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DEFINITION OF STANDARDIZED LIFETIME AND USAGE IN PRACTICE

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Abstract:

The research develops new principles for lifetime analysis of water-purifying membrane filters, although no adequate method exists for identical assessment, even in other fields, of parts failing under differing conditions.

To supply commensurable exposure values, it introduces the concepts of "Lifetime chlorine exposure", "Equivalent operating time" and "Equivalent lifetime" (lasting until final breakdown) based on analogies. Filter module lifetime analyses are performed with the creation of a "Lifetime database" to prove the calculation method in practice.

The method of integrating the lifetime database into the quality management system and the logic of the procedure has been developed. Based on real data, this method gives an extensively useful solution for the maintenance of existing objects, improvement and new product design.

Keywords:

membrane filter, lifetime, equivalent lifetime, lifetime database, chlorine exposure, quality control

1 METHOD DEVELOPED FOR THE STANDARDIZATION OF OPERATING AGE AND LIFETIME OF MEMBRANE FILTERS

1.1 Standardization of operating age and lifetime

Actual *operating age* and *lifetime* (at final breakdown) expressed in calendar time gives imprecise information and distorts the comparison, if stress levels occurring during operations and other enhancing factors are not considered. The research develops new concepts and a calculation method for solving this problem.

An extendable method is developed in the field of membrane filtration that continuously takes into account some operational parameters. A prerequisite of this method is the transport and processing of operational variables via a computer network.

The method has been developed for a certain field. However, with numerically definable parameters, using these analogies, it is suitable for the calculation of equivalent operational times, besides the cumulating damaging factors, in any industrial field.

New terms of "EQUIVALENT OPERATING TIME" and "EQUIVALENT LIFETIME", as well as calculation method for them were created, and applied in the experiments, thus taking into account the accumulation of the lifetime reducing factors and their combined effect more precisely than formerly, and making them comparable within operation under differing conditions.

$$\tau_e = \sum_{i=1}^{n} t_{e_i} = \sum_{i=1}^{n} t_i \cdot \Phi_i \cdot TCl_i \cdot h_i \quad \text{where} \tag{1}$$

τ_e – equivalent lifetime

t_e – equivalent operating time

t – calendar time elapsed under identical circumstances

ϕ – hydrodynamic exposure factor necessary for maintaining the flux

TCl – combined factor simultaneously taking into account temperature and chlorine exposure

h **–** factor taking into account the coagulation propensities of the medium's individual components

The above calculation can provide more exact input information for product planning, and for the planning of operation, maintenance, or even greater investment processes.

1.2 Development of Database Structure for the Calculation and Tracking of Lifetime Combined with Exposures

The database created for data recording and calculations includes the following types of information for the tracking of lifetime.

Table 1: Data and variables used in the database

DATA	*operational and generated VARIABLES*
for the identification of individual products	for the tracking of current **filter loads** affecting the individual product and the factors calculated from it
for the identification of plants where the product is located	for the tracking of current **chlorine exposure** affecting the individual product and the factor calculated from it
for the identification of technical units where the product is located and the installation position	for the tracking of current **temperature** affecting the individual product and the factor calculated from its effects
for the recording of the date of installation (and perhaps resetting) and of final breakdown	for the tracking of the harmful **coagulation propensities** of the **medium** and of the factor calculated from it
for the recording of non-numerical data concerning the products	for the calculation of **equivalent operating time** and as a summary, of **equivalent lifetime**

Besides recording data and variables, the database also

- calculates factors from operational data,
- knowing the factors, it calculates equivalent operating time and equivalent lifetime
- automatically generates transcripts, deletions, disables
- archives.

2 TEST ON THE EFFECT OF CHLORINE EXPOSURE ON LIFETIME

2.1 Lifetime chlorine exposure

The lifetime reducing effect of chlorine – applied either occasionally in small amounts or in greater amounts for maintenance or recovery purposes – accumulates during the membranes' lifetime, which can be expressed with the total dose suffered during these processes and can be characterised with the numerical value *Chlorine exposure* as deteriorating factor. Chlorine exposure (LCl), already introduced as an expression, in a more simply form, can be quantified with the below equation:

$$Lcl_{total} = \sum LCl_o + \sum LCl_K + \sum LCl_F \text{ , [ppmh]} \qquad (2)$$

As the temperature and chlorine concentration of the treatments deteriorates the polymer materials at a differing rate, the expression "lifetime chlorine exposure" (LCl_{total}) was introduced for this exposure factor. According to the exposure levels calculated for the three working states:

- the normal operation *(LCl_0),*
- maintenance treatments performed approximately monthly *(LCl_K),*
- and the recovery treatment performed approximately twice a year *(LCl_F).*

Reactions caused by chlorine content – like aging – are greatly influenced by the temperature in the different working states. Chlorine exposure is, therefore, modified by a "temperature factor" (T*) that does not carry any dimension.

Correlation analyses were executed by means of the above introduced calculation.

2.2 The connection between chlorine exposure and lifetime

Firstly in the research the real relationship between chlorine exposure sustained by the elements in their life and lifetime had to be established. For this purpose, a correlation analysis was performed between "*lifetime chlorine exposure*" and "*equivalent lifetime*", introduced earlier. The established weak negative (but not significant) correlation indicates that equivalent lifetime is influenced by other factors as well; anyhow, greater chlorine exposure probably results in shorter lifetime.

The damaging effect of chlorine is better demonstrated by a second correlation analysis, in which a specific value was examined. Here, the connection between the chlorine dose specified for one month of the lifetime and the equivalent lifetime was statistically significant.

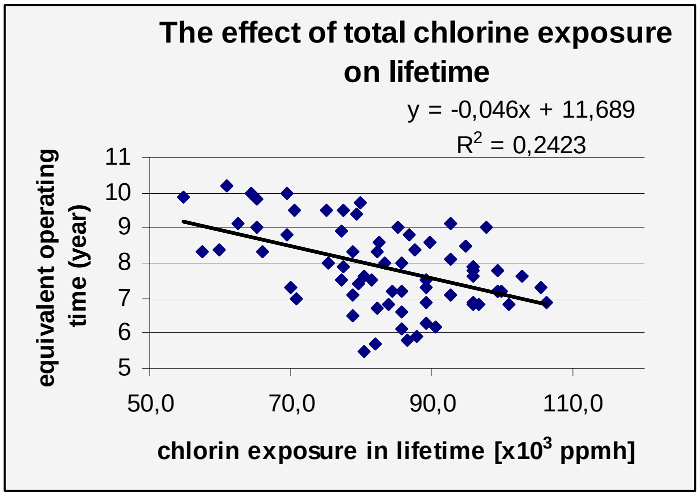

Figure 1: Equivalent operating time calculated on the modules with cumulated chlorine exposure of their lifetime [x10^3 ppmh]

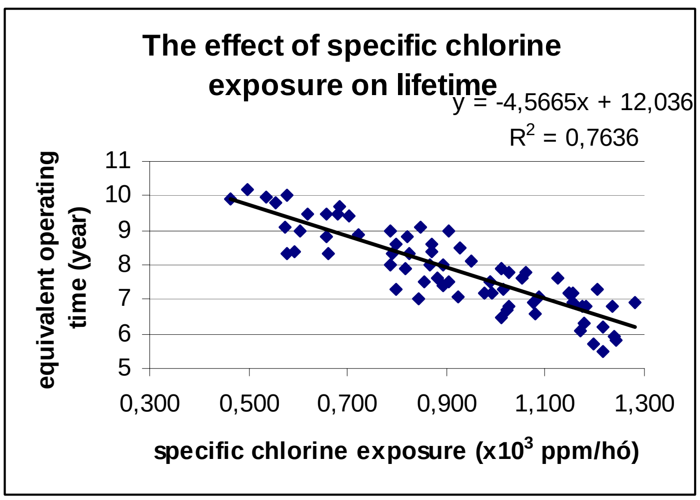

Figure 2: Equivalent operating time calculated on the modules with chlorine exposure specified for one month

3 THE FLOW OF LIFETIME DATA FROM THEIR ORIGIN TO THEIR UTILIZATION

The research elaborates the problem of the lifetime analysis of textile-based membrane filters used in water purification. A manufacturing company, classified among the leading enterprises of the world, provided opportunity for the recognition and analysis of these problems. Although this present analysis is solely concerned with ultrafiltrating membrane tubes, its statements and methods can be considered valid and applicable in every field of lifetime analysis, in other industries, after the necessary adaptations.

Experiments are being made also in these days in the following fields, to verify the adequacy of the developed methods and our statements. In these fields observations will be started after the necessary adaptations (identification of equivalencies, calculation of critical parameters, simplifications or more detailed elaborations).

- Catering trade; lifetime analysis of textiles used in catering and in hotels,
- Furniture industry; observance of furniture door structures,
- Test of pump seals.

Lifetime analyses of the above mentioned membrane tube filters are based on three information sources:

- ***Complaints***, informing about details of the most important problems, the breakdown events. The problem concerning this type of information is that a relatively small amount of information is gathered about one version of a specific product, and they reflect only catastrophic failures caused by more serious manufacturing or maintenance defects, not the normal operation.
- ***Feedback from Operators*** concerning final breakdown, and, in state of art practice, the tracking of operation with measurable parameters in relocated factories. Most information concerns operation conditions and not deterioration. It provides a large amount of data, however, the less problematic the operation is, the longer is the feedback time towards product manufacturing and maintenance.
- ***Testing with Accelerated Testing Equipment.*** It provides exact information concerning deterioration, the problem is, however, that it is only economical with limited sample numbers. A further problem is that the "acceleration method" and the excessively regulated conditions resulting in a distorted deterioration process out of the ordinary one, might lead to incorrect conclusions.

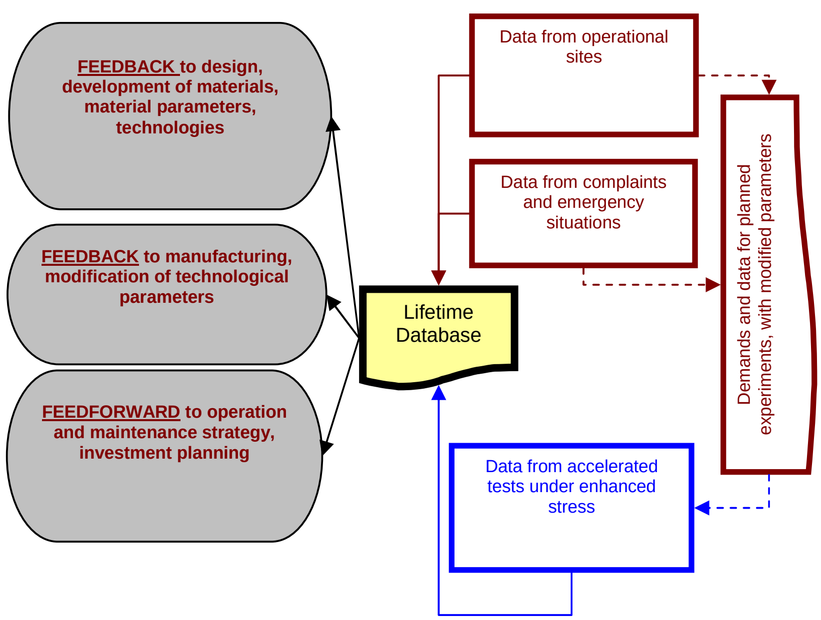

Figure 3: Aim and environment of the creation of lifetime database

The solution would be to process the results of the three information sources in a newly developed database and to develop exact calculation methods for the transformation of the data together with ensuring adequate instrumentation of the process. Moreover, it is necessary to develop and introduce a methodology adequate for the selection of parameters critical for the given product's lifetime and the creation of a unified concept system concerning its stress characteristics.

Thus, a further aim of the present research is to ensure that, observing the deterioration process in any given environment, the calculation of exposures converted into equivalent units directly ensure comparability concerning the products' breakdown.

4 APPLICATION FIELDS OF THE RESEARCH RESULTS AND INTEGRATION INTO THE QUALITY MANAGEMENT SYSTEM

Lifetime statistics are suitable to give a basis for treatments. The logic of the procedure is based on the results of statistical analyses. The speciality of the procedure is that it applies characteristic rises and points of the lifetime curve on the Weibull Plot. Results of accelerated tests and expectations based on preliminary experience are compared, and the difference generates the treatment.

Since the control of product planning and production process is at a high level, their control is executed on the basis of validation results and production process statistics. Lifetime data can be used in the operational maintenance most efficiently.

Maintenance and operating procedures developed for certain products should be modified on the basis of lifetime statistics. These modifications affect the further lifetime. The point of the procedure is to achieve the planned shape of the lifetime curve. Treatments can be e.g. modifications to the cleaning and maintenance time periods, chlorine concentrations, operational pressure limits, aeration intensity and timing.

Quality-related realization of this procedure is shown in the following flow-chart.

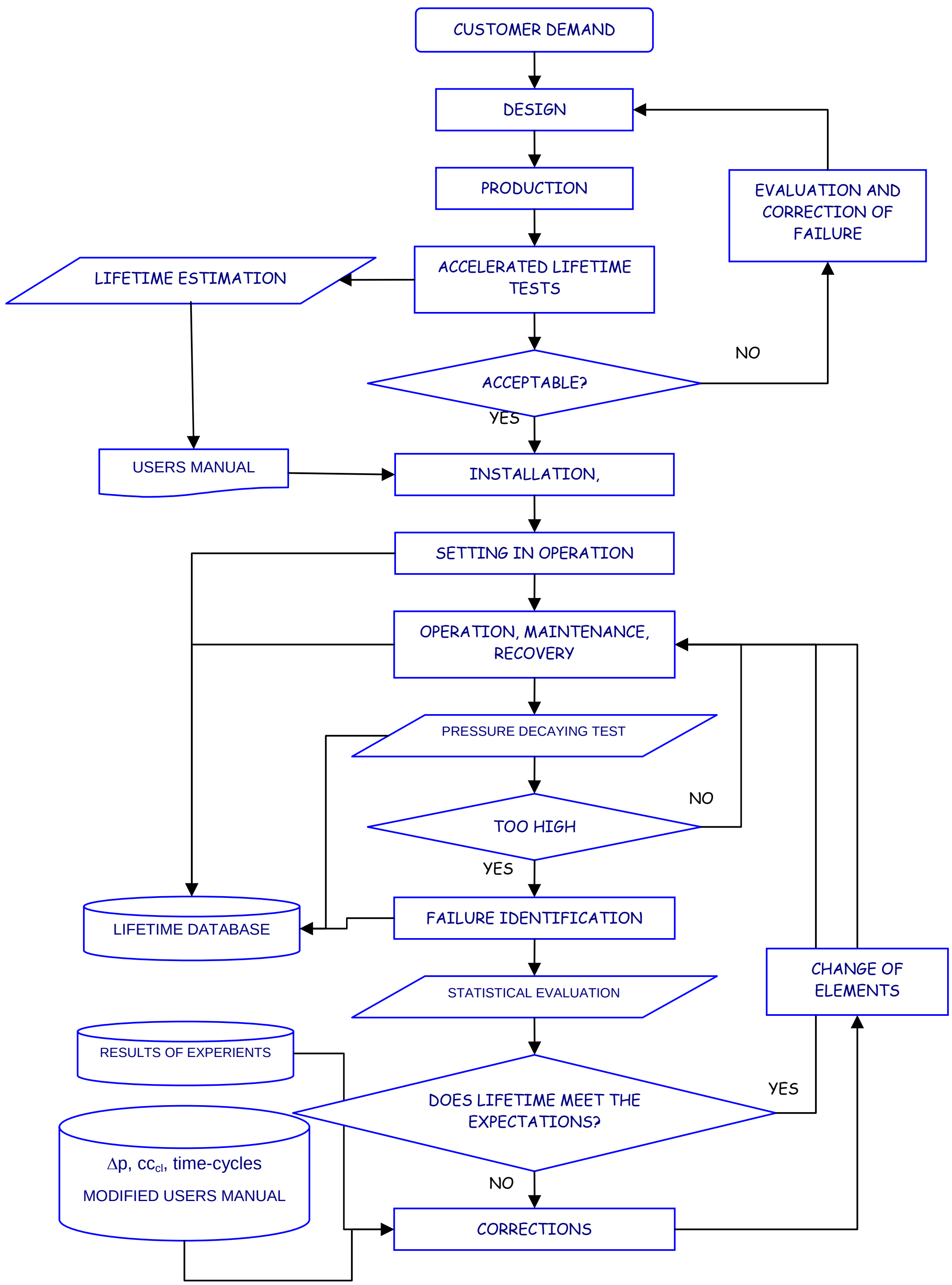

Figure 4: Quality procedure for the operational and maintenance process

5 CONCLUSIONS

The research develops new principles for lifetime analysis of water-purifying membrane filters, although no adequate method exists for identical assessment, even in other fields, of parts failing under differing conditions.

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