5. Informacionno-izmeritel"nye sistemy s adaptivnymi preobrazovanijAmi. upravlenie gibkost"jU funkcionirovanijA /Muha Ju.P., Avdejuk O.A., Koroleva I.Ju.monografija / Ju. P. Muha, O. A. Avdejuk, I. Ju. Koroleva; Volgogradskij gosudarstvennyj tehnicheskij universitet. Volgograd, 2010.

6. K. Bushmeleva, I. Plyusnin, S. Uvaisov, Processing and data logging system of complex remote sensing. Sensors and Systems, 2011, 5, 24 - 29.

INFLUENCE OF THE QUALITY OF TECHNICAL SYSTEMS ON THE RELIABILITY CHARACTERISTICS OF THEIR ELEMENTS

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Considered are the questions of influence of quality of Technical Systems on the reliability of their Elements. It is shown that the improvement of the quality Systems affect the structure of the models of field failure rate. An example of the influence of quality of Cooling System of the model structure of the failure rate for class "Filters" and recommendations to improve the accuracy of this model.

Keywords: quality, reliability, technical systems, failure rate

This study (research grant № 14-05-0038) supported by The National Research University - Higher School of Economics' Academic Fund Program in 2014. As is known, the reliability of the Elements of Cooling Systems of Electronic Equipment is largely dependent on the regime of their use. The analysis of methods and means of reliability prediction procedures for mechanical equipment of such systems is provided in [1-3].One of the components of such systems are the Filter Elements. Figure 1 shows a typical circuit Cooling System, which uses a Filtering Element.

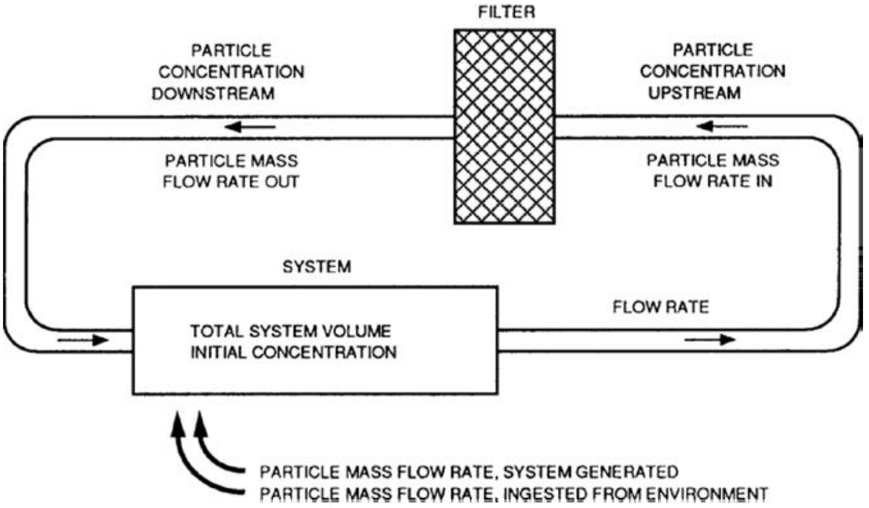


Figure 1 - Simplified Fluid System containing Filter

Let's consider the mathematical model of the failure rate (λ_F) for Filters (Filter Elements), contained in the American standard of NSWC-98/LE1 [4], developed by specialists of Carderock Division of the U.S. Navy:

$$\lambda_F = \lambda_{F,B} \cdot C_{DP} \cdot C_{CF} \cdot C_V \cdot C_T \cdot C_{CS} \cdot C_E \tag{1}$$

where: $\lambda_{F,B}$ - base failure rate of the Filter; C_{DP} - multiplying factor which considers the effects of the Filter differential pressure; C_{CF} - multiplying factor which considers the effects of cyclic flow; C_V - multiplying factor which considers the effects of vibration; C_T - multiplying factor which considers the effects of temperature; C_{CS} - multiplying factor which considers the effects of cold start-up conditions; C_E - multiplying factor which considers the effects of incompatible fluids and materials.

Figure 2 shows the typical structure of such Element.

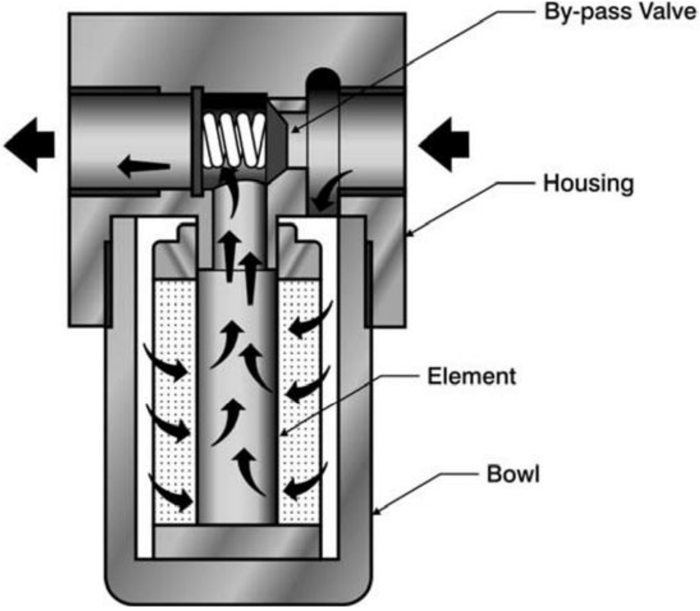


Figure 2 - Typical Filter Construction

The value $\lambda_{F,B}$ in the formula (1) is assumed constant for all types of Filters:

$$\lambda_{F,B} = 2{,}53 \cdot 10^{-6}.$$

The value of the multiplying factor C_{DP} is calculated by the model:

$$C_{DP} = \frac{P_i' \cdot a^2 - P_o' \cdot b^2 + \dfrac{a^2 \cdot b^2 \left(P_o' - P_i'\right)}{r^2}}{P_i \cdot a^2 - P_o \cdot b^2 + \dfrac{a^2 \cdot b^2 \left(P_o - P_i\right)}{r^2}}, \tag{2}$$

where: P_i' - inside pressure; P_o' - outside pressure; P_i - inside pressure in nominal operating mode; P_o - outside pressure in nominal operating mode; a - inside radius; b - outside radius; r - radius, corresponding to maximum stress.

The value r in the model (2) can only take one of two values: a or b.

The value of the multiplying factor C_{CF} is calculated by the model:

$$C_{CF} = 1 + \frac{1{,}7 \cdot a^2 \cdot \left(2 \cdot P_{i\max}' - 0{,}3 \cdot P_{i\min}'\right) - 0{,}7 \cdot P_{o\max}' \cdot \left(a^2 + b^2\right) - 0{,}3 \cdot P_{o\min}' \cdot \left(a^2 + b^2\right)}{1{,}4 \cdot T_S \cdot \left(b^2 - a^2\right)}, \tag{3}$$

where: $P_{i\min}'$ - minimum inside pressure; $P_{i\max}'$ - maximum inside pressure; $P_{o\min}'$ - minimum outside pressure; $P_{o\max}'$ - maximum outside pressure; T_S - tensile strength of filter media.

The value of the multiplying factor C_V depends on the characteristics of the vibration impact on the filter on the object installation and is determined according to the standard NSWC-98/LE1 [4]/

For $System\ Type$ Aircraft and Mobil:

$$C_V = 1{,}25 \tag{4}$$

For other $System\ Type$ value of the multiplying factor C_V is assumed to be 1.

The value of the multiplying factor C_T for $150 < T < 250$ is calculated by the model:

$$C_T = \left(\frac{T}{200}\right)^{-4{,}97}, \tag{5}$$

where: T - fluid temperature in the working mode.

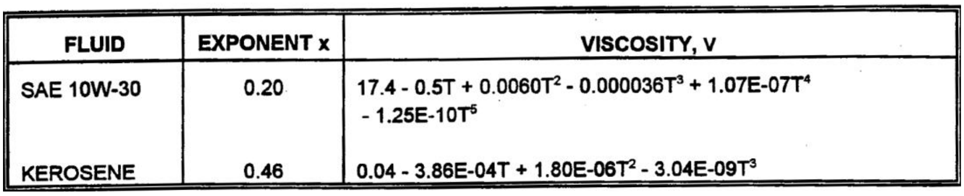
For $T < 150$ value of the multiplying factor C_T is assumed to be 1.

The value of the multiplying factor C_{CS} is calculated by the model :

$$C_{CS} = \left[\frac{\nu(T_{coldstart})}{\nu(T_{normal})}\right]^x, \tag{6}$$

where: $\nu_{coldstart}$ - viscosity at cold start temperature; ν_{normal} - viscosity at nominal operating mode; $T_{coldstart}$ - cold start temperature; T_{normal} - nominal operating mode temperature; x - exponent depending on the type of fluid.

The value of the viscosity and exponent x is defined according to the model (see figure 3):

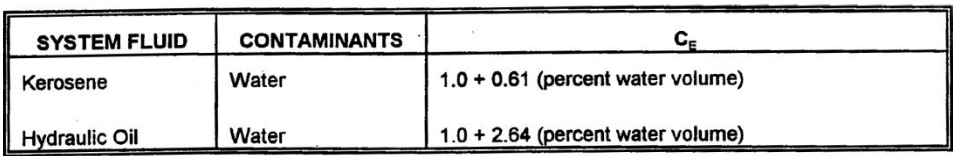


FLUID	EXPONENT x	VISCOSITY, V
SAE 10W-30	0.20	$17.4 - 0.5T + 0.0060T^2 - 0.000036T^3 + 1.07E{-}07T^4 - 1.25E{-}10T^5$
KEROSENE	0.46	$0.04 - 3.86E{-}04T + 1.80E{-}06T^2 - 3.04E{-}09T^3$

Figure 3 - Value of the exponent x and the temperature dependence of viscosity

For other types of liquids value of the multiplying factor C_{CS} is assumed to be 1.

The value of the multiplying factor C_E is calculated by the model (see figure 4):



SYSTEM FLUID	CONTAMINANTS	C_E
Kerosene	Water	1.0 + 0.61 (percent water volume)
Hydraulic Oil	Water	1.0 + 2.64 (percent water volume)

Figure 4 - Model multiplying factor C_E

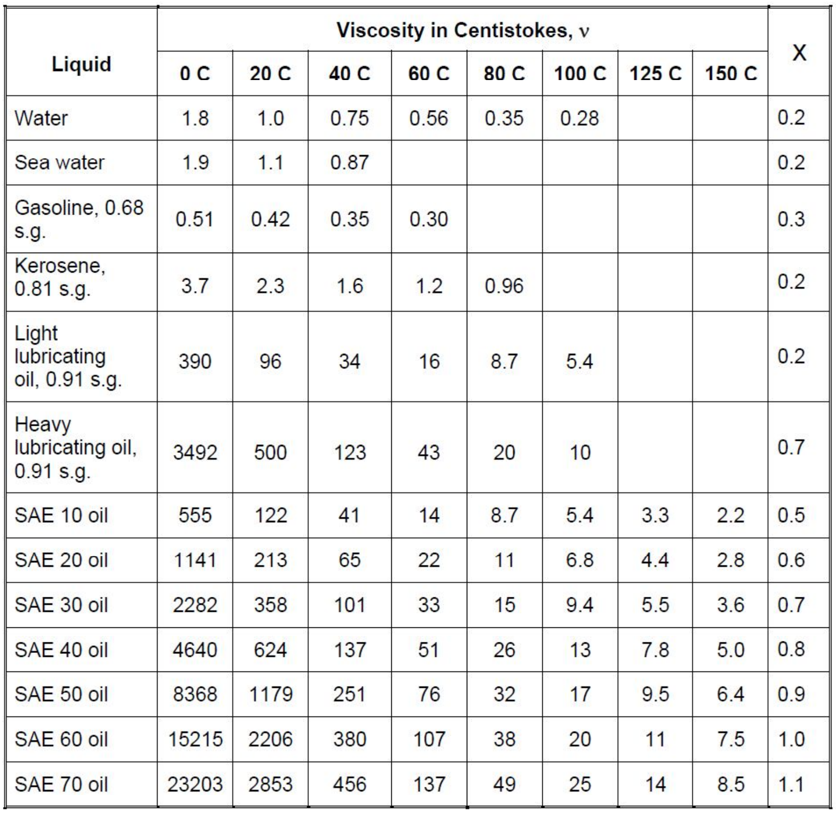
For other types of fluids and contaminants value of the multiplying factor C_E taken equal to 1.

Analysis of the above models showed that only options $\lambda_{F,B}$, P_i, P_o, T_S and ν_{normal} directly or indirectly depend on the specifics of constructive and technological performance of the Filter, and all the rest - from the regime of its use in the Cooling System [5, 6].

When, therefore, improvement of the Cooling Systems has led to the fact that the probability of pollutants in the working fluid has been reduced almost to zero, as amended standard NSWC-06/LE10 [7] of the mathematical model of the failure rate (1) multiplying factor C_T, and C_E and their mathematical models were withdrawn:

$$\lambda_F = \lambda_{F,B} \cdot C_{DP} \cdot C_{CF} \cdot C_V \cdot C_{CS} . \tag{7}$$

At the same time expanded the nomenclature of types of liquids (see figure 5), for which we can calculate the value of the multiplying factor C_{CS}.



Liquid	Viscosity in Centistokes, ν								X
	0 C	20 C	40 C	60 C	80 C	100 C	125 C	150 C	
Water	1.8	1.0	0.75	0.56	0.35	0.28			0.2
Sea water	1.9	1.1	0.87						0.2
Gasoline, 0.68 s.g.	0.51	0.42	0.35	0.30					0.3
Kerosene, 0.81 s.g.	3.7	2.3	1.6	1.2	0.96				0.2
Light lubricating oil, 0.91 s.g.	390	96	34	16	8.7	5.4			0.2
Heavy lubricating oil, 0.91 s.g.	3492	500	123	43	20	10			0.7
SAE 10 oil	555	122	41	14	8.7	5.4	3.3	2.2	0.5
SAE 20 oil	1141	213	65	22	11	6.8	4.4	2.8	0.6
SAE 30 oil	2282	358	101	33	15	9.4	5.5	3.6	0.7
SAE 40 oil	4640	624	137	51	26	13	7.8	5.0	0.8
SAE 50 oil	8368	1179	251	76	32	17	9.5	6.4	0.9
SAE 60 oil	15215	2206	380	107	38	20	11	7.5	1.0
SAE 70 oil	23203	2853	456	137	49	25	14	8.5	1.1

Figure 5 - Temperature dependence of viscosity and value of the exponent x

Further improvement of quality Cooling Systems has led to that level and pressure pulsation flow of liquid from the pump was negligible, so in the next edition of the standard NSWC-10 [8] of the mathematical model of the failure rate (7) multiplying factor C_{CF} and its mathematical model (3) were seized:

$$\lambda_F = \lambda_{F,B} \cdot C_{DP} \cdot C_V \cdot C_{CS} . \tag{8}$$

In addition, improvement materials filters led to the fact that the effect of the surface application of the maximum pressure was also insignificant. This simplified model of the multiplying factor C_{DP}, which is reflected in the revised standard NSWC-11 [9]:

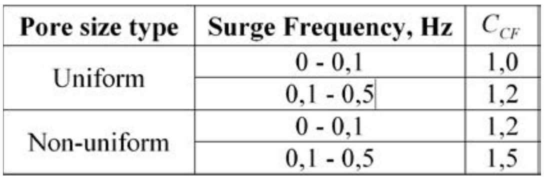
$$C_{DP} = 1,25 \cdot \frac{P_o}{P_R} , \tag{9}$$

where: P_o - operating upstream filter pressure; P_R - rated filter pressure.

The standard NSWC-11 [9] in the model (8) once again returned to the multiplying factor C_{CF}:

$$\lambda_F = \lambda_{F,B} \cdot C_{DP} \cdot C_V \cdot C_{CS} \cdot C_{CF} . \tag{10}$$

The value of the multiplying factor C_{CF} is selected depending on the type of pore size filters materials and surge frequency (see figure 6).

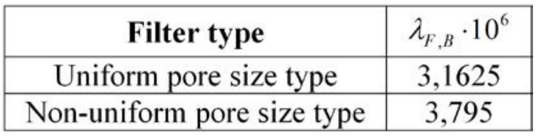


Pore size type	Surge Frequency, Hz	C_{CF}
Uniform	0 - 0,1	1,0
	0,1 - 0,5	1,2
Non-uniform	0 - 0,1	1,2
	0,1 - 0,5	1,5

Figure 6 - Value of the multiplying factor C_{CF}

We will notice that models of multiplying factors C_{DP} and C_{CF} the standard NSWC-11 [9] contradict definition $\lambda_{F,B}$, which characterizes failure rate of the filter in normal conditions at a rated load. In other words, at value C_{DP} for $P_o = P_R$ it has to be equal 1, also as well as value at C_{CF} for $Surge\ Frequency = 0\ \text{Hz}$.

Then $\lambda_{F,B}$ will have the following values (see figure 7).



Filter type	$\lambda_{F,B} \cdot 10^6$
Uniform pore size type	3,1625
Non-uniform pore size type	3,795

Figure 7 - Value of the base failure rate

Thus value C_{DP} is determined by model:

$$C_{DP} = \frac{P_o}{P_R}, \tag{11}$$

and value C_{CF} for $Surge\ Frequency = 0{,}1 - 0{,}5\ \text{Hz}$ is determined by model:

$$C_{CF} = \begin{cases} 1{,}2 - for\ Uniform\ pore\ size\ type \\ 1{,}25 - for\ \text{Non-}Uniform\ pore\ size\ type \end{cases}. \tag{12}$$

For other ranges of frequencies value of the multiplying factor C_{CF} taken equal to 1.

Thus, parameters P_o, $System\ Type$, $T_{coldstart}$ and $Surge\ Frequency$ in model (10) characterize quality of Cooling System. The peculiarities of the design-technological Filter in nominal operating mode ($\lambda_{F,B}$) are defined only parameter $Pore\ size\ type$ (see figure 7). Therefore, when using model (10) for increase of accuracy of calculations of $\lambda_{F,B}$ it is necessary to use value of $MTBF$:

$$\lambda_F = \frac{C_{DP} \cdot C_V \cdot C_{CS} \cdot C_{CF}}{MTBF}, \tag{13}$$

where: $MTBF$ - Mean Time Before Failure of the Filter in a nominal mode.

Thus, comparing models (1), (7), (8), (10) and (13), it is possible to draw a conclusion that the structure of model of failure rate for Filters is defined only by quality of Liquid Systems in which they are applied. And in process of improvement of these systems the structure of models becomes simpler.

References

1. Zhadnov, V.V. Metody i sredstva ocenki pokazatelej nadezhnosti mehanicheskih i e'lektromehanicheskih e'lementov priborov i sistem. / V.V. Zhadnov. // Datchiki i sistemy. - 2013. - № 4. - s. 15-20.

2. Zhadnov, V. Methods and means of the estimation of indicators of reliability of mechanical and electromechanical elements of devices and systems. / V. Zhadnov. // Reliability: Theory & Applications: e-journal. - 2011. - Vol. 2, No 4. - p. 94-102.

3. Markin, A.V. Metody oczenki nadyozhnosti elementov mexaniki i elektromexaniki elektronnyx sredstv na rannix etapax proektirovaniya. / A.V. Markin, S.N. Polesskij, V.V. Zhadnov. // Nadyozhnost'. - 2010. - № 2. - s. 63-70.

4. NSWC-98/LE1. Handbook of reliability prediction procedures for mechanical equipment. - CARDEROCDIV, 1998.

5. Zhadnov, V.V. Modeli prognozirovaniya bezotkaznosti fil'trov dlya zhidkostnyh sistem ohlazhdeniya e'lektronnoj apparatury. / V.V. Zhadnov. // Innovacionnye informacionnye tehnologii: Materialy mezhdunarodnoj nauchno-prakticheskoj konferencii. / Otv. red. I.A. Ivanov, pod obshch. red. S.U. Uvajsov. - M.: MIE'M NIU VShE', 2013. S. 123-129. - t. 3.

6. Monahov, M.A. Razrabotka bazy dannyh dlya sistemy ASONIKA-K-SCh po harakteristikam nadezhnosti mehanicheskih e'lementov klassa «Fil'try». / M.A. Monahov, V.V. Zhadnov. // Sovremennye problemy radioe'lektroniki: sb. nauch. tr. / nauch. red. G.Ya. Shajdurov; otv. za vyp. A.A. Levickii. - Krasnoyarsk: Sib. feder. un-t, 2013. - s. 366-369.

7. NSWC-06/LE10. Handbook of reliability prediction procedures for mechanical equipment. - CARDEROCDIV, 2006.

8. NSWC-10. Handbook of reliability prediction procedures for mechanical equipment. - CARDEROCDIV, 2010.

9. NSWC-11. Handbook of reliability prediction procedures for mechanical equipment. - CARDEROCDIV, 2011.

PECULIARITIES OF MEASURING SIGNALS PROCESSING DURING DETAIL'S DYNAMIC COUNTERBALANCING

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The question of processing of sinusoidal signals from piezoelectric sensors of a dynamic balancing stand, summarized with high level noise, is discussed. Special methods and devices for amplification and digital filtration the signals are used during the signals' processing.

Keywords: counterbalancing, measurement, signal, noise, filtration, frequency of detail's rotation.

Being balanced a dynamically unbalanced part made in a form of long rotation rigid body is considered to be a completely balanced rigid rotor, and point unbalanced mass are fastened in its correction planes which are perpendicular to the rotor axle. According to literature [1] and other sources it is known that it is enough to measure load or vibration of supports of a rigid rotor at a constant rotation frequency in order to determine two disbalance vectors operating in two correction planes and determining its dynamic disbalance completely. As well as any vector disbalance is determined by a numerical value and an angle which determines the position of the rotor coordinate system. In order to ensure dynamic balancing of good quality obtained experimental data about disbalance parameters used for the consequent trim analysis are to be precise and creditable. During the trim experiment performed on the balancing stand, disbalance parameters in the correction planes are calculated from the results of the vector parameters measurements – values and angles –vibration of supports which a controlled part rotates around a fixed axle in.