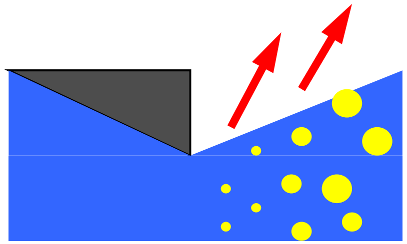
USIT Case Study 5. Increase the Foam Ratio of Porous Polymer Sheet



References:

[1] Source: Case Study made by Toru Nakagawa, at USIT 3-day Training Seminar (Instructor, Ed Sickafus), on March 10-12, 1999, in Detroit

[2] Original report: "USIT Case Study (2) Increase the Foam Ratio in Forming a Porous Sheet from Gas-Solved Molten Polymer", Toru Nakagawa (Osaka Gakuin Univ.), "TRIZ Home Page in Japan", Jul. 2, 1999 (in Japanese); Aug. 26, 1999 (in English)

[3] Conference presentation: "Approaches to Application of TRIZ in Japan", Toru Nakagawa, TRIZCON2000, Apr. 30 - May 2, 2000, Nashua, NH, USA, pp. 21-35; posted in "TRIZ Home Page in Japan", May 8, 2000 (in English); Feb. 28, 2001 (in Japanese)

[4] Description of this case study: "USIT Case Study 5. Increase the Foam Ratio of Porous Polymer Sheet", Toru Nakagawa (OGU), May 15, 2015 (in Japanese), Jun. 10, 2015 (in English)

USIT Case Study 5. Increase the Foam Ratio of Porous Polymer Sheet

Introduction: Outline and Significance of this Case Study

This Case Study was developed by Toru Nakagawa at the 3-day USIT Training Seminar instructed by Dr. Ed Sickafus, the original USIT developer, in Mar. 1999. Its report published in "TRIZ Home Page in Japan" in Jul. 1999 was in fact the first paper introducing how to apply USIT in the world.

Nakagawa applied USIT to solve a real problem which was faced in a polymer manufacturer, though he is not a specialist in the field. On the third day of the seminar, the problem was solved as one of 4 parallel group practices. This is useful as a case study where conceptual solutions were obtained smoothly.

Particles Method is mainly used. This is the first case which I applied Particles Method, and yet the method was applied vividly and the report was described well and in detail.

At the initial stage of USIT application in Japan, we used, in accordance to Sickafus' suggestions, either the Function-Attribute Analysis (for understanding the present system) or the Particles Method (for understanding the ideal system). This case study was much used as a typical case for using the latter method.

The conceptual solutions obtained were reported to the polymer manufacturer, and their responses are described at the end of this case study.

A real problem in the field of chemical engineering is solved with the Particles Method

USIT Case Study 5. Increase the Foam Ratio of Porous Polymer Sheet

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[Case 5. Porous] Step 1. Define the Problem (1) Preparation: R&D Project

In the Real World, raise an issue and prepare for a Project of problem solving

(1) Preparation: R&D Project in the Real World

This case study has Two stages of Real World:
(1) R&D project in a Manufacturer and
(2) USIT Training Project

Situation: As a leading manufacturing company in the area of polymers, R&D of technologies and products are crucial activities.

Target: For empowering R&D capability in engineering divisions and laboratories, it is decided to introduce the new problem solving method TRIZ/USIT and try to apply it to ongoing real problems.

Project One of real, regular projects in engineering research laboratories.
At an initial stage of a theme of technology development. .

Activities: An R&D project carried out by a small research team.

Team: Several researchers/engineers.
One of the members is a beginner in TRIZ/USIT.

Theme: A topic in the field of chemical engineering. Technology for producing porous polymer sheets.

[Case 5. Porous] Step 1. Define the Problem (1) Preparation: USIT Training

In the Real World, raise an issue and prepare for a Project of problem solving

(1) Preparation: USIT Training by use of real problems

This case study has Two stages of Real World:
(1) R&D project in a Manufacturer and
(2) USIT Training Project

Situation: In Nov. 1998 Nakagawa was impressed with the USIT presentation by Dr. Ed Sickafus at the First TRIZ International Conference. Reading his USIT Textbook, I asked him to open a USIT training Seminar. Sickafus conducted the 3-day USIT Training Seminar in Mar. 1999.

Target: To understand and master USIT and to apply USIT to a real problem for myself.

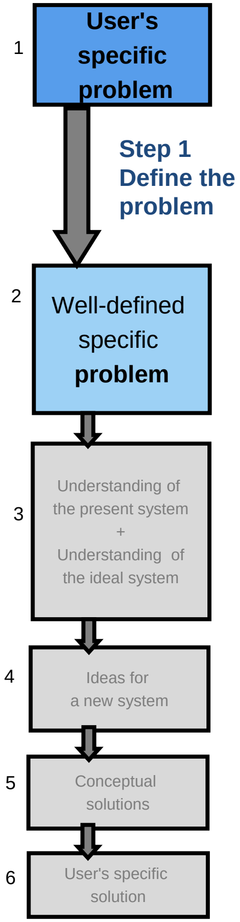
Project The 3 -day Training Seminar was openly held with 10 participants.
1st day: General introduction and small exercises;
2nd day: Group practices with 4 real problems (with mostly Function-Attribute analysis);
3rd day: Group practices with different 4 real problems (with mostly Particles Method). .

Activities: The 10 participants made 4 groups, and practiced to solve different problems in parallel.
3 cycles of lecture/group-practices/discussions were carried out in a day.

Team: Toru Nakagawa and Ravi Chona (Texas A&M Univ.). Problem owner: Toru Nakagawa.

Theme: A topic in the field of chemical engineering. Technology for producing porous polymer sheets.

[Case 5. Porous] Step 1. Define the Problem (2) Clarify the problem situations



Define the Problem: Clarify the problem situations and focus the scope

Step1: Define the Problem (in the USIT standard template)

Toru Nakagawa (Mar. 1999, USIT Training Seminar)

(a) An unwanted effect:

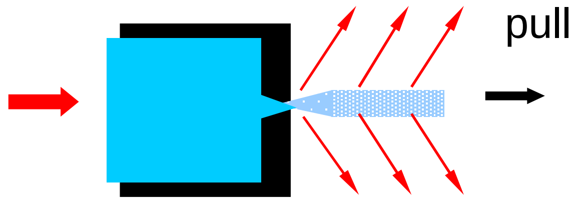
For producing porous polymer sheets, a high-temperature molten polymer, in which gas is dissolved with a high pressure, is pushed out through a slit-shaped nozzle and pulled for extension. The foam ratio, as measured by the volume expansion, however, is as low as 2 to 3 times in comparison with the theoretical value of 10.

(b) Task statement:

Improve the volume expansion ratio in forming porous polymer sheets from gas-dissolved molten polymer, up to as close as the theoretical value.

(c) Simple sketch of the problem situation:

molten polymer
gas
dissolved with high pressure

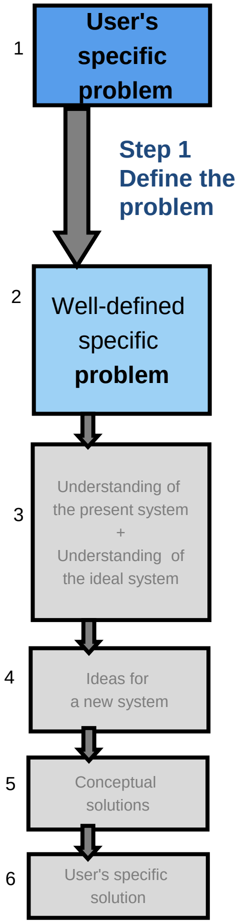


porous
polymer sheet

Volume expansion ratio
Calculated maximum : x 10
Current experimental : x 2-3

Note: In this slide, technical details (e.g., names of polymer and gas, pressure, mechanism of pushing, etc.) are omitted intently. USIT considers and solve the problem at a conceptual level as shown here.

[Case 5. Porous] Step 1. Define the Problem (2) Clarify the problem situations



(d) Plausible root causes:

Escape of the gas through the surface,

Not many bubbles, not large bubbles

Note: **A discussion** was made during the seminar:
Are these really "Root causes' or aren't they just "Results" caused by some more deeper facts?
Certainly, there are various underlying facts such as:
- Temperature and pressure distributions inside the polymer just after getting out of the nozzle which can determine the conditions of bubble formation,
- Molecular structure and thermo-dynamic properties of the polymer, etc.

When we go down to the causes deeper and deeper, the real situations and relationships become more and more complex and can not be revealed before examinations.
The present statements of root causes show the causes **at a phenomenological level**, and it is clear that if we can improve these aspects, we can certainly solve the problem.

(e) Minimal set of relevant objects:

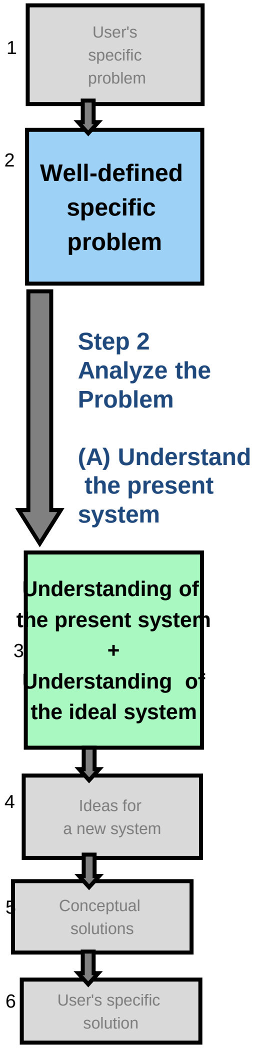
Porous polymer sheet, Molten polymer, Gas, Nozzle, Air

Note: **Air** in the environment is apt to be overlooked, but is actually involved in cooling the polymer on the surface and in the flow of gas.

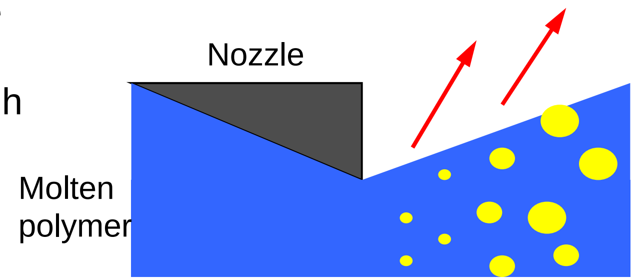
[Case 5. Porous] Step 2: Analyze the Problem (A) Understand the present system

(A1) Understand the Space Characteristics

Draw the figures and consider the mechanism



Enlarged sketch of the part where the molten polymer is pushed out through the nozzle (an image).



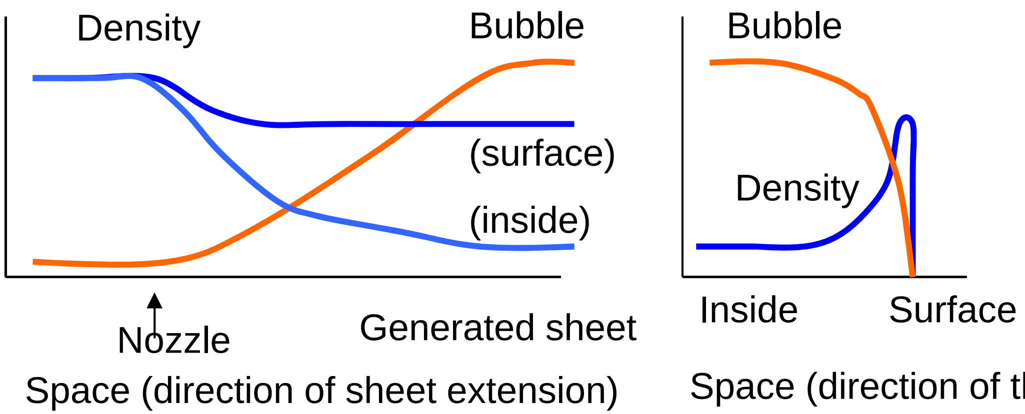
The gas is going out of the polymer surface.

Not many bubbles are generated.

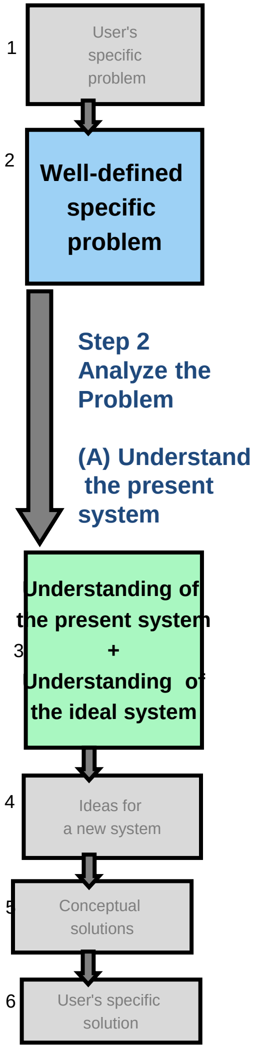
Bubbles do not grow large..

At high temperature and under high pressure the gas is dissolved in the molten polymer → Out of the nozzle, the pressure is released → Many small bubbles come out and grow. → The polymer gets cooled, and gradually becomes a porous sheet containing the bubbles inside.

Characteristics

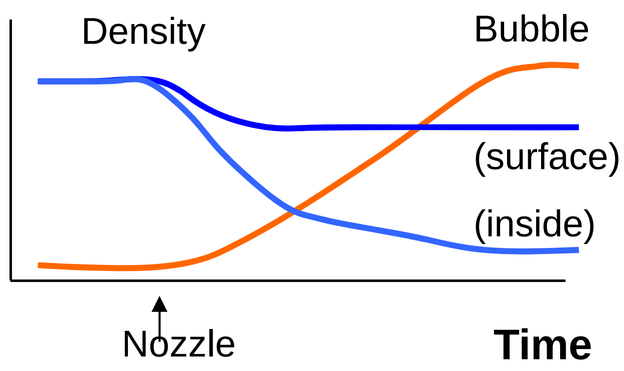


Consideration of the spatial difference in the thickness direction is useful.
The polymer is cooled from the surface and gets solid while containing the gas bubbles inside.



(A2) Understand the Time Characteristics

Suppose a small volume of molten polymer.
It is pushed out of the nozzle, and is extended and gradually cooled to form the porous polymer sheet.
In this graph the time is taken as the abscissa.



In this case, the time characteristics is qualitatively same as the space characteristics inthe sheet extension direction.

At high temperature and under high pressure the gas is dissolved in the molten polymer → Out of the nozzle, the pressure is released → Many small bubbles come out and grow. → The polymer gets cooled, and gradually becomes a porous sheet containing the bubbles inside.

It is desirable for a specialist to be able to estimate qualitatively various characteristics such as:

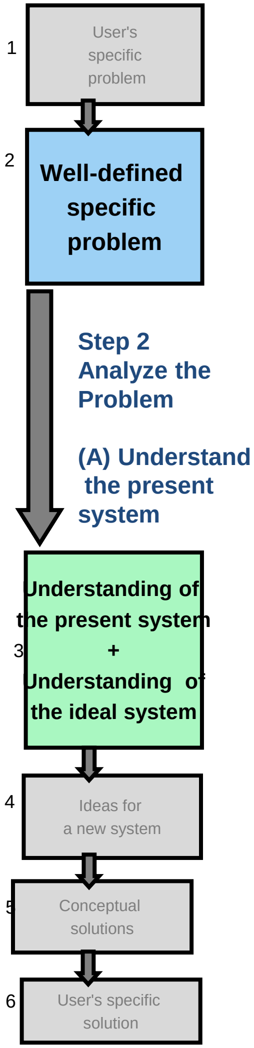
- External pressure and pressure distribution in the polymer,
- Temperature distribution in the polymer (inside and near surface),
- Viscosity distribution in the polymer (inside and near surface),
- Size and number of bubbles, and pressure of gas in the bubbles

Specialists in (or around) the project may be able to obtain these information through simulation.

[Case 5. Porous] Step 2: Analyze the Problem (A) Understand the present system

(A3) Understand the Attributes (properties)

This step was skipped in the Seminar, and inserted here newly.



It is not easy to describe this part, because we need subject matter knowledge. The table below is tentative.

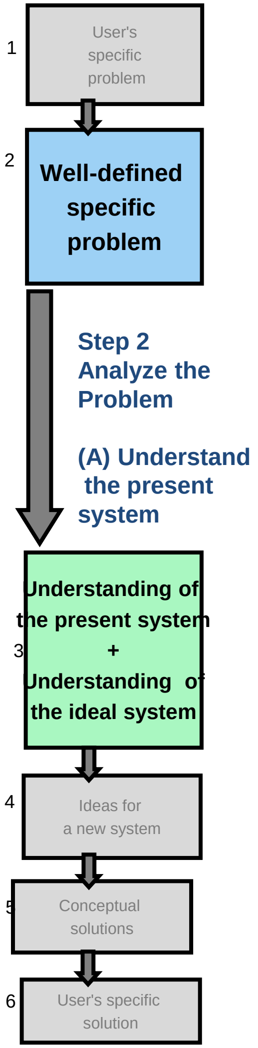
When the molten polymer is released through the nozzle, the gas dissolved in the polymer forms bubbles and escape partly through the surface. Cooling occurs by the air on the surface and by the bubble formation and escaping of the gas. This makes complex and dynamic situations of spatial distribution of temperature, pressure, viscosity, etc. in the polymer and the bubbles are formed and grow. Such situations change rapidly in time. All these situations can be understood properly only through detailed simulations.

Object	Attributes enhancing the bubble formation and growth	Attributes preventing the bubble formation and growth	Attribute enhancing the gas to escape	Attributes preventing the gas from escaping	Other attributes
Polymer (in molten sate)	Solubility of gas				
Polymer (going out of nozzle)	Internal (bulk) temperature	Viscosity	Temperature near the surface	Viscosity near the surface	
Polymer (in the solid state)				Thickness of the sheet	
Gas	Solubility of gas, pressure				
Nozzle, and wall					
Air (environ-ment)			Surrounding temperature	Air flow for cooling	
Others	Time duration for the bubbles to be generated, Number of places of bubble formation		Speed of extension of the polymer sheet		

[Case 5. Porous] Step 2: Analyze the Problem (A) Understand the present system

(A4) Understand the Functional Relationships

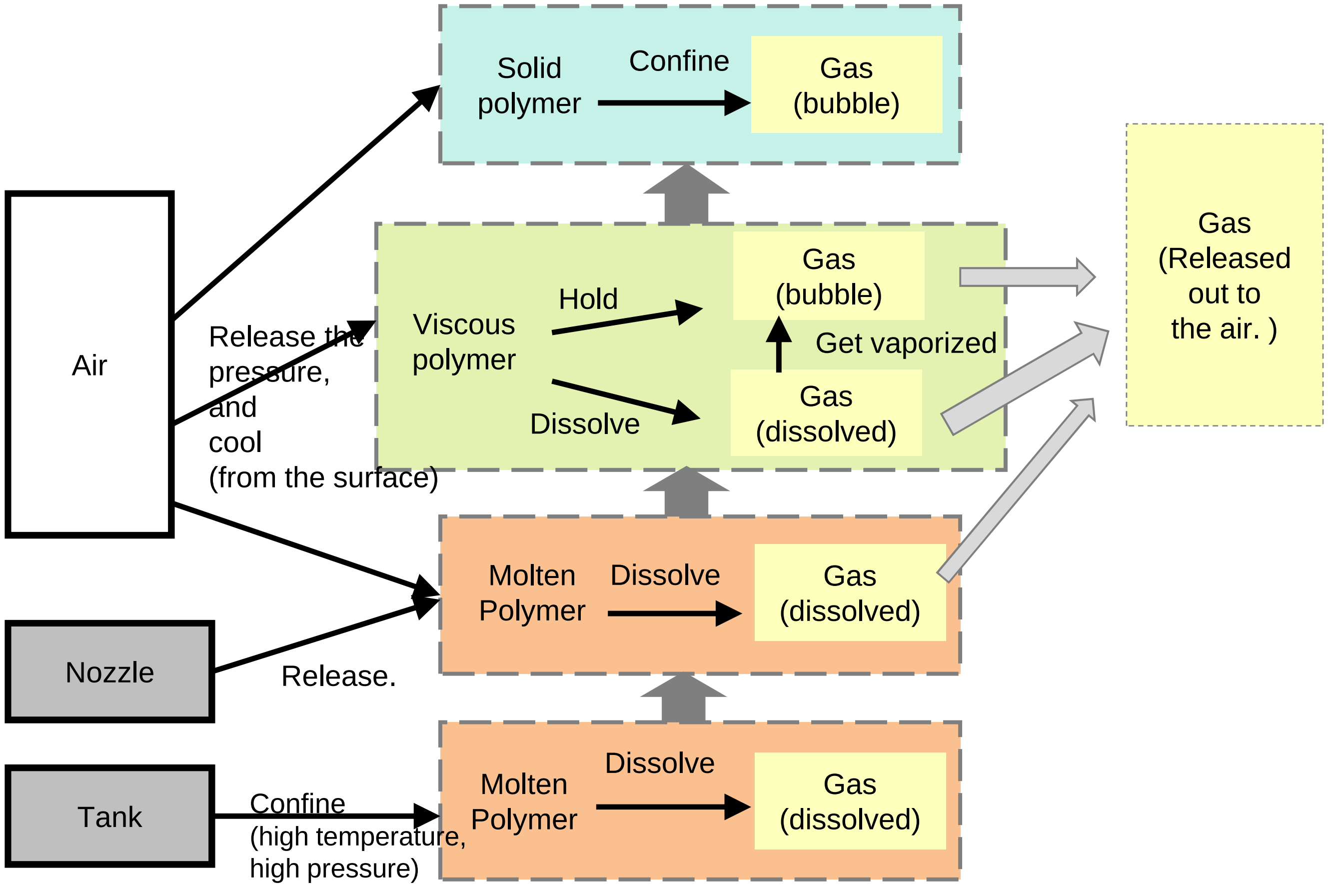
This step was skipped in the Seminar, and inserted here newly.



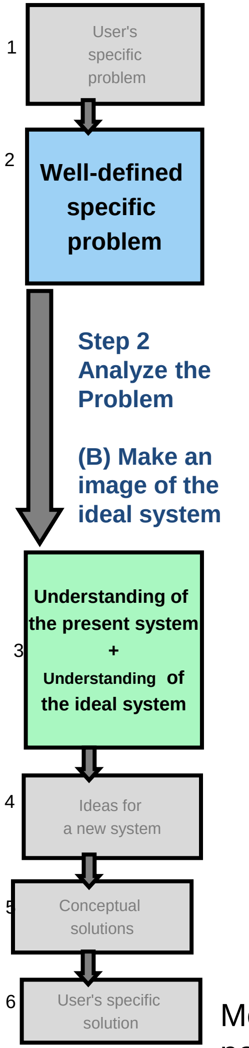
It is not easy to describe this part also, because we need to show a process. The following is a trial.

Selecting four typical stages of the process, functional relationships of relevant objects in each stage are described, and the time dependent changes are also drawn in a consistent manner.

Porous polymer sheet



[Case 5. Porous] Step 2: Analyze the Problem (B) Make an image of the ideal system



(B2) Consider the Ideal system with the Particles Method (Sickafus' method)

The Particles Method was applied vividly and effectively in this case study.

Particles Method is the core of this case study.

A good example.

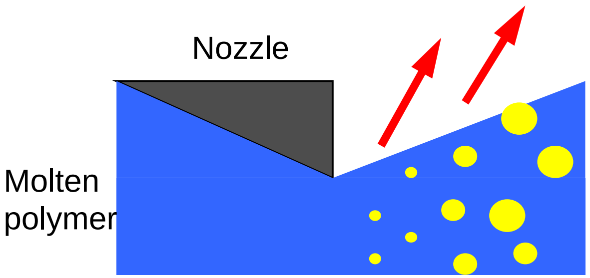
(a) Sketch the present system

Draw the sketch so as to illustrate the mechanism of the problem (unwanted effect).

(b) Sketch the ideal system (as the result of achievement)

Never try to draw "how to achieve the ideal results",
because such means and mechanisms are not known at the present stage
(before any idea generation and any solution construction).

(a) sketch of the present system:



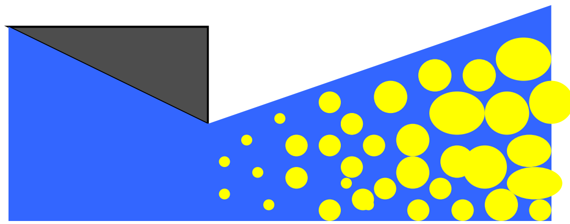
The gas is escaping

Not many bubbles

Not large bubbles

This close-up construction was suggested by Dr. Sickafus.

(b) Sketch of the ideal system:

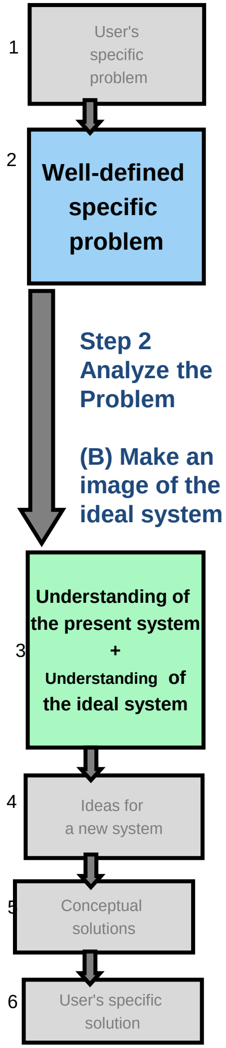


The gas is NOT escaping

More bubbles

Larger bubbles

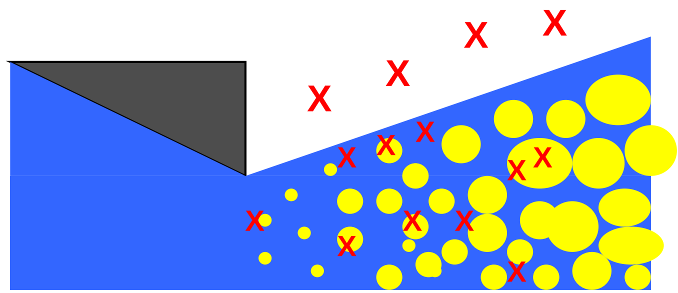
[Case 5. Porous] Step 2: Analyze the Problem (B) Make an image of the ideal system



(B2) Consider the Ideal system with the Particles Method (continued)

(c) Draw x marks (i.e., Particles) at the places of differences between (a) and (b).

xxx "Particles":
Magical substances/ Fields"
having any desirable properties, and
able to do any desirable actions



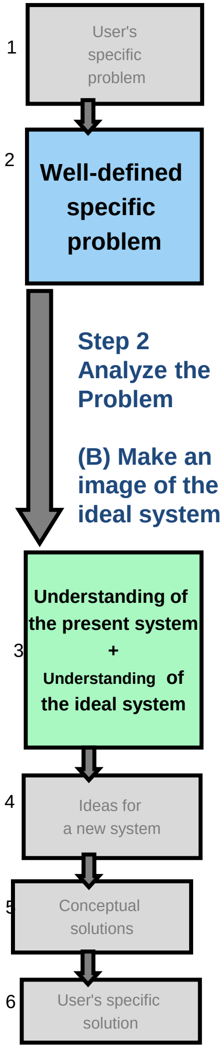
Particles **XXX** are placed outside the polymer surface and inside the polymer, in and around the bubbles.

"Particles" are magical things which can do anything desirable.

Suppose we have such magical things, and let's think what we would like to ask them. We should imagine freely.

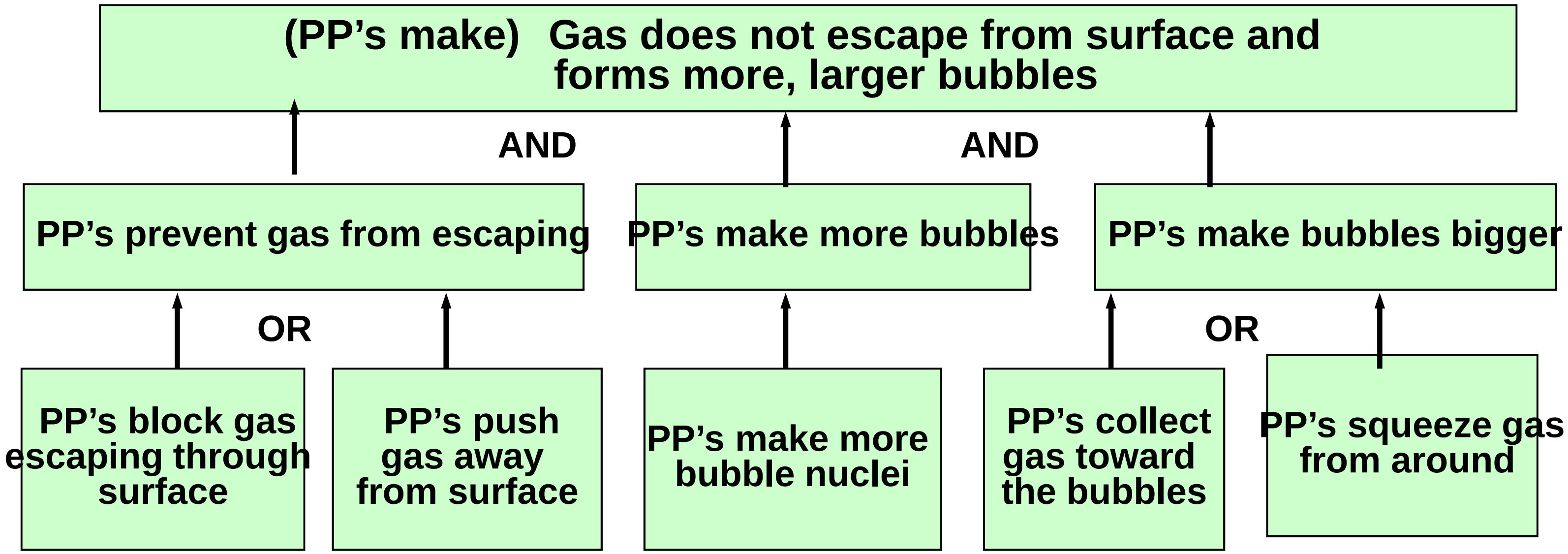
(At the later steps we will generate ideas which can realize such imaginary thoughts in accordance to sciences.)

[Case 5. Porous] Step 2: Analyze the Problem (B) Make an image of the ideal system



(B2) Consider the Ideal system with the Particles Method (continued)

(d) Think about Desirable Behaviors

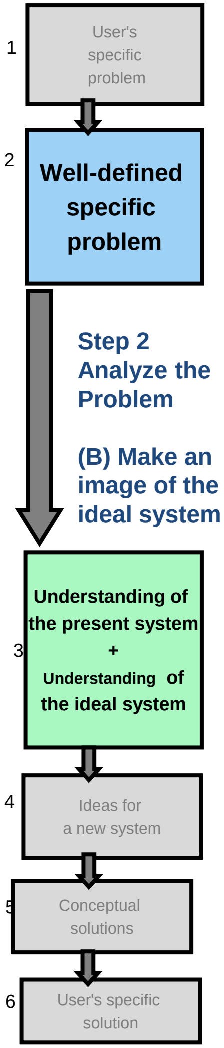


At the top, write the target to do in a sentence. (You may take it from the Task statement (of Step 1(b)) or the keywords expressing your ideal system (Step 2B(2)).

Ask the Particles (PP's) to do any action you want; or rather imagine how such smart magical particles are behaving to achieving the target for you.

Express such behaviors in a hierarchical tree diagram. Top-down thinking is recommended, even though random/bottom-up idea generation are also OK.

Use plain words, in place of technical terms for avoiding Psychological Inertia of technical terms.



(B2) Consider the Ideal system with the Particles Method (continued)

(e) List up Desirable Properties for the Particles may have

For each desirable behavior at the bottom of the preceding tree diagram, list up desirable properties the Particles may have. Think them widely and freely.
Do not try to criticize any feasibility or effectiveness of them.

PP's block gas escaping through surface
- container
- pressure
- electric field
- magnetic field
- ....

PP's push gas away from surface
- temperature difference
- pressure difference
- distribution of the bubble nuclei
- composition difference,

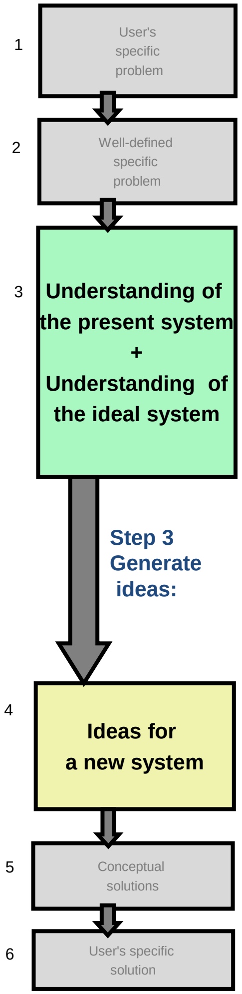
PP's make more bubble nuclei
- seeds for bubble nuclei
- container surface
- additional interface
- reaction for forming bubble nuclei
- taking time

PP's collect gas toward the bubbles
- absorption
- inter molecular force
- electrical field
- magnetic field
- taking time
- ....

PP's squeeze gas from around
- temperature difference
- pressure difference
- polymer's crystal formation
- solubility
- ....

When we write down such a property, we may naturally make images of applying/realizing it.
They form good bases for generating ideas in the next step.
Remember or write it down separately in a card (e.g., Post-It-Note).
Group discussion of them will be done later at the Step 3(1).

[Case 5. Porous] Step 3: Generate ideas:



(1) Write down the ideas freely with the stimulation of the analyses

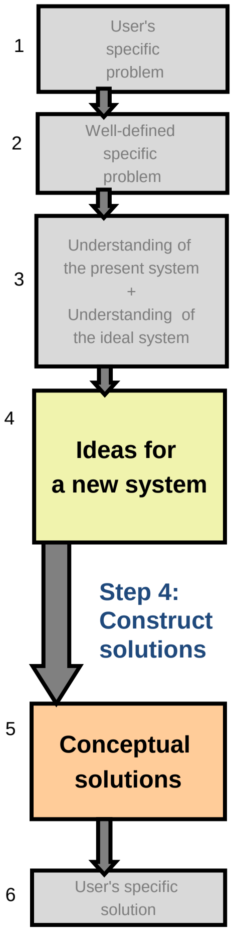
At the Training Seminar, we ended up with the previous step 2(B)(5).
Since various ideas were already in my mind, I wrote them down a few days later.

- **First, in order to generate more bubbles:**
  Since the bubbles are generated in the homogeneous molten polymer, we need some form of **inhomogeneity**.
  ==> To put **seeds** for starting the bubble formation.
  We should have **longer time period** having suitable condition for bubble generation.
- **For the generated bubbles to stay inside** the polymer:
  We should arrange so that the bubbles would not escape from the polymer surface.
  ==> We should make a wall of the instrument.
  E.g., **Attach some parts in front of the nozzle** and constrain the expansion of the polymer.
  ==> **Cool the surface first** and make the surface part of polymer solid,
  so that the gas has no pass to escape through the surface.
  Cool the bulk of the polymer slowly, and keep the condition of bubble formation longer,
  so that many bubbles are generated and kept enclosed in the polymer.
- **We should control the temperature and pressure distribution inside the polymer** while cooling down in a desirable way.
  At present, we are simply pushing out the molten polymer and extend it forwards.
  By controlling the pressure and temperature distribution, we can arrange the viscosity distribution of the polymer, bubble formation speed of the gas, and time dependence of various conditions .
  Thus, we will be able to control the number and sizes of the bubbles and the escape of the gas out of the polymer, etc.
- **We need to analyze how to control these factors by use of theoretical simulation.**

[Case 5. Porous] Step 4: Construct Solutions (2) Construct the conceptual solutions

Construct the conceptual solutions

These solution concepts were written down a few days after the Training Seminar.



(1) To put seeds for accelerating the bubble nuclei formation.

Nonhomogeneous elements are necessary in the homogeneous solution.
Solid powder; porous, surface active, gas absorbing, etc.
To take time for forming bubble nuclei around the seeds.

(2) To put an attachment in front of the nozzle and to control the pressure/temperature distribution

Do not release the pressure at once. To let the attachment be a container/holder.
To generate the conditions suitable for the formation and growth of the bubbles, and to keep the conditions for some time along the polymer pass.

(3) Not to form bubbles on/near the surface and to prevent gas from escaping

To cool the surface of the sheet and to form dense polymer layer on the surface.
To generate temperature difference between surface and inside, and control the conditions for bubble generation.
To keep the attachment surface inactive/preventive for the bubble formation.

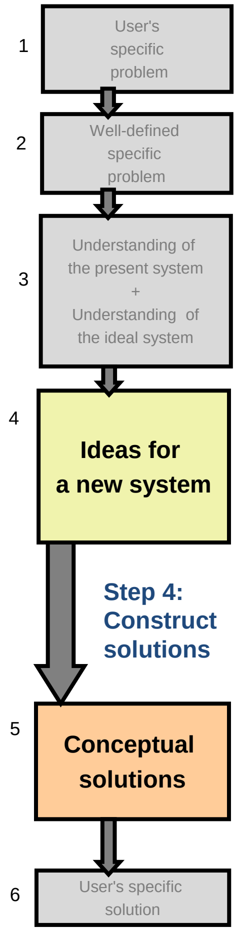
(4) To let all the gas contribute to the bubbles inside the sheet.

To form suitable temperature/pressure conditions along the polymer pass (i.e. along the time of sheet formation)

These concepts are executable at the same time. It seems to be technically feasible.
A technical simulation and the design are necessary.

[Case 5. Porous] Step 4: Construct Solutions (3) Report the results

Finalize as a Case Study and Report it. Conclusion as the Case Study.



USIT was applied to a real technological R&D problem,
i.e., "To increase the foam ratio of porous polymer sheet", and
we obtained a set of conceptual solutions.

This was my first experience to learn USIT in a 3-day USIT Training Seminar.
This case study was carried out on the third day. Even in such a short time,
I understood well how to apply USIT for analyzing the problem and for generating ideas,
through the practices of case studies.

This Seminar (conducted by Dr. Sickafus) was very helpful for me to learn
how to apply USIT and also how to conduct USIT training seminars.

The present case study is excellent especially for using **the Particles Method.**

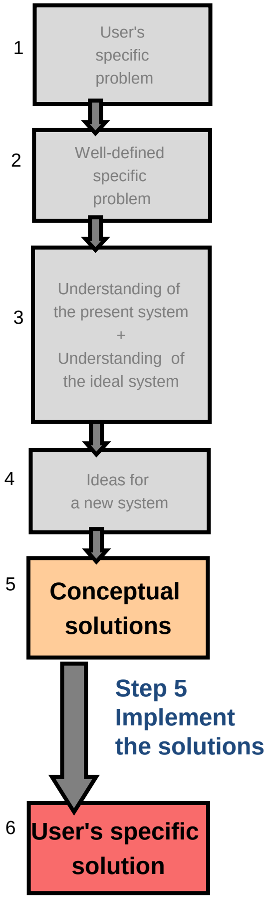
On the basis of the records written in cards and big paper sheets in English at the Seminar,
I made slides and documents of this case study both in Japanese and in English in a week
and reported them to the people involved in the real project.

The slides and the detailed documents of this case study and the USIT Training Seminar
were publicly posted in "TRIZ Home Page in Japan" in Jul. 1999.

I also gave presentations and seminars on this case study many times
in conferences, lectures, and training seminars.

[Case 5. Porous] Step 5: Implement the Solutions : (Real activities in the 'Real World')

Examine and evaluate the results in the parent project.



I reported about the whole result of USIT case study to the manager of the R&D project.
(The problem solving process with USIT, contents of the intermediate thinking process, and the final results of the conceptual solutions, etc.).

The manager responded to say:
"**These solution concepts are ideas already known individually, and look quite orthodox**."

For a problem at an early stage of technology R&D for several months,
a non-specialist have analyzed and solved by use of USIT to have generated
a set of conceptual solutions which are evaluated 'orthodox' by the project manager
-- this must be a very positive result, I believe.

We should note here that
the creative problem solving must not always seek for astonishing/strange/inventive solutions.

Dr. Ed Sickafus wrote about the aims of USIT as:
"In industries, rather than seeking for inventions, we should better generate
multiple concepts which solve real industrial problems as rapidly and creatively."

In the industry of this problem, after checking the present conceptual solutions,
they carried out some experiments and technology developments further;
but I do not know any detail.

USIT Case Study 5 [Porous] (Overview). Increase the Foam Ratio of Porous Polymer Sheet

A real problem in the field of chemical engineering is solved with the Particles Method

Toru Nakagawa (1999)