Chemical Product Design

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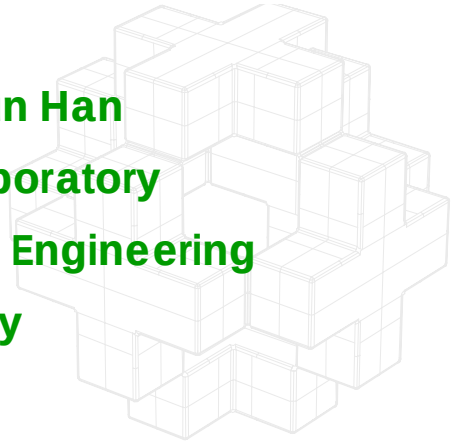
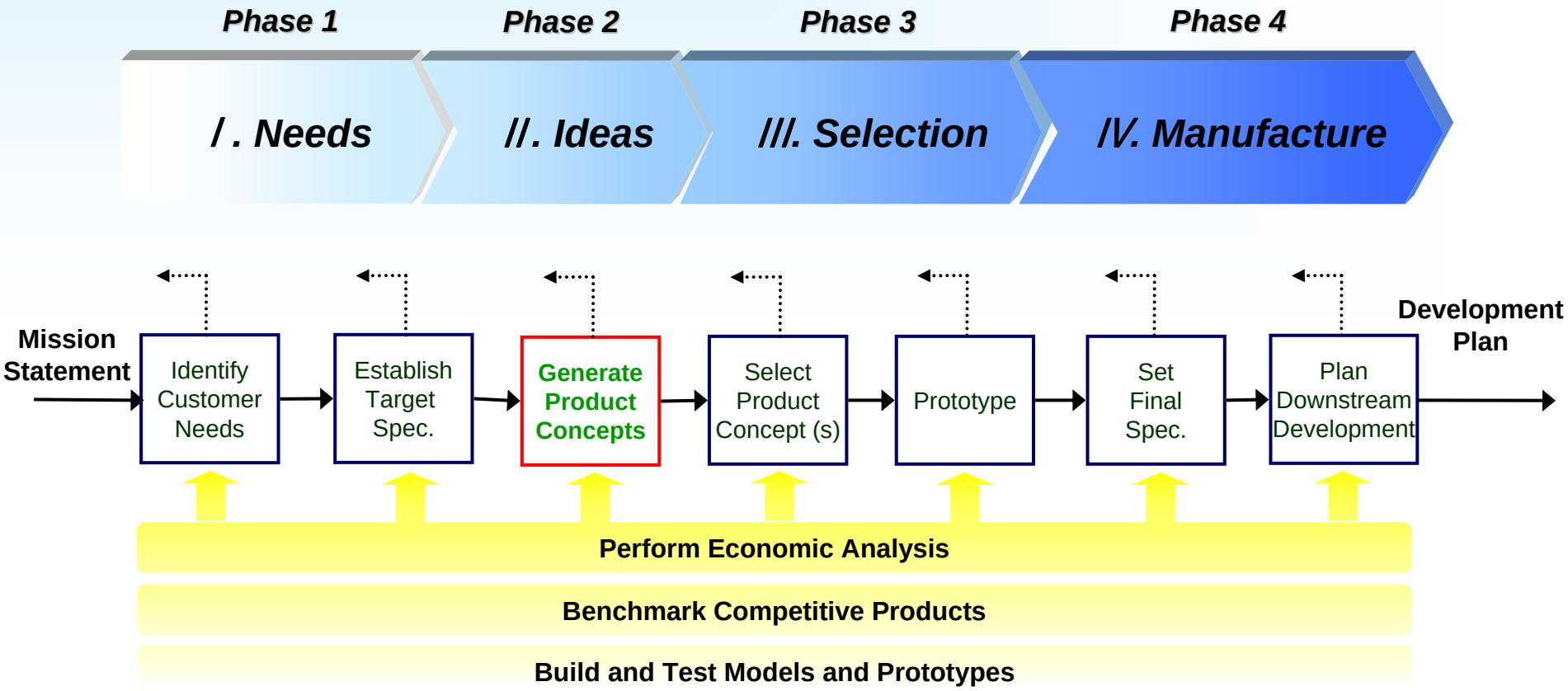


PART VII. Concept Generation

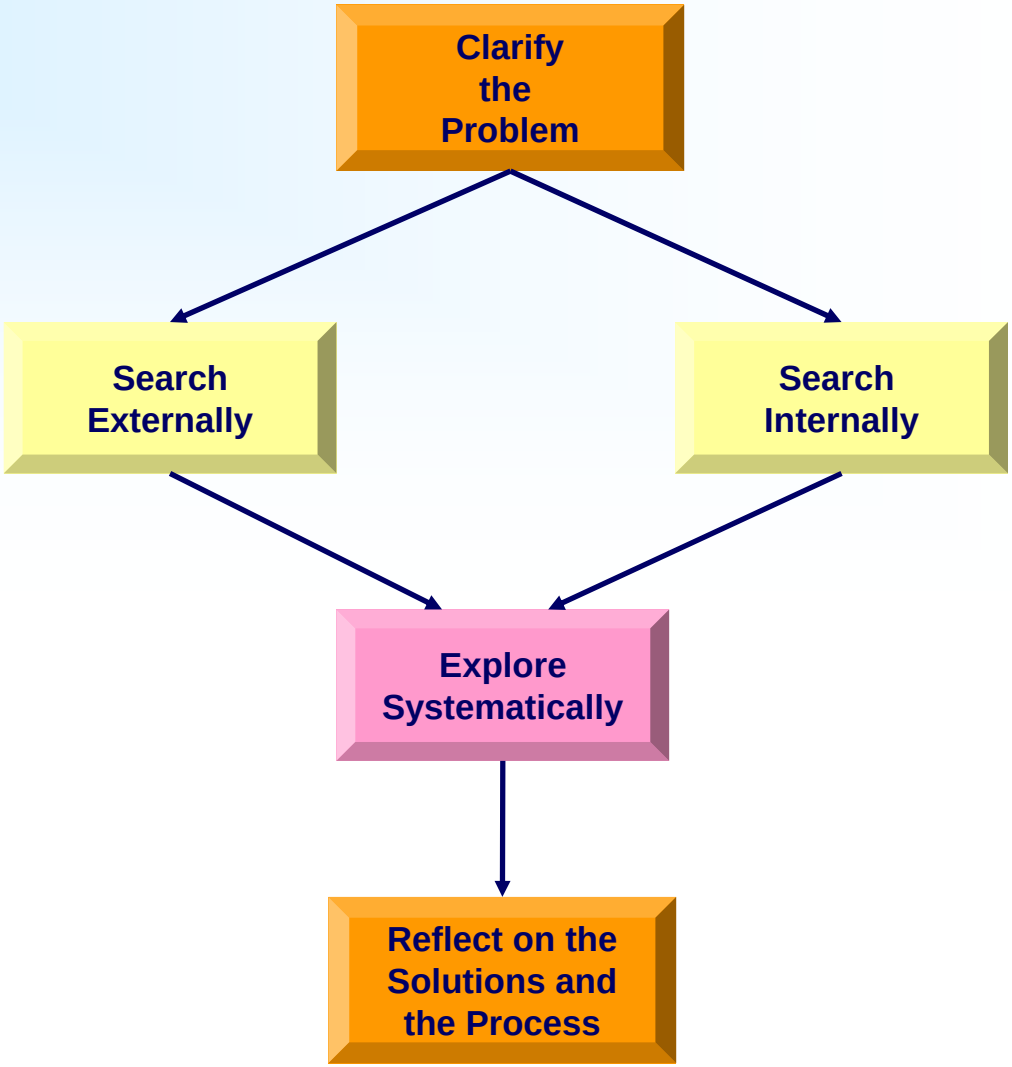
- Clarify the Problem
- External Search
- Internal Search
- Systematic Exploration
- Reflect on the Process

Procedure


Phase 1
Phase 2
Phase 3
Phase 4
I. Needs
II. Ideas
III. Selection
IV. Manufacture
Mission Statement
Identify Customer Needs
Establish Target Spec.
Generate Product Concepts
Select Product Concept (s)
Prototype
Set Final Spec.
Plan Downstream Development
Development Plan
Perform Economic Analysis
Benchmark Competitive Products
Build and Test Models and Prototypes

Concept Generation Process

1. **Clarify the Problem**
   - Problem Decomposition
2. **External Search**
   - Lead Users
   - Experts
   - Patents
   - Benchmarking
3. **Internal Search**
   - Individual Methods
   - Group Methods
4. **Systematic Exploration**
   - Classification Tree
   - Combination Table
5. **Reflect on the Process**
   - Continuous Improvement

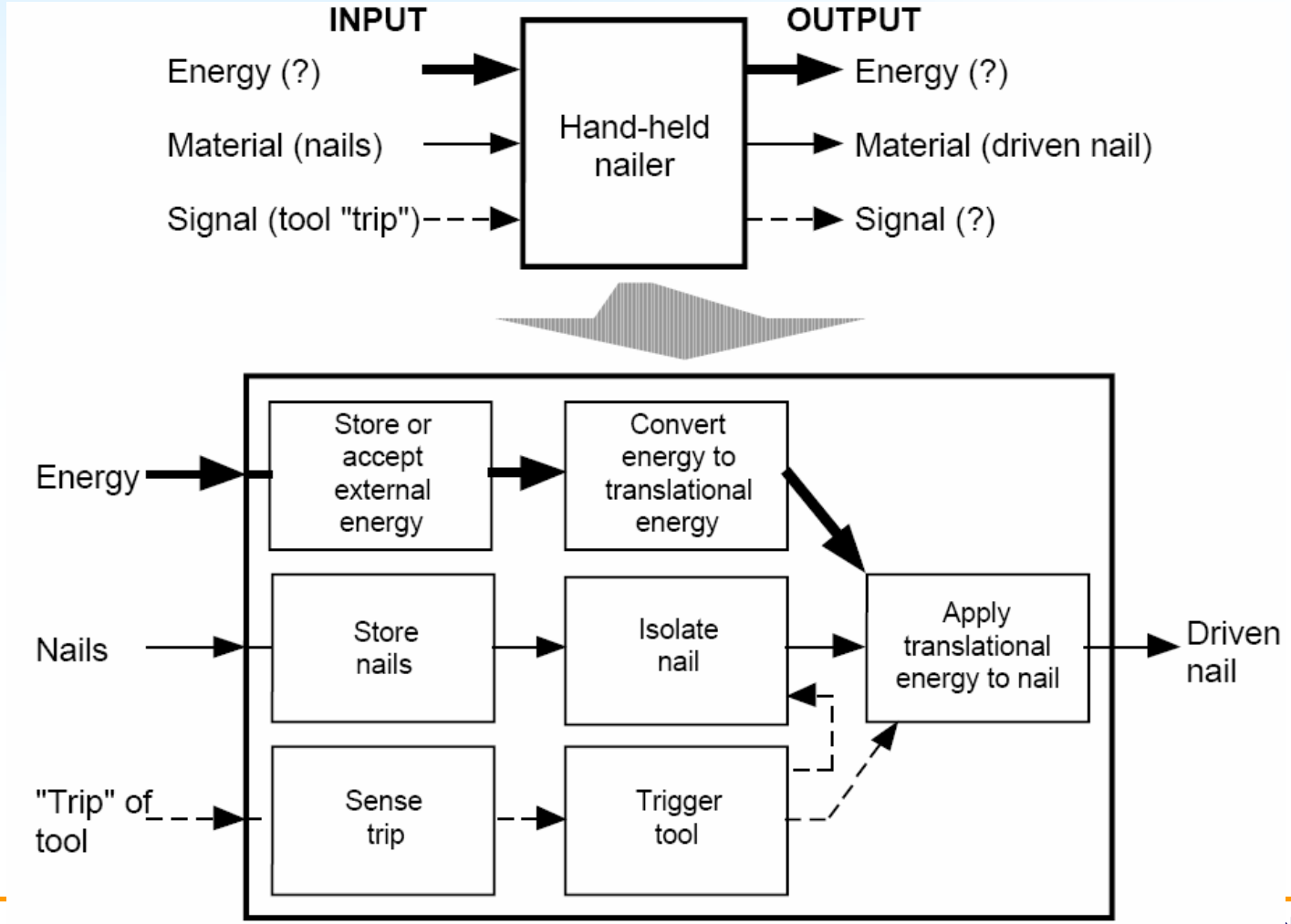


Problem Decomposition

Example – Power Nailer

Problem Decomposition

Function Diagram



External Search

Hints for Finding Related Solutions

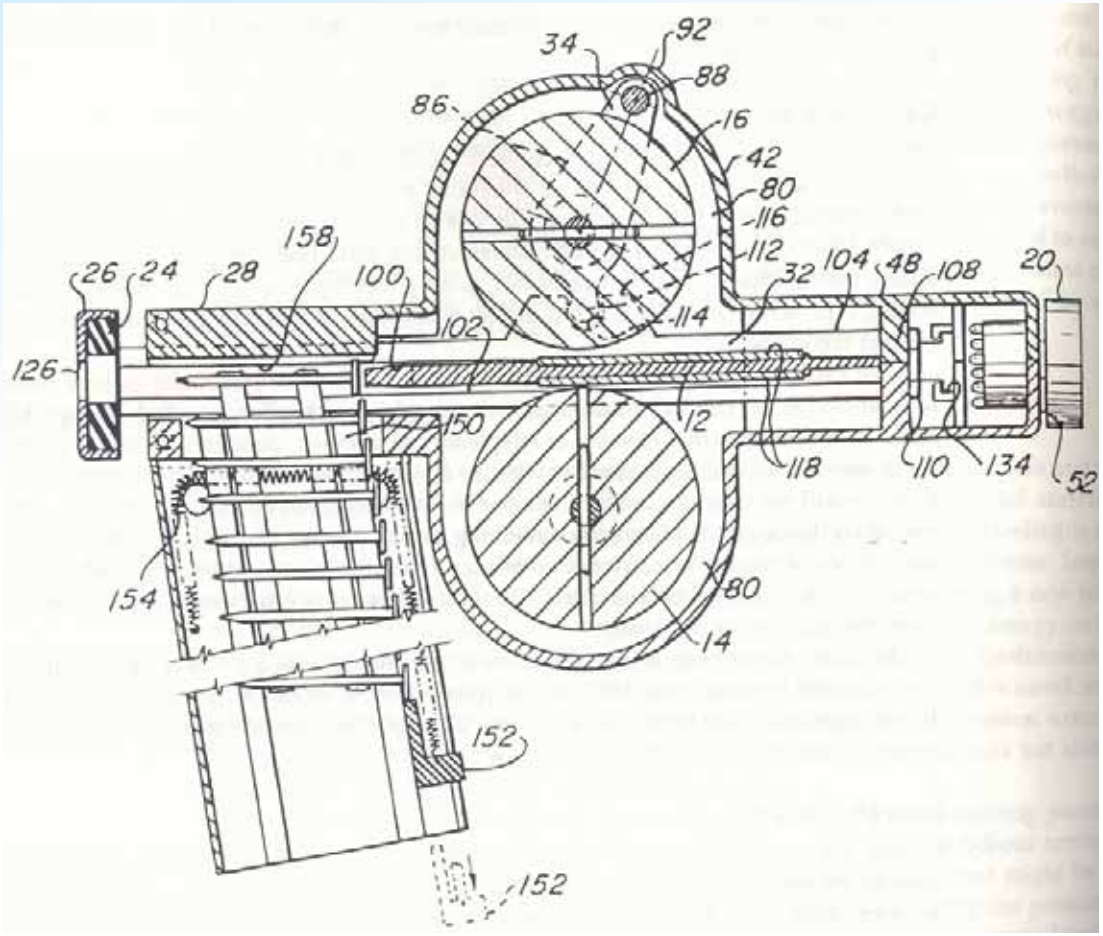
- **Lead Users**
  - *benefit from improvement*
  - *innovation source*
- **Benchmarking**
  - *competitive products*
- **Experts**
  - *technical experts*
  - *experienced customers*
- **Patents**
  - *search related inventions*
- **Literature**
  - *technical journals*
  - *trade literature*

Internal Search

Hints for Generating Many Concepts

- Suspend judgment
- Generate a lot of ideas
- Infeasible ideas are welcome
- Use graphical and physical media
- Make analogies
- Wish and wonder
- Solve the conflict
- Use related stimuli
- Use unrelated stimuli
- Set quantitative goals
- Use the gallery method
- Trade ideas in a group

Systematic Exploration

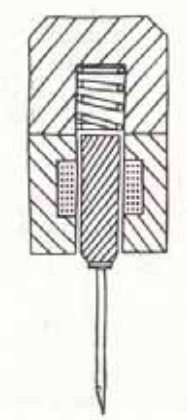


Concept from motor-driven double-flywheel nailer patent (U.S. Patent 4,042,036).

The accompanying text describing the patent is nine pages long.

Systematic Exploration

Convert Electrical Energy to Translational Energy	Accumulate Energy	Apply Translational Energy to Nail
Rotary motor w/ transmission	Spring	Single Impact
Linear Motor	Moving Mass	Multiple Impacts
Solenoid		Push Nail
Rail Gun		



In this solution concept, a solenoid compresses a spring and then release it repeatedly in order to drive the nail with multiple impacts.

Systematic Exploration

Convert Electrical Energy to Translational Energy	Accumulate Energy	Apply Translational Energy to Nail
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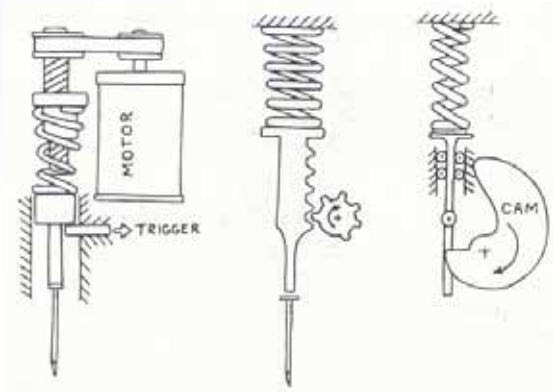

Multiple solutions arising from the combination of a motor with transmission, a spring, and single impact.

The motor winds a spring, accumulating potential energy which is then delivered to the nail in a single blow.

Systematic Exploration

Convert Electrical Energy to Translational Energy	Accumulate Energy	Apply Translational Energy to Nail
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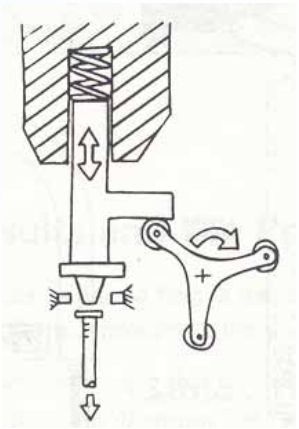

Solution from the combination of a motor with transmission, a spring, and multiple impacts.

The motor repeatedly winds and release the spring, storing and delivering energy over several blows.

Systematic Exploration

Convert Electrical Energy to Translational Energy	Accumulate Energy	Apply Translational Energy to Nail
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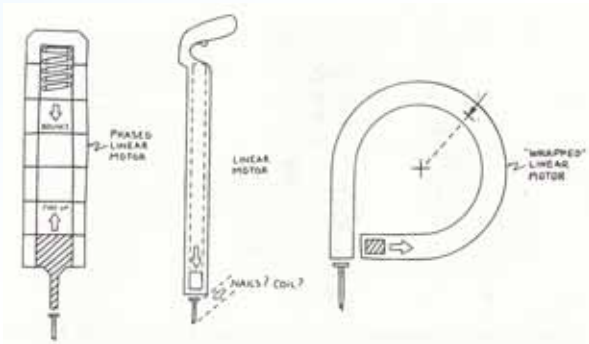
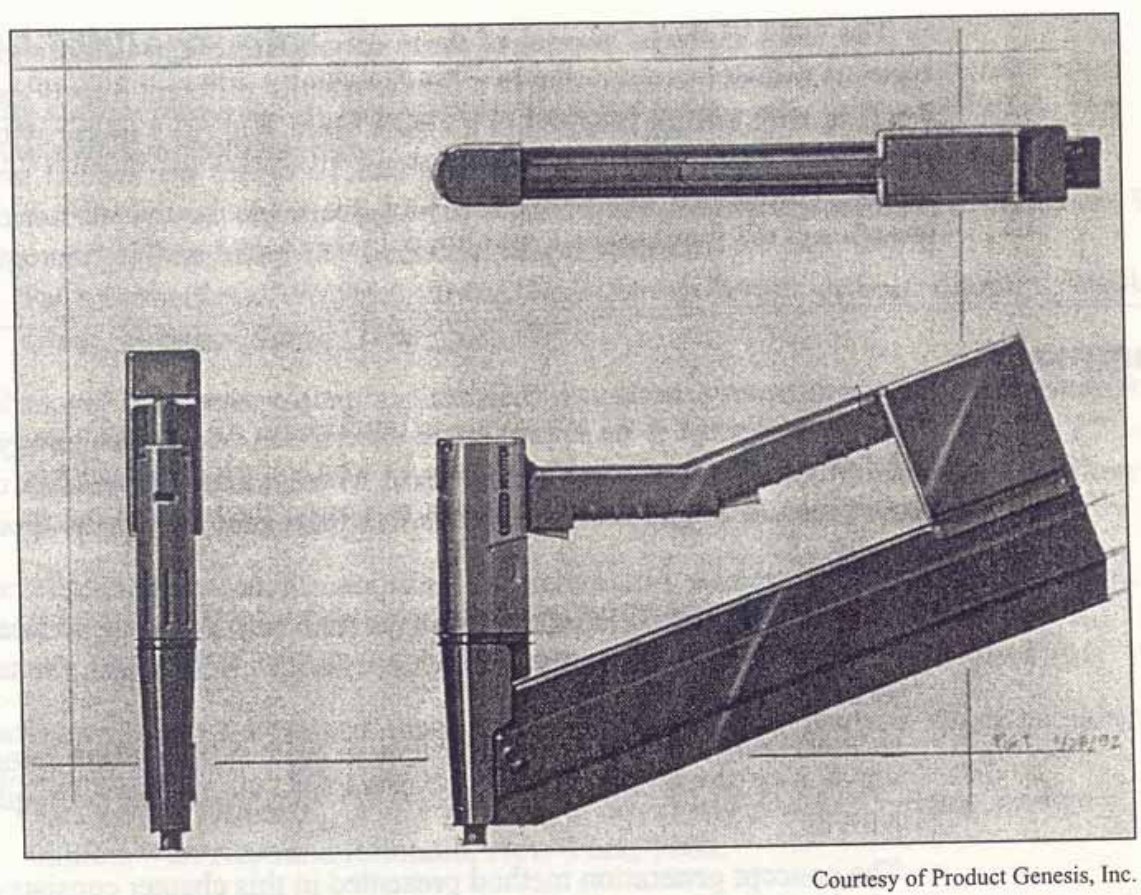
Rail Gun		



Multiple solutions arising from the combination of a linear motor, a spring, and single impact. A linear motor accelerates a massive hammer, accumulating kinetic energy which is then delivered to the nail in a single blow.

Systematic Exploration



Courtesy of Product Genesis, Inc.

One of several refined solution concepts

Chemical Industry Example

Chemical Sources of Concepts (Ideas)

◆ Natural Product Screening

- During the past century, this has been a major source of complex chemical species

ex) Pharmaceutical industry: aspirin and opium, quinine and colchinine all first came from nature

Other industries: Sunillin is a plant-based antifungal pesticide

Bulletproof jackets are made from same structure of the fibers of spider's silk

◆ Random molecular Assembly

- Not thinking about chemical mechanisms at all

- Have a vague idea of the type of molecule but we are uncertain about its chemical structure

◆ Combinatorial Chemistry

- Identify possible active ingredients or molecular fragments and to test all of them and in all possible combinations

Chemical Industry Example

Three Routes to Chemical Ideas

Parameter	Natural Product Screening	Random Assembly	Combinatorial Chemistry	Remarks
Typical Starting Information	**Potions from folk medicine**	**Similar chemicals of known structure**	**Similar chemicals of known structure**	**Note that we must have some chemical knowledge to begin**
Chemical Synthesis	**None**	**Random assembly of known fragments**	**Planned assembly of known fragments**	**We may not know what we have made**
Trials for Efficacy	**Use entire potion**	**Use entire product mixture**	**Use each known product**	**We will discard most of the chemical species present**
Chemical Analysis	**Identify active ingredients**	**Identify active ingredients**	**None**	**We know what we have made only in the third case**

Note: **Natural product screening is well developed and combinatorial chemistry is evolving rapidly. Random assembly is less often used.**

Chemical Industry Example

Concepts (Ideas) for an Adhesive for Wet Metal

1. Wipe the metal surface with a cloth (F)
2. Change the metal's composition
3. Change to a new adhesive (V)
4. Make the adhesive water absorbing
5. Use a plant that sticks to a ship (V)
6. Use a natural rubber
7. Electrostatically charge the metal
8. Put a magnet in the in the current adhesive (R-7)
9. Use a super glue (i.e., a cyano acrylate) (V)
10. Use a different resin (V)
11. Make a resin with a hydrophilic part
12. Treat the surface with zeolite
13. Use a zinc coating primer
14. Spray on a silicone coating
15. Use neoprenephenolic as the adhesive (R-59)
16. Invent an adhesive that reacts with water
17. Use a silica gel for surface treatment (F)
18. Choose a van der Waals bonding material
19. Try ionic bonding (F)
20. Use a water scavenger in the adhesive base
21. Treat the surface with alkali
22. Use corn starch (F)
23. Use an adhesive with a functional group that reacts with water
24. Use an isocynate with a water reactive part (R-23)
25. Inject acidic salt in the metal (F)
26. Use more adhesive (F)
27. Use a concrete cement
28. Choose a water catalyzed polymer
29. Choose an adherent with a water reactive part (R-23)
30. Use a water scavenging adhesive (R-20)

F = folly V = vague R = redundant

Chemical Industry Example

Concepts (Ideas) for an Adhesive for Wet Metal

31. Add a catalyst to speed up the reaction
32. Invent coupling chemistry (V)
33. Adapt dental adhesives (V)
34. Try a polymer with a protective layer and heat to use
35. Use heat catalyzed polymer (V)
36. Coat the surface before applying adhesive (V)
37. Invent an adhesive that reacts with metal
38. Welding with a laser (F)
39. Replace the metal (F)
40. Solder (F)
41. Use a sugar solution (V)
42. Use a reversible glue (F)
43. Apply a vacuum adhesive (V)
44. Use an adhesive developed for the bathroom (V)
45. Use candle wax (F)
46. Try water based adhesive (R-11)
47. Use natural rubber (R-6)
48. Use spider web (F)
49. Use asphalt
50. Eliminate metal from cars (F)
51. Use rope to tie up the metals
52. Use bubble gum (F)
53. Make plastic or fiberglass cars (F)
54. Don't use cars (F)
55. Use flower tapes (F)
56. Blow dry the surface
57. Use toluene as the base solvent
58. Get water resistance y using nitrocellulose/polyisobutylene
59. Use a phenolic group
60. Use a zipper (F)

Chemical Industry Example

Sorted Ideas for Wet Metal Adhesives

Improvements in Existing Adhesives

A. Choose a van der Waals bonding material (18)

B. Use an adhesive + a functional group that reacts with water (23)

C. Add catalyst to speed up the reaction (31)

D. Coupling chemistry (32)

E. Apply a vacuum adhesive (43)

Water-Absorbing Adhesives

A. Make the adhesive water absorbing (4)

B. Make a resin with a hydrophilic part (11)

C. Invent an adhesive that reacts with water (16)

D. Use a scavenger in the adhesive base (20)

E. Choose a water catalyzed polymer (28)

Surface Treatments

A. Treat surface with zeolite (12)

B. Use zinc coating primer (13)

C. Spray on a silicone coating

D. Treat the surface with alkari (21)

E. Try a polymer with a protective layer and heat (34)

F. Blow dry the surface (56)

Chemical Industry Example

Sorted Ideas for Wet Metal Adhesives

New Innovations

A. Change the metal's composition (2)

B. Use a natural rubber (6)

C. Electrostatically charge the metal (7)

D. Invent an adhesive that reacts with metal (37)

E. Get water resistance with nitric cellulose / polyisobutylene (58)

F. Use a phenolic group (59)

Curiosities

A. Use a concrete cement

B. Use asphalt

C. Use rope to tie up the metals

Note: The numbers in parentheses refer to previous table. The ideas in boldface are felt to be the most promising