordingly.

Comment:

43. Self-controlling substances are substances that modify their state in a specific way in response to changes in environmental conditions (e.g., loose their magnetic properties when heated above the Curie point). Applying the self-controlling substances allows the system to be changed or its state modified without any additional devices.

7.2. preliminary estimation of the solution concept

Check the preliminary solution concept.

Control questions:

a) Does the solution concept provide the main requirement of IFR-1 (the element without complicating the system…)?
b) Which Physical Contradiction (if any) is resolved by the solution concept?
c) Does the new system contain at least one easily controlled element? Which element? How is it controlled?
d) Does the solution concept found for the "single-cycle" Problem Model fit the real conditions, multi-cycle conditions?

If the solution concept does not comply with all of the above, return to step 1.1.

7.3. checking the priority of the solution concept through patent funds

Check the novelty of the solution concept via a patent search.

7.4. estimation of sub-problems for implementing the obtained solution concept

What sub-problems might appear during the realization design of the new technical system? Write down those possible sub-problems that might require invention, design, calculation, the overcoming of organizational challenges, etc.

PART 8. APPLYING THE OBTAINED SOLUTION

8.1. estimate the changes to the super-system
8.2. find a new application for the obtained solution
8.3. apply the solution concept to other problems

A true innovative idea not only solves the particular problem, but also provides a universal "key" to many other analogous problems. The purpose of Part 8 of ARIZ is to maximize the utilization of resources unveiled by the obtained solution concept.

8.1. estimate the changes to the super-system

Define how the super-system that includes the changed system should be changed.

8.2. find a new application for the obtained solution

Check whether the changed system or super-system can be applied in a new way.

8.3. apply the solution concept to other problems

Apply the solution concept to solving other problems:

a) Formulate a general Solution Principle.
b) Consider direct application of the Solution Principle to other problem solving situations.
c) Consider applying the opposite Principle to other problems.
d) Create a morphological matrix (e.g. "parts location" versus "phase states of the product" or "applied fields" versus "phase states of the environment", etc.) that includes all possible modification of the solution concept, and consider every combination produced by the matrix.
e) Consider the modifications to the Solution Principle that would result from changing the dimensions of the system or its main parts, imagine the result if the dimensions were to approach zero or stretch toward infinity.

Comment:

44. If the purpose is not just to solve a particular technical problem, by carefully following step 8.3 one might initiate the development of a general theory based on the Solution Principle.

PART 9. ANALYZING THE PROBLEM SOLVING PROCESS

9.1. compare the proposed and the real process
9.2. compare the obtained solution concept and knowledge from TRIZ

Every problem solved using ARIZ has to increase the creative potential of the person. To achieve that, however, a thorough analysis of the solution process is required. This is the main purpose of the final part of ARIZ, Part 9.

9.1. compare the proposed and the real process

Compare the real process of problem solving with the theoretical one (that is, according to ARIZ). Write down all, if any, differences.

9.2. compare the obtained solution concept and knowledge from TRIZ

Compare the obtained solution concept to the information in the TRIZ knowledge base (Inventive Principles, Inventive Standards, and Pointer to Physical Effects and Phenomena). If the knowledge base does not include a principle that applies to the obtained solution concept, document this principle in the preliminary knowledge base.

WARNING!
ARIZ-85C has been tested on many problems – on nearly every available problem fund – and utilized for studying/teaching. Some users forget this and suggest improvements to ARIZ based on their experience in solving one problem. Even assuming that a given suggestion is good for a particular problem, as a rule, improving the solving of one problem renders the solving of other problems more difficult…
For this reason, any suggestions should first be tested outside ARIZ, as was the case, for instance, with the Simulation with Little Creatures. Then, after being included in ARIZ, any change should be tested by solving at least 20-25 reasonable challenging problems.
ARIZ is constantly being developed and therefore needs new ideas. But these ideas should first be carefully tested.

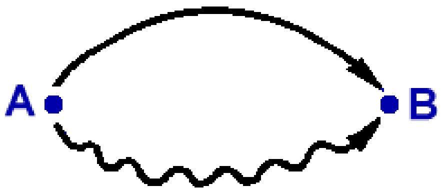
Table 1. Typical Graphic Models of Technical Contradictions

1.

COUNTERACTION

A usefully acts upon B (plain arrow), however, in certain stages a reverse harmful action occurs (wavy arrow).
It is necessary to eliminate the harmful action, and to keep the useful one.

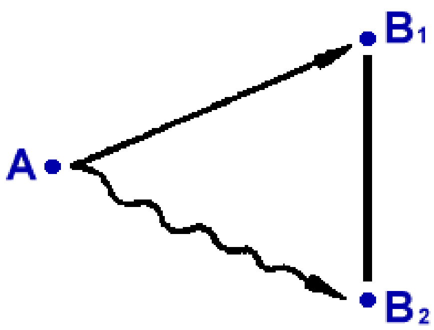
2.



CONJUGATED ACTION

The useful action of A on B at the same time generates a harmful action upon B (e.g. for different working stages the action can be useful or harmful).
It is necessary to eliminate the harmful action, and to keep the useful action.

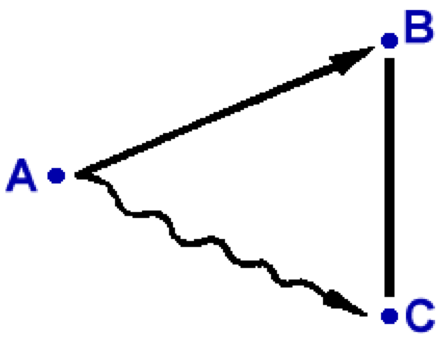
3.



CONJUGATED ACTION

The useful action of A to one part of B generates a harmful action on another part of B.
It is necessary to eliminate the harmful action to B_2, and to keep the useful action to B_1.

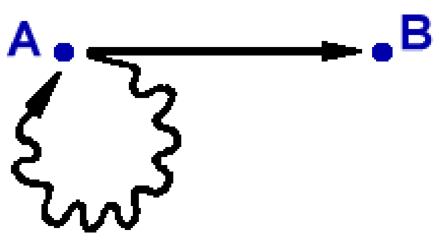
4.



CONJUGATED ACTION

The useful action of A on B generates a harmful action on C (A, B, and C are parts of one system).
It is necessary to eliminate the harmful action, and to keep the useful action without destroying the system.

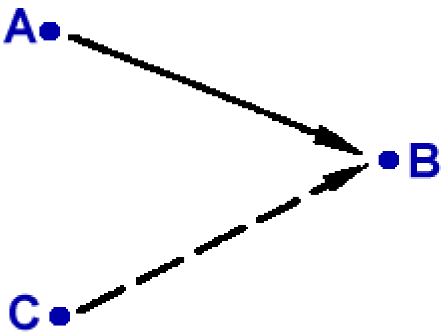
5.



CONJUGATED ACTION

The useful action of A on B generates a harmful action on A itself (e.g. increases A's complexity).
It is necessary to eliminate the harmful action, and to keep the useful action.

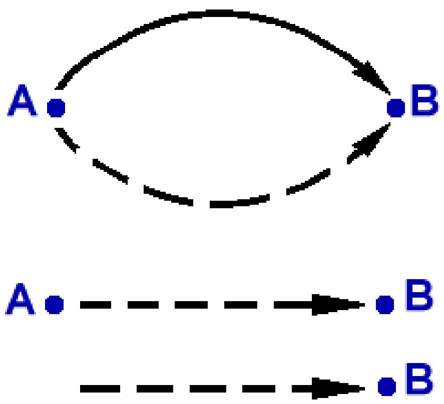
6.



INCOMPATIBLE ACTION

The useful action of A on B is incompatible with the useful action of C on B (e.g. treatment is incompatible with measurement).
It is necessary to provide the action of C on B, without changing the action of A on B.

7.



INCOMPLETE ACTION OR INACTION

A provides one useful action on B whereas two different actions are required or A does not act on B at all (dotted line). Sometimes A is absent: it is necessary to change B, but it is not clear how this should be achieved.
It is necessary to provide an action on B, with the simplest A.

8.

"SILENCE"

There is no information about A, B or about the interaction between A and B. Sometimes only B is given.
It is necessary to obtain the needed information.

9.

UNREGULATED (IN PARTICULAR, EXCESSIVE) ACTION

Interaction between A and B is uncontrollable (e.g. constant) while a controllable action (e.g. variable) is required.
It is necessary to make the action of A on B controllable (dash-dot line).

Examples for Typical Graphic Models of Technical Contradictions

1.

> *A mould forms the walls from concrete during construction. But it is difficult to remove the mould after the concrete solidifies because the friction forces between the mould's surface and the concrete's surface increases. It is proposed to add an electrolyte to the concrete mixture and to pass an electric current through it. (Electrolysis[1] phenomena) [A.c.628266]*

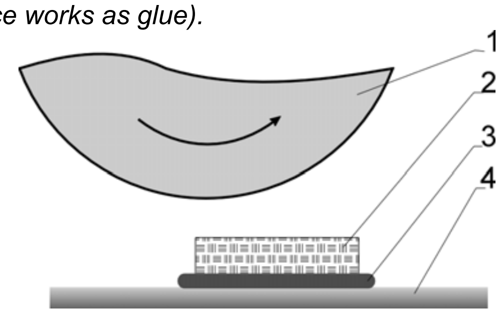
[1] the producing of chemical changes by passage of an electric current through an electrolyte [(c) 1994 Merriam-Webster, Inc. All Rights Reserved]

2.

It is necessary to include an additive in an iron melt. The additive is a powder of needed chemical elements. The additive improves the qualities of iron, but the additive does not mix well with the melt. It is proposed to use an exothermic mixture of the needed powder and put it under the metal level. As a result, the heat of the melt generates the needed energy to mix the additive. [A.c.541864]

3.

Small ceramic parts should be fastened to the desk before polishing. Usually in this case a specific paste made from rosin and paraffin (i.e., glue) is used. This carries out a useful action. After grinding it is necessary to remove the small parts, but it is difficult. This is a harmful action from a productivity viewpoint. (B1 - grinding operation; B2 - unfastening operation) It is proposed to ice the small ceramic parts by freezing water (ice works as glue).



1. Grinding wheel; 2. Detail; 3. Glue; 4. Desk

4.

A rope is used to control the exhaust valve of a stratosphere balloon. If the exhaust valve is opened, part of the gas is let out, and the stratosphere balloon can go down. The balloon-car is air-proof, because the stratosphere balloon flies at a high altitude (low pressure, low temperature).

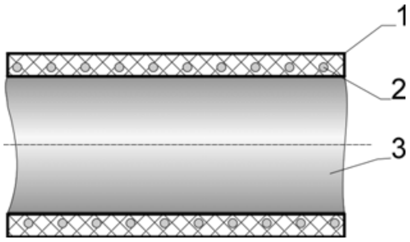
The first pilot of a stratosphere balloon was August Piccard. It was necessary to use a rope to control the exhaust valve, but the balloon-car had to be air-proof to protect the pilot from high altitude conditions. If the rope passed through the wall of the air-proof balloon-car, it would have compromised the air-tightness. If the hole for the rope was too small it would have been dangerous, because the rope could have stuck. (A - rope; B - exhaust valve; C - wall of balloon-car).

It was proposed to use a "liquid part of the wall". The rope was passed through a pipe with mercury.

5.

It is necessary to coat metallic surfaces with a thick layer of isolation. From time to time it is necessary to remove this layer. To enable this, a steel wire is placed underneath the layer of isolation. When it is necessary, the wire cuts the thick isolation. But when the wire cuts the isolation, difficulties appear: if a thin wire is used, it cuts the isolation well, but it can break; if a thick wire is used, it doesn't break, but it increases cutting forces, and material consumption. (A - wire; B - isolation layer).

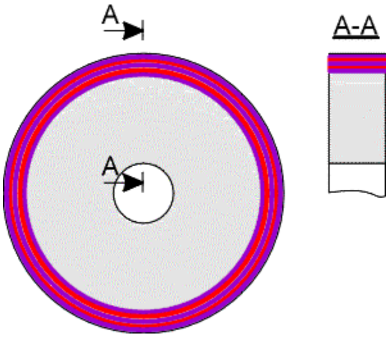
It is proposed to conduct through the thin wire an electric current before cutting the isolation. Cutting forces are decreased.



1. Thick layer of isolation; 2. steel wire; 3. metallic surface.

6.

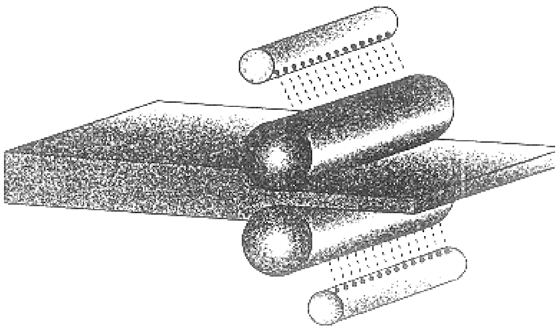
> *It is necessary to measure the diameter of a grinding wheel with 0.01mm accuracy. The grinding wheel can be depicted as concentric circles with 0.01mm distance between them. In this case it is necessary to detect the transition from one circle to another. It is possible to estimate the diameter by determining the transitions and their quantity.*
>
> *It is proposed to use different colors for the concentric layers.*



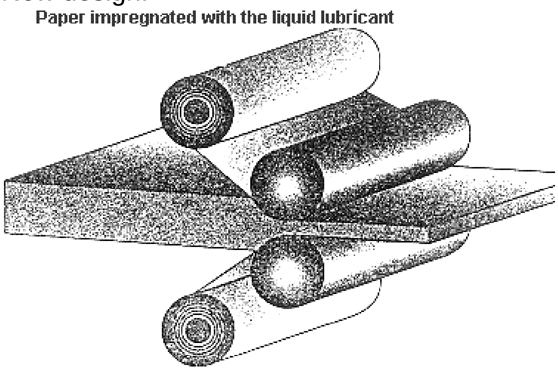
7.

> *Hot rolling of metals requires lubrication in the deformation zone. Special brushes or sprayers usually supply the liquid lubricant. This technique does not provide uniform distribution of the lubricant in the deformation zone, the oil splashes around, and much of it is lost.*
>
> *It is proposed to use a paper impregnated with the liquid lubricant. Paper is fed between the rollers and the metal. The paper is burnt away due to the high temperature in the deformation zone. [A.c.589046]*

Old design:



New design:



8.

> *It is necessary to measure the height of a cave. But the light of a pocket flashlight does not reach the top of the cave. It is impossible to climb up the vertical surface of the cave. However, mountain-climbers and speleologists do not like additional weight.*
>
> *It is proposed to use an air-balloon to measure the height of the cave with a length of thread.*

9.

> *When sealing a glass ampoule containing liquid medicine, overheating the glass might destroy the medicine. It is proposed to put the ampoules into water and leave the ampoule's tip above the water. The water protects the medicine in the ampoules from overheating [A.c.264619].*

Table 2. Principles for Eliminating Physical Contradictions

1. Separation of conflicting properties *in space*.

> *To suppress dust in a mine during mountain works, a spray of dispersed water drops is used. Small water drops work well however they turn into mist, but large drops do not remove dust. It is proposed to surround the jet of small drops by a "cone" formed by large drops [A.c.256708].*

2. Separation of conflicting properties *in time*.

> *The bandwidth of a welding electrode changes depending on the width of the welding gap (seam) [A.c.258490].*
>
> *The aircraft with changeable wing geometry.*
>
> *See Inventive Standard 2.3.3*[2]*.*

3. System transition 1a: Combination of homogeneous or heterogeneous systems into a super-system.

> *To process the sides of a thin glass plate, several plates are combined into a block by gluing them together and this prevents the thin glass from breaking [US Patent 3567547].*
>
> *Computers are combined in a network which gives the possibility of using one printer or Internet connection for the whole group.*
>
> *See Inventive Standard 3.1.1.*

4. System transition 1b: Transition from a system to an anti-system, or combination of a system with an anti-system.

> *To stop bleeding, a napkin with the blood of a different group is used. [A.c.523695]*
>
> *See Inventive Standard 3.1.3.*

5. System transition 1c: the entire system has a property X while its parts have a property opposite to X (anti-X).

> *The working parts of a vice which is used to grip complex shapes are made from segmented brushes that are capable of moving in relation to one another. Elements of various shapes can be gripped quickly and easily. The parts are solid, but the fixing device is "soft" [A.c.510350].*
>
> *Koulikov's antenna includes brushes on a string. Each part (i.e., each brush) is rigid while the antenna as a whole is flexible.*
>
> *See Inventive Standard 3.1.5.*

6. System transition 2: transition to a system that works on the micro-level.

> *To increase accuracy, instead of using a mechanical tap a "thermal tap" is used. The parts of the "thermal tap" have a different coefficient of thermal expansion. A gap is formed on heating [A.c.179479].*
>
> *See Inventive Standard 3.2.*

7. Phase transition 1: substitution of the phase state of a system's part or external environment.

> *It is proposed to use liquefied gas, instead of compressed gas for pneumatic systems in a mine [A.c.252262].*
>
> *See Inventive Standard 5.3.1.*

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[2] System of Standard Solutions for Inventive Problems (76 Inventive Standards).

8. Phase transition 2: dual phase state of a system part (using substances capable of converting from one phase to another according to the operating conditions).

> *To improve the performance of a heat exchanger it is proposed to make "petals" (small flat parts on the surface) from a nickel-titanium alloy. When the temperature increases, the "petals" are unbent and the working area of the heat exchanger increases (the shape memory effect) [A.c.958837].*
>
> *See Inventive Standard 5.3.2.*

9. Phase transition 3: using phenomena associated with phase transitions.

> *To transport frozen loads it is proposed to use bars of ice as support (friction is decreased through the ice melting) [A.c.601192].*
>
> *See Inventive Standard 5.3.3.*

10. Phase transition 4: substitution of a mono-phase substance with a dual-phase state.

> *To polish some elements, the polishing media consists of melted lead (plumbum) with ferromagnetic abrasive particles [A.c.722740].*
>
> *See Inventive Standards 5.3.4, 5.3.5.*

11. Physical-chemical transition: substance appearance-disappearance as a result of decomposition-combination, ionization-recombination.

> *The rubbing surface of a wooden bearing is plasticized by ammonia. To increase productivity and reduce the cost of the process it is proposed to use an ammonium salt (for instance $(H_4)_2CO_3$) that decomposes under heating during the process (source of heat – elements friction) [A.c.342761].*
>
> *See Inventive Standards 5.5.1, 5.5.2.*

■

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