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A STUDY OF ENVIRONMENTAL CONDITIONS IN INDUSTRIAL PROJECT EVALUATION WITH SPECIAL REFERENCE TO THE PRODUCTIVITY OF LABOUR

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A modern industrial project must ensure the compatibility of the technical and human factor in the production process aiming at raising labour productivity. The usual approach is, however, to stress the technical and technological side of the project which is useful from the economic point of view. Employees on better working environment and conditions, on the other hand, does not necessarily promote economy since the creation of an ideal working environment requires additional capital expenditure. Consequently the economic effeciency of the project is reduced by these capital expenditures.

The purpose of this study is to show how improving working conditions and designing ideal standard working environment raises labour safety and labour hygiene and generally facilitates the labour output to a considerable degree. Our task is to prove that this reduction of the exertion in work by no means conflicts with the objective of maximum effectiveness and economy in the production-process of an industrial plant. On the contrary, a favourable working environment is conducive to labour productivity and may positively influence the economical effectiveness of industrial investments.

As the paper deals with the problem of the relation between the ideal standard working environment and the productivity of labour, it is necessary to start with a brief explanation of productivity and intensity of labour and to show the way these terms are understood in this presentation.

Productivity of labour is the relation between the amount of expended labour and the achieved results, that means, the produced goods. This may be expressed by means of a simple formula

$$P = \frac{q}{y}, \text{ where}$$

P = productivity of labour
q = quantity of produced products
y = amount of expended labour

To apply this formula one needs to measure the amount of work needed to produce a certain quantity of products. It is well known that the amount of expended labour may be most easily measured by the length of its duration, thus by means of time units. The work is lasted for a certain period of time T, that is = T. We measure time, in which work is being done, and doing this we find the amount of labour. In this case we refer to the so called extensive amount of labour. It is evident, that the amount of labour cannot be defined only by means of the length of time, during which it is performed, but that it depends also on the speed in which it is being done. It depends not only on the length of time, but also on the number of working motions performed in one unit of time, that means it depends on the density of work, or its strain, on the effort with which it is being carried out, i.e. on its intensity. The amount of the performed work is therefore being defined by both its extensity and its intensity.

If a worker raises his intensity of labour, it means, that he works with a greater strain, he fills his working time more intensely, he works with more concentration. That means that in the same period of time under the same conditions he uses more of his physical and brain abilities, he uses more working energy than before. The substance of raising the intensity of labour is nothing else than increasing the amount of work performed in a certain period of time.

The higher intensity of labour contributes to the fact, that the amount of labour wanted for the production of a certain quantity of products is being spent in a shorter time and conversely the lower intensity of labour means, that a certain amount of working energy will last a longer period of time.

Hence follows the important conclusion that the raising of the intensity of labour is not a real saving of labour performed in producing certain products. It results in saving the working time, but not in saving working energy.

From such a point of view it is necessary to consider the validity of the equation

$$= T .$$

If worker A works for example for 10 hours and worker B for 9 hours, it holds good, that T_A T_B provided that the labour performed by both workers has the same degree of concentration, the same intensity of labour I, so that $I_A = I_B$. If we want to express, that the amount of the expended labour has its quantity both extensive and intensive, we may write

$$= T . I$$

In our case $W_A = T_A . I_A$, $W_B = T_B . I_B$.

As $I_A = I_B$, it runs, that T_A T_B and thus W_A W_B.

Worker A performed more work, expended a greater amount of working energy. In this sense we may alter the formula expressing the productivity of labour as the relation of the quantity of produced products to the amount of labour expended for their production:

$$P = \frac{Q}{T . I}$$

This expression, similarly like the relation between the productivity and intensity of labour, brings in a lot of theoretical problems and opinions. As far as the consideration on the relation between the working environment and the productivity of labour is concerned, it is not necessary to deal with these problems any more. From the above, however, we may draw the following conclusion :

That the productivity of labour may be increased by means of constantly improving the technique of production, by modernizing technological procedure, by raising the effectiveness of organization of work, etc.

Other methods of increasing the productivity of labour consist in labour saving, in facilitating the labour output.

All arrangements, for facilitating labour output and diminishing the labour effort, reduce the amount of working energy expended for the production of a certain product. This reduction in the amount of labour required for the production of every single product is the essence of promoting the productivity of labour.

When formulating new industrial projects therefore, the prospects of promoting labour-productivity through an improved work environment should not be overlooked. The productivity of labour in the future production of an industrial plant can be increased in two ways.

One method lies in working out a project that would ensure the most perfect technological and organizational side of the production, the other lies in working out an ideal standard working environment project.

In a really perfect project, both these ways must be materialized to achieve a complete harmony of all the conditions necessary for the maximum rise of the productivity of labour. So far the importance of ideal standard working environment is not fully appreciated in practice. In designing an enterprise, the problem of making ideal standard working environment represents a rarely used opportunity of raising the productivity of labour to a considerable extent.

The setting up of an ideal standard working environment implores that all the basic conditions influencing the man at work are being made ideal. In the broader sense the working environment is understood as a complex of all conditions, under which the production process is being carried out by means of given instruments of production and productive forces.

From this broader point of view even the human relations, the organization of work, rewarding and other working motives etc. form also a part of working environment.

In the narrower sense a certain part of the production premises is being understood by the working environment, that forms a section of the whole complex of organizational and productive, as well as commercial and economical process. From this point of view the working environment is first of all a complex of conditions of physical and technical character, that influence a man during his work.

When we further define the term working environment, we arrive at the term working place (micro - site), which means a certain section of the production area, assigned to the worker or a group of workers, who are equipped with different facilities according to the nature of work. It is natural, that the very conditions of the micro - site influence the man most immediately intensively.

The working environment is usually formed by the whole series of very complicated factors of different character, affecting the environment in various ways, which form a resultant complex influencing the central nervous system of the working man and his psychology.

When designing the working environment not all these conditions can be immediately formulated and influenced. In a project it is possible to a certain degree to influence the social classification of workers, or the relations among them, but it is not possible to specify the best schedule of work and rest etc. In the project, some conditions of a definitely technical character can be influenced by the designer to a certain degree, but he is not able to define them completely, although they have a great influence on the psychology and labour output of the man. These are : the shape and appearance of machines, tools and equipment, the arrangement and the form of panel controls, ensuring the most suitable working position by making correct dimensions of the machines, equipment etc.

These important technical conditions are specified by the machine and equipment designer, furniture designer etc. The working environment designer must take them into account, he can influence them, but he himself usually does not design them.

Therefore it is clear, that when designing the working environment we consider the environment in the narrower sense, i.e. first of all with reference to the interior conditions of physical and technical character. Within the framework of these conditions, we then consider only those that may be immediately influenced in the scheme, as the following figure shows.

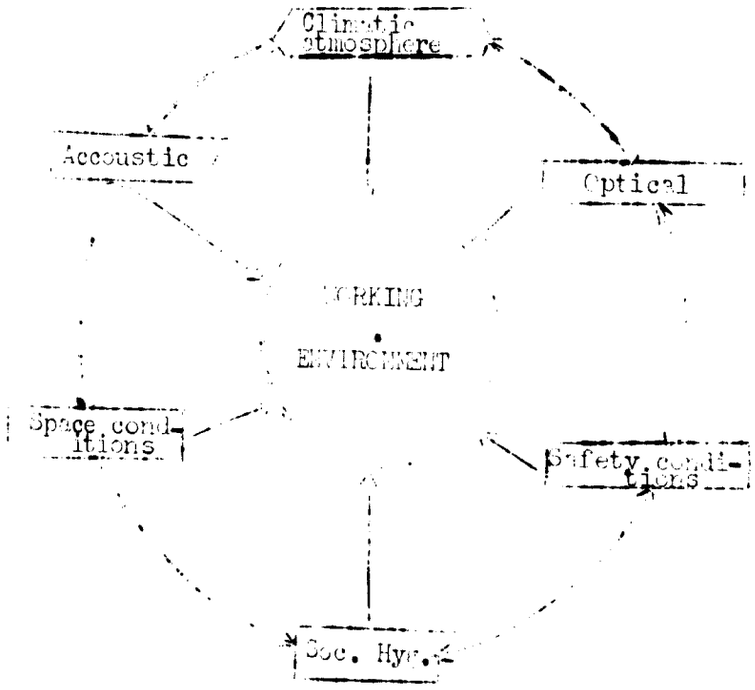

Fig. No. 1 - The basic factors of the working environment that may be immediately influenced in the design.

The whole set of various influences and environment properties are included in these single factors of the working environment. In connection with designing we reduce them only to those that may be directly influenced by the project. Thus the air temperature and humidity, the constitution of air and its cleanliness and last but not least the air pressure are included in the climatic atmospherical

conditions. The intensity of light and its colour, the kind and way of lighting the working environment and the colour effect of the environment belong to the optic conditions. The acoustic conditions refer to volume of sound, frequency and intervals of noise and vibration. The space conditions of the workplace are formed first of all by the dimensions of the working-place and its space arrangements, i.e. in the lay - out of machines, equipment and furniture, organization of transport routes, passages, store rooms, assembly lines and dismantling areas, the character of working floor etc.

The complex of hygiene and social conditions is formed by various health and social amenities, as e.g. water supply, sewers, cloakrooms, lavatories, lounges, dining-rooms etc. Beyond the framework of the work-place itself there belong various all - factory facilities, such as sports and recreational facilities, passenger transport in the plant etc.

Indispensable to an ideal standard working environment is the creation of safety conditions of labour in the work-place. Machines located in a suitable way, enough space, well solved transport routes etc. reduce the possibility of work accidents. Similarly ideal standard optical conditions raise the safety of labour. A sufficiently illuminated workplace with diffused and non-glare light enables the worker to follow exactly the technological procedure and various signalling and control indicators and permits him to concentrate on his work. The safety of labour can also be considerably raised by reducing the level of noise. The worker does not feel tired by unnecessary noise, can hardly miss the warning sounds signalling danger, and can fully concentrate on his work in the absence of noisy distrations.

As already mentioned, the above factors are only a part of the whole complex of working environment conditions. But those are basic factors of vital importance to the quality of working environment. Hence an ideal standard working environment cannot be achieved without affecting them. If one of these basic factors in the project - given in the diagram - is omitted, it is followed by a considerable reduction of

the effectiveness of ideal standard factors. Thus for example, improving organization of work or bettering the social relations on the workplace cannot fully achieve the desirable result, when the negative influence of e. . acoustic conditions is not solved, that means, if the excessive noise is not removed simultaneously with the above quoted measures. The positive influence of some working environment factors, understood in the broader sense, may be even completely paralysed by the negative influence just of these basic factors mentioned in the diagram.

As far as the influence of the workplace on the man is concerned, the workplace may assume a negative, neutral or ideal standard (optimum) character. A neutral workplace does not affect the worker considerably in either way and thus does not influence his labour output and the productivity of labour. The working man does not feel the influence of single factors of the working environment, and they do not affect his productive turn-out.

From this point of view, in many cases neutralizing the working environment may be considered a desirable course as it implies a removal of negative influences of working conditions or of the technological process itself. The technological process reduces considerably the working output of a man by its negative influence, it exhausts his muscular organs and nervous system, making the control of working motions difficult. This aggravates work - exertion and results in lowering the interest in work, in laxity, inalertness and eventually a complete loss of a substantial part of the worker's capacity to work. To enable the working environment to manifest itself in a neutral way, it is necessary to neutralize all the negative factors. This is the most difficult step towards making ideal standard working environment.

An environment may be considered negative, where one or more factors have a disturbing, almost harmful effect on the worker, making his work unpleasant and difficult. A workplace may be considered ideal in which the worker feels the positive influence of environmental factors. It is a workplace that makes the work pleasant, helps concen-

tratin; on work and has a stimulating effect on the whole.

hen projectin; the workin; environment the following problems are dealt with:

(a) removal and restriction of the environmental negative factors caused by the adherent conditions and technolo;y of production,

(b) creatin; factors facilitatin; the man's stay at the workplace, facilitatin; his labour output and makin; work more pleasant.

hen e.g. desi;nin; a workplace with noise insulation, we reduce in this way the influence of the negative factor of the workin; environment. If a proper colour scheme is proposed in the project, a positive factor is being formed by this. Thus it follows that makin; ideal standard working place means:

(a) estriction of negative factors to the lowest level,

(b) Creatin; positive factors or intensifyin; them to the hi;hest standard.

These ways of makin; ideal standard conditions are represented on the followin; diagram.

Figure o. 2

orking environment before havin; been made ideal

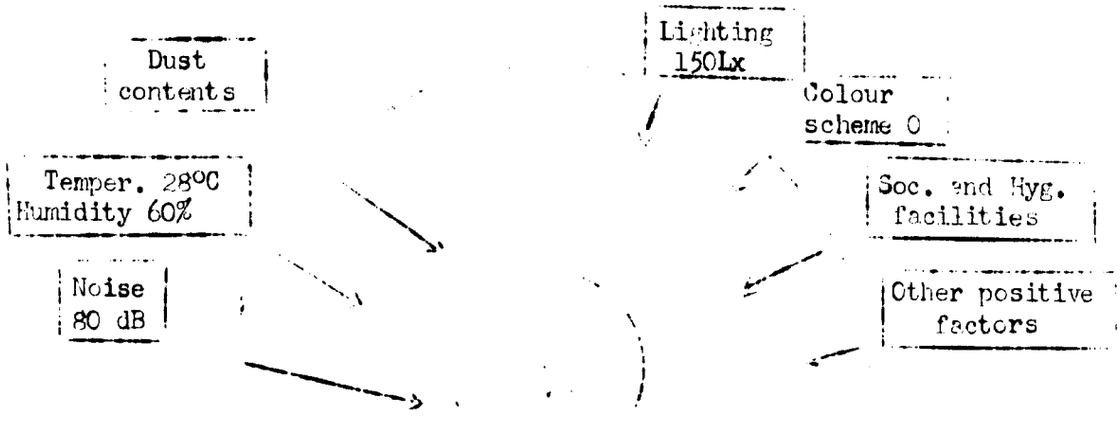

Figure No. 3

Working environment after ideal standard measures have been used

The diagram of making ideal standard working environment may be applied to a concrete example. The following table illustrates the working environment before and after making it ideal.

Table 1

Evaluation of the working environment

	Climatic-atmosph. conditions			Optical conditions		Acoustic conditions		Productivity
	Temperature degrees	Humidity per-cent	Dust contents mg/cm³	Lighting lx	Colour scheme	Noise dB	Vibration	per-cent
Before modification	28	60	8,08	80	0 [1]	80	-	100 [2]
After modification	20	50	3,12	150	2	60	-	108
Difference	- 8	- 10	-4,96	+70	+2	-20	-	8

Note: 1) A scale of evaluation of colour scheme
0 - without influence
1 - partial "
2 - intense "
3 - very intense influence

2) Measured at an average fulfilment of efficiency standard

3) Vibration not measured

4) Dust measured by means of the method of weighing the filter. It is expressed in mg per 1 m^3.

5) The character of work: easy and medium, automatic machines, production of parts for the electric instruments

The workplace illustrated in our example exerts a strong negative influence. First of all there is rather a high noise level (intensity of acoustic pressure = 80 dB); further, disadvantageous temperature (28° C at 60 per cent relative humidity) and lastly excessive dust contents (8.08 mg/m^3) that are to blame. Lighting (80 lx) was not too bad and there were no complaints, when the workers were asked by means of a questionnaire concerning the working environment.

The workplace was not well designed as far as the colour scheme is concerned. The walls were very thickly covered with dust, and the machines and equipment were of a dirty grey colour. From the colour scheme point of view the workplace influence was neutral, almost negative. Hygiene and social facilities were installed in the workplace, but their internal furnishing were not sufficient, so that they could not exercise any positive influence.

Making ideal standard (optimum) working environment is aimed first of all at neutralization of negative factors. In this case, restriction of noise from 80 dB to 60 dB was achieved after the workshop had been reconstructed, so that the acoustic factor exercises its negative influence only in a very small degree. The climatic conditions were solved by installing the air conditioning equipment,

that maintains the temperature of 20°C at 50 per cent of relative humidity. The air is being cleaned. The climatic conditions exercise a positive influence. Powerful exhaust fans have been mounted on the machines, where during the production much dust was formed. The contents of the dust in the atmosphere was considerably reduced, so that this negative factor was neutralized. The intensity of lighting was raised to 150 Lx. At the same time also the location of luminous lights and the colour of the light was considered, so that the original neutral, almost negative influence of the optic factor was changed to an appreciably positive influence. The next important factor in our example when making an ideal standard working environment, was the colour scheme. The colour of walls, floors, machines and equipment were chosen respecting the character of production, the character of working people etc. In this way a very intense positive influence was created. Improving the social and hygiene facilities of the workplace and some other measures also have had a strong positive influence. The ideal standard working environment thus erected has been facilitating the work and helping to create the feeling of well-being and satisfaction from work.

These factors manifested themselves quite clearly in a better, more economical production, characterized by the productivity of labour. The reconstruction of the workplace having been carried out, an increase of productivity of labour by 8 per cent was achieved during one year. (The economic effectiveness of making ideal standard conditions has not yet been investigated in our example and that is why the money expended on these reconstructions is not considered.)

In the quoted example, the analysis of the working environment, that preceded the design of reconstruction project, was very simple and approximate. Usually, however, it will be necessary to carry out a detailed investigation and analysis of the working conditions. Therefore it is important, to work out a unified and not too expensive methodology of this investigation which would enable to record and express accurately and with knowledge all the factors of working environment that must be

influenced in the project. In practice, there are still many imperfections - having to a certain degree a general character - in projecting the working environment. That means these imperfections exist in practice of various projecting organizations in various countries, to a lesser or greater extent. 1)

A common imperfection is to carry out supplementary modifications of certain working environment factors after the production process has started. This imperfection is caused by the fact, that the working environment is being schemed only in approximate features, without concrete details. The project is not based on an analysis of technological and other factors, that will exercise their influence on the worker at the beginning of the production. Therefore only during the production procedure some individual partial imperfections begin to emerge, such as some shortcomings in ventilation system, heating, lighting etc. In such cases the whole process of making ideal standard environment is understood in a wrong way as realization of some supplementary measures, aiming at the restriction of those negative factors.

But the supplementary modifications of the working environment are less effective and have a smaller economical effect when compared with purposeful and complete solution of problems already during the first phases of projecting. It is far more difficult to carry out different modifications of the working environment subsequently and often in the time when the production has already started. These modifications are more expensive and cannot solve the problem completely, but only partially and require various interruptions or restrictions of production, which are always connected with economic loss.

Another imperfection of projecting the working environment is caused by insufficient expertness and by a process of a trial and error.

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1) The methodology for an architectonic project has been worked out by Dr. I. Gilwann, M.Eng. from the department of Industrial Construction at the Technical University in Brno - Czechoslovakia.

The importance of projecting the working environment is not yet fully appreciated and we often let the designer without expert knowledge do the whole complex task. Such a designer tackles his task only on the basis of some general faint ideas and on the basis of partial experience. The acquired piece of knowledge is then applied without a thorough investigation of the concrete facts. The designer is usually not qualified in this field to the same extent, as compared with his knowledge in the field of technological projecting.

Owing to advertising and publicity reasons, the working environment project also often aims at only superficial and external effect. The external power of attraction and conspicuous character is usually skin deep and may evoke even adverse consequences, i.e. deterioration of the environment that the man works in. Of course the best publicity of the good relation of the factory management to the employees is not this outward power of attraction and false aesthetization, but the real accomplishment of the project objectives, i.e. improving the working conditions, that results in facilitating labour and in raising its productivity.

An imperfection appearing rather often is caused through non-complex isolated solution of individual factors of working environment. We have pointed out above the importance of solving the complex of factors influencing a man at work. In general practice however, this complex solution is being omitted and only that factor of working environment is being solved which exerts the most negative influence on the man, e.g. extreme temperature, high noise intensity etc. This method has usually positive results. Those are - at all events - lesser than results achieved by a complex approach.
Another imperfection of measures carried out without connection with other factors of the working environment, is often the fact, that they are applicable for a short time only. That is to say, the achieved results are being reduced and cancelled out by other negative influences. Thus e.g. the improvement of optical conditions in the workshop soon looses its effectiveness, if the dust contents problem

is not being solved at the same time. A suitable lay-out of the machines and equipment at the workplace has no lasting effect, if the most suitable organization of work at the workplace is not being stabilized at the same time etc.

Another imperfection that leads in turn to other failings is the inability to fully appreciate the importance of and the eventual economy resulting from the establishment of an ideal standard working environment. We are usually most thrifty in those parts of the project, which affect the worker immediately. Any excess in the planned budget in the technological part of the project is compensated by saving on expenses incurred in improving the working environment. This is alone often on a false presumption that the investments into the working environment are of little effectiveness or that they have a too long return. These opinions are still being maintained, although actual experience itself disproves them.

If the project of the working environment should be really effective and should fulfill its task, it must be organically incorporated into the whole projecting process. It must be its integral part and must evolve from the various phases of the project.

It must be realized that to a certain degree the productivity of labour in the future plant is affected by the skill level and age pattern of the future labour force. The influence of travelling to work manifests itself in the productivity of labour, controlled from the point of view both of the enterprise and of the whole economy. In the initial project design phase the output of the future worker and employee may be substantially influenced.

Insufficiently concrete projects omitting details, manifest themselves immediately as negative factors in production. These deficiencies must be modified or removed by means of supplementary measures later on. Sometimes there are shortcomings in the organization of work (lay-out of workplaces, machines etc.) of such a character that they cannot be removed completely by later supplementary measures. Owing to

its character the executive project belongs to the phase of " micro-site project ", i.e. the phase where it is necessary to solve the concrete influence of the environment on the worker and his labour output.

The necessity to respect the individual and his needs in the production process is manifested most clearly in designing the individual workplace. All factors influencing the worker must be made ideal standard (optimum) in the highest possible degree. Any action in this field has an immediate influence on the productivity of labour on his efficiency, degree of fatigue etc.

Owing to the diversity of factors involved in a working environment it is proper to solve its problem in close cooperation with the experts of many special branches. Owing to the variety of specializations, it is necessary to ensure the closest cooperation in the complex solution of the problem. This is realized through some form of team work.

For practical purposes, when projecting working environment of an industrial plant, it is essential to use especially the expert knowledge of industrial economics, safety technique, industrial hygiene and industrial psychology in addition to the different specializations of technical-designing and architectural-designing character.

Projecting the working environment imposes extraordinary demands upon every specialist in the branch. A broad extended knowledge, ability to approach the problem in a complex way, sufficient experience and the ability to tackle sensitively the problem of the working environment are essential conditions to achieve success.

If the projecting organization does not have a sufficient number of specialists, it is far more advantageous to contract specialists and advisers from outside establishments either native or foreign for various forms of assistance.

Making an ideal standard working environment brings in an evident economical effect as it creates conditions for raising productivity of labour. The direct influence of single factors of the working environment on the productivity of labour has been proved both by experiments of laboratory character and by production practice as well. In practice however, it is very difficult to isolate a certain factor of the working environment from the whole complex and to measure precisely its influence on the productivity of labour. Therefore the results quoted in literature are rather diverse. All data however explicitly confirm, that improving the working environment results in raising the productivity of labour.

For instance it may be clearly demonstrated by making the climatic conditions ideal (optimum). It has been quoted in the literature, that reducing the temperature e.g. from 30°C to 20°C, when simultaneously reducing the relative humidity from 70 per cent to 50 per cent, resulted in raising productivity of labour as much as by 30 per cent. The data from various industrial branches measured in different countries confirm for example, that when exceeding the optimum temperature the number of accidents increases. (The range between 17.8°C - 22.0°C at the relative humidity of 30 - 60 per cent is usually considered an ideal standard (optimum) temperature). It depends of course on many further circumstances connected with climatic conditions that may considerably influence the expected result. It is evident however, that to make an ideal standard working environment is unthinkable without modifying the climatic factors. That is especially important in enterprises with extreme high or low temperature and humidity caused by either technological conditions or geographical environment.

Lowering the level of intensity of sound on the workplace has also an evident and direct influence on raising the productivity of labour. Reducing the noise in the assembly shop of one Czechoslovak engineering enterprise from 30 dB to 50 dB through installing the noise

insulation and replacing too noisy fans, resulted in raising the average output by 3 per cent. Similar results have been achieved in many industrial branches. Thus for example in the cotton weaving mills the increase of productivity of labour by 1[illegible] per cent was achieved by reducing the volume of noise from the original 96 db to about 80 db through provision of ear plugs for individual workers. In their experiments Weston and Adams [1] proved in 1935, that the annual average of labour productivity arose by 5[illegible] per worker. The unfavorable influence of noise on the health of man was thoroughly proved as well. This influence manifests itself most decisively for example in the telephone exchange and in the computers centers etc.

The dependence of the working output on the intensity of lighting was been also proved. We may observe, that along with raising the lighting intensity also the labour output is being raised and it reaches its maximum stage at the ideal standard (optimum) lighting. The rise above the limit causes - after a short stagnation - a rapid drop of output. The more delicate work and thus more demanding on lighting, the steeper rise and sharper drop of the curve expressing the relation between the output and the lighting. In one workshop of a Czechoslovak ball bearings factory, the intensity of lighting was raised from the original about 60 Lx to about 215 Lx which lead to the raising of the productivity of labour by 17.5 per cent on the average. The lighting having the intensity of 215 Lx does by no means represent the ideal (optimum) conditions. The Soviet writers D.A. Silber and V.P. Busanov investigated the increase of labour output under considerably higher initial and final values of the intensity of lighting and recorded the increase of the productivity of labour by about 1[illegible] per cent, when increasing the intensity of lighting from initial 300 Lx to 8[illegible] Lx. The experience gathered from practice,

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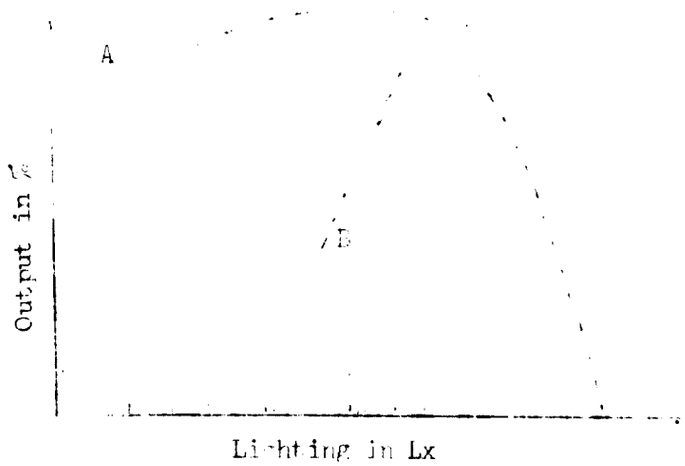
[1]) Weston H.C. - Adams S. Industrial Health Research Board, Rep. No. 70. 1935 London, H.M.S.O.).

verified in a number of factories, confirmed the possibility of raising the productivity of labour by 5 - 15 per cent as a consequence of raising the intensity of lighting. These measures when materialized needed by no means excessive investments.

Figure o. 4

The dependence of the labour output on the intensity of lighting.



The achieved results were considerably higher, if the delicate work was considered, such as assembling electric measuring instruments, precision turning, grinding etc. The results were more pronounced in the large batches (large series) production than in the pieces production, or small-lot (small-series) production.

From the economical point of view colour scheme arrangement of the workplace usually has most positive results. The increase of the productivity of labour achieved by this arrangement may be estimated only approximately in the practice of the Czechoslovak factories. The English firm Cambridge Instrument Company informs us, that after a scientific modification of the colour scheme of the working environment, the labour output was raised on the average by 15 per cent. The Moscow institute of technical aesthetics also quotes the raising of labour output by 10 - 15 per cent, some West European countries however give

even better results. A many-sided function of colour in the working place and its positive influence on the working man was verified also in many Czechoslovak factories.

As an example we mention the design of the interior in iron-works and wire-drawing mills. The colour scheme design respects the micro-climate of the environment. The main motive in designing the colour scheme in the warm part of the factory is using the cold and " soothing " colour compensating the high temperature and the noise during the operations. On the contrary, in the machining shop and in auxiliary services warm colours are suggested to achieve well-being, when performing a monotonous work on machines. The supporting structure (pillars), window frames in all the parts of the hall are pastel-grey. Crane runways are deep blue in the warm part of the workplace, black in other parts. The steel roof construction and the skylights are painted in ivory shade. The crane bridges are light blue with the yellow cabin, the hooks and trucks have a safety black-yellow hatching. The walls in their lower part are cream coloured, in the machining shop they are in brick-red colour. In harmony with the above factor the significance of the colour scheme of the machines and equipment is also being realized. The dangerous places are being emphasized. The design recommends to furnish the workplace with warning signs and to write all the indications and inscriptions according to the principles of modern typography.
(The scheme was worked out by Ing. Gilvann from the department of Industrial Construction of the Technical University in Brno).

The experiments concerning the modification of optical conditions of the workplace, lighting and colour scheme arrangement manifested themselves expressively also in the decrease of work accidents. In the TOS (metal cutting machines) factory the number of accidents decreased, after the modifications had been carried out in two years by nearly 50 per cent. In the ball bearings factory too, it decreased by 32 per cent in two years.

The above mentioned results were achieved by making only a certain factor of the working environment an ideal standard (optimum) .

aking a complex ideal standard environment manifests itself in more pronounced results, and it is only this complex way that can create a really amiable environment facilitating the labour output to the maximum degree and contributing to the worker's satisfaction and well-being. Labour saving results from the fact that the man produces more products with the same quantity of working energy. To produce one single product he needs less work than before. Thus the basic economical effect of making ideal standard environment is the increase of productivity of labour. The increase achieved in this way is usually less expensive, as far as the investment is concerned, and more effective than the rise of productivity of labour achieved in the region of production-technique and technology.

In general however, it is difficult to express the results of making an ideal standard working environment in numbers, they are nearly never complete and exact. The raising of the productivity of labour is the basic economic contribution caused by making ideal standard conditions. The influence of the working environment on the productivity of labour, however, acts simultaneously with the influence of technique and technology. Yet in practice the achieved results are usually attributed to this production-technical influence. It is also difficult to determine the probable intensity of positive influence of individual factors of the working environment. If we presume that the design of an ideal standard working environment could result in the productivity of labour being raised, say, by 8 per cent as compared to the normal average, it is not possible to determine for example, exactly the part played by making optical and acoustic conditions ideal (optimum) . It is comparatively easy to express in numbers the influence of one single factor on the productivity of labour, only if not a new investment but a reconstruction is considered, so that all the previous economical results of the production are well-known.

We shall now deal with the importance of reconstruction for determining economical effectiveness of making an ideal standard working

environment. For the present it is evident, that it is relatively easy to determine numerically the influence of one single factor of the working environment on the productivity of labour, as far as the modification and the innovation of the already existing working environment is concerned, where only this single factor is being made ideal (optimum), while the other environment conditions, as well as the production-technique and technological procedures remain unaltered.

It may be desirable to express the rise of productivity of labour in quantifiable terms as a function of factors which determine ideal standard working environment. The creation of environment, however, leads to results that cannot be immediately quantified but have in many cases even a greater overall economic effect than the results achieved directly. We shall deal with these positive results in productivity increase that are not achieved directly and that cannot be judged numerically.

One such positive result of making ideal standard working environment is the improvement in the quality of products. This result forms a transition between the immediate and easily enumerated results and the derived results that can be expressed in numbers only with some difficulty. It goes without saying, that an environment favourably affecting the worker enables him to concentrate on his work and to work without excessive exertion in work which will manifest itself in the increased quality of products. From the technological reasons certain branches of production, e.g. fine mechanics, optics require the cleanest, air conditioned, noiseless workplace with optimum lighting etc. In general we may say, that in a working environment that exerts a negative influence, it is not possible to produce the products the quality of which would be competitive with the standard of economically developed countries.

A working environment having a favourable influence makes the worker dependent on it from psychological point of view. The man likes his work and is satisfied with it. He prefers to keep his position

in the factory and does not want to change. In this way the factory gains a stable working group possessing the necessary experience and skills which form one of the basic conditions of the high quality of the product. Investigations have proved that the working people often tend to change to some other place because of the bad working conditions and look for a position in enterprises with a more favourable working environment. The loss caused to the factory by the fluctuation of man-power is considerable and is represented first of all by the expenses spent in hiring a new employee, on his training and is connected with the debased quality of the products. In American data the whole loss caused by the leave of a skilled worker is estimated at 180. The part played by the fluctuation of man-power caused by unfavourable working environment has not yet been investigated in Czechoslovakia. It has been found, however, that the average percentage of fluctuation is conspicuously higher in enterprises where there is an out-and-out unfavourable working environment. This fact shows evidently what an economical effect would be achieved by making ideal standard working environment, if the reduction of the fluctuation e.g. by 10 per cent were achieved.

The ideal standard working environment leads to an economical effect and to increased productivity of labour - as understood in a broader sense - also by means of reducing accident rate and absenteeism due to illness. This very pronounced economical influence of the working environment is realized in several ways :

a) by forming direct safety measures on the workplace
b) by neutralizing the negative factors which would cause occupational diseases and create the risk of accident
c) by reducing the exertion in work whereby the risk of employment accident or occupational diseases is diminished.

The forming of effective safety measures and the neutralizing of the negative factors of the working environment are the ways representing the basic methods of making ideal standard environment. That is

why it is obvious, that for example by reducing the noise level at the workplace, or by removing the dust, we not only make the general working conditions more pleasant, but above all we eliminate or help to reduce the occurrence of occupational diseases that are caused by these factors (diseases caused by noise, dust, etc.)

In spite of all the modernization of industry on a world-wide scale, the number of occupational diseases as well as the number of employment accidents do not decrease. On the contrary the recent years have shown a rising trend which is most true of the very countries that are expanding greatly their industry. The absolute and the relative frequency of occupational accidents has a growing tendency in all countries with modern developed industry. This fact may have different reasons in different countries.

However, it may be concluded, that the analysis regarding the making of ideal standard working environment and the basic requirement of safety are widely neglected in the process of designing an industrial plant. The speed of working environment improvements in the industry seems to lag behind that of development of industrial production.

The negative influence of the work accidents and occupational diseases on the productivity of labour is evident. Absenteeism interrupts the continuity of production process, makes the organization of work difficult, and causes considerable economic loss. The lost opportunity to create national income due to the unutilized production facilities during the time the worker was absent is estimated on the average per worker and per shift to 314 crowns, i.e. 7,500 crowns a month and 90,000 crowns a year, which (just for comparison sake) represents a sum equal to the price of 30 TV sets, or 60 cameras of high quality etc. The experience gained in industrial practice shows, that the number of employment accidents rises in the period of increased intensity of work and of fatigue. It is known, that in a favourable and as far as hygiene is concerned, perfect working environment and in such a system of work, that avoids the fatigue by various preventive measures,

even the common diseases appear more rarely than in a negative working environment in which the man performs the work connected with excessive fatigue almost exhaustion. e may differentiate three distinct stages of fatigue, i.e. simple fatigue, excessive fatigue and exhaustion.

Simple fatigue is the consequence of normal work and is removed by rest. Excessive fatigue is a consequence of too intensive work, or of a work lasting too long, or performed in an unfavourable working environment, when all common abilities of the organism to work have been exceeded. The attentiveness begins to be affected, the ability of exactly focusing one's attention deteriorates, the coordination of motions on movement begins to be disordered, the time needed to respond to certain situations is extended. The state of exhaustion already approaches a pathological state, during which irreversible changes in organism may appear.

In a modern industrial enterprise with a mechanized nearly automatic production the preventive measures taken to avoid fatigue are of great importance and it is much more important than before to ensure those measures. That means that the character of work approaches more and more the character of mental exertion. In the work of a man working at a complicated modern machine the control of the working process, the reading of informations from the indicators and control panels and other similar acts prevail. Every omission or lack of attention results in a considerable material loss, eventually in an employment accident or in a possibility of fatality.

Therefore it is absolutely necessary to prevent fatigue by all means. One of these means is making an ideal standard environment. A scientifically planned working environment may contribute to an important extent to ensuring continued and safe work which would have an important economical effect.

Work performed with less effort, with less strain and with less energy results evidently in a lower rate of wearing out of working

ability. Thus the average working age is prolonged and this has favourable economical consequences from the viewpoint of the factory itself or the whole society alike. (Savings on too-early old-age benefit or disability benefit and invalid pension etc.). From the social point of view it is very undesirable to employ ideal standard working environment only for the reason that the maximum labour output of the workers and employees may be achieved. In such a case, no doubt, the effort associated with performing a certain working operation is being reduced, but at the same time the worker's efficiency standard is being raised. The result of making an ideal standard environment is then a unilateral condensation of the working hours, the growth of intensity of labour and not decreasing the exertion in work and diminishing the whole quantity of working energy spent during the shift. In such a case the worker works no doubt, in a modern, hygienic environment, but he leaves the work being excessively tired, almost exhausted. He loses his work ability precociously and is to a lesser or greater degree thrown upon government support.

Making ideal standard working environment in industrial plants has another social importance in a country which has only just begun to build up its industry and to develop it. In such a country a modern industrial plant becomes an institution responsible for civilization and culture. Under civilized working conditions the working man himself becomes a civilized man. In this connection the working environment has not only a direct economical importance but also a social-educational effect. This social-educational function has its positive economical consequences, which of course cannot be either estimated or expressed in money.

When investigating the economical effectiveness of an ideal standard working environment, it is evident that not only positive results must be enumerated, that is the increase in the productivity of labour caused by making this environment ideal standard (optimum). But, at the same time it is necessary to ascertain the expenses that

ought to be invested into this process. When dealing with a new investment, it is usually easier to determine the expenditures needed to improve the working environment, rather than the savings that will be achieved by the increased productivity of labour resulting from this improvement.

The coefficient of economical effectiveness of improving the working environment may be calculated so that the project with ideal standard working environment is considered to be one investment variant, the project without it the second variant. The coefficient may be calculated by means of a formula commonly used in a designer's practice to compare two or more design variants.

$$C_{ef} = \frac{V_1 - V_2}{\quad}, \text{ where}$$

C_{ef} - coefficient of effectiveness of design variants

V_2 - complete total costs of annual production in the second variant, presuming in our case modifications of the working environment

V_1 - complete total costs of annual production in the first variant where no modifications of the working environment are presumed

l_1 - investment costs of the first variant

l_2 - investment costs of the second variant

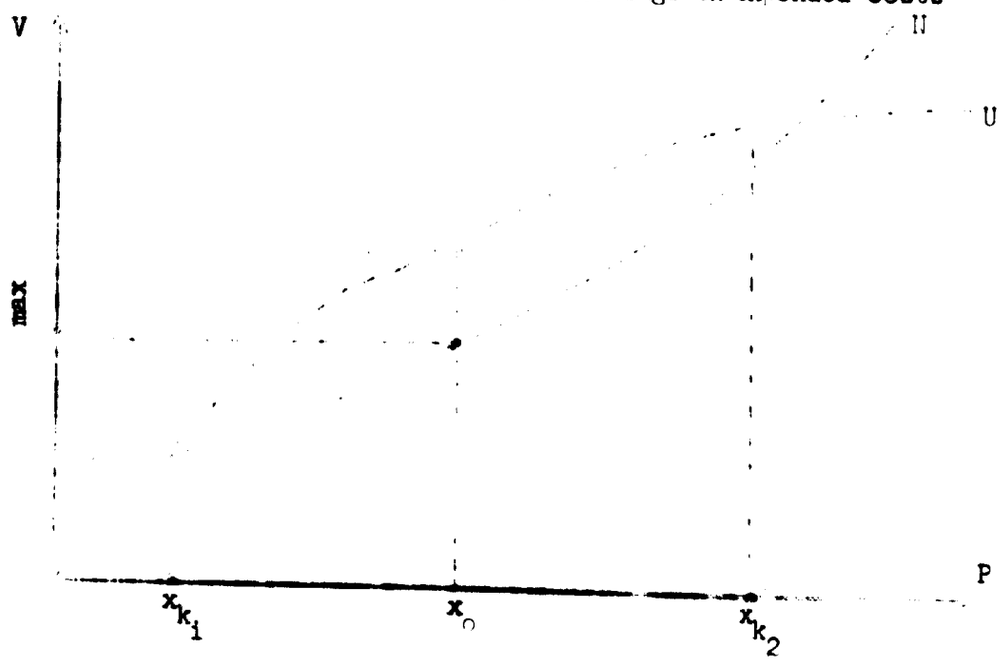
In our case l_1 l_2, V_1 V_2, (V_1, V_2, reduced to the same volume of industrial output).

The presumed saving achieved by making the working environment ideal (optimum) will appear then as savings on the total costs of the production. The total costs of the production will decrease as a consequence of savings on the wages and savings on overhead expenses. If the designed ideal standard environment is to be economically effective, then in general, the savings achieved by it must be greater than expenses

spent on it. Even here we may investigate the relation of the resumed investment expenditures to the presumed savings in total costs of the production and we may choose the most suitable amount of investment expenditures, the most suitable point on the curves as demonstrated briefly on our graph.

Figure No. 8

The dependence of achieved savings on expended costs



P = Parameters of making ideal standard conditions (optimization parameters)

V = money units

N = expended capital

U = savings

x_{k1}, x_{k2} = critical points for N = U

x_o - optimum point for U - N = max

This type of analysis however is highly questionable. It means that we shift the point along the curve of investments and eventually reduce the investments. Then the result cannot be of course a real and complete ideal standard working environment. In the field of savings, an important part is being played by various results - as emphasized before - that can be very difficult to assess and do not fall within the region of direct economic evaluation.

The making of an ideal standard working environment is being materialized in practice not only when building a new enterprise, e.g. the whole industrial plant or certain factory, etc. but also when carrying out some reconstruction and modernization of the existing buildings and equipment. Reconstruction is not an ideal way as far as the achievement of really best results, when making an ideal standard working environment, is concerned. Usually it seems, that the positive factors of the workplace which emerged from the existing production are being removed afterwards. Making the ideal standard working environment in the framework of reconstruction, the designer is considerably restrained by various factors, that he cannot change, as for example the lay-out of heavy machines in the factory-hall, lay-out of production lines etc. But even in this case this additional reconstruction of the working environment may have important economical consequences, as it is usually aimed at solving the most pressing and most topical problems of a certain workplace.

The additional modification of working environment supplies valuable data much needed for comparison and thus for ascertaining actually achieved savings and also data much needed for evaluation of economical effectiveness of measures undertaken. When projecting a new investment, the economic effectiveness of the ideal standard working environment cannot be determined exactly. We may only anticipate an economic contribution on the basis of experience drawn from similar cases. When reconstructing the working environment, an opportunity of comparing the previous situation with the results achieved after

reconstruction arises. The economical effect may be determined by means of a method founded on the same basis as the calculation of effectiveness coefficient of individual project-variants. We compare expenditures spent on the reconstruction of the working environment with the savings achieved by it. To express the savings in numbers it is presumed, that we know the situation in the production before the modifications have been carried out. It is the same method by means of which we determine in the simplest and approximate form the effectiveness of whatever measures in the field of technique development.

We start with a simple formula

$$C_{ef} = \frac{U}{I}, \text{ where}$$

C_{ef} = coefficient of effectiveness of the carried out modifications of the working environment

I = expenditures on additional modifications of the working environment

U = savings achieved by the new measures.

The practical application of the formula is demonstrated by the following example taken from practice, simplified and slightly modified for the purpose of our explanation. When reconstructing an assembly line manufacturing electrical measurement instruments, where 20 women workers were working, the following expenditures were expended :

			Total
1.	New lighting installation	10,000 crowns	10,000
2.	Decorating (painting, the workshop according to the design of an architect ..	5,000 "	15,000
3.	Noise insulations and other reduction noise measures	30,000 "	45,000
4.	New air conditioning installation	15,000 "	60,000
5.	Purchase of 20 modern chairs	6,000 "	66,000
6.	Purchase of 20 pieces of spec. overalls ..	2,000 "	68,000
7.	A new lay-out of assembly benches and equipment and repairs of this equipment ..	5,000 "	73,000

8.	The reconstruction of windows	4,000 crowns	77,000
9.	The expenditures on design and further various modifications	8,000 "	85,000

Direct costs spent on improvement of the working environment represented 85,000 crowns. After the modifications were carried out the average daily labour output of the woman workers increased by approximately 6.5 per cent, which represents average daily savings of about 2.5 crowns per one worker. The average annual savings on wages of all women achieved by raising the productivity of labour represent approximately 20,000 crowns and on overhead expenses about 5,000 crowns. The service life of the measures carried out is very different. However we may safely assume that the life averages to 5 years. That means that the total savings during the 5 years represent approximately 5 . (20 + 5), that is 125,000 crowns.

$$C_{ef} = \frac{U}{N} = \frac{125,000}{85,000} = 1.47$$

C_{ef} 1, that means that the measures carried out are economically effective. The time - T - during which the money invested will return is approximately 3 and a half years, as

$$T = \frac{N}{n} = \frac{85,000}{25,000} = 3.5$$

n = average annual savings.

It is necessary to point out again, that the calculation of economical effectiveness of modifications and improvement of the working environment is only approximate and that a lot of important positive results cannot be recorded, as for example contentment of the working people, the stability of workers, restricted fluctuation of man-power, a good attitude to the work, raised quality of production etc.

Both in reconstructing an old working environment as well as in designing a new one it is necessary to apply - to a reasonable and suitable extent - the principle claiming, that it is not of great advantage to save too much when making ideal standard working environment and to apply the same principles which are usually employed when estimating the effectiveness of investment of production-technical character.

The experience drawn from the countries with a developed and modern industry confirms, that the increase of productivity of labour achieved by means of modifying the working environment is on the average relatively appreciable, so that the expenses spent on this modification are often even economically more effective than expenses in the purely production-technological field.

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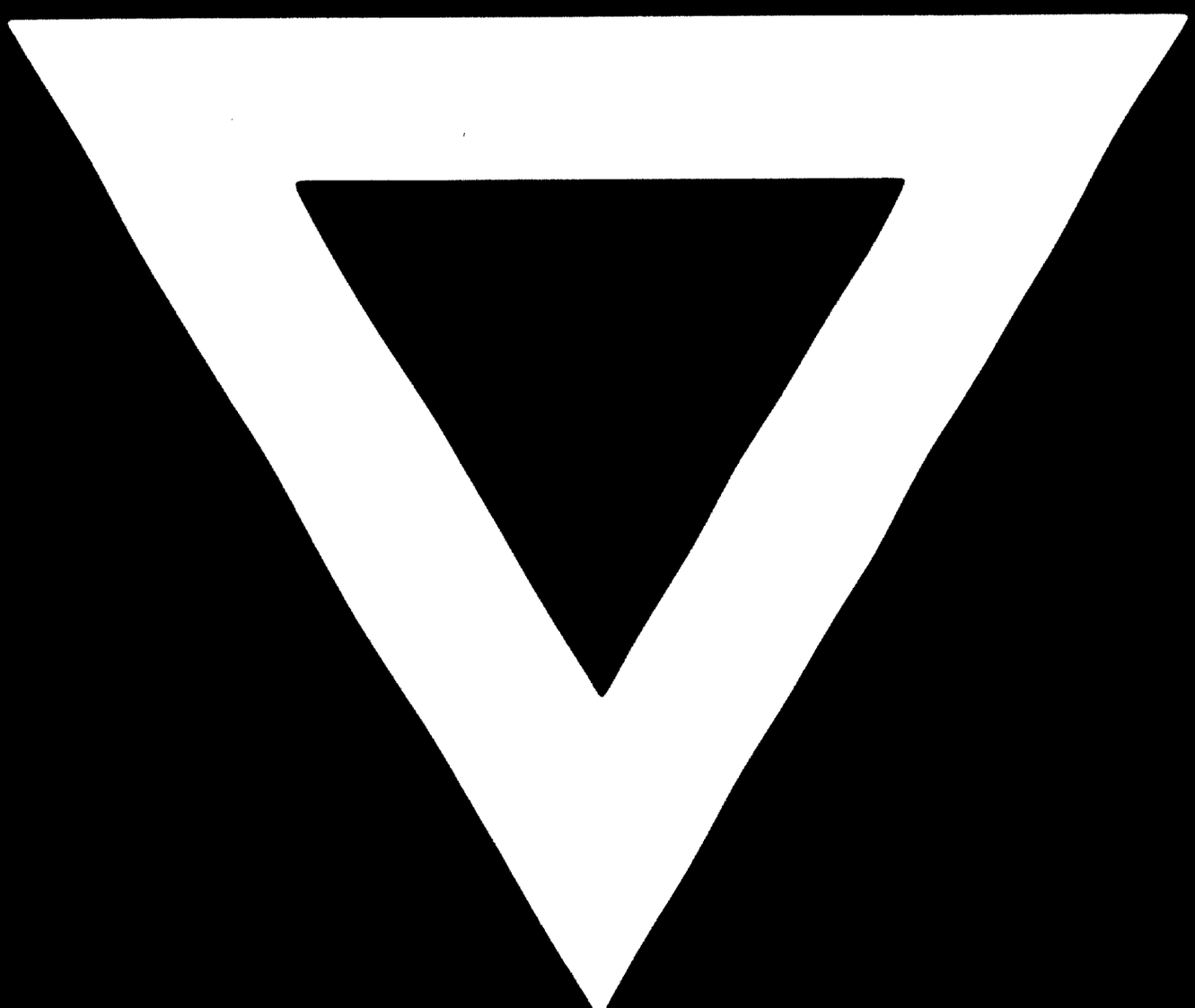

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