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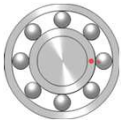
2.3 Rolling contact bearings

Why rolling-elements bearings?
The rolling creates much lower friction than sliding



Two races carry the rolling elements

1

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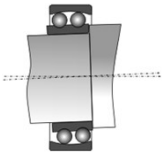

Sven Wingqvist around 1926.

The company was founded on Sven Wingqvist's 1907 Swedish patent No. 25406, a multi-row self-aligning radial ball bearing.

2

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Assar Gabrielsson, SKF sales manager and Björn Prytz, Managing Director of SKF were the founders of Volvo AB in 1926. In the beginning, the company functioned as a subsidiary automobile company within the SKF group. SKF funded the production run of the first thousand cars, built at Hisingen, in Gothenburg, beginning in 1927. SKF used one of the company's trademarked names: AB Volvo, which derives from the Latin "I roll", with its obvious connotations of bearings in motion. The ownership of Volvo lasted until 1935 when the last shares were divested.

3

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Get manufacturer's catalogs! Printed or online

4

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Some early vibration monitoring projects

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Xielalin Consulting
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In the 1970s, Swedish Road Administration (Vägverket) was to build a new highway E6 in Mölndal.
Very close to Ericsson Microwave Systems.

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Ericsson had production of high quality microwave equipment.

They demanded *monitoring of the vibration* inside the factory during the whole project.

We in 3K, Tre Konsulter, got the project, Vägverket paid.

What and where to measure?

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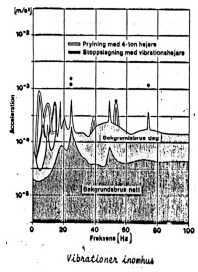
Vägverket claimed there was no problem, as the impact from the construction was no bigger than the impact from already existing sources.

TOTALLY WRONG!
But what to do?



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Response Analysis!
Ericsson gave us a number of critical machines to investigate, such as surface grinders.

Experimental Modal Analysis gave us the resonance frequencies and mode shapes. Example:

First bending mode	No relative motion between tool and work piece
First torsional mode	No relative motion
Second bending mode	Relative motion

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We measured a lot of floor vibrations and calculated responses at critical modes.

We built a system around a single card computer and recorded raw and analyzed data on digital magnetic tape. Reported frequently to Vägverket and Ericsson.

The highway construction was finished in 1981 without serious disturbances for Ericsson.

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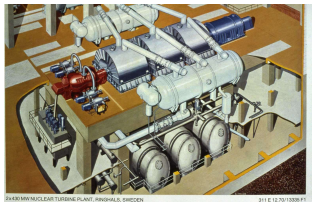
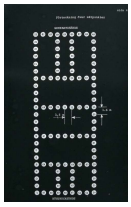
We used the Mölndal monitoring system for our first Experimental Modal Analysis on a nuclear power plant steam turbine foundation, Ringhals 3.





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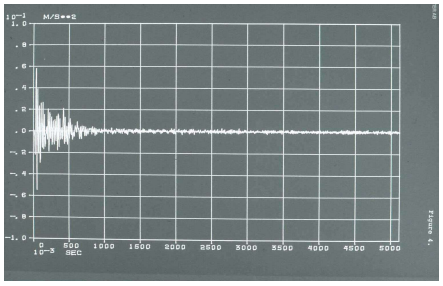

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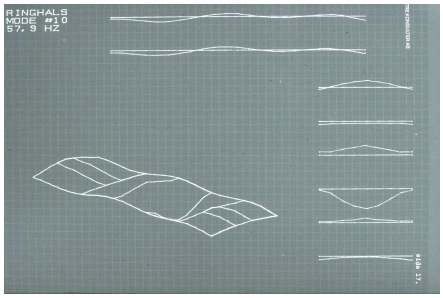

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The success with the turbine foundation led to a close cooperation with STAL in many projects.

One of these gave as a result our joint project Steam Turbine Vibration Condition Monitoring System, TVM.

Built on our Time Record Acquisition System, TRAS.

We contributed with hardware and software, STAL contributed with Steam Turbine knowledge

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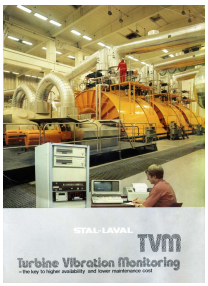

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TRAS systems were running an absolute program

- Low level language.
- No operating system, no overhead
- I had complete control
- As fast as hardware allowed
- I was programming with oscilloscope view on computer hardware
- In TVM real time speed was optimized

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First TVM installation was at Olkiluoto nuclear power plant, unit 1, start October 1979.

Wikipedia:
Units 1 and 2 consists of two BWRs, each producing 890 MW of electricity. The main contractor was ASEA-Atom, now a part of Westinghouse Electric Sweden AB. Turbine generators were supplied by Stal-Laval.

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There was a learning process in the beginning.

I made it possible for STAL to take control over the system from Finspång over telephone lines

Then dramatic things started to happen!

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Case IV. Cracked rotor in a turbo generator

The incident with rotor crack which is reported in this case occurred in a 700 MW turbogenerator, January 1981. The location of the propagating crack is indicated in figure 11. The monitoring system was in operation and in the end of January a change in the vibration of the rotor was observed. During the final week, changes were such that it was decided that the rotor should be stopped and examined. Ultrasonic measurements revealed a crack through half the diameter of the rotor.

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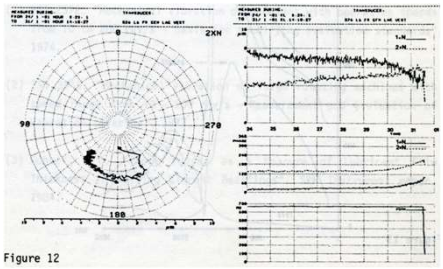

Figure 12

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We sold 12 TVM systems!

STAL suggested we should form a company
MONITOR AB together

Steam turbines together
Gas turbines STAL
Water turbines 3K

We had things going on with hydro-electric power plants

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Svarthålsforsen. Three Kaplan turbines.
One lost a turbine blade 1980. One year to get a new one
Welded back the lost blade!


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Svarthålsforsen was not allowed to change upstream water level.

Meant very different instant power production. Use the water you have!

Maybe certain power levels dangerous for the repaired turbine?

We were contracted to find out and monitor!

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Experimental Modal Analysis of turbine blades in turbine.

Calculations and measurements on model blade. Which mode was to blame?

What to measure? Pressure in turbine chamber!

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The Mariners' Museum and Park

100 Museum Drive Newport News, VA 23606

I visited in 2004
Shock & Vibration Symposium
Virginia Beach

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We knew the critical vibration mode!

Signal from pressure transducer in the turbine chamber was band pass filtered.

Rms value of the filtered signal was shown in the control room.

In that way they could avoid critical modes for the turbine.

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Due to, (or in spite of) the monitoring, the blade stayed intact until the new one arrived!

Svarthålsforsen was our playground for condition monitoring of hydro-electric power plants!

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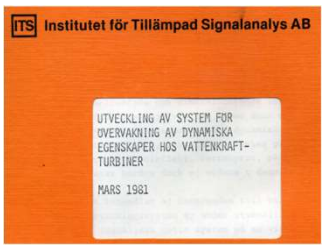

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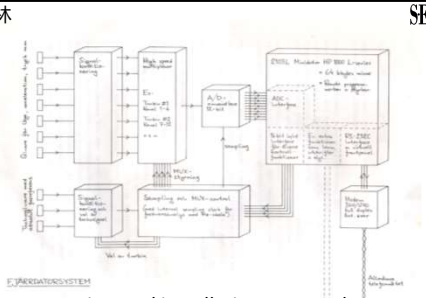

An experimental installation was made at Svarthålsforsen!

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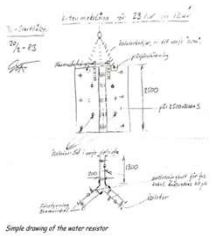
Spectacular RPM sweep measurement with 13 MW power at 12 kV was made 1983!

24 measurement channels were recorded.

RPM corresponding to 25 to 60 Hz electric frequency.



Simple drawing of the water resistor

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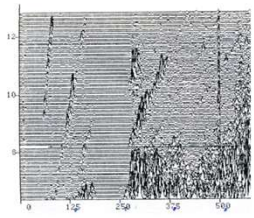

Example of RPM spectral map

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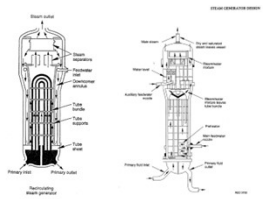
Meanwhile, I had been involved in of what turned into my biggest project ever!
The steam generator D3 at Ringhals 3, 1981 - 1982!



In the early-to mid-1980s, excessive wear in the preheater sections of steam generators led licensees to expand tubes into the support plates in model D4, D5, and E steam generators and *to modify the original impingement plate assemblies in the preheaters of model D2 and D3 steam generators to minimize tube vibration/motion and, hence, to decrease wear-at these locations*.

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Wikipedia:
Ringhals 3 entered commercial operation on September 9, 1981 and is a three-loop pressurized water reactor built by Westinghouse.

Shortly after starting, problems with vibrations and leakage in the steam generators were encountered, which was solved with a *minor redesign of the inlet of these.*

Seems like easily fixed! But 33 nuclear power plants were involved!

谢拉林 SEES

Vattenfall built a full-scale model of the critical part of the steam generator at their lab in Älvkarleby.
I was involved for measurements from the start.

Control room personnel from Ringhals 3 run the model. Water flow by two fire extinguisher pumps used at oil platforms. We had finally some 150 sensors in the model, most of them under water.

From May 1982 Westinghouse hired the model to make tests of suggested modifications, a total of 45 Americans! 700 people in a Pittsburgh Task Force.

Big drama! Westinghouse did not want me to record anything!

"We will give Vattenfall all analysis data!"

Vattenfall said "If you don't allow our consultant to record, forget about hiring the model!"

A telephone call between generaldirektör Norrby and Westinghouse CEO was needed!

Westinghouse recorded signals on FM tape recorders and sent the tapes to Pittsburgh for analysis in FFT analyzers.

I recorded and analyzed signals in a 40 chl TRAS system.

Before the FM tapes had reach Arlanda, I had printed an analysis report.

I overheard a comment: "Thank God that 3K recorded everything!" After three weeks I was in practice working for Westinghouse, but I sent the bills to Vattenfall!