BODY REFERENCE : WP4/S9F25/REV.C

TITLE:	SPECIFICATION OF EDP FUNCTIONS: "COMPUTE MSV - GUIDE VANES CLEARANCE (S9)", "PERFORM TREND ANALYSIS OF MSV - GUIDE VANES CLEARANCE (F25)"
SOURCE:	EDP
STATUS:	FINAL DOCUMENT
EDITORS:	ALEXANDRE FERREIRA DA SILVA ANÍBAL CARVALHO
VERIFIED BY:	
DISTRIBUTION:	WP4 AND WP5 TEAM MEMBERS
DATE:	FIRST ISSUE: JUNE 1997 FINAL ISSUE: JULY 1997
NUMBER OF PAGES:	9
INTERNAL REFERENCE:	J:\DOK\13\REMAFEX\WP4\S9F25.DOC

CONTENTS

PREFACE

This document contains a description of the maintenance functions «Compute MSV - Guide vanes clearance (S9)» and «Perform trend analysis of MSV - Guide vanes clearance».

These functions (called sub-functions hereafter) are an uncomplicated task and illustrate how the monitoring of start/stop sequences time delay can allow to supervise the status and performance of some components. Illustrate also the combination of on-line measurements with off-line measurements.

1. OBJECTIVE OF FUNCTION

The function objectives are to reveal the actual guide vanes clearance condition resulting from wear due to silt or other abrasive content in water and to forecast clearance degradation (in terms of the remaining operating hours) .

2. FUNCTION ENVIRONMENT

The sub-function «compute MSV» is a part of the supervision/monitoring maintenance domain whereas the sub-function «perform trend analysis of MSV» is a part of the forecasting maintenance domain.

The sequence of requests and responses necessary to utilise these sub-functions is the following:

Event	Request/Response (RQ/RS)	From	To
Perform computation of MSV	RQ	MO or Event	Function
Acknowledge	RS	Function	MO
Acquire data from event communication flow	RQ	Function	Event communication flow
Compute clearance from fluid mechanics formulae	RQ	Function	Function
Acquire historical data (spiral water pressure settling time and clearance)	RQ	Function	Historical Data Base
Perform cross-correlation of spiral water pressure settling time and clearance values and forecast clearance current value	RQ	Function	Function

Event	Request/Response (RQ/RS)	From	To
Present results	RS	Function	MO
Perform trend analysis of MSV	RQ	MO	Function
Acquire historical data (spiral water pressure settling time, clearance and operating hours)	RQ	Function	Historical Data Base
Perform trend analysis of clearance values and forecast remaining operating hours	RQ	Function	Function
Present results	RS	Function	MO

3. INPUT DATA DEFINITION

Acquired data (from event communication flow):

1 by-pass valve closed position switch state, Boolean
2 main valve upstream gauge pressure ($p_{1'}$), Pa
3 downstream gauge pressure (p_2), Pa
4 spiral gauge pressure (p_{sp}), Pa
5 spiral case water pressure switch state, Boolean
6 headwater level (z_3), m
7 tailwater level (z_4), m
8 water temperature (Θ), K
9 ambient pressure at machine reference level (P_{amb}), Pa

Calculated data (from event communication flow):

1 spiral water pressure settling time (t_{sp} , time delay since by-pass valve closed position switch off till pressure switch on), s

Configured data (equipment technical data and historical data):

Equipment technical data

1 by-pass orifice area (A), m^2
2 coefficient of discharge of by-pass orifice (C_d)
3 coefficient of discharge of guide vanes clearance (C_d')
4 guide vanes pitch diameter (d), m
5 guide vanes stem diameter (d'), m
6 guide vanes height (b), m
7 number of guide vanes (n)
8 spiral case water pressure switch limit (p_l), Pa
9 upstream section elevation (z_1), m

10 downstream section elevation (z_2), m

Historical data

1 spiral water pressure settling time (time series), s
2 guide vanes clearances (average) acquired manually (time series), mm

clearance between guide vanes and facing plates

guide vane	1	2	3	...	n
clearance, mm					

clearance between the edge and the surface of the closed guide vanes

guide vane	1	2	3	...	n	1
clearance, mm						

3 operating hours (time series), hours

Tuning data:

1 initial spiral water pressure for clearance computation (p_i), Pa
2 time interval for clearance computation ($\Delta t = t_f - t_i$), s
3 limit value of guide vanes clearance, mm
4 limit value of spiral water pressure settling time, s
5 headwater reference level ($z_3^{'}$), m
6 plant reference head ($H_g^{'}$), m

Tuning data 1 and 2 use is illustrated on page 6 figure. Tuning data 3 and 4 are limit values defined by maintenance operator to forecast (into the future) the remaining operating hours via guide vanes clearance trend and/or spiral water pressure settling time trend.

4. OUTPUT DATA DEFINITION

Output from function:

Sub-function compute MSV - clearance computation component:

1 Configured data

2 Acquired data

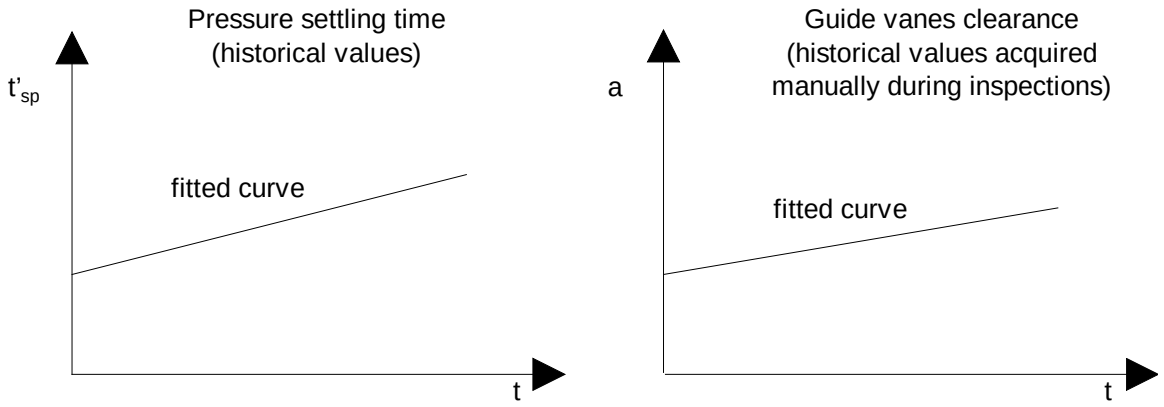
spiral water pressure settling time (t), s

graphic: $p_{1'}$, p_2 and p_{sp} plotted against time (since by-pass valve closed position switch off till time t_f)

3 Computed guide vanes clearance, mm

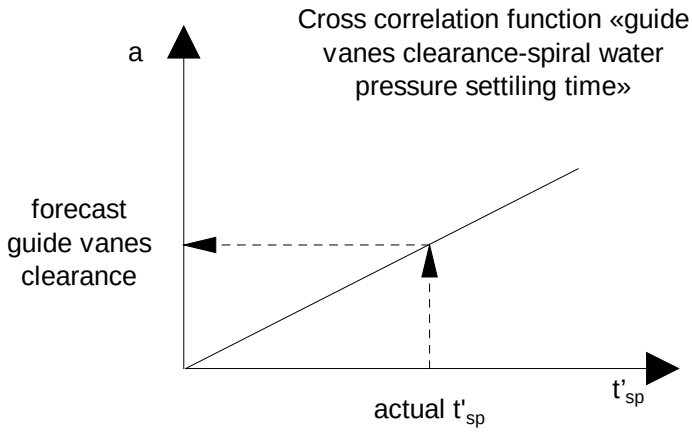
Sub-function compute MSV - clearance forecasting component:

1 graphic 1: time series of spiral water pressure settling time and guide vanes clearance and the related fitted curves



2 graphic 2: cross-correlation function «spiral water pressure settling time - guide vanes clearance»

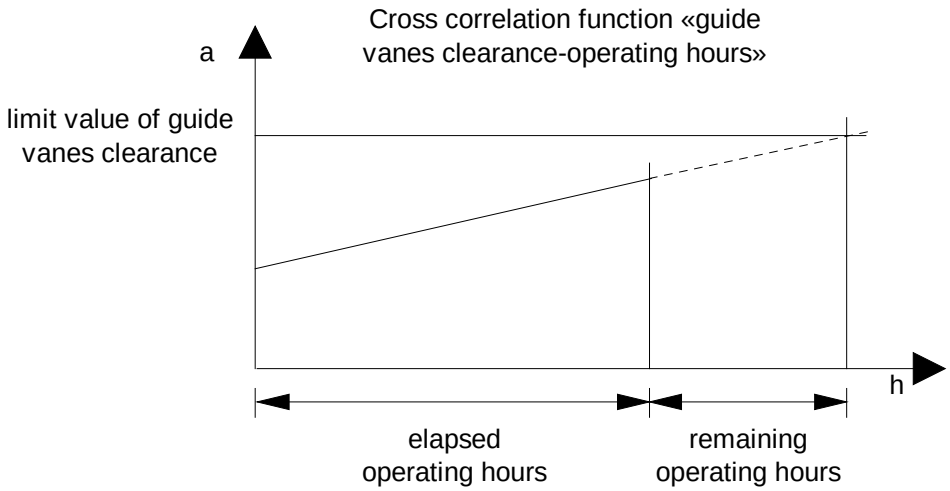
3 forecast guide vanes clearance, mm



Sub-function perform trend analysis of MSV:

1 graphic: cross-correlation functions «spiral water pressure settling time - operating hours» and/or «guide vanes clearance - operating hours»

2 forecast remaining operating hours



5. DYNAMIC BEHAVIOUR

The function is activated on maintenance operator request.

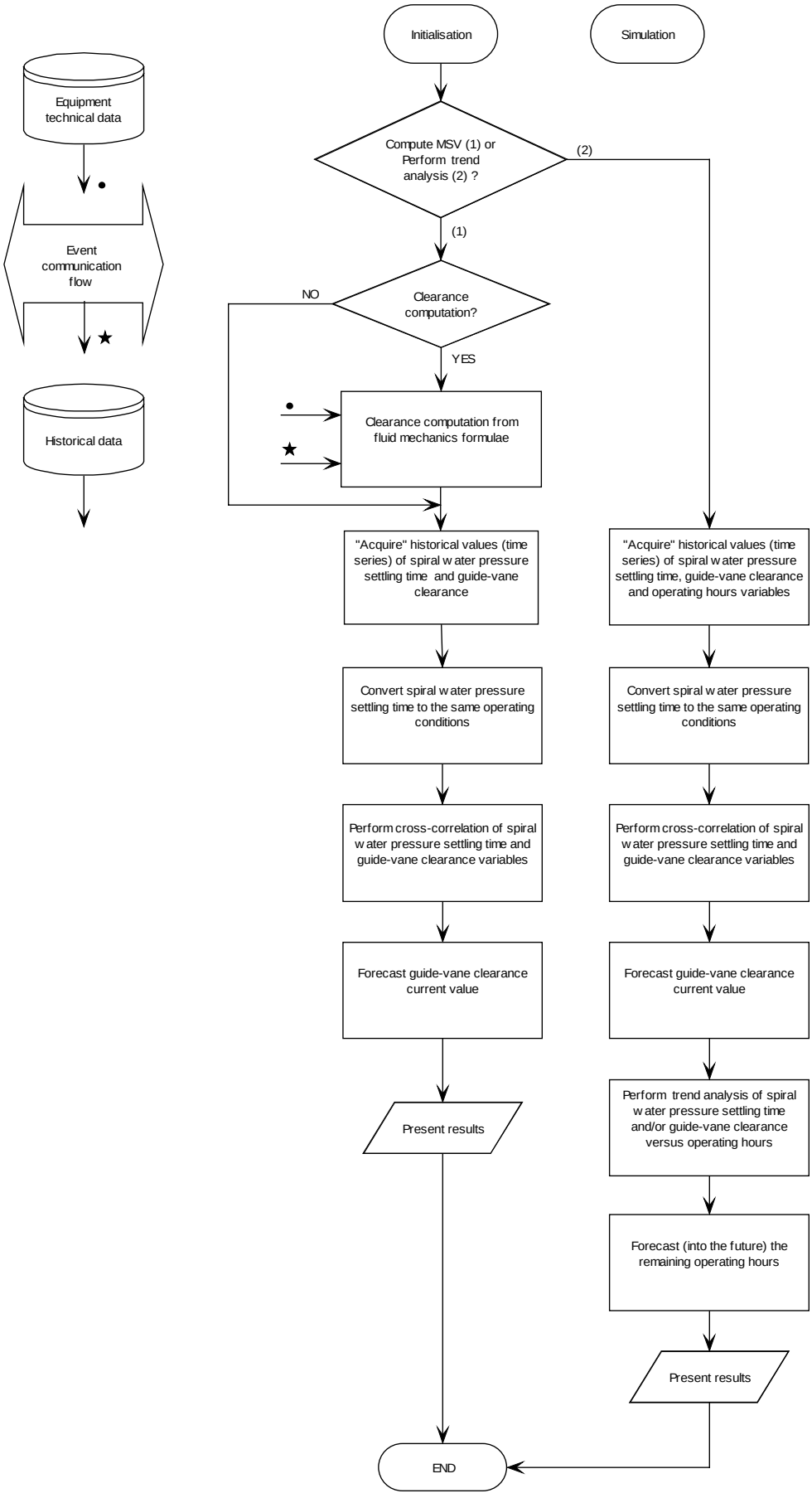
Operator activation shall be done at sufficiently regular intervals to detect the presence of trends in advance of excessive wear (machine breakdown).

REMAFEX platform must acquire spiral water pressure settling time (t) from event communication flow and warn maintenance operator if its value exceed a defined limit (maintenance alarm).

Guide vanes clearance historical data are off-line measured values acquired during machine inspections. Therefore, the set-up of the function implies a previous collection of data.

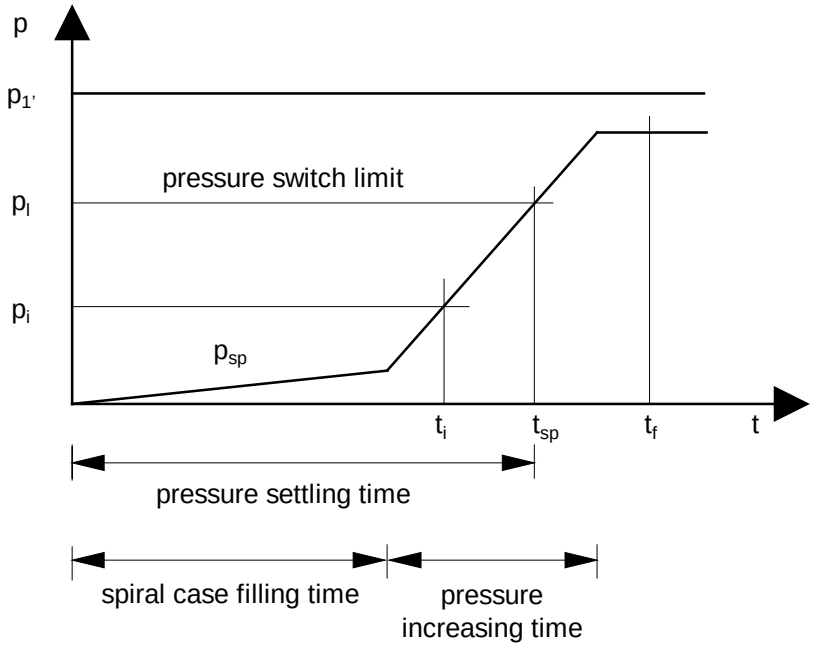
6. DATA PROCESSING (ALGORITHM)

The overall algorithm is shown on the following figure:


Initialisation
Simulation
Equipment technical data
Compute MSV (1) or Perform trend analysis (2) ?
(2)
(1)
Event communication flow
NO
Clearance computation?
YES
Historical data
Clearance computation from fluid mechanics formulae
"Acquire" historical values (time series) of spiral water pressure settling time and guide-vane clearance
"Acquire" historical values (time series) of spiral water pressure settling time, guide-vane clearance and operating hours variables
Convert spiral water pressure settling time to the same operating conditions
Convert spiral water pressure settling time to the same operating conditions
Perform cross-correlation of spiral water pressure settling time and guide-vane clearance variables
Perform cross-correlation of spiral water pressure settling time and guide-vane clearance variables
Forecast guide-vane clearance current value
Forecast guide-vane clearance current value
Present results
Perform trend analysis of spiral water pressure settling time and/or guide-vane clearance versus operating hours
Forecast (into the future) the remaining operating hours
Present results
END

Clearance computation

The following diagram shows pressure evolution during spiral case filling (if spiral case is above tailwater level) and pressurisation (main valve remaining closed after t):



Fluid mechanics formulae to determinate clearance value (a) are:

$$\int_{t_i}^{t_f} (Q(t) - Q_l(t)) \cdot dt = 0$$

$$Q(t) = C_d \cdot A \cdot \sqrt{2 \cdot \frac{p_{1'}(t) - p_{sp}(t)}{\rho}}$$

$$Q_l(t) = C_d^{'} \cdot A^{'} \cdot \sqrt{2 \cdot \frac{p_{sp}(t) - p_{dw}(t)}{\rho}}$$

where:

Q - water flow through main valve by-pass, m^3/s
Q_l - guide vane leakage, m^3/s
t_{sp} - spiral water pressure settling time, s
C_d - discharge coefficient of by-pass orifice
$C_d^{'}$ - discharge coefficient of guide vanes clearance
$p_{1'}$ - main valve upstream gauge pressure, Pa
p_{dw} - guide vanes downstream gauge pressure, Pa

p_{sp} - spiral gauge pressure, Pa
ρ - water density (is a function of water temperature Θ and absolute pressure $p_{abs1'} = p_{1'} + p_{amb}$ and is given in table EII of reference [1]), kg/m^3
A - by-pass orifice area, m^2
A' - guide vanes clearance area, m^2

Guide vanes clearance area has the form:

$$A' = 2 \cdot (\pi \cdot d - n \cdot d') \cdot a + \sum_{i=1}^{n} b \cdot c_i$$

where:

a - clearance between guide vanes and wearing plates, m
c - clearance between the edge and the surface of the closed guide vanes, m
d - guide vanes pitch diameter, m
d' - guide vane stem diameter, m
b - guide vanes height, m
i - guide vane number
n - number of guide vanes

or neglecting the clearance between the edge and the surface of the closed guide vanes:

$$A' = 2 \cdot (\pi \cdot d - n \cdot d') \cdot a \square$$

Gauge pressure downstream guide vanes p is calculated as follows:

$p_{dw} = 0$, if spiral case is above tailwater level, and

$p_{dw} = p_2 + \rho \cdot g \cdot (z_2 - z_1)$, if spiral case is below tailwater level.

Conversion of spiral water pressure settling time values to the same operating conditions

Conversion of spiral water pressure settling time historical values to the same operating conditions can be made using the following formulae:

$t'_{sp} = t_{sp} \cdot \sqrt{\frac{z'_3 - z_1}{z_3 - z_1}}$, if spiral case is above tailwater level, and

$t'_{sp} = t_{sp} \cdot \sqrt{\frac{H'_g}{H_g}}$, if spiral case is below tailwater level.

where H_g is the plant head which can be assumed equal to the geodetic height of the plant Z_g (difference in elevation between headwater level z_3 and tailwater level z_4).

7. INTERFACES

Maintenance operator interface shall be capable of display both real-time data (measurements data) and historical data (equipment technical data).

System interface to the external world must allow to display the results (tables and graphics) remotely.

8. ERROR MANAGEMENT

Errors manager must display messages describing the cause of an error or a fault: network error, internal error, missing data, ...

9. CONSTRAINTS

The constraints to execute correctly the function are described in sections 5.

10. HARDWARE AND SOFTWARE REQUIREMENTS

The function can be implemented on a standard PC hardware and using standard software, like Microsoft Excel.

The output display should be of the SVGA type and able of presenting colour information.

11. TEST PLAN

It must be possible to test the function independently of data acquisition hardware and in a modular way. The components to test are described in section 6.

Errors cause simulation must also be possible.

The tuning parameters for trend analysis (limit value of guide vanes clearance and limit value of spiral water pressure settling time) will be adjusted during experimentation phase.

12. REFERENCES

[1] IEC 41(1991): Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines

[2] James W. Dally: Instrumentation for Engineering Measurements