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HYDROCYLINDER DIAGNOSTIC PARAMETERS

By diagnostics, as a rule, two stage of acquiring initial information and its subsequent transformation into a finite one while diagnosing are meant. Success at every stage is ensured mainly by the right choice of diagnostic parameters. Unfortunately, as it often happens one's own experience and intuition are not enough. It is necessary to resort to logical description of the object under investigation. And a good example of this is the model of structure and effect, cause and effect relationship. Such models can be worked out for any object of diagnosing on the basis of the analysis of its structural scheme and concrete conditions of functioning etc.

Ключевые слова: complex of diagnostic parameters, diagnostics, hydrocylinder.

According to the structure of technical diagnostics the whole complex of methods of acquiring initial information and its subsequent transformation into a finite one while diagnosing should be meant by diagnostic method. Their contents is mainly determined by a complex of diagnostic parameters (CDP) on the choice of which great attention is justly focused.

As a rule, while choosing the CDP one of the means of logical description of the object under investigation is used [1]. So for the choice of the parameters of complex technical objects they more often resort to the creation of analytical and functional matrix and models in the form of formula of connection between direct and indirect diagnostic parameters, processes equation systems, taking place in the object under investigation during its functioning and so on.

The model of structure and effect relationship is the most suitable logical description of simple objects such as hydraulic drive hydrounits of road and building machinery. These models are worked out on the basics of the analysis of structural scheme of the object under investigation and conditions of its work having regard to the conformities with laws of structural parameters degradation. Similar models for the CDP choice of cylinder piston group, oil pump and others have been developed and mentioned in some papers [1, 2]. As a rule, they include the following six levels: an object of diagnosing; its elements; structural parameters; object defects; diagnostic signs (symptoms); diagnostic parameters. However the existing models have a number of drawbacks decreasing effectiveness of their usage.

In the first place, the object of diagnosing in these models is represented as a group of structural elements with the result that no interaction of elements within the object can be traced and as it is not unusual that important structural parameters are lost.

In the second, there is no connection between limiting change of structural parameters and particular variety of technical state. That is while analyzing them it is not clear that happens to the object being diagnosed at the limiting change of one or several structural parameters we are interested in: if the object is fit for work with regular or irregular functioning, or it loses its fitness for work utterly.

In the third place, chains of cause and effect relationship of damages of the object of diagnosing with diagnostic signs are represented in a simplified form, which may result in losing accuracy when controlling diagnostic parameters, distorting measuring (starting) information and reducing reliability of diagnosing.

In the fourth place, mainly for the same reason using the chosen CDP it is impossible to localize a particular damage of the object.

And lastly, the fact that there are no rules, instructions and recommendations for the search of optimal CDP often makes the process of its choosing intuitive.

To eliminate the above-mentioned drawbacks the authors have worked out an expanded model of structure and effect, cause and effect relationship (EMSECER). As an illustration we take the EMSECER of a hydraulic cylinder of dual action with a unilateral rod. However it should be noted that the procedure of making EMSECER given below can be applied to any other technical object.

So the EMSECER in Fig.1 contains 13 levels: I – an object of diagnosing (OD); II – constructive elements groups of OD; III – OD constructive elements proper; IV – structural parameters of object elements; V – OD elements characteristic defects and damages; VI – boundaries of the greatest evolution of OD technical state at a maximum qualitative or quantitative change of a particular structural parameter; VII – diagnostic signs (symptoms); VIII – diagnostic parameters; IX – their controllable components; X – the matrix of interconnection; XI – OD characteristic qualitative peculiarities, degradation of which as it is operated is connected with evolution of the technical state; XII – specific weights of object failures caused by its concrete constructive elements defects; XIII – and finally prices of each of them.

The contents of the EMSECER levels I - V and VII and VIII is clear from Fig.1 and requires no further explanation. As to levels VI, IX and X - XIII it is suitable to consider it at greater length. So level VI is the boundary of OD technical state evolution.

As it is known [3] variations of object structural parameters values come about within it under the influence of external factors and due to interaction of elements when the object is operated. These values change from predetermined ones to the limiting ones, the result of which is a similar change of values of its technical and economic functional parameters and those of the attendant processes. And this change is invariably accompanied by the transition of an object

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from one complex of technical state into another one, that is from one variety of technical state into another one. It goes without saying that evolution of object technical state types occurs within the limits of operative (+O) and inoperative (-O), fit for work (+F) to unfit (-F), from the state of regular functioning (+RF) to that of irregular one (-RF). There is no doubt that: an operative object is always fit for work while the object fit for work may be both operative and inoperative; an inoperative object may be both fit for work and unfit for work or failed; the failed object is always inoperative; the inoperative object but fit for work may be characterized by both regular functioning and irregular one; the operative fit for work object is always characterized only by regular functioning.

From this it follows that the evolution of any object technical state as it is operated occurs from complex of technical state types which is characterized by working order, fitness for work and regular functioning (+O+F+RF) through variabilities (-O+F+RF) and (-O+F-RF) to complex of state types which is characterized by unfitness for work (-O-F). In a special case not every stage of technical development is necessary and the appearance of the latter is not desirable.

The intensity of evolution stages change having prevailing significance for working out the algorithm and prognostic governing rules increases with its operation as the object elements accumulate defects, that is because of continuing qualitative and quantitative change of its structural parameters and is mainly determined by constant deteriorating interacting conditions of elements within the object and the increase of external factors influence on it. Thus while diagnosing a technical object having already been operated and consequently characterized by a definite operating time it may be stated with certainly that its technical state must in no way correspond to the type complex (+O+F+RF), which simplifies considerably the task of further identification. And as the loss of fitness for work (-O-F) of such a technical object as a hydraulic drive unit can be determined easily by an operator while working with it and eliminated only by repair action under stationary conditions then the task of identifying the object technical state in general is reduced to identifying two remaining variations: (-O+F+RF) and (-O+F-RF). The exact identification of the latter is important as this type complex precedes the region of failures (-O-F).

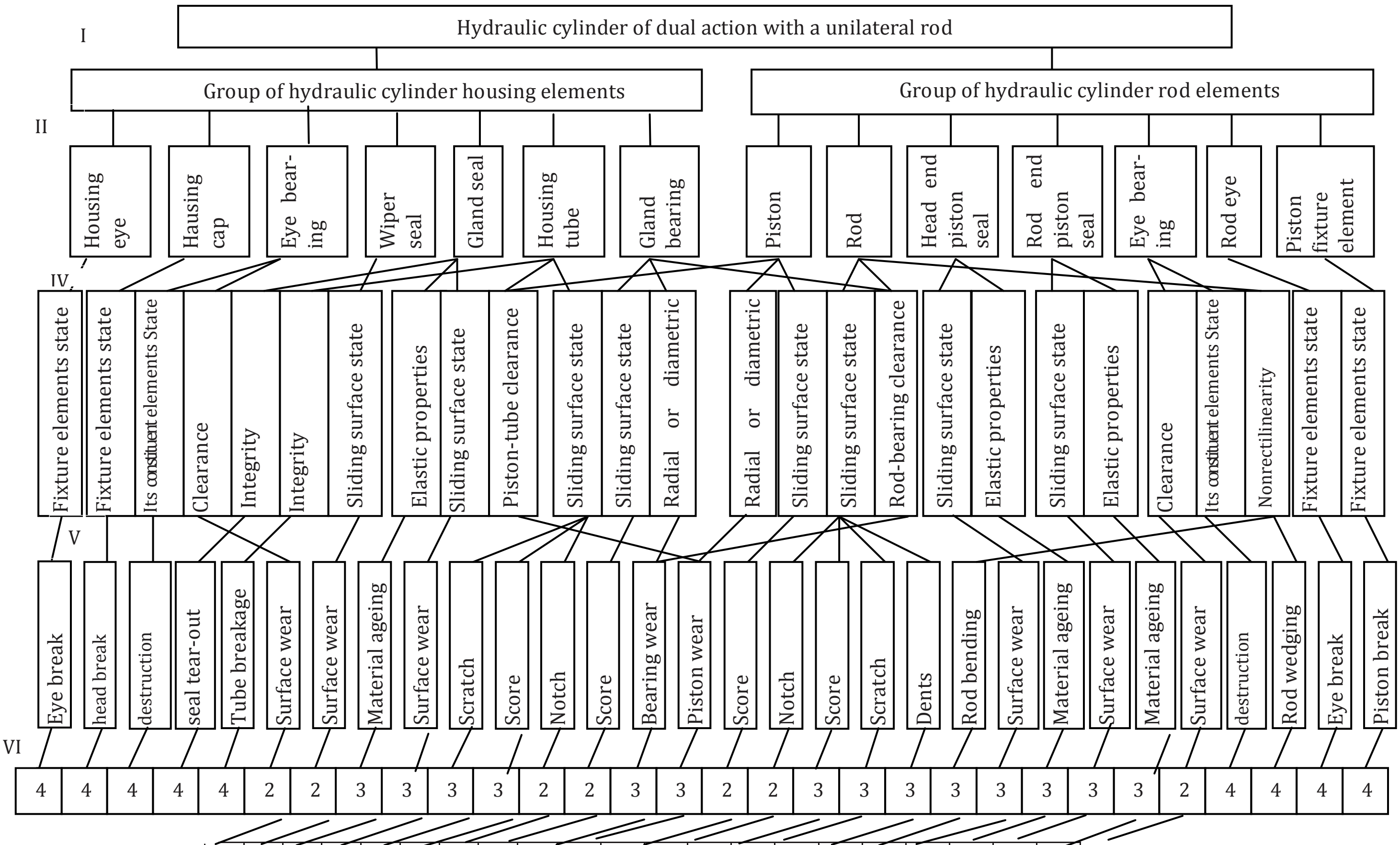
Thus level VI shows to which type complex the OD technical state will correspond at a maximum qualitative and quantitative change of a particular structural parameter, type complex 3 meaning conditional and partial object failure as a result of which there occurs decrease of differential exit effect or there is not provided specified value of integral exit effect [3] and complex 4 – the full failure which results in complete loss of object fitness for work. Since complete hydraulic cylinder failures are evident [3] they have no further continuation in EMSECER, that is they are not connected with diagnostic signs (level VII), diagnostic parameters (level VIII) and their controllable components (level IX).

It is obvious that the alteration of complexes in operation of a technical object manifests in appearance or quantitative change of diagnostic signs interconnected with diagnostic parameters. Both of them are connected with characteristic defects of OD elements (level V) through the matrix of interrelation (level X). The latter is divided into cells the contents of which reflects the manifestation character of arising particular diagnostic signs (Fig. 2), the letters "p", "r" and the symbol "*" in the matrix cell denoting the moment of defect appearing in signs and meaning respectively: "p" – defect manifests in this sign only at working fluid discharge into the head end of a cylinder, "r" – defect manifests in this sign only at working fluid discharge into the rod end of a cylinder, "*" – when hydraulic cylinder head ends are switched off completely. "0" in the matrix cell indicates that the given defect is in no way connected with this or that diagnostic sign.

The character proper of defect manifestation in diagnostic signs is represented in the matrix of interrelation (Fig. 2) as one – or multisectional cause and effect relations which are lettered by capital Latin alphabet. They mean: "A" – comprehensive decrease of contact pressure of sealing packers because of their wearing and material ageing; local decrease of sealing packers is because of: "B" – relative eccentric element displacement of conjugation because of wearing; "C" – relative angular displacement of conjugation elements caused by their gaps; "D" – relative angular displacement of conjugation elements caused by elastic deformation of long measuring elements of a hydraulic cylinder; "E" – relative angular displacement of conjugation elements caused by residual strain of a hydraulic cylinder rod; "F" – appearance of unpacked space in conjugation; increase of complete hydraulic cylinder deflection is because of: "G" – increase of angular misalignment of its rod and housing as a result of centering elements wearing; "H" – operational increase of rod axis deviation from straightness, that is because of its distortion; increase of frictional force is due to: "I" – reaction rising in conjugations because of arm increase of longitudinal compressive stress application; "J" – rising coefficient of friction because of conjugated surfaces roughness change; "K" – getting of impurity particles into conjugated gaps; lowering frictional force due to: "L" – all-round decrease of contract pressure of pressurizing and dustproof packers because of their wearing and material ageing; "M" – decrease of contact pressure of pressurizing packers because of pressure differential dropping.

The signs "+" and "-" before the Latin alphabet letters in case of possible dual manifestation of particular damage in a given diagnostic sign indicate whether its action deteriorates or hinders its development. For instance, on the one hand, pressurizing packer surface wearing through the cause and effect chain "+A" deteriorates hydraulic cylinder effective power lowering, and on the other – through the chains "-L" and "-M" decreases frictional force action and thereby brakes the development of this diagnostic symptom, the sigh "+" is not put.

The indices “I” and “2” in the upper right part of the Latin symbols localize the place of prevailing action of an arising damage manifesting in a diagnostic sign. So “I” is for the hydraulic cylinder rod packing unit, and “2” is for the piston one. For example, on supplying working fluid into the rod end of a cylinder and at piston wearing the hydraulic cylinder volumetric performance lowering takes place pertly because of local decrease of contact pressure of a piston pressurizing packer due to relative eccentric displacement of piston conjugation elements “+D²” and on insert wearing – that of the rod one “+DI”. That it is necessary to distinguish between them is quite clear



	VII	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	VIII	IX
1	Efficiency drop	0	0	r	r	pr	pr	pr	0	pr	pr	0	r	r	r	r	pr	p	p	r	r	0	Volumetric efficiency	Leakage etc
2	Rod shrinkage	0	0	r	r	pr	pr	pr	0	pr	pr	0	r	r	r	r	pr	p	p	r	r	0	Shrinkage	Shrinkage in time
3	Outer leakage	0	0	pr	pr	0	0	0	0	pr	p	0	pr	pr	pr	pr	pr	0	0	0	0	0	Leakage	Leakage
4	Rod speed drop	0	0	r	r	pr	pr	pr	0	pr	pr	0	r	r	r	r	pr	p	p	r	r	0	Rod speed	Speed
5	Stroke non-uniformity	0	0	0	0	pr	pr	pr	0	pr	pr	0	r	r	r	r	pr	0	0	0	0	0	Rod speed	Speed in stroke
6	Cycle duration increase	0	0	r	r	pr	pr	pr	0	pr	pr	0	r	r	r	r	pr	p	p	r	r	0	Cycle duration	Time
7	Pressure differential drop	0	0	r	r	pr	pr	pr	0	pr	pr	0	r	r	r	r	pr	p	p	r	r	0	Pressure differential	Pressure
8	Pulsation occurrence	0	r	0	0	pr	pr	pr	pr	0	0	pr	r	r	r	r	0	0	0	0	0	0	Pressure pulsation	Pressure in time and in stroke
9	Force drop	0	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	0	Force	Force
10	Capacity drop	0	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	pr	0	Effective capacity	Pressure, flow, Force, speed
11	Deflection increase	*	0	0	0	0	0	0	0	p	p	0	0	0	0	0	pr	0	0	0	0	*	Deflection	Deflection
12	Rod-housing angle increase	0	0	0	0	0	0	0	0	*	*	0	0	0	0	0	0	0	0	0	0	0	Angular misalignment	Angle
13	Beat with rod speed change	pr	0	0	0	0	0	0	0	pr	pr	0	0	0	0	0	0	0	0	0	0	pr	Radial and axial beat	Beat rate
	XI	c	c	l	l	cl	cl	cl	c	cfl	cfl	c	cl	cl	cl	cl	cfl	l	l	l	l	c		
	XII	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}	x_{21}		
	XIII	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}	y_{11}	y_{12}	y_{13}	y_{14}	y_{15}	y_{16}	y_{17}	y_{18}	y_{19}	y_{20}	y_{21}		

Fig.1. Hydrocylinder EMSECER.

	Sign	Pumping	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	
			Elements Characteristic Defects and Damages																					
Diagnostic signs	1	p	0	0	0	0	+F	+F	+F	0	+(CD)	+B(CD)	0	0	0	0	0	+E	+AF	+A	0	0	0	Diagnostic parameters
		r	0	0	+A	+AF	+F	+F	+F	0	+B^{1}+C	+B^{2}C	0	+F	+F	+F	+F	+E	0	0	+AF	+A	0	
	2	p	0	0	0	0	+F	+F	+F	0	+(CD)	+B(CD)	0	0	0	0	0	+E	+AF	+A	0	0	0	
		r	0	0	+A	+AF	+F	+F	+F	0	+B^{1}C	+B^{2}C	0	+F	+F	+F	+F	+E	0	0	+AF	+A	0	
	3	p	0	0	+A	+AF	0	0	0	0	+$B^{1}CD^{1}$	+CD^{1}	0	+F	+F	+F	+F	+E	0	0	0	0	0	
		r	0	0	+A	+AF	0	0	0	0	+B^{1}C	+C	0	+F	+F	+F	+F	+E	0	0	0	0	0	
	4	p	0	0	0	0	+F	+F	+F	0	+(CD)	+B(CD)	0	0	0	0	0	+E	+AF	+A	0	0	0	
		r	0	0	+A	+AF	+F	+F	+F	0	+B^{1}C	+B^{2}C	0	+F	+F	+F	+F	+E	0	0	+AF	+A	0	
	5	p	0	0	0	0	+F	+F	+F	0	+(CD)	+(CD)	0	0	0	0	0	+E	0	0	0	0	0	
		r	0	0	0	0	+F	+F	+F	0	+C	+C	0	+F	+F	+F	+F	+E	0	0	0	0	0	
	6	p	0	0	0	0	+F	+F	+F	0	+(CD)	+B(CD)	0	0	0	0	0	+E	+AF	+A	0	0	0	
		r	0	0	+A	+AF	+F	+F	+F	0	+B^{1}C	+B^{2}C	0	+F	+F	+F	+F	+E	0	0	+AF	+A	0	
	7	p	0	0	0	0	+F	+F	+F	0	+(CD)	+B(CD)	0	0	0	0	0	+E	+AF	+A	0	0	0	
		r	0	0	+A	+AF	+F	+F	+F	0	+B^{1}C	+B^{2}C	0	+F	+F	+F	+F	+E	0	0	+AF	+A	0	
	8	p	0	0	0	0	+FJ	+FJ	+FJ	+J	0	0	+J	0	0	0	0	0	0	0	0	0	0	
		r	0	+K	0	0	+FJ	+FJ	+FJ	+J	0	0	+J	+FJ	+FJ	+FJ	+FJ	0	0	0	0	0	0	
	9	p	0	+K-L	-L	-L	+FJ-M	+FJ-M	+FJ-M	+J	+(CD)+J	+B(CD)J-M	+J	+J	+J	+J	+J	+EJ-M	+AF-LM	+A-LM	-L	-L	0	
		r	0	+K-L	+A-LM	+AF-LM	+FJ-M	+FJ-M	+FJ-M	+J	+B^{1}C-M	+B^{2}C-M	+J	+FJ-M	+FJ-M	+FJ-M	+FJ-M	+E	-L	-L	+AF-LM	+A-LM	0	
	10	p	0	+K-L	-L	-L	+FJ-M	+FJ-M	+FJ-M	+J	+(CD)+J	+B(CD)J-M	+J	+J	+J	+J	+J	+EJ-M	+AF-LM	+A-LM	-L	-L	0	
		r	0	+K-L	+A-LM	+AF-LM	+FJ-M	+FJ-M	+FJ-M	+J	+B^{1}C-M	+B^{2}C-M	+J	+FJ-M	+FJ-M	+FJ-M	+FJ-M	+EJ-M	-L	-L	+AF-LM	+A-LM	0	
	11	p	+G	0	0	0	0	0	0	0	+G	+G	0	0	0	0	0	+H	0	0	0	0	+G	
		r	+G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+H	0	0	0	0	+G	
	12	p	0	0	0	0	0	0	0	0	+G	+G	0	0	0	0	0	0	0	0	0	0	0	
		r	0	0	0	0	0	0	0	0	+G	+G	0	0	0	0	0	0	0	0	0	0	0	
	13	p	+G	0	0	0	0	0	0	0	+G	+G	0	0	0	0	0	0	0	0	0	0	+G	
		r	+G	0	0	0	0	0	0	0	+G	+G	0	0	0	0	0	0	0	0	0	0	+G	

Fig. 2. Interrelation EMSECER hydrocylinder matrix presentation.

Brackets enclosing two Latin letters indicate their incompatible action. For instance, piston wearing results in increase of elements angular misalignment among other things that of piston conjugation and causes local decrease of pressurizing packers contact pressure as a result of relative angular displacement of conjugation elements due to the presence of gaps in them – "+C". On the other hand, piston wearing through hydraulic cylinder deflection increase $Y_\alpha(x)$, $Y_p(x)$, and $Y_\Sigma(x)$ [4] contributes to its long measuring elements elastic deformation increase, the result of which is local decrease of piston pressurizing packers contact pressure, but it is connected with the cause and effect chain "+D". And as the directions of these angular displacements are opposite, their actions at local decrease of piston pressurizing packers are incompatible, that is the cause and effect chain "$+B^2$+(CD)" takes place where the chain "$+D^2$" prevails (Fig.3). It should be stressed that the case under discussion in no way relates to the hydraulic cylinder rod packing unit [4].

Now let's direct our attention to level XI – that is to OD characteristic qualitative features. As it is known [4] the evolution while operating hydraulic cylinder is connected, as a rule, with lowering or complete loss of one or two of its capacities: packing unit pressurizing one and its loading one. As it has already been mentioned the evolution intensity increases in the course of time of hydraulic cylinder operation as its elements accumulate damages and is determined mainly by constant deterioration (which is caused by them) of hydraulic cylinder operating conditions and its structural elements. According to this it is good practice to consider as characteristic qualitative features of a hydraulic cylinder (Fig. 1): pressurizing capacity of packing units (f); its loading capacity (l) and conditions for hydraulic cylinder and its elements operation (c). Thus it is not difficult to determine particular volume of structural parameters or damages to be embraced which cause the state (-O+F+RF).

The right CDP choice may be checked by means of the introduction of the quantitative indices of OD reliability in continuation of level XI as specific weights (level XII) of object failures caused by its concrete constructive elements defects and finally the prices (level XIII) of each of them.

In conclusion let's consider some recommendation on the CDP choice while using the above given EMSECER:

- CDP must be minimum in volume but maximum in embracing structural parameters and characteristic damages;
- CDP must describe all the evolution stages of OD technical state;
- CDP must characterize all the OD qualitative features;
- CDP must localize particular damage of OD elements;
- diagnostic signs described by the chosen CDP must be unambiguously connected with the complex of structural parameters and characteristic damages;
- cause and effect chains of structural parameters and diagnostic signs connection must be characterized qualitatively as far as possible.

Thus the following innovations are introduced in the EMSECER:

- the range of structural parameters limiting changes is correlated with the evolution stages of OD technical state which makes it possible to find the finite number of structural parameters whose limiting qualitative and quantitative change results in the appearance of a particular variety of a technical state;
- here are also represented cause and effect chains of manifestation of particular damages influencing the appearance, qualitative and quantitative change of particular diagnostic signs, which allows to reveal and evaluate the character of particular structural parameters change manifestation in diagnostic sign;
- here you also find the connection of structural parameters with OD characteristic qualitative features, which makes it possible to reveal the finite number of structural parameters and damages corresponding to degradation of OD particular features;
- we also offer some recommendation on CDP choice.

So hydraulic cylinder EMSECER being its simplest logic description makes it possible not only to simplify the CDP choice but to optimize the contents and the volume of further theoretical and experimental research for the purpose of rising its reliability

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