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Measurement and Detection Standards from The Theory of Inventive Problem Solving

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TRIZ: The Theory of Inventive Problem Solving

- **Systematic Problem Solving Methodology**
  - **Empirically Derived Techniques**
    - Ideality
    - Technical Contradiction Theory
    - Levels of Innovation
    - Maturity Mapping
    - Technology Forecasting
  - **Heuristics**
    - Psychological Bias
    - Ideal Final Result
    - Physical Contradiction Theory
    - System Approach
    - ARIZ
    - **Substance-Field Modeling**
      - **76 Standard Solutions and algorithm**

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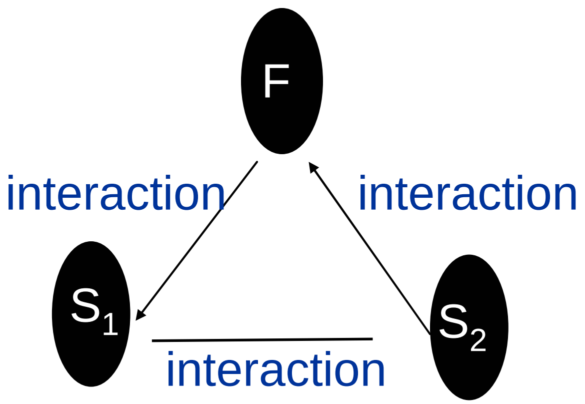
SFM: Substance-Field Modeling

- **Modeling Technique**
  - **Describes the Interactions within a System Triad:**
    - – **Field, F**
    - – **Substance 1, S_1**
    - – **Substance 2 , S_2**



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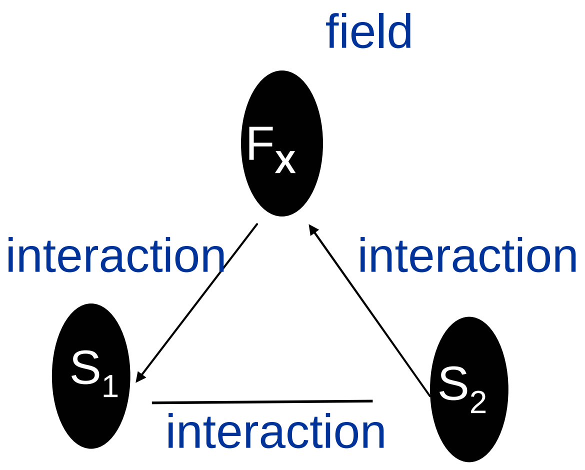
The Fields, F_X

- **Mechanical, F_{Me}**
- **Electrical, F_E**
- **Thermal, F_{Th}**
- **Chemical, F_{Ch}**
- **Magnetic, F_M**
- **Electromagnetic, F_{EM}**
- **Nuclear, F_N**

- **Compound Fields:**
  - **E-Me**
  - **Th-Ch**
  - **E-Ch, etc.**



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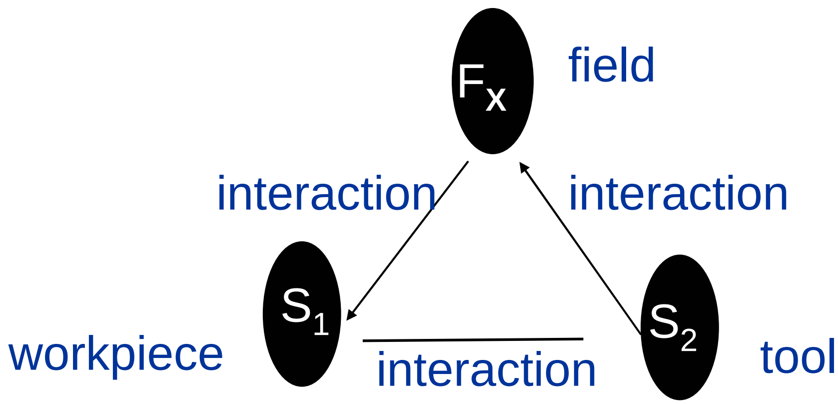
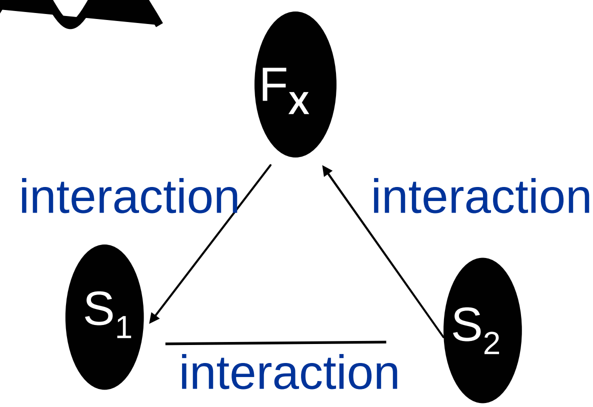
The Substances: S_1 and S_2

- S_1 is known as the ***workpiece***
- S_2 is the ***tool***
- The ***tool*** is applied to the ***workpiece*** and the interaction is described by a ***field*** and the resultant ***interactions***
- Energy flows from the ***tool*** to the ***workpiece***



The Interactions

- Sufficient:
- Insufficient:
- Harmful:



Modeling Examples

- S1: wall
- S2: person
- F: painting

- S1: wall
- S2: paint
- F: adhesion

- S1: wall
- S2: brush
- F: application

- S1: paint
- S2: brush
- F: application

- S1: brush
- S2: person
- F: moving application

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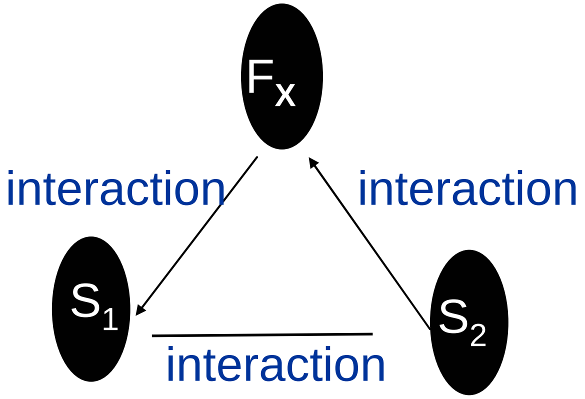
Incomplete, Insufficient, or Systems with Harm

- The minimum functioning system model involves a complete triad: F_X, S_1, S_2, and each interaction (3 minimum)
  - A system that is missing any of those elements is <u>incomplete</u>
  - An <u>incomplete</u> should be completed



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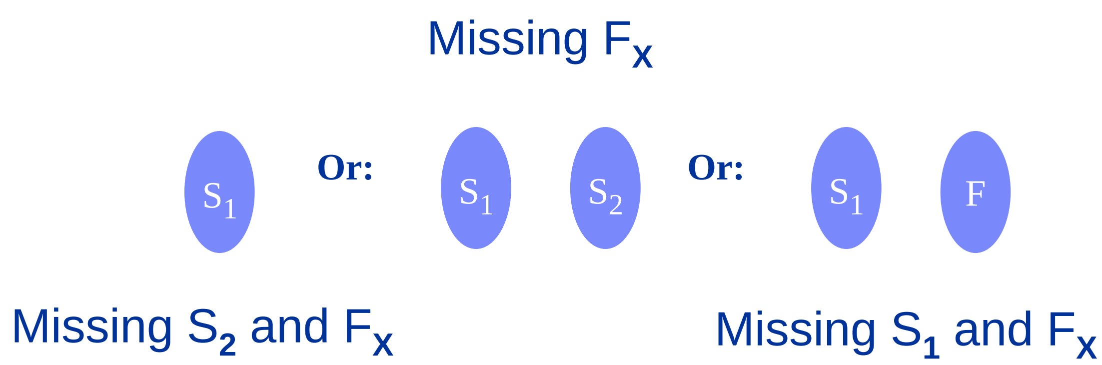
The Incomplete Model

One or two elements of the minimum technical system are missing



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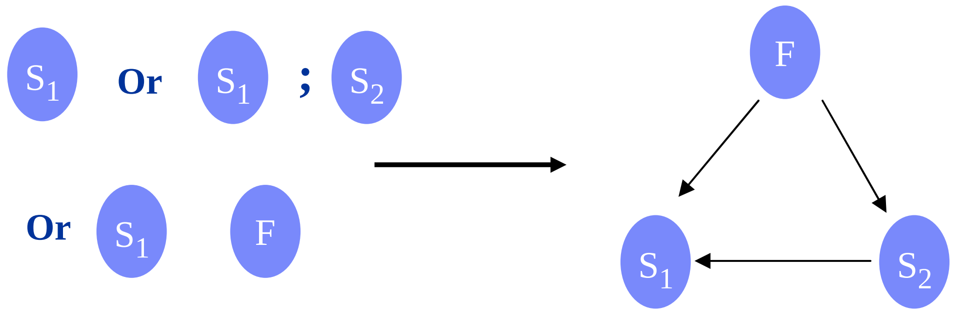
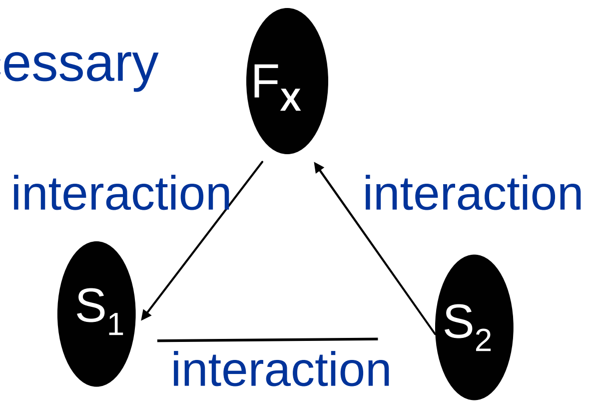
Standard Solution

Add the missing element of the model: F_X, S_1, or S_2
Explore each field: Me, E, Th, Ch, M, EM, or N



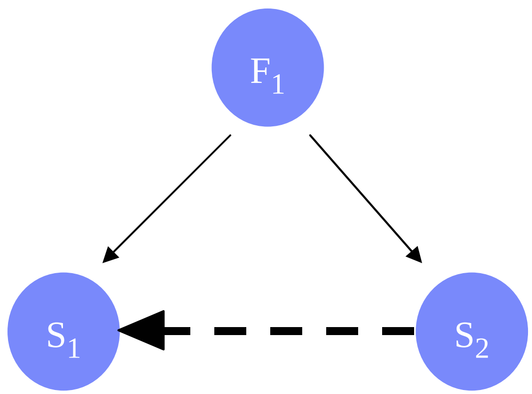
Incomplete, Insufficient, or Systems with Harm

- The minimum functioning system model involves a complete triad: F_X, S_1, S_2, and each interaction (3 minimum)
  - A system that contains at least one insufficient interaction is an insufficient system
  - An insufficient system should be made sufficient by adding the necessary elements to resolve the insufficiency



Insufficient Model

An insufficient model reflects a situation where all three elements are in place, but the useful field (F) is not sufficient



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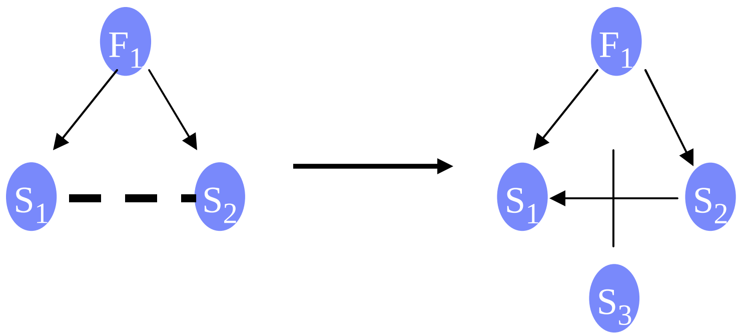
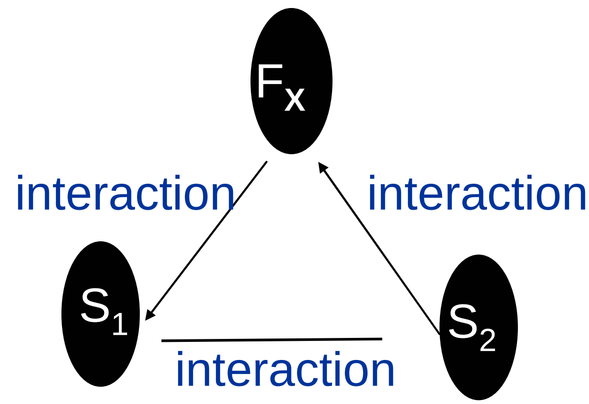
Standard Solution

Insert a substance (S3) which is a modification of S1 or S2 or both that causes the interaction to become sufficient



Incomplete, Insufficient, or Systems with Harm

- The minimum functioning system model involves a complete triad: F_X, S_1, S_2, and each interaction (3 minimum)
  - A system that contains at least one harmful interaction is a system with harm
  - A system with harm should be made to have no harm



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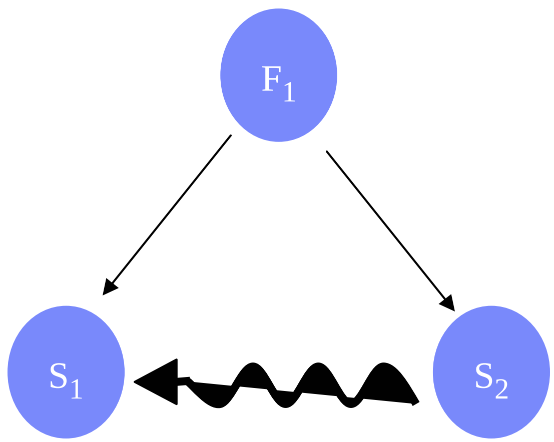
System with Harm

All three elements are in place, but the interaction between S1 and S2 is harmful or undesired or F_1 is harmful



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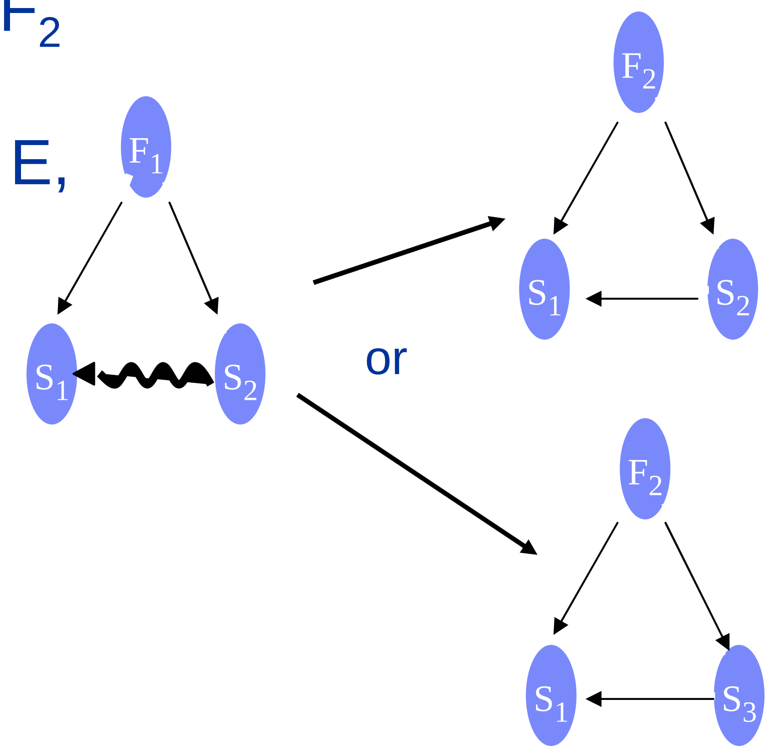
Standard Solution

Replace F_1 (or F_1 and S_2) with another set: F_2 or (F_2 and S_3)

Explore each field: Me, E, Th, Ch, M, EM, or N



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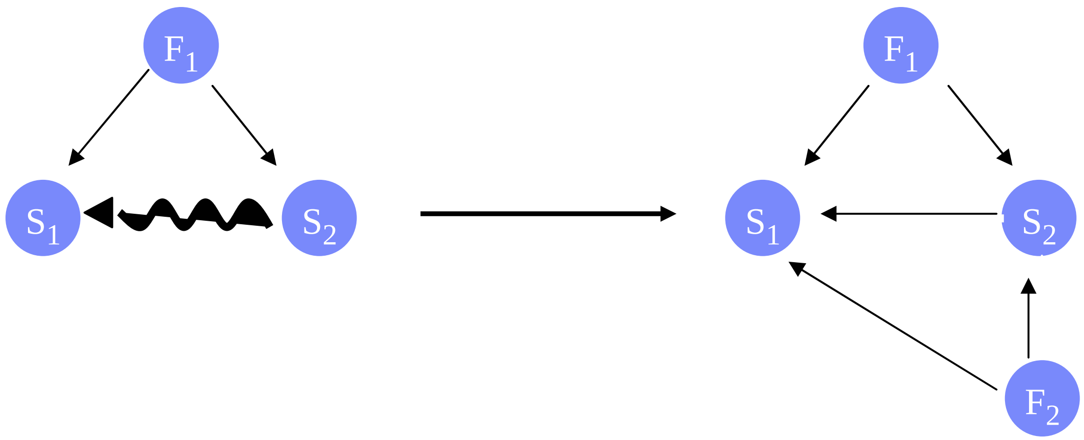
Standard Solution

Add another field (F_2) to intensify the desired effect
Explore each field: Me, E, Th, Ch, M, EM, or N



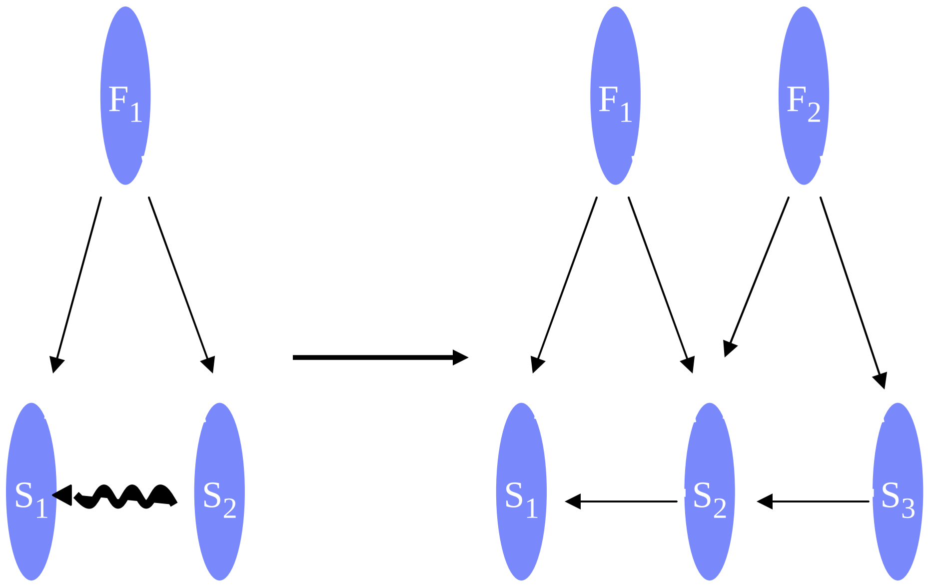
Standard Solution

Insert a substance (S_3) and add another field (F_2).

S_3 and F_2 enhance the desired effect

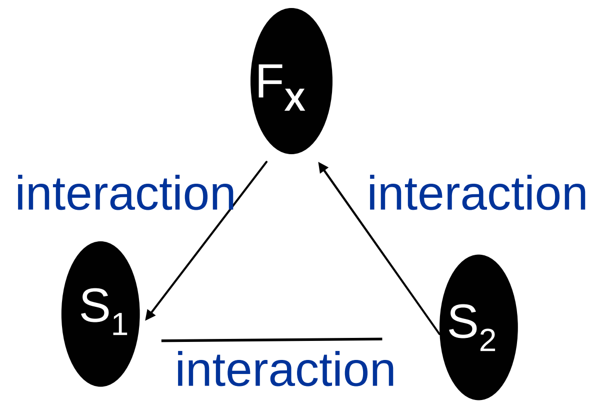
Explore each field:

Me, Th, Ch, E, M, EM, or N



Standards

- There is a body of standard solutions called the 76 Standard Solutions



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The 76 Standard Solutions: 5 Classes

CLASS 1. COMPOSITION AND DECOMPOSITION OF SFMS
- GROUP 1-1: SYNTHESIS OF A SFM
- GROUP 1-2: DECOMPOSITION OF SFMS

CLASS 2. EVOLUTION OF SFMS
- GROUP 2-1: TRANSITION TO COMPLEX SFMS
- GROUP 2-2: EVOLUTION OF SFM
- GROUP 2-3: EVOLUTION BY COORINATING RHYTHMS
- GROUP 2-4: FE

CLASS 3. TRANSITIONS T
- GROUP 3-1: TR
- GROUP 3-2: TRANSITION TO MICROLEVEL

Notice that class 4 is focused on measurement and detection problems

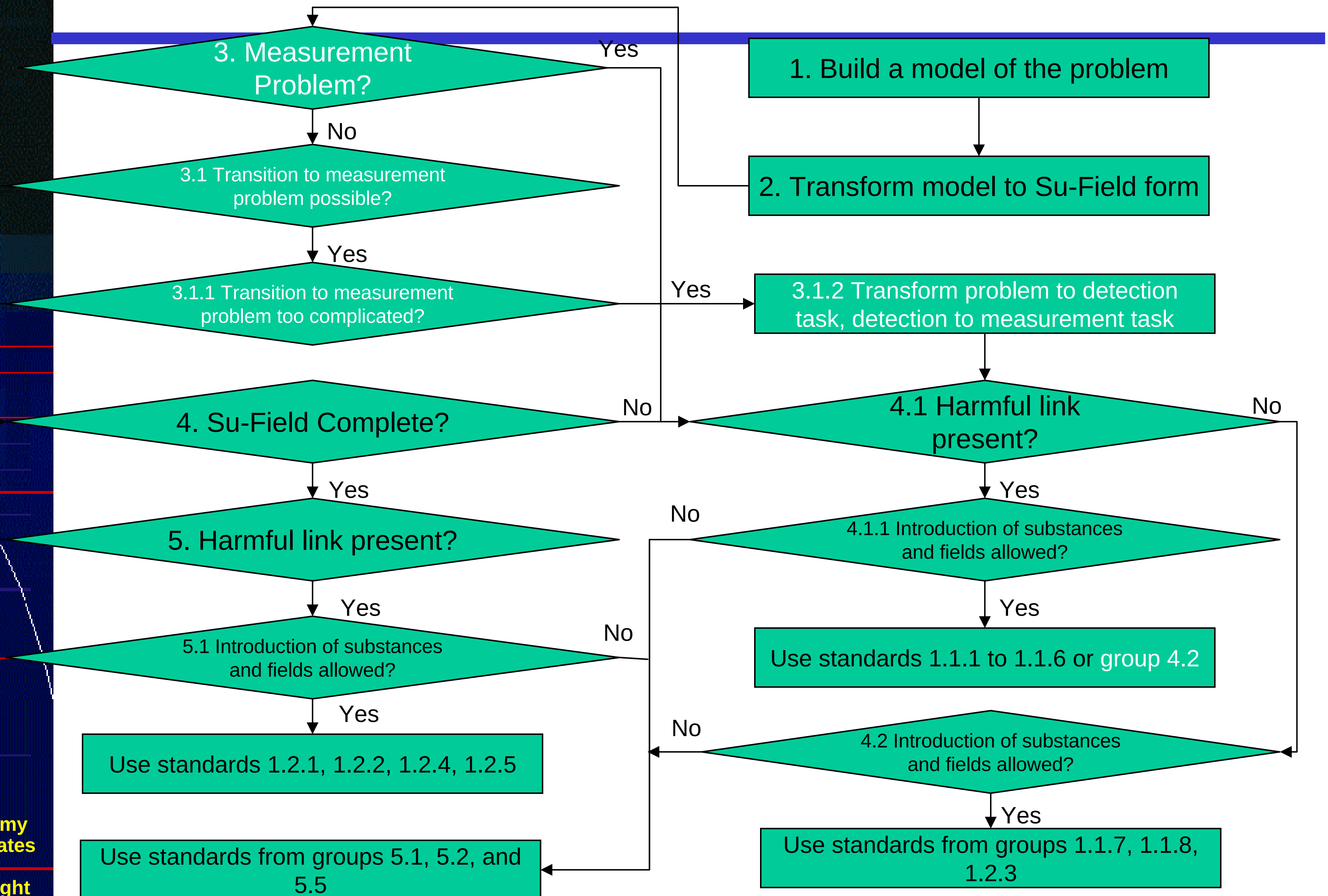
CLASS 4. MEASUREMENT AND DETECTION STANDARDS
- GROUP 4-1: INSTEAD OF MEASUREMENT AND DETECTION - SYSTEM CHANGE TO SOMETHING ELSE
- GROUP 4-2: SYNTHESIS OF A MEASUREMENT SYSTEM
- GROUP 4-3: ENHANCEMENT OF MEASUREMENT SYSTEMS
- GROUP 4-4: TRANSITION TO FERROMAGNETIC MEASUREMENT SYSTEM
- GROUP 4-5: EVOLUTION OF MEASUREMENT SYSTEMS

CLASS 5. SPECIAL RULES OF APPLICATION
- GROUP 5-1: SUBSTANCE INTRODUCTION
- GROUP 5-2: INTRODUCTION OF FIELDS
- GROUP 5-3: USE OF PHASE TRANSITIONS
- GROUP 5-4: PHYSICAL EFFECTS USE
- GROUP 5-5: SUBSTANCE PARTICLES OBTAINING

How Does it All Work?

- Identify the measurement and/or detection problem(s) in the system
- Create a SFM of the problem area(s)
- Analyze the SFMs for any deficiencies
  - Incomplete
  - Insufficient
  - Contains harm
- Utilize the SFM Algorithm to identify the appropriate solution standard(s)
- Apply standard solutions to create generic approaches for problem resolution
- Convert generic approach to specific solution using analogic thought

76 Standards Algorithm



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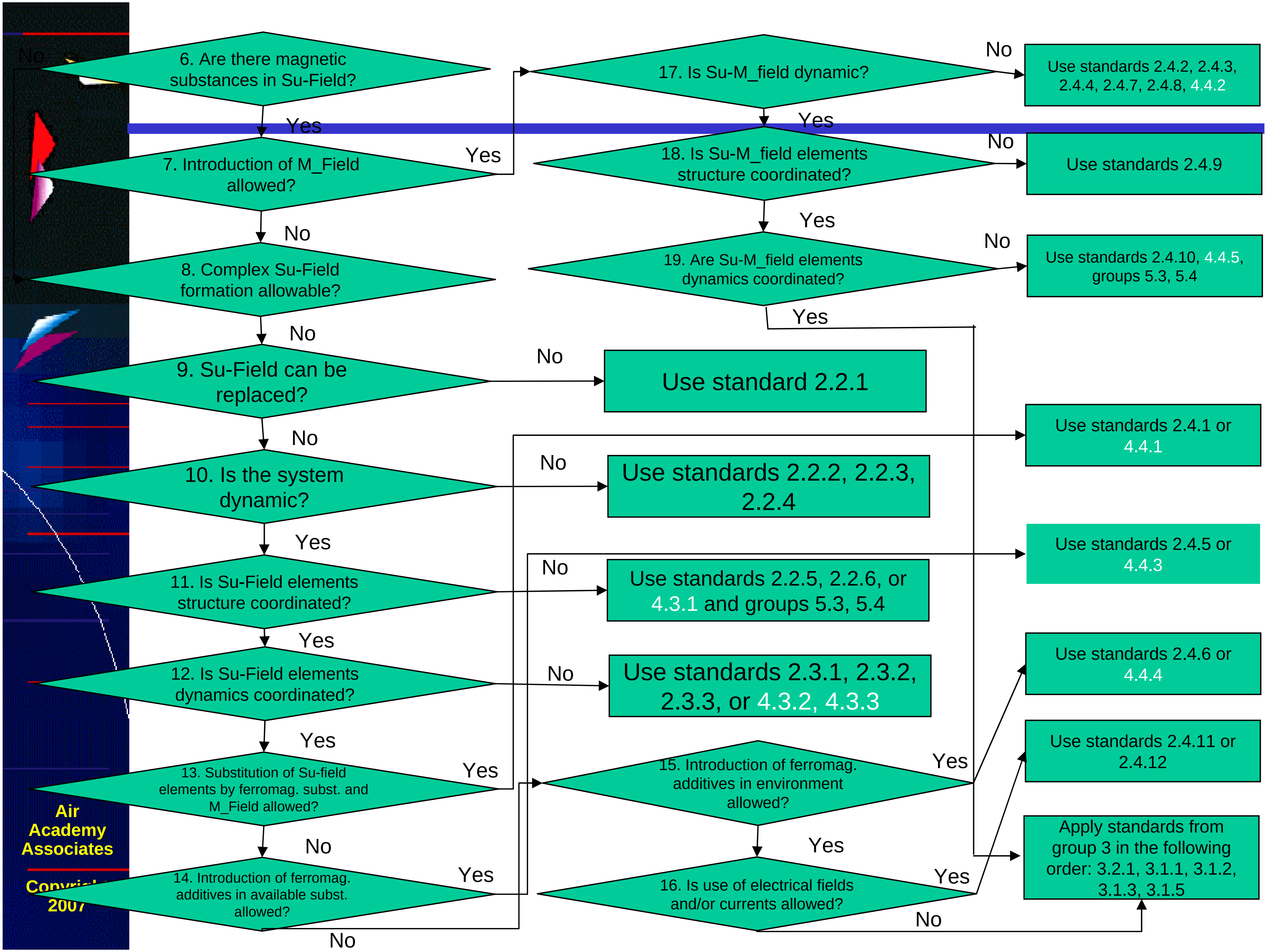

6. Are there magnetic substances in Su-Field?
No
Yes
7. Introduction of M_Field allowed?
Yes
No
8. Complex Su-Field formation allowable?
No
9. Su-Field can be replaced?
No
Use standard 2.2.1
No
10. Is the system dynamic?
No
Use standards 2.2.2, 2.2.3, 2.2.4
Yes
11. Is Su-Field elements structure coordinated?
No
Use standards 2.2.5, 2.2.6, or 4.3.1 and groups 5.3, 5.4
Yes
12. Is Su-Field elements dynamics coordinated?
No
Use standards 2.3.1, 2.3.2, 2.3.3, or 4.3.2, 4.3.3
Yes
13. Substitution of Su-field elements by ferromag. subst. and M_Field allowed?
Yes
No
14. Introduction of ferromag. additives in available subst. allowed?
Yes
No
17. Is Su-M_field dynamic?
No
Use standards 2.4.2, 2.4.3, 2.4.4, 2.4.7, 2.4.8, 4.4.2
Yes
18. Is Su-M_field elements structure coordinated?
No
Use standards 2.4.9
Yes
19. Are Su-M_field elements dynamics coordinated?
No
Use standards 2.4.10, 4.4.5, groups 5.3, 5.4
Yes
Use standards 2.4.1 or 4.4.1
Use standards 2.4.5 or 4.4.3
Use standards 2.4.6 or 4.4.4
Use standards 2.4.11 or 2.4.12
15. Introduction of ferromag. additives in environment allowed?
Yes
Yes
16. Is use of electrical fields and/or currents allowed?
Yes
No
Apply standards from group 3 in the following order: 3.2.1, 3.1.1, 3.1.2, 3.1.3, 3.1.5
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Conclusions

- Problem solving may often include the need for the collection of information from the system in question
  - Measure phase of DMAIC
- Collecting this information can be its' own problem
- The TRIZ methodology provides techniques specifically designed to resolve measurement and detection problems
  - Su-field Mode (SFM)
  - 76 Standard Solutions
  - SFM Algorithm

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Measurement and Detection Standards from the TRIZ Methodology

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Class 4 Standards with Examples

STANDARD 4-1-1

If a problem involves detection or measurement, it is proposed to change the problem in such a way, so that there should be no need to perform detection of measurement at all.

Example: **To prevent a permanent electric motor from overheating, its temperature is measured by a temperature sensor. If to make the poles of the motor of an alloy with a Curie point equal to the critical value of the temperature, the motor will stop itself.**

STANDARD 4-1-2

If a problem involves detection of measurement, and it is impossible to change the problem to eliminate the need for detection or measurement, it is proposed to change/detect properties of a copy of the object (e.g. picture).

Example: **It might be dangerous to measure the length of a snake. It is safe to measure its length on a photographic image of the snake, and then recalculate the obtained result.**

GROUP 4-1: CHANGE INSTEAD OF MEASUREMENT AND DETECTION

STANDARD 4-1-3

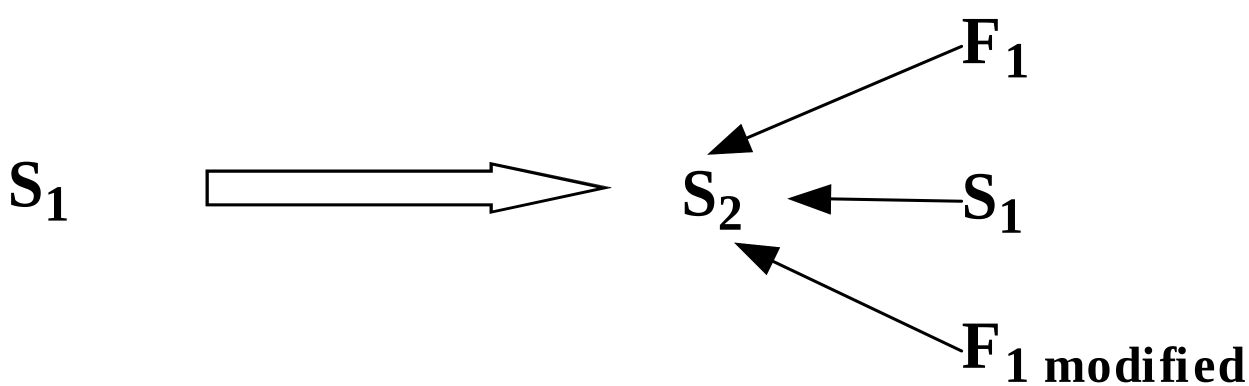
If a problem involves detection or measurement, and the problem cannot be changed to eliminate the need for measurement, and it is impossible to use copies or pictures, it is proposed to transform this problem into a problem of successive detection of changes.

Notes: Any measurement is conducted with a certain degree of accuracy. Therefore, even if the problem deals with continuous measurement, one can always single out a simple act of measurement that involves two successive detections. This makes the problem much simpler.

Example: **To measure a temperature, it is possible to use a material that changes its color depending on the current value of the temperature. Alternatively, several materials can be used to indicate different temperatures.**

STANDARD 4-2-1

If a non-SFM is not easy to detect or measure, the problem is solved by synthesizing a simple or dual SFM with a field at the output. Instead of direct measurement or detection of a parameter, another parameter identified with the field is measured or detected. The field to be introduced should have a parameter that we can easily detect or measure, and which can indicate the state of the parameter we need to detect or measure.



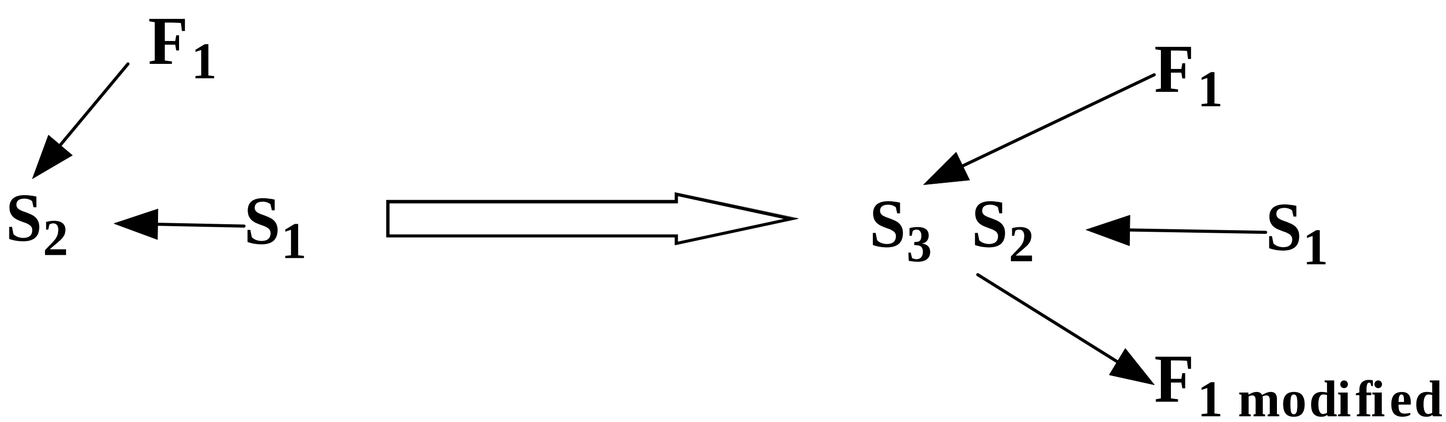
Example: To detect a moment when liquid starts to boil, an electrical current is passed through the liquid. During boiling, air bubbles are formed - they dramatically reduce electrical resistance of the liquid.

CLASS 4: MEASUREMENT AND DETECTION STANDARDS

GROUP 4-2: Synthesis of Measurement System

STANDARD 4-2-2

If a system (or its part) does not provide detection or measurement, the problem is solved by transition to an internal or external complex measuring SFM, introducing easily detectable additives.



Example: To detect leakage in a refrigerator, a cooling agent is mixed with a luminescent powder.

STANDARD 4-2-3

If a system is difficult to detect or to measure at a given moment of time, and it is not allowed or not possible to introduce additives into the object, then additives that create an easily detectable and measurable field should be introduced in the external environment. Changing the state of the environment will indicate the state of the object.

Example: **To detect wearing of a rotating metal disc contacting with another disc, it is proposed to introduce luminescent powder into the oil lubricant, which already exists in the system. Metal particles collecting in the oil will reduce luminosity of the oil.**

STANDARD 4-2-4

If it is impossible to introduce easily detectable additives in the external environment, these can be obtained in the environment itself, for instance, by decomposing the environment or by changing the aggregate state of the environment.

Notes: **In particular, gas or vapor bubbles produced by electrolysis, cavitation or by any other method may often be used as additives obtained by decomposing the external environment.**

Example: **The speed of a water flow in a pipe might be measured by amount of air bubbles resulting from cavitation.**

STANDARD 4-3-1

Efficiency of measuring SFM can be improved by the use of physical effects.

Example: **Temperature of liquid media can be measured by measuring a change of a coefficient of retraction, which depends on the value of the temperature.**

STANDARD 4-3-2

If it is impossible to detect or measure directly the changes in the system, and no field can be passed through the system, the problem can be solved by exciting resonance oscillations (of the entire system or of its part), whose frequency change is an indication of the changes taking place.

Example: **To measure the mass of a substance in a container, the container is subjected to mechanically forced resonance oscillations. The frequency of the oscillations depends on the mass of the system.**

STANDARD 4-3-3

If resonance oscillations may not be excited in a system, its state can be determined by a change in the natural frequency of the object (external environment) connected with the system.

Example: **The mass of boiling liquid can be measured by measuring the natural frequency of gas resulting form evaporation.**

STANDARD 4-4-1

Efficiency of a measuring SFM can be improved by using a ferromagnetic substance and a magnetic field.

Notes: The standard indicates the use of a non-fragmented ferromagnetic object.

STANDARD 4-4-2

Efficiency of detection or measurement can be improved by transition to ferromagnetic SFMs, replacing one of the substances with ferromagnetic particles (or adding ferromagnetic particles) and by detecting or measuring the magnetic field.

STANDARD 4-4-3

If it is required to improve the efficiency of detection or measurement by transition to a ferromagnetic SFM, and replacement of the substance with ferromagnetic particles is not allowed, the transition to the F-SFM is performed by synthesizing a complex ferromagnetic SFM, introducing (or attaching) ferromagnetic additives in the substance.

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STANDARD 4-4-4

If it is required to improve efficiency of detection or measurement by transition to F-SFM, and introduction of ferromagnetic particles is not allowed, ferromagnetic particles are introduced in the external environment.

STANDARD 4-4-5

Efficiency of a F-SFM measuring system can be improved by using physical effects, for instance, Curie point, Hopkins and Barkhausen effects, magneto-elastic effect, etc.

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STANDARD 4-5-1

Efficiency of a measuring system at any stage of its evolution can be improved by forming bi- and poly-system.

Notes: **To form bi- and poly-systems, two or more components are combined. The components to be combined may be substances, fields, substance-field pairs and SFMs.**

Example: **It is difficult to accurately measure the temperature of a small beetle. However, if there are many beetles put together, the temperature can be measured easily.**

STANDARD 4-5-2

Measuring systems evolve towards measuring the derivatives of the function under control. The transition is performed along the following line:

Measurement of a function → measurement of the first derivative of the function → measurement of the second derivative of the function.

Example: **Change of stress in the rock is defined by the speed of changing the electrical resistance of the rock.**

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