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# ENVIRONMENT ENTHROPIZATION IN THE MANUFACTURE AND USE OF METALLIC MATERIALS

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*Based on the principles of thermodynamics, the (neg)entropic transformations of the metal material along its life cycle are analyzed in this paper. We considered the follows items:*

- *The negentropy of consumed natural resources;*
- *The negentropy obtained by technological processes;*
- *The negentropy consumed through social utilities;*
- *The negentropy of secondary material reintegration;*
- *The entropies of secondary materials (residues) obtained through:*
  - *Technological process;*
  - *Use (degradation);*
  - *Reintegration.*

*We find the inequation of environment anthropization following the manufacture and use of the metal materials.*

**Keywords**: entropization, metallic materials, Sankey diagram, negentropy

## 1. Introduction

The process of finding modalities to maximize the performance in metalworking engineering must be currently designed and operationalized on the coordinates of two modern concepts (models) of evolution:

- Global knowledge;
- Durable and sustainable development of the society.

In a context like the one above, it becomes necessary for the metalworking engineer to investigate the interconditiong and interactions existing in the *convergence zones* of the following three systems:

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- The social system – S.S. (the quality of life in relation to the socio-cultural needs);
- The natural-ecological system - N.E.S. (the quality of environment in relation to the prevention of environmental pollution);
- The technological system - T.S. (in connection with the qualitative maximization of the technological parameters of manufacturing and use of metal materials).

**The anthropization of N.E.S.** is one of the most serious dysfunctions induced by these interactions, which adversely influences the *durability* and s*ustainability* of the systems. *It consists in increasing the entropy stock of the environment (N.E.S.) due to the anthropic activity carried out in the metal materials industry.*

The environment entropy increase can be studied based on the principles of thermodynamics. [1]

Through the implied transformations, the anthropic activity can have two effects in the systems (including within the materials outline):

- Decreasing the degree of ordering (increasing the degree of chaos) of the matter (substance);
- Increasing the clustering degree (decreasing the degree of chaos) of the matter (substance).

The **entropy** ***(S)*** is the thermodynamic parameter that measures the degree of matter clustering. The increase of the clustering degree is caused by the increase of entropy *(S)*, calculated with the expression:

$$\Delta S = \frac{\Delta Q}{T} \ ,[J/K] \tag{1}$$

The **negentropy** ***(nS)*** or **anti-entropy** ***(aS)*** is the parameter that measures the ordering degree of the matter. The increase of ordering degree is caused by the increase of negentropy, calculated with the expression:

$$\Delta nS = -\frac{\Delta Q}{T} \ ,[J/K] \tag{2}$$

***Note!*** In some papers, for “negentropy” the authors used the terms *“low entropy”* and *“negative entropy”* [2, 3].

The entropy and negentropy are two forms of *preservable energy* (stored inside the material). According to the first principle of thermodynamics, the transformation from one form to another $(|S| \Leftrightarrow |nS|)$ is carried out in such a way that their sum in absolute values remains constant, i.e.:

$$(|S| + |nS|) = ct \tag{3}$$

This means that the increase of one of them determines the decrease of the other one in equivalent values, and vice versa. This assertion is also supported by other papers, in which it was shown that the increase of negentropy in a certain area (temporal or spatial) due to the *ordering and improvement* of the systems and materials may have, as effect, the increase of entropy in another area. [9]

***Note!*** The concomitant existence of negentropy and entropy within a system outline, as two contradictory but complementary forms of energy, could be likened to the *yin-yang structure* found in the ancient Chinese philosophy and metaphysics. In this respect, in a system the *light side* coexists with the *dark side*, and each one can turn into the other one. [4]

From the negentropic point of view, in a preliminary assessment the materials can be characterized as such:

- The *natural resources (raw materials)* have a certain degree of matter ordering; therefore, they are carriers of a certain level of negentropy $nS_{n.r.}$;
- Due to the technological process, which increases the degree of ordering of the substance from the natural resource, the *primary materials (useful materials),* resulted in the industry, are deposits of negentropy at a higher level than that of the natural resource; in case of a technological system, it is found that the production of *goods and needs with social utility* is made through a process of *over-ordering* of the matter provided by the natural-ecological system; as a consequence, it can be said that the *technology itself appears as a specific stock of negentropy* [5]; *the negentropy created through a technological process is* $nS_{t.p.}$;
- The *secondary materials (waste and residues)* are forms with a high clustering degree, at least from the point of view of social utility, and therefore they are considered to be entropy-carriers; the entropy carried by the secondary materials at the output of T.S. and SS is $S_{s.m.}$ .

The negentropic transformations occurring in an industrial manufacturing flow are shown, as examples, in Figure 1.

***Note!*** The engineers are a social category gifted with the skill (grace) to create negentropy.

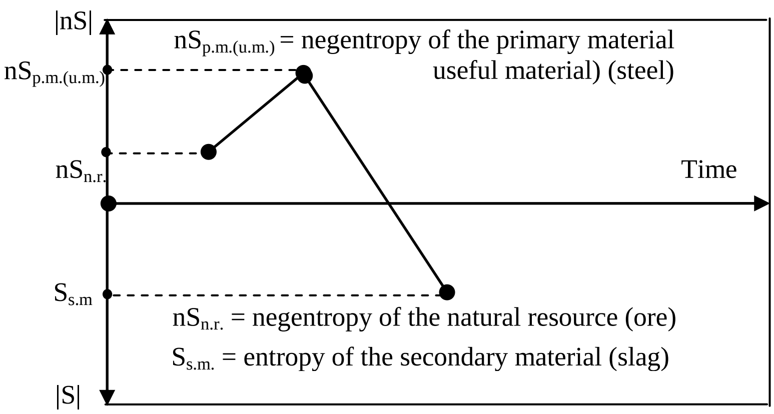


Fig.1. (Neg)entropic transformations over a manufacturing and use flow of the material.

## 2. Analysis of anthropization on the phases of metal material life cycle

**a) Extraction, processing and utilization of the natural resources (n.r.) in the technological processes of metal material manufacture**

The natural resources, as ordered material states, are natural *sources of negentropy* usable in the technological processes, denoted by $nS_{n.r.}$. Due to the irreversible nature of the entropic degradation of matter and energy (for example, due to the continuous wear that causes waste), the degraded goods have to be replaced, which means new consumption of resources, i.e. new consumption of negentropy from the environment, $nS_{n.r.}$. We consider that:

- The place left free by negentropy is occupied by an equivalent value of entropy, in such way that their sum remains constant;
- The replacement of negentropy by entropy is a process of increasing the entropy in the environment after the consumption of natural resources; this actually represents the first phase of environmental anthropization.

**b) Manufacture of materials**

Two processes occur within the T.S.:

*b.1. The process of over-ordering of the matter*

This process includes into the system the technological process negentropy, $nS_{t.p.}$.

*b.2. Production of secondary materials*

In this case, the secondary materials, *consisting of waste (w.t.p.)* and *residues (rs.t.p.)* are carrying with them the entropy of the secondary materials of the technological process, $S_{s.m.t.p.}$

$$S_{s.m.t.p.} = S_{w.t.p.} + S_{rs.t.p.} \quad (4)$$

The **technological classification of materials** includes the classes mentioned below (Fig. 2).

- The *primary material (p.m.)* or the *useful material (u.m.)* is the material considered to be the *main objective* of the technological process;
- The *secondary material (s.m.)* is the material which, for technological reasons, results as *auxiliary* material - *companion* of the primary one. In some situations, it can be exploited by reintegration (r) using the *3R* technologies (recirculation, recycling and regeneration). There are several categories:
  - The *byproduct (sbp)* is the secondary material *recirculated* within its own T.S. (main T.S.);
  - The *waste (w)* is the secondary material *recycled* in other manufacturing cycles (adjacent T.S.);

−The *residue (rs)* is the secondary material which, for objective reasons, cannot be reintegrated; it is disposed into the environment; it is a *polluting substance*.

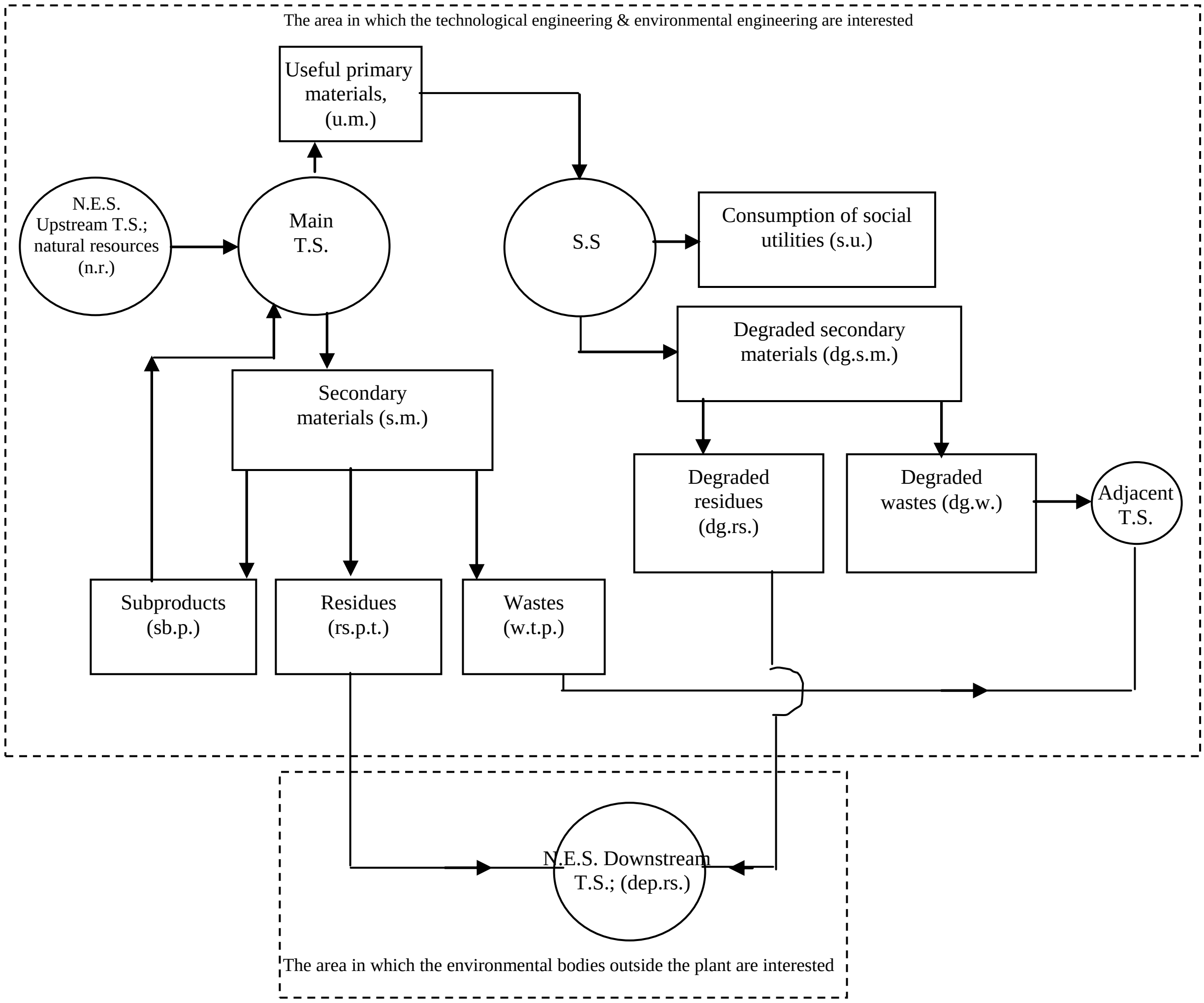


Fig.2. Stages of ecotechnological transformations of metal materials over a life cycle.

**c) Use of material**

Two events occur within this phase of the life cycle.

*c.1. Use of material*

In this phase occurring within the S.S., the *social utility negentropy (n.$S_{s.u.}$)* is consumed, and its place is taken by the entropy $S_{s.u.}$.

$$|nS_{s.u.}| = |S_{s.u.}| \tag{5}$$

*c.2. Degradation of material*

This event refers to the transformation, caused by the use of the useful material (u.m.), into *secondary degradation materials (dg.s.m.).* They are considered as *cluttered (degraded) materials,* i.e. entropy carriers, as sum of the waste and residue entropies:

$$S_{dg.s.m.} = S_{dg.w.} + S_{dg.rs.} \tag{6}$$

**d) The removal from use** has the size of a moment rather than a phase. However, it must be distinguished from other items, as it marks the transition of material from *useful material (primary)* into *secondary material.*

**e) Reintegration of the secondary materials**

The *reintegration* is the sustainable technology of *post-use exploitation* by reintroducing some secondary materials (waste) into the manufacturing circuits.

*The reintegration processing* is the process by which the waste acquires the re-integration properties required for manufacturing and use.

*The reintegration properties* are the properties that characterize the reintegration capacity of the waste by using 3R technologies, which is primarily assessed by *compatibility*.

*The compatibility* is the property of a system of relationships, in which its parts are not excluding each other, but, on the contrary, they are in correlation relationships.

*The reintegration compatibility* provides information on the capacity of the waste that, through its properties, to do not adversely affect the material to be manufactured.

As it is known, the waste is a *metastable form of matter*, which means that an outside intervention can transform it qualitatively [10 - 12].

*The reintegration process* is the intervention from outside which, by technological operations, transforms the waste from original entropy-carrier material

$$S_w = S_{w.t.p.} + S_{dg.w.} \tag{7}$$

into *reintegrated material (r.m.),* carrier of the *reintegrated material negentropy,* $nS_{r.m.}$ .

According to the first principle of thermodynamics, the reintegration processing has losses, materialized in the *reintegration residue (r.rs),* carrier of the *entropy* $S_{r.rs.}$. Using absolute values, we can write:

$$|nS_{r.m.}| = |S_w| - |S_{r.rs.}| \tag{8}$$

The graphical interpretation of the above described issues is shown in Figure 3.

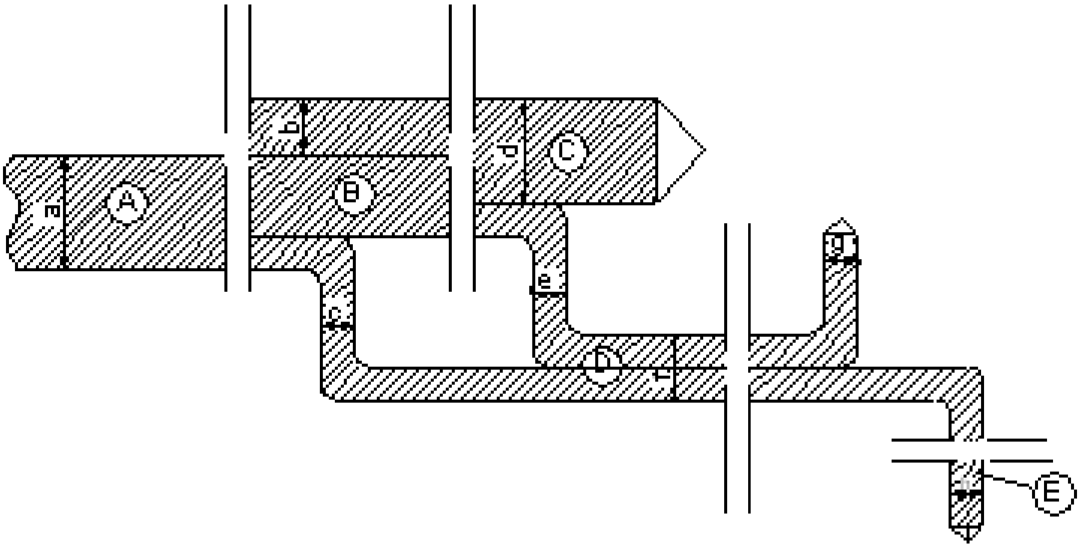


Fig. 3. Sankey diagram for the (neg)entropic transformations over the life cycle of the metal materials.
A) N.E.S. upstream T.S. - manufacturing; B) T.S.; C) S.S.; D) T.S. - reintegration;
E) N.E.S. downstream T.S.: a) $nS_{n.r.}$; b) $nS_{t.p.}$; c) $S_{s.m.t.p.}$; d) $nS_{s.u.}$ e) $S_{dg.s.m.}$; f) $nS_{r.m.}$; g) $S_{w.}$; h) $S_{rs.}$

The double role of the recirculated secondary materials can be expressed as follows:

∗ The recirculated materials are substitutes for the material natural resources, which is why they contribute to the preservation of the global natural stock of negentropy;

∗ As an information system element, the recirculated materials are introducing within the outline of the technological process an information which the initial input parameters do not have; it is about the information on waste generation dysfunctions; using such information, the material engineer can correct the process parameters for reducing the amount of waste (usually, scrap).

**f) Disposal of residues**

The secondary materials which are not reintegrated are disposed into the environment. This means that the entropic stock of the environment is enriched with an entropy quantity equal to the entropy $S_{s.m.d}$ of the disposed secondary materials, i.e. of the *disposed residues (d.rs.)*. Therefore:

$$S_{s.m.d.} \equiv S_{d.rs.} = S_{rs.t.p.} + S_{dg.rs.} + S_{r.rs.} \qquad (9)$$

## 3. The inequation of anthropization of the natural-ecological system

**The environment anthropization is the objective and irrevocable phenomenon of increasing the entropic stock of N.E.S.** Such an assertion is supported by the principles of thermodynamics and the history of civilization. [2, 3, 7, 8]

The anthropization of the environment, as a fundamental negative impact of the anthropic activity, is caused by certain objective events, such as:

- Modification of the negentropy ↔ entropy equilibrium in favour of the latter, caused by the consumption of resources from the environment, which are carrying natural negentropy;
- Increase of the natural entropy deposit by the entropy supplement brought by the entropy of the residues deposited in the environment;
- The use of natural resources and the reintegration are processes with subunit yields, i.e. they are processes that inevitably produce *new entropy-carrying residues*.

Based on the above, the anthropic activity along the life cycle of the material can be characterized by an inequation which, written in absolute values, looks as follows:

$$\left(\left|nS_{n.r.}\right| + \left|S_{s.m.d.}\right| + \left|nS_{s.u.}\right|\right) > \left(\left|nS_{t.p.}\right| + \left|nS_{r.m.}\right|\right) \tag{10}$$

The expression (10) represents the ***inequation of environment anthropization*** due to the anthropic activities of *manufacture and use of metal materials.*

The magnitude of environment anthropization (decrease of negentropic stock $\Delta nS_{environment}$ and, respectively, increase of the entropic stock $\left|\Delta S_{environment}\right|$) is: [6]

$$\left|\Delta nS_{environment}\right| = \left|\Delta S_{environment}\right| = \left(\left|nS_{n.r.}\right| + \left|S_{s.m.d.}\right|\left|nS_{s.u.}\right|\right) - \left(\left|nS_{t.p.}\right| + \left|nS_{r.m.}\right|\right) \tag{11}$$

*The above relationships are theoretically substantiating the technical and technological methods by which the material engineer can minimize the environment anthropization.*

The foregoing demonstrates that the current *great trouble* of the modern society is not the waste but the residues, as due to the *engineering activity of technological reintegration*, the waste does not fully contribute to the environment anthropization. In this context, it becomes obvious that the technical and technological development induces dysfunctions that can only be solved in a technical manner. Thus, the ecological imbalances induced by the expansion of new techniques and technologies are going to be mitigated especially by using *new technical means*. [13 - 16] More colourfully, one can say: *the engineer destroys, but also fixes*.

## 4. The interpretation of original sin in ecological paradigm coordinates

**First act: Adam's entropic activity:**

- According to the ecological paradigm, the environment is investigated, identified, characterized and made available by principles, methods and methodological tools that highlight the *priority importance* of N.E.S. as *foundation system*.
- At the beginnings, God stood before a universe characterized by total chaos, measured by the global entropy, $S_{univ_I}$ .
- He transformed it into an environment characterized by total order, measured by the global negentropy $nS_{univ_I}$ .
- Adam eats the apple, which represents the negentropy of a natural resource (n.r.):

$$nS_{n.r.} \equiv nS_{apple} \tag{12}$$

- The entropy $S_{apple}$ is introduced in the place left empty by the apple:

$$|nS_{apple}| = |S_{apple}| \tag{13}$$

- Adam releases into the environment his excrements (exc.) and the apple stub (a.s.), which at that time were secondary materials for disposal, $S_{s.m.d.}$.

$$S_{exc.} + S_{a.s.} = S_{s.m.d.} \tag{14}$$

- Adam uses a part of $nS_{n.r.}$ for his social utilities.

$$|nS_{s.u.}| = |S_{s.u.}| \tag{15}$$

- The energy balance leads to the situation:

$$|nS_{apple}| \langle\langle |S_{exc.}| + |S_{a.s.}| + |S_{s.u.}| \tag{16}$$

- *Conclusion:* The first human being who contributed to the environment anthropization was Adam.

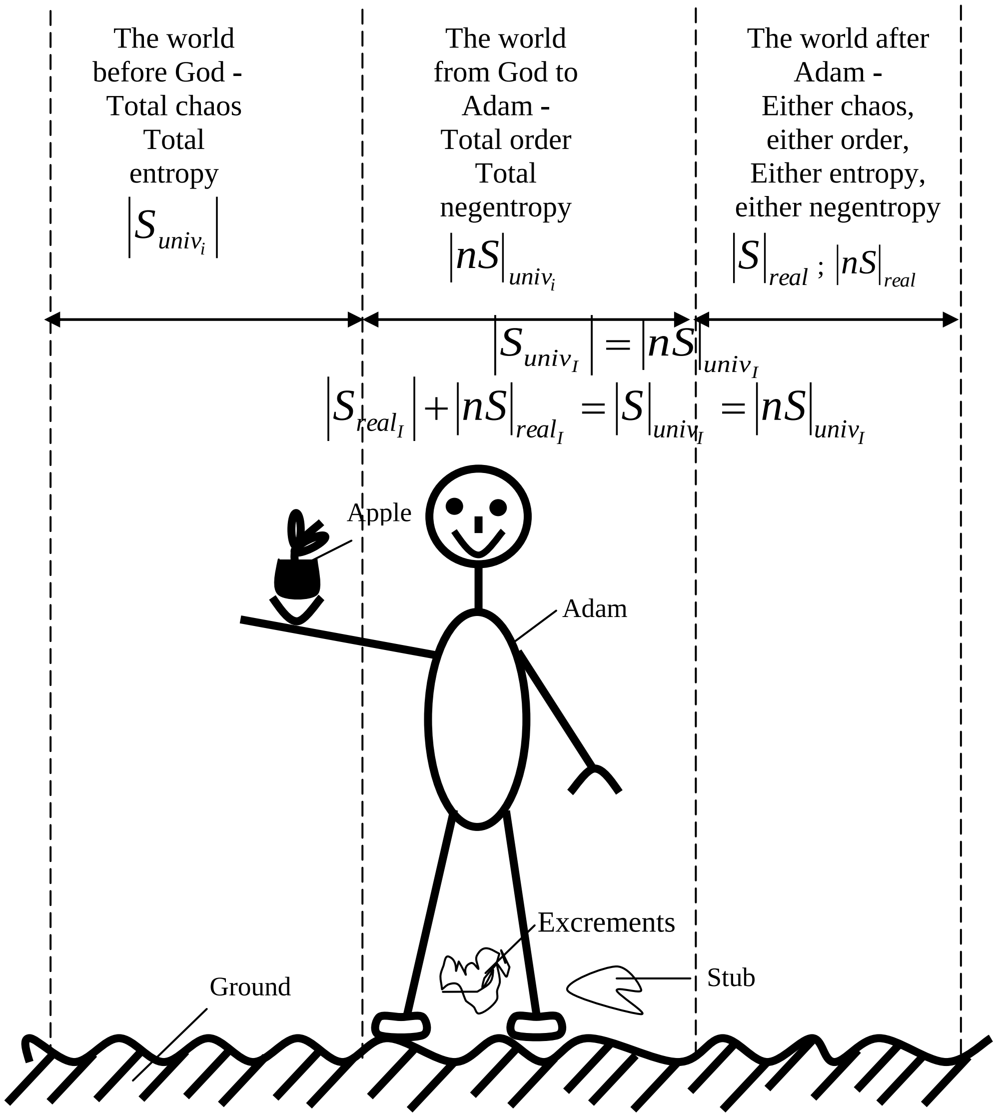

Fig.4 Adam's anthropic activity

**Second act: Eve's negentropic activity (Fig.4)**

- God realizes that, due to the development, $nS_{n.r.}$ could be exhausted very quickly (accelerated consumption of natural resources).
- He teaches Eve the technological process of making apple jam (a.j.), by which she gets the negentropy $nS_{a.j.}$

$$nS_{a.j.} \equiv nS_{t.p.} \tag{17}$$

- In this case, the energy balance leads to the situation:

$$\left|nS_{apple}\right|+\left|nS_{a.j.}\right|<\left|S_{exc.}\right|+\left|S_{a.s.}\right|+\left|S_{s.u.}\right| \tag{18}$$

• ***Conclusion:*** The first human being who, through technological processes, slowed down the environment anthropization was Eve.

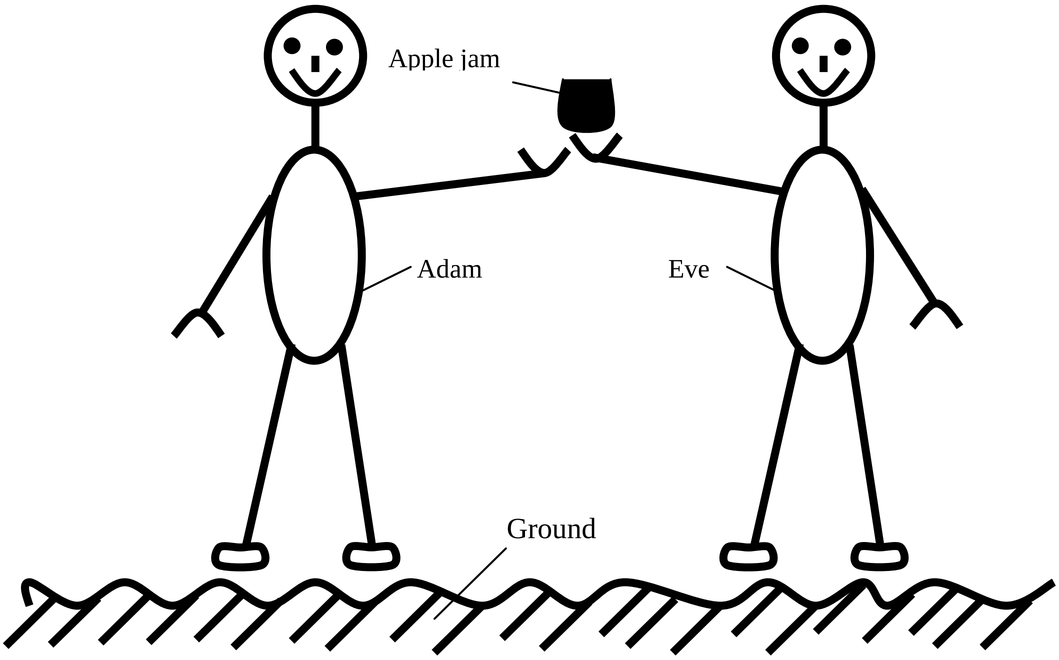


Fig.5 Eve's anthropic activity

## 5. Conclusions

In the manufacture and use of metal materials, the human beings contribute to the imbalance of the environmental balance entropy ↔ negentropy, because:

On the one hand, they consume natural resources and dispose pollutant residues into the environment (anthropization processes);

On the other hand, they create negentropy through technological processes and reintegration of the secondary materials (neganthropization processes).

The inequation of environment anthropization, set out in this paper, can serve as a basis for substantiating the technical measures aimed to slow down the anthropization phenomenon through the anthropic activity.

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