A proposal and verification of antithetical analogical approach to creativity method with the use of TRIZ

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Biography

Masao Oda joined Mitsubishi Electric and engaged in R&D for production engineering. Having served as planning representative for production engineering, design manager of production engineering center, VE manager of LCD division, strategy planning manager and deputy-general manager of production engineering center, he is currently serves GM of Monozukuri Engineering Department at HRD center.

Abstract

Companies are required to provide their customers with value creation which brings new sensation. In order to do so, they must respond to their customer's visible needs, discover their potential needs and create a basic concept of product or service equipped with new value.

The author tries to generate ideas conceptually antithetical against the development subject, and gains new viewpoint based on the features of antithetical, then creates basic concept on how to respond do the potential needs of the customer. This paper applies the TRIZ invention principles to the creativity method to add more widely applicable technical viewpoints for increased effectiveness.

This paper verifies that application of antithetical analogical approach to creativity method with the use of TRIZ techniques enables generating highly reliable innovative ideas in line with intended technical policy. This method was applied to the development of a system used to recover coolant, CFC (chlorofluorocarbon), in recycling plants, which achieved the highest-ranking recovery rate of CFC in Japan.

1. Introduction

Companies are expected to generate new values which give emotional appeal to customers. Innovative ideas are essential for the generation of new values, for which thinking based on the basic VE approach, i.e. Blast, Create and Refine, proposed by Miles, the originator of VE. At the first stage of development design which is the planning stage, it should be remembered that it is important to break away from conventional methods and start from the beginning, according to the idea of “Blast”, the starting point of VE.

The author tries to generate ideas conceptually antithetical against the development subject, and gains new viewpoint based on the features of antithetical, then creates basic concept on how to respond do the potential needs of the customer.

This paper intends to verify that application of the antithetical analogical approach to creativity method with the use of TRIZ techniques to the VE activity at the planning stage may generate highly reliable, innovative ideas in line with intended technical policy.

2. TRIZ

TRIZ is an innovative method of technical problem solving, comprising invention principles for resolving technical contradictions as well as patterns of technological advancement, which was inductively derived from the result of analyzing hundreds of thousands of patents by Altshuller, who was a patent examiner of the former Soviet Union. In the unique approach of TRIZ, mathematical approach, such as logical solution based on quadratic equations, is considered ideal, and it is carried out through three steps as indicated below [1].

[Step 1] According to TRIZ, a specific problem is redefined from the viewpoint of technical contradictions, etc. and represented in an abstract manner. (Mathematically, it turns a specific quadratic equation $3x^2+5x+2=0$ into an abstract form to obtain general equation ax^2+bx+c.)

[Step 2] With TRIZ, an abstract solution is derived by using 40 invention principles, etc. which are formula for creativity.(Mathematically, it is to apply quadratic solution formula to obtain a general solution $x=\{-b\pm(b^2-4ac)^{1/2}\}/2a$.)

[Step 3] With TRIZ, ideas are generated using analogical approach, and abstract solutions are concretized. (Mathematically, it involves substituting a given value for the coefficient of general solution to obtain a specific numerical solution $x=1, -2/3$.)

Altshuller built a system of “Invention Principles (organized into 40 principles)” effective in resolving modeled typical technical contradictions, and using them as a clue developed an approach to innovative idea generation free from conventional measures.

As the 40 invention principles are derived from analysis of a vast number of patents, analogical thinking based on the invention principles enables highly reliable idea generation which is technically grounded.

3. Antithetical analogical approach to creativity method with the use of TRIZ

3.1 Antithetical analogical approach to creativity method

Creativity method by antithetical analogical approach involves finding a subject conceptually antithetical to the subject under study, using the characteristics of the antithetical subject as a clue, and obtaining new points of focus. And through analogical thinking from such points of focus, ideas for meeting customers’ potential requirements are generated. In this context, the word “antithetical” refers to the state where the subject under study and the clue have totally different characteristics.

What follows is a description of Steps 1 through 5 of the antithetical analogical approach to creativity method. Following this procedure enables generation of ideas for meeting potential requirements of customers.

[Step 1] Enlist characteristics of subject to be developed and obvious requirements of customers.

[Step 2] Generate ideas about characteristics of an antithetical subject and the subject itself, based on the subject to be developed and its characteristics.

[Step 3] Generate new points of focus, based on the antithetical subject and its characteristics, as well as on customers' obvious requirements.

[Step 4] From among the new points of focus obtained, identify viewpoints which customers might show strong interest. From those viewpoints, think about requirements for subject to be developed, add customer requests to make potential requirements.

[Step 5] Create ideas for producing new values based on customers' potential requirements.

Antithetical analogical approach to creativity method involves finding antithetical clues, through bringing oneself far away from the subject under study and surrounding conditions, based on the "Blast" concept. This helps one to derive unexpected points of focus from clues found in the process, leading one to create innovative ideas freely.

Generation of ideas left to free thinking, however, has a shortcoming of bringing one, at times, far from intended technical policy. Where such a shortcoming reveals itself, deriving principle-based design solutions from obtained ideas becomes difficult when it is necessary to technically explore principle and structure of operation, such as in cases of product or equipment development.

3.2 10 Antithetical invention principles

The process proposed in this paper aims at increasing effectiveness of antithetical analogical approach, utilizing TRIZ invention principles. The point here is to select and utilize, of all 40 TRIZ invention principles, those which help producing unexpected ideas. The selection process led to identify 10 invention principles, referred to hereafter as "10 antithetical invention principles", which inherently contain antithetical concept vastly different from the subject under study.

Steps 1 and 2 out of the total of 5 steps of creativity method with antithetical approach help generating ideas about antithetical subject and its characteristics as opposed to subject under study and its characteristics, using 10 antithetical invention principles as a guide.

Antithetical subject and its characteristics conceptualized using the 10 antithetical invention principles represent an outstanding feature of TRIZ, which shows a generalized method for solving technical issues. Clues obtained by the combined use of TRIZ and antithetical analogical approach with their superior features may generate points of focus in idea generation, enabling creating highly reliable and innovative ideas in line with intended technical policy.

(1) Selection of antithetical invention principles

Takagi (2014), noting that 40 invention principles have certain sequence and that as the sequence number increases principles become more and more concrete than abstract ones, divided invention principles into 9 groups, each containing around 4 principles, and named each group [2]. Furthermore, he divided principles broadly into three types, i.e. Conceptual type, consisting of 3 groups and 12 principles (1-12); Technical type, of 4 groups and 16 principles (13-28); and Material type, of the last 2 groups and 12 principles (29-40), for easier explanation and learning.

Conceptual type principles include: "Divide 1-4", which is used to overcome complex situation through sorting and reorganization; "Combine 5-8" used to create new ideas by combining two things; and "In advance 9-12"for making preparation in advance. The conceptual type principles are the most widely applicable invention principles hardly bound by any concrete things.

Technical type principles include: "Change shapes 13-16" for devising shapes of things; "Increase efficiency 17-20" for improving motions or efficiency of things; and "Eliminate harm 21-24" used to control negative effects of working of things; and "Labor saving 25-28" for reducing operational cost of functions.

Technical type principles help devising ideas about more tangible things, and are generally applicable to materialistic systems.

Material type principles consist of: “Change of material 29-33 and 40” involving direct change of shapes/forms of materials: and “Change of phase 34-39” pertaining to the control of three phases of materials and surrounding environment. Material type principles are the most highly concrete invention principles. Although the scope of application may be limited, these principles are capable of producing results quickly.

From these 40 invention principles organized systematically, 10 principles were selected which comply with the purpose of antithetical invention principles. The process of selecting them is shown in Fig. 1.

First of all, a type which does not match antithetical concept was removed from the three types, i.e. Conceptual, Technical, and Material types. Next, groups which did not match the concept were eliminated, and eventually those principles which match antithetical concept were selected.

Of the three types of principles, material type ones (29-40) are not suitable as antithetical invention principles, because, being bound by concrete and specific concept of change in material forms and/or conditions, they are unlikely to help generating very unusual antithetical concept.

Next, out of Conceptual and Technical types of principles (7 groups altogether), “Combine” and “In advance” (5-12) cannot be antithetical invention principles, for these two groups inherently are used to combine multiple things which already exist or to prepare predictable things, and their common nature of using known characteristics does not lead to antithetical concept.

Eventually invention principles which match antithetical concept were selected out of the remaining 20 principles of conceptual and technical types (1-4,13-28). What remained after selection are 10 principles, i.e. 1 Segmentation; 2 Extract/taking off; 4 Asymmetry; 13 The other way around; 14 Curvature; 15 Dynamics; 17 Another dimension; 19 Periodic action; 22 Blessing in disguise; and 27 Cheap short-living objects. Names of all of these ten principles themselves manifest antithetical characteristics, enabling to derive characteristics opposite to those of the subject under study immediately. These 10 principles, referred to as antithetical invention principles, are shown in Fig. 2, together with pairs of characteristics antithetical to each other.

Lastly, invention principles dropped in the selection process of antithetical invention principles were verified. While 3 Local quality, 24 Intermediary, and 26 Copying are principles for utilizing homogeneous concept, 16 Partial or excessive actions, 18 Mechanical vibration, 20 Continuity of useful action, 21 Skipping, 23 Feedback, 25 Self-service, and 28 Mechanics substitution, are principles which utilize known concepts, and therefore, none of them contain antithetical concept.

(2) Utilization of antithetical invention principles

Following steps 1-3, 10 antithetical invention principles can be utilized to conceive new ideas.

[Step 1] Compare the subject under study against each of 10 antithetical invention principles shown in Fig. 2 (1. Segmentation/ Whole, 2. Extraction/ Mixture, …., 10.Temporary/ Permanent) one by one, to select characteristics matching the subject. For example, with regard to the first antithetical invention principle (Segmentation), it should be considered whether antithetical characteristics of either Segmentation or Whole applies to the subject under study. If the subject under study is made up of integral construction, “Whole” may be selected as characteristics, and if the subject under study is composed of multiple modules, “Segmentation” may be selected as characteristics.

[Step 2] Characteristics of the subject under study selected from antithetical invention principles already make pair with antithetical characteristics. This means that where characteristics of the subject under study is “Whole” or “Extraction”, antithetical characteristics is “Segmentation” or “Mixture”, respectively, and therefore, antithetical characteristics can be identified immediately, helping to generate ideas about antithetical subject. Specifically, if antithetical characteristics of a subject under study is “Segmentation”,

ideas can be generated, for example, of composing the subject under study of independent parts/ components or making it disassemblable.

[Step 3] Apply all 10 antithetical invention principles one by one to the subject under study, generate ideas about antithetical subject and its characteristics, and then, using them as a guide, find points of focus to generate innovative ideas.

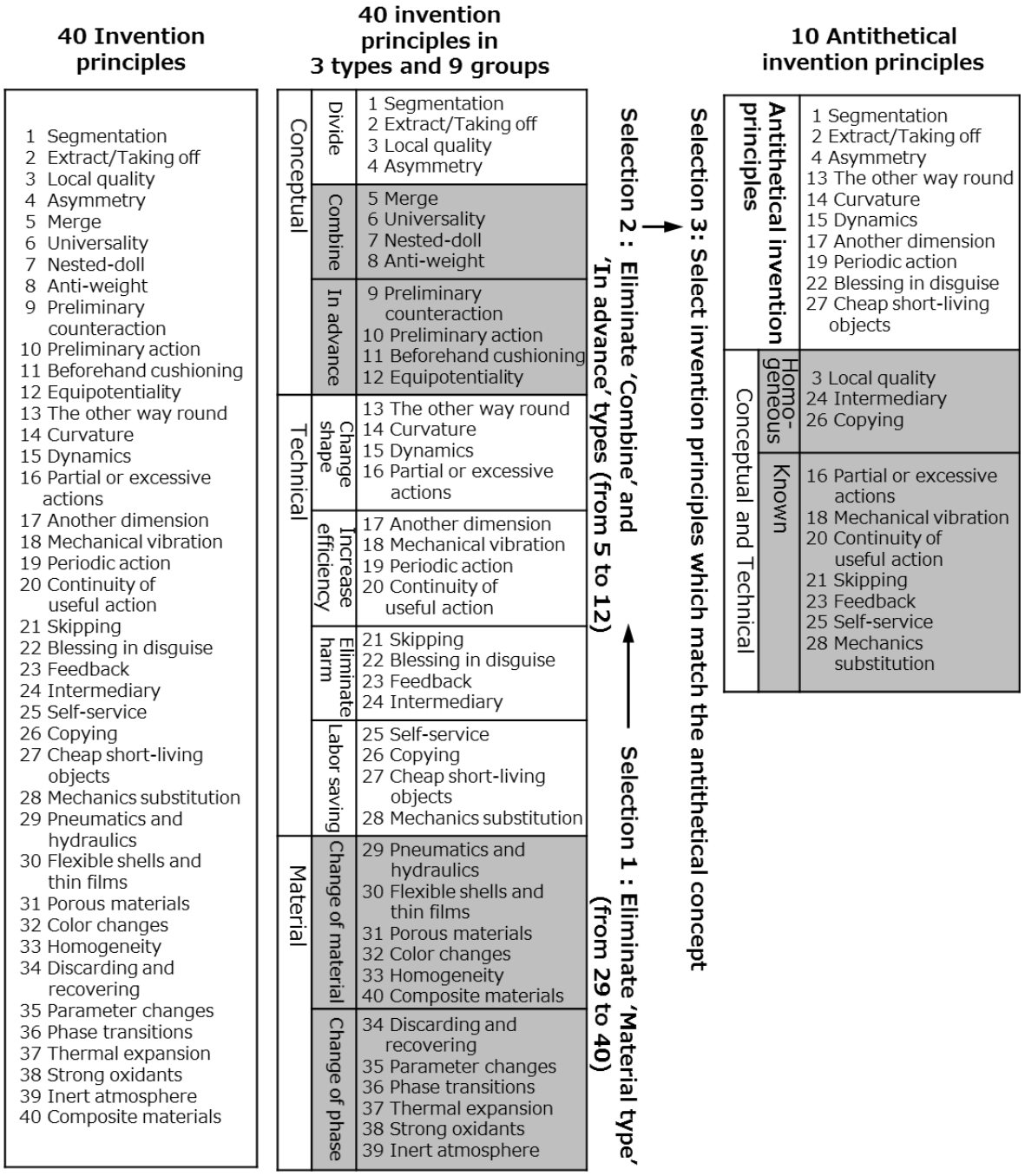


Fig. 1 Process of selecting 10 antithetical invention principles out of 40 invention principles

No.	Antithetical invention principles	Description of principle	Characteristics of antithetical subject
1	1 **Segmentation**	Segment into mutually independent parts	Segmentation Whole
2	2 **Extract/Taking off**	Extract only necessary characteristics	Extraction Mixture
3	4 **Asymmetry**	Replace symmetrical subject into asymmetrical one	Asymmetrical Symmetrical
4	13 **The other way round**	Execute opposite action of the one stated in specification	Reverse Forward
5	14 **Curvature**	Utilize curve, circle, spherical surface, and spiral	Curvature Plane
6	15 **Dynamics**	Change a subject under study from immobile to mobile or variable	Variable Fixed
7	17 **Another dimension**	Replace line with surface/ replace surface into three-dimensional object	Surface Line
8	19 **Periodic action**	Replace continuous action into a periodic one	Periodic Continuous
9	22 **Blessing in disguise**	Convert harmful subject under study into something useful	Disadvantage Benefit
10	27 **Cheap short-living objects**	Replace expensive subject under study with inexpensive aggregate	Temporary Permanent

Fig. 2 10 Antithetical invention principles and characteristics of antithetical subject

3.3 Application of creativity method

Having received a request from a customer planning to construct a new recycling plant, a small project team was organized to work on the development of a line for recovering CFC (chlorofluorocarbon) used as a coolant from used refrigerators. At the planning stage, the leader of the team discussed with the customer for deciding on specifications, who also generated ideas by applying the antithetical analogical approach applying the 10 invention principles described above.

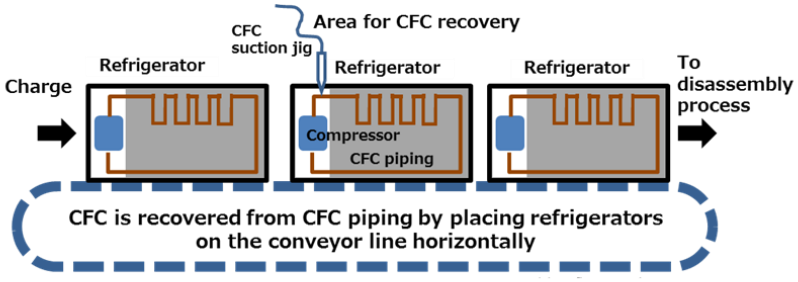
These ideas, generated from highly universal technical viewpoints, produced innovative ideas about the recovery line by applying antithetical concept. The project team successfully developed technology necessary in materializing the ideas, and established a CFC recovery method with the highest-level efficiency in Japan.

(1) General CFC recovery method used in recycling plants

CFC, used as coolant, is sealed in the CFC piping and compressors of used refrigerators. Being a harmful material contributing to the depletion of ozone layer as well as global warming, it is exigent that CFC be recovered from used refrigerators and processed appropriately.

Typically such recovery is conducted using the line configuration delineated in Fig. 3 (a), which is described in 1)-5) below.
1) Load used refrigerators onto the conveyor line so that they lay on their side. Refrigerators move on the conveyor line towards the CFC recovery position.
2) As a refrigerator arrives at the CFC recovery section, CFC suction jig in the form of injection needle is stuck into the CFC piping of the refrigerator.
3) CFC recovery machine connected to the CFC suction jig by tubing sucks CFC sealed in the CFC piping and compressor, and sucked CFC is stored in a recovery tank.

4) Immediately before the refrigerator passes through the CFC recovery section, the CFC suction jig is removed from the CFC piping to complete CFC recovery.
5) Refrigerator is unloaded from the conveyor line and sent to the next process for disassembly.



(a) General method of recovering CFC

CFC : chlorofluorocarbon

No.	Antithetical invention principles	**[Step 1]** Characteristics of object / **[Step 2]** Antithetical characteristics and object	**[Step 3]** Points of focus
1	1 **Segmentation**	**[1] Whole**: CFC piping and compressor are combined **[2] Segregation**: CFC piping and compressor are divided	**[3-1]** Separate CFC piping and compressor, and recover CFC separately
2	2 **Extract/Taking off**	**[1] Mixture**: Compressor and other parts coexist in refrigerator **[2] Extract**: Compressor is removed from refrigerator	**[3-2]** Remove compressor from refrigerator and recover CFC
3	4 **Asymmetry**	**[1] Symmetry**: Refrigerators move horizontally in alignment **[2] Asymmetry**: Refrigerators move slanting and out of alignment	**[3-3]** Recover CFC by placing refrigerator vertically
4	13 **The other way round**	**[1] Forward**: Disassemble refrigerators after recovery of CFC **[2] Reverse**: Recover CFC after disassembling refrigerators	**[3-4]** Recover CFC after disassembling refrigerator partially
5	14 **Curvature**	**[1] Plane**: Refrigerators move linearly in horizontal position **[2] Curvature**: Refrigerators move in vertical position while rotating	**[3-5]** Form CFC recovery line in letter U shape
6	15 **Dynamics**	**[1] Movable**: Refrigerators move **[2] Immobile**: Refrigerators stand still	**[3-6]** Recover CFC while keeping refrigerator in standstill condition
7	17 **Another dimension**	**[1] Line**: Linear CFC recovery line **[2] Surface**: Branched CFC recovery line	**[3-7]** Separate lines for CFC recovery from CFC piping and compressor
8	19 **Periodic action**	**[1] Periodic**: CFC recovery time is cyclic **[2] Continuous**: CFC recovery time is continuous	**[3-8]** Set the point of stopping CFC suction at the level where specified volume of CFC recovery is reached
9	22 **Blessing in disguise**	**[1] Disadvantage**: Troublesome CFC recovery operation for each refrigerator **[2] Benefit**: CFC recovery operation can be carried out for multiple refrigerators together	**[3-9]** Recover CFC for multiple compressors together
10	27 **Cheap short-living objects**	**[1] Permanent**: Operators maintain jigs for operation [2] **Temporary**: Use disposable jibs	**[3-10]** Standardize jigs, and make some jigs disposable

(b) Characteristics of object, those of antithetical object and focus points obtained by utilizing 10 antithetical invention principles

Fig. 3 Application of creative method – General method of recovering CFC

	Step 1: Sealing	Step 2: CFC recovery from main body	Step 3 : CFC recovery from compressor
Point of focus	**[3-1]** Separate CFC piping and compressor, and recover CFC separately **[3-3]** Recover CFC by placing refrigerator vertically **[3-10]** Standardize jigs, and make some jigs disposable	**[3-2]** Remove compressor from refrigerator and recover CFC **[3-4]** Recover CFC after disassembling refrigerator partially	**[3-6]** Recover CFC while keeping refrigerator in standstill condition **[3-7]** Separate lines for CFC recovery from CFC piping and compressor **[3-8]** Set the point of stopping CFC suction at the level where specified volume of CFC recovery is reached **[3-9]** Recover CFC for multiple compressors together
Basic idea	Place refrigerator vertically on conveyor, and separate CFC piping and compressor in the refrigerator by using a sealing tool whose blade tips are disposable.	Recover CFC from CFC piping while removing compressor from refrigerator at the same time.	Set removed compressors on holder and recover CFC from multiple compressors together

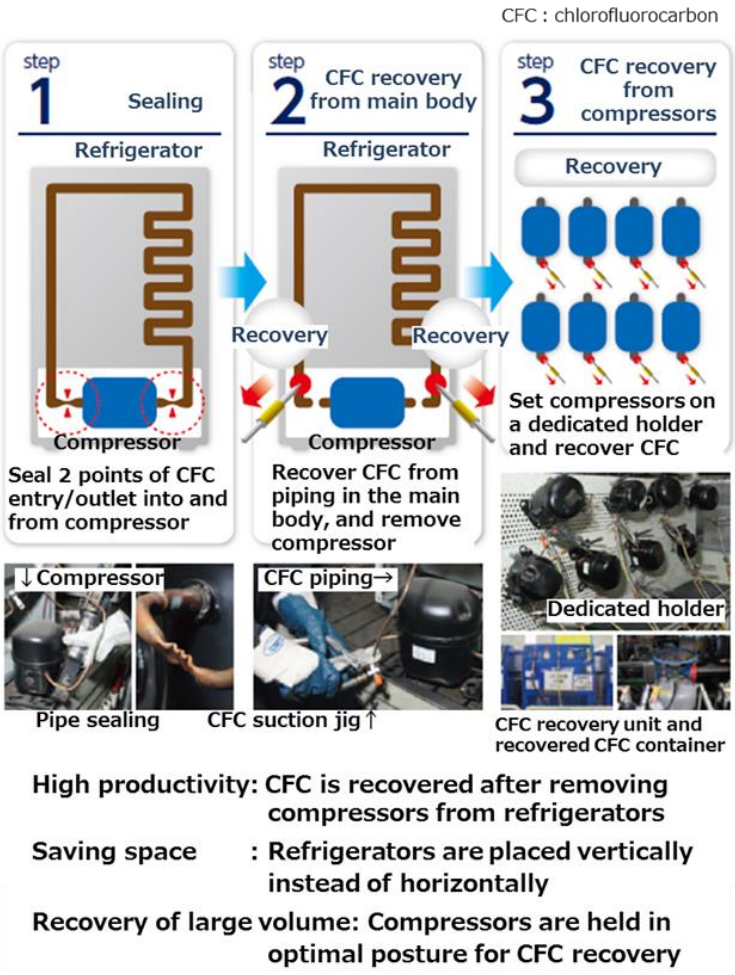


Fig. 4 Application of creative method – Innovative CFC recovery

As described above, with typical CFC recovery method, duration of CFC recovery time, during which CFC can be sucked, equals to the duration of time a refrigerator passes through the CFC recovery section.

If the length of CFC recovery section is long and conveyor line speed is low, recovery rate of CFC increases. Problems which arise are: that increased length of CFC recovery section will increase the length of the entire CFC recovery line; and that lower conveyor line speed would reduce the number of refrigerators to be processed in a given period of time.

(2) Innovative CFC recovery system developed by application of creativity method

Conventional CFC recovery method, which is the subject under study, was compared with 10 antithetical invention principles to identify antithetical subject, and based on the clues obtained, points of focus were identified and ideas were generated. Fig. 3(b) shows: characteristics of the subject under study obtained by utilizing antithetical invention principles (Step 1); antithetical subject and its characteristics (Step 2); and points of focus (Step 3). Points of focus which otherwise could not be obtained, including from [3-1]: Separate CFC piping and compressor through [3-10]: Use of disposable jigs, were identified.

These points of focus contributed to generating ideas by means of divergent thinking and organizing them into basic ideas, resulting in conceiving an innovative CFC recovery method. Step 1 through 3, as well as points of focus and basic ideas for each Step, are indicated in Fig. 4. Out of the total of 10 points of focus, 9, excluding [3-5] became the starting point of conceiving basic ideas.

As opposed to typical CFC recovery method, in which CFC is recovered during the time when refrigerators pass CFC recovery section, the innovative CFC recovery method involves removing and placing compressors on a dedicated holder to allow continuous suction and total recovery of CFC. And the new method also drastically improves efficiency of the recovery of CFC from compressors, which is troublesome and considered a bottleneck of the operation, by working on several compressors together.

4. Conclusion and discussion

For the step of creation of VE job plan (functional analysis/ creation/ evaluation and decision) at the planning stage of development design type VE, basic ideas were obtained by utilizing the proposed creativity method. The project team went on to VE for the preliminary design stage as well as to VE for detail design stage, and successfully developed and designed equipment and jigs/ tools for materializing ideas of Step 1 through 3 shown in Fig 4.

While basic ideas of CFC recovery method conceived by applying the proposed creativity method were truly innovative, different from conventional methods, individual new ideas used for each step were not unrealistic, and therefore, development of the line was completed and put into practical use in a short period of time by team design. This resulted in achieving Japan’s highest level efficiency in CFC recovery.

By finding clues which are equipped with superior features of both TRIZ and antithetical analogical approach, creating highly reliable, innovative idea in line with intended technical policy was possible.

An important point about the process of creating new values in this example is that, 10 antithetical invention principles were applied to, and antithetical analogical approach was employed for, the conventional method itself, rather than making problems/issues of conventional method under study as a starting point. The innovative system developed is the product of “Blasting” conventional system, followed by “Creating” and “Refining” based on the “Blasting” result, and thus eliminating inherent problems of conventional system altogether.

[References]

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