Application of RIA for High Sensitive Wear Diagnostics in Medicine Technique and Industry

1. RTM - Radionuclide Technique in Mechanical Engineering

1.1 Principle of Function
1.2 Measurement Methods
1.3 Measurement Instruments
1.4 Thin Layer Activation Technique

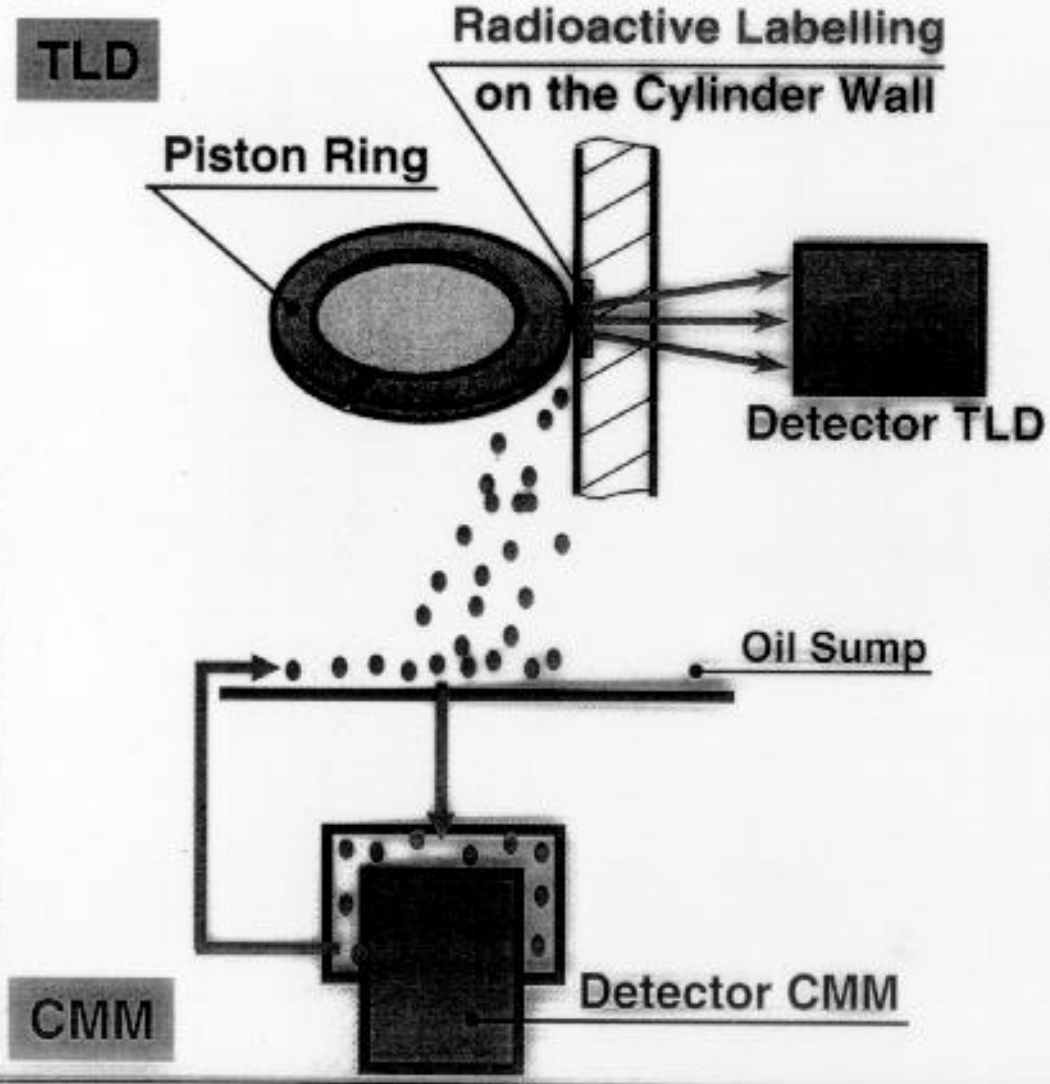
2. Application of RIA to Radioactive Labeling

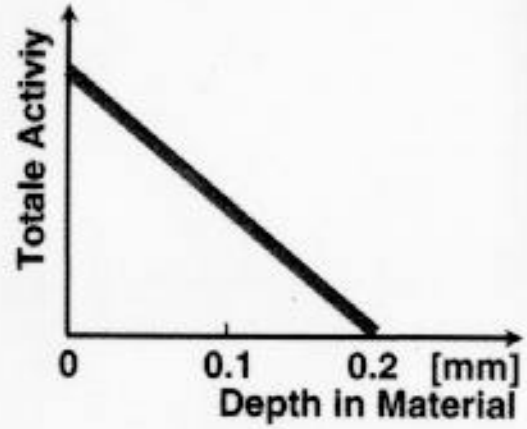
2.1 The Advantages of RIA
2.2 Specification of Radioactive Labeling by ^{7}Be and ^{22}Na

3. First Online Wear Measurements in Prosthetics

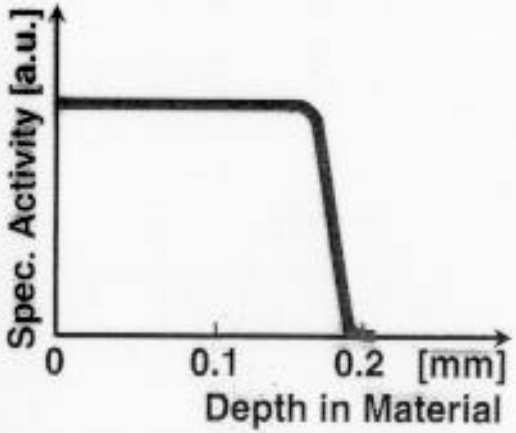
3.1. The Measurement System
3.2. Results

Working Principle of RTM





Calibration



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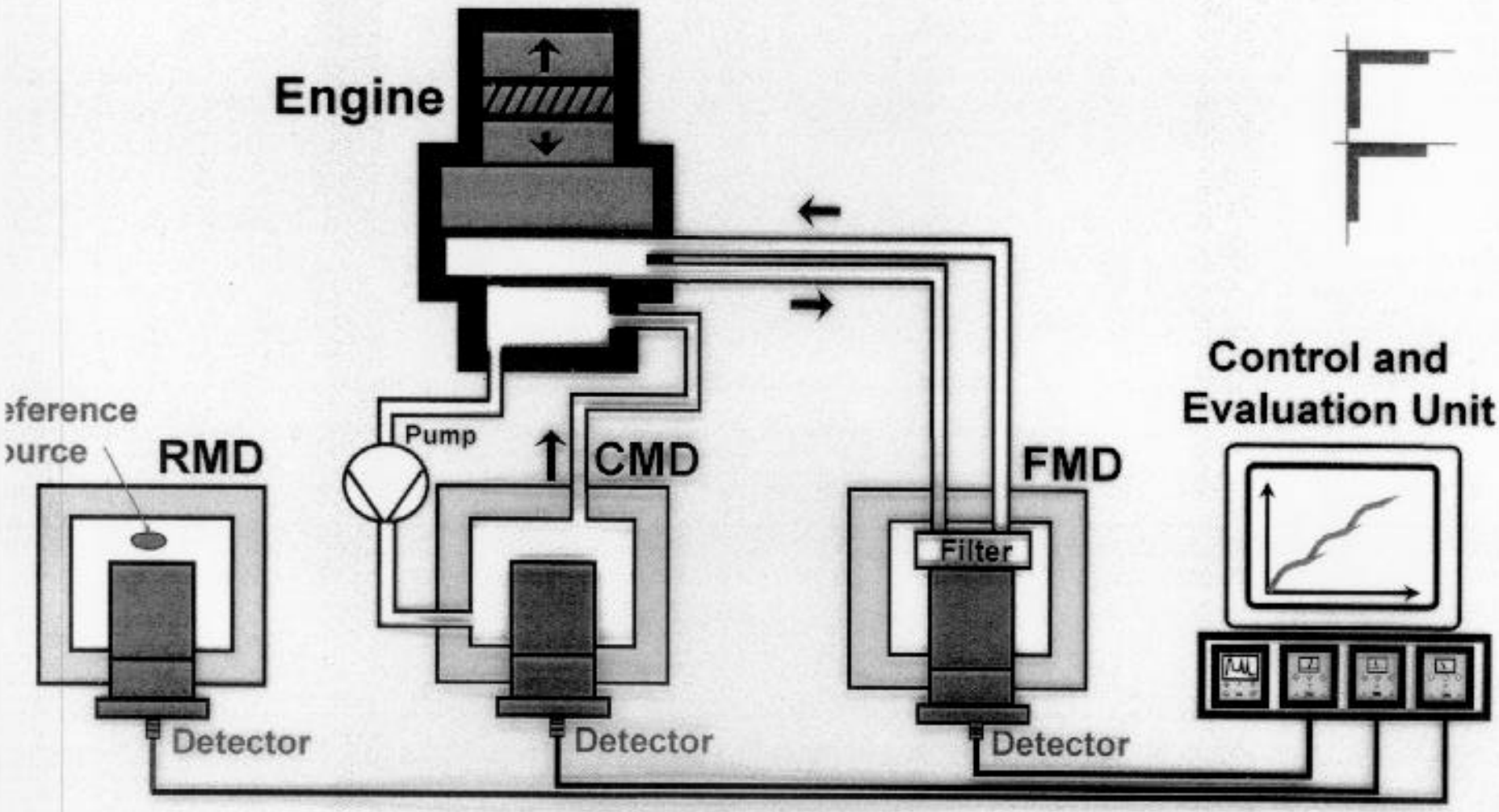
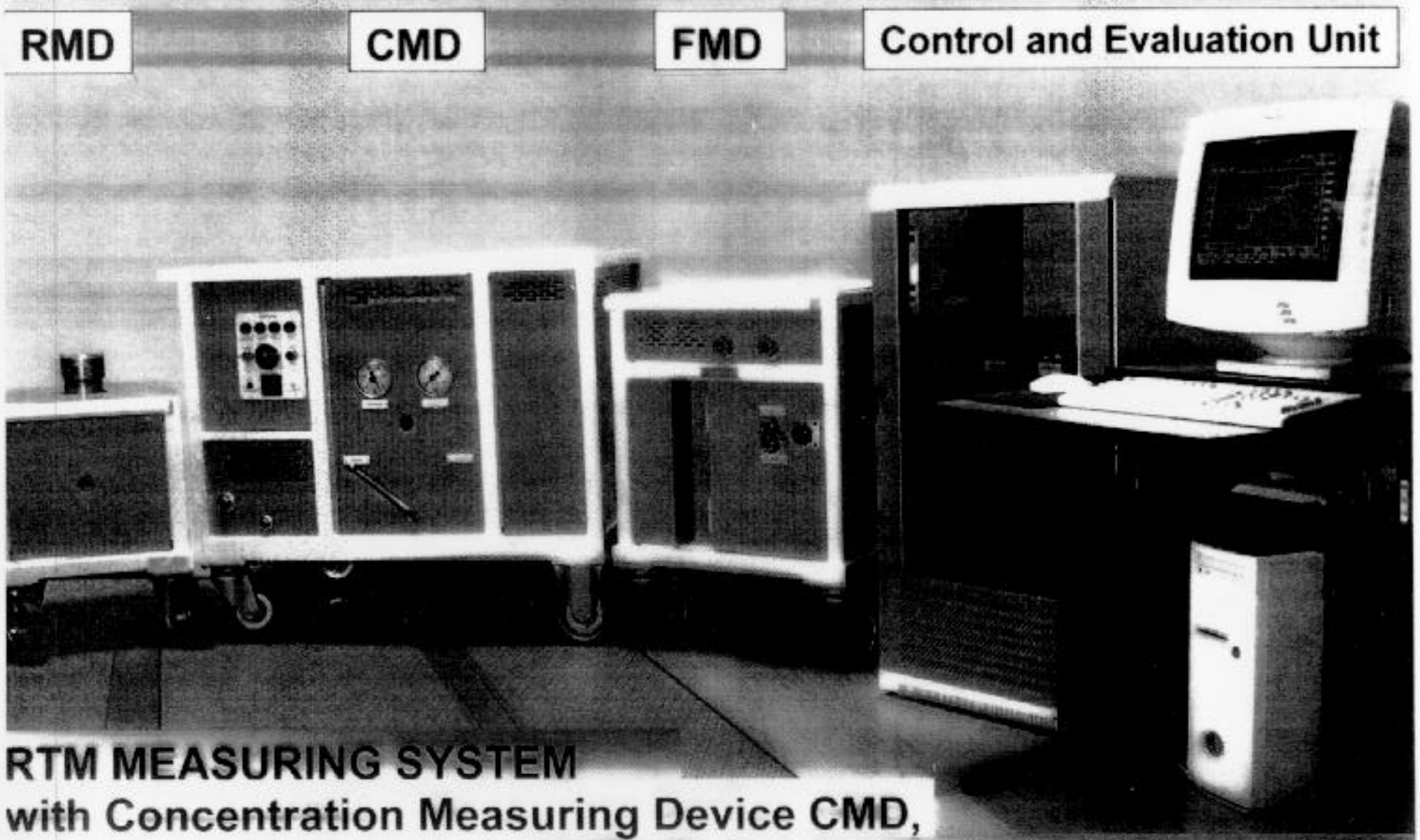


ear Measurement System with Concentration Measurement Device (CMD), ilter Measurement Device (FMD), Reference Measurement Device (RMD)



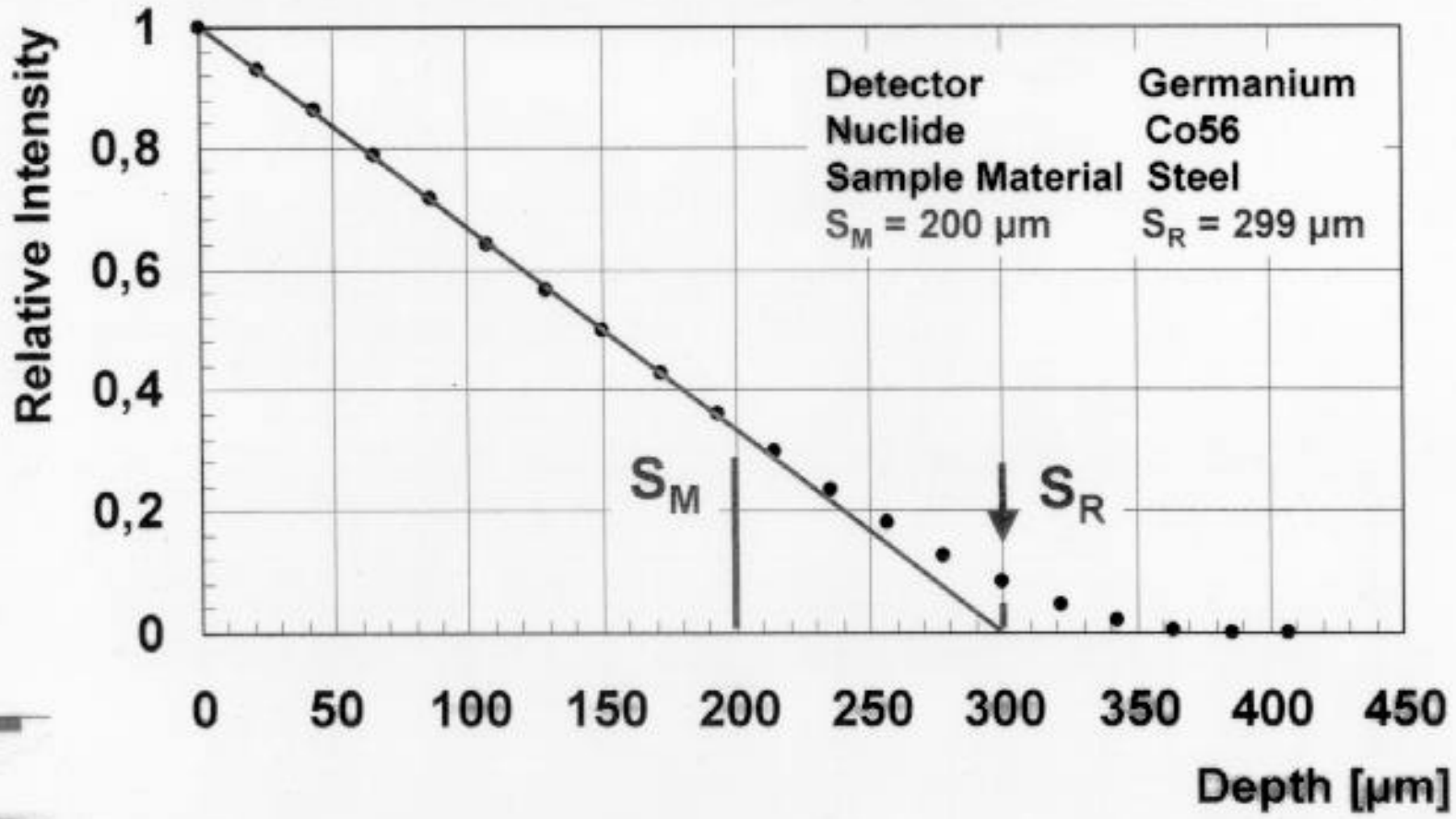
RTM MEASURING SYSTEM
with Concentration Measuring Device CMD,
Filter Measuring Device (FMD), Reference Measuring Device (RMD)

$$^{56}_{26}Fe\,(\overset{\downarrow}{p}\,,\,\overset{\uparrow}{n})\,^{56}_{27}Co$$

$E_P = 14$ MeV $\qquad T_{1/2} = 78$ d

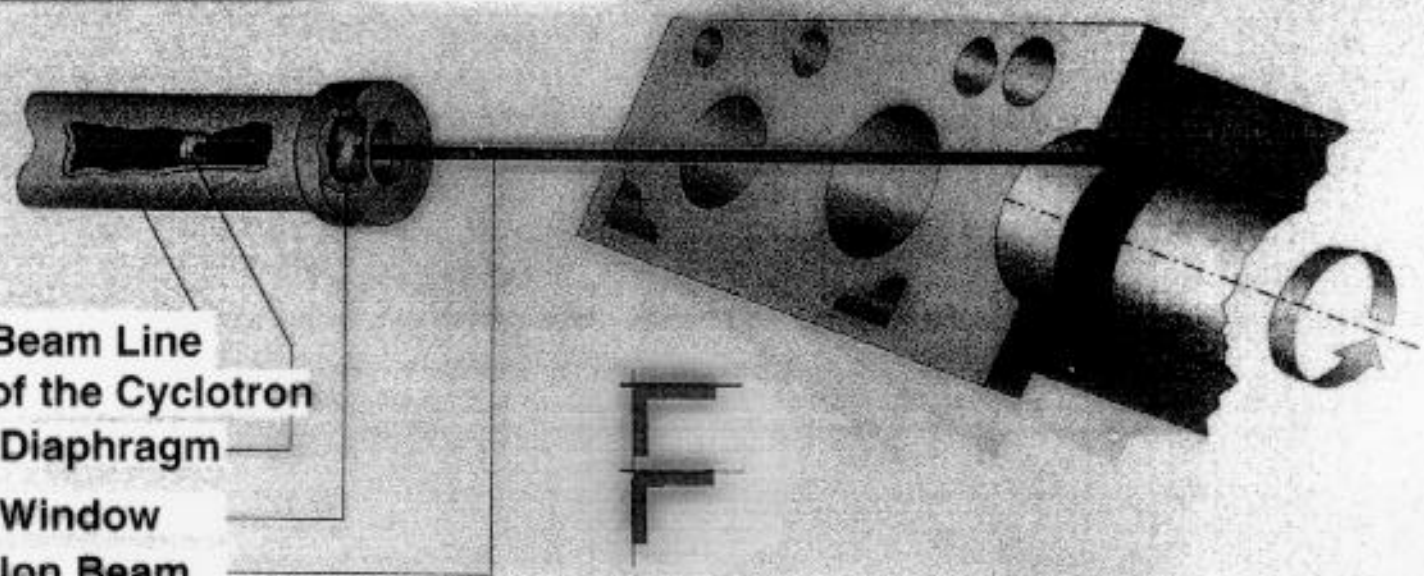
$$\frac{N_{Co56}}{N_{Fe}} = 10^{-9}$$

$$^{56}Co \longrightarrow {}^{56}Fe + \gamma$$

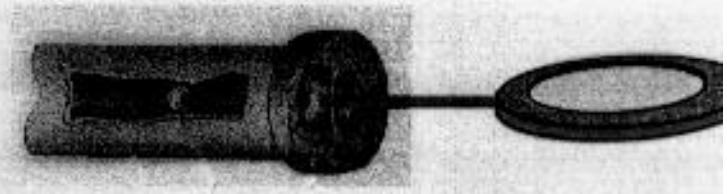


Calibration Curve

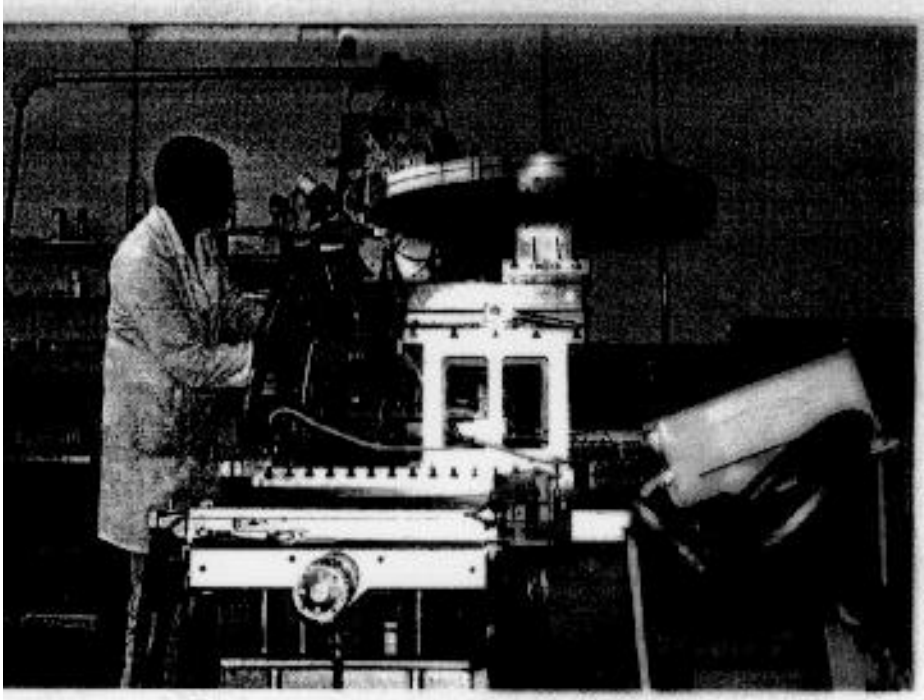
Cyclotron Activation



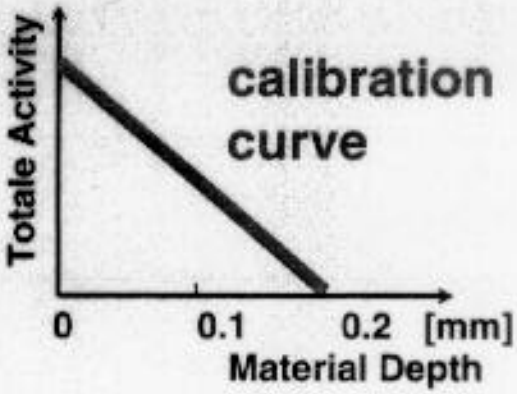
RTM - Activation Service



nstallation of a piston ring for a marine diesel engine



constant specific activity in the activated volume



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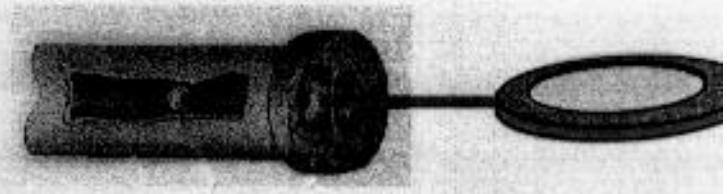

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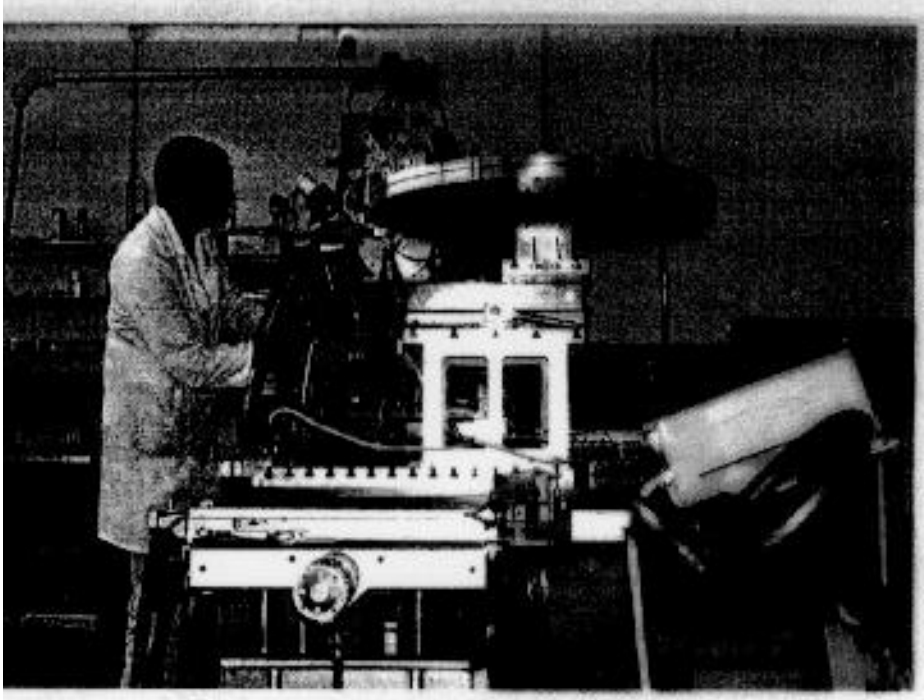

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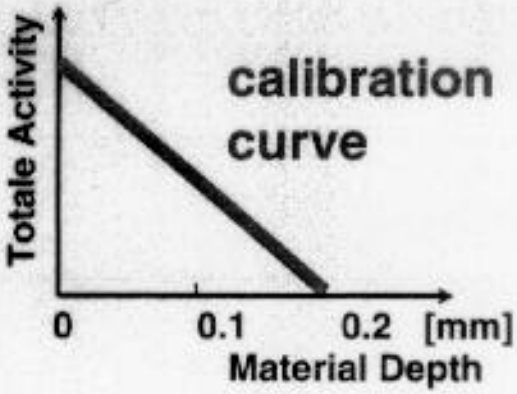
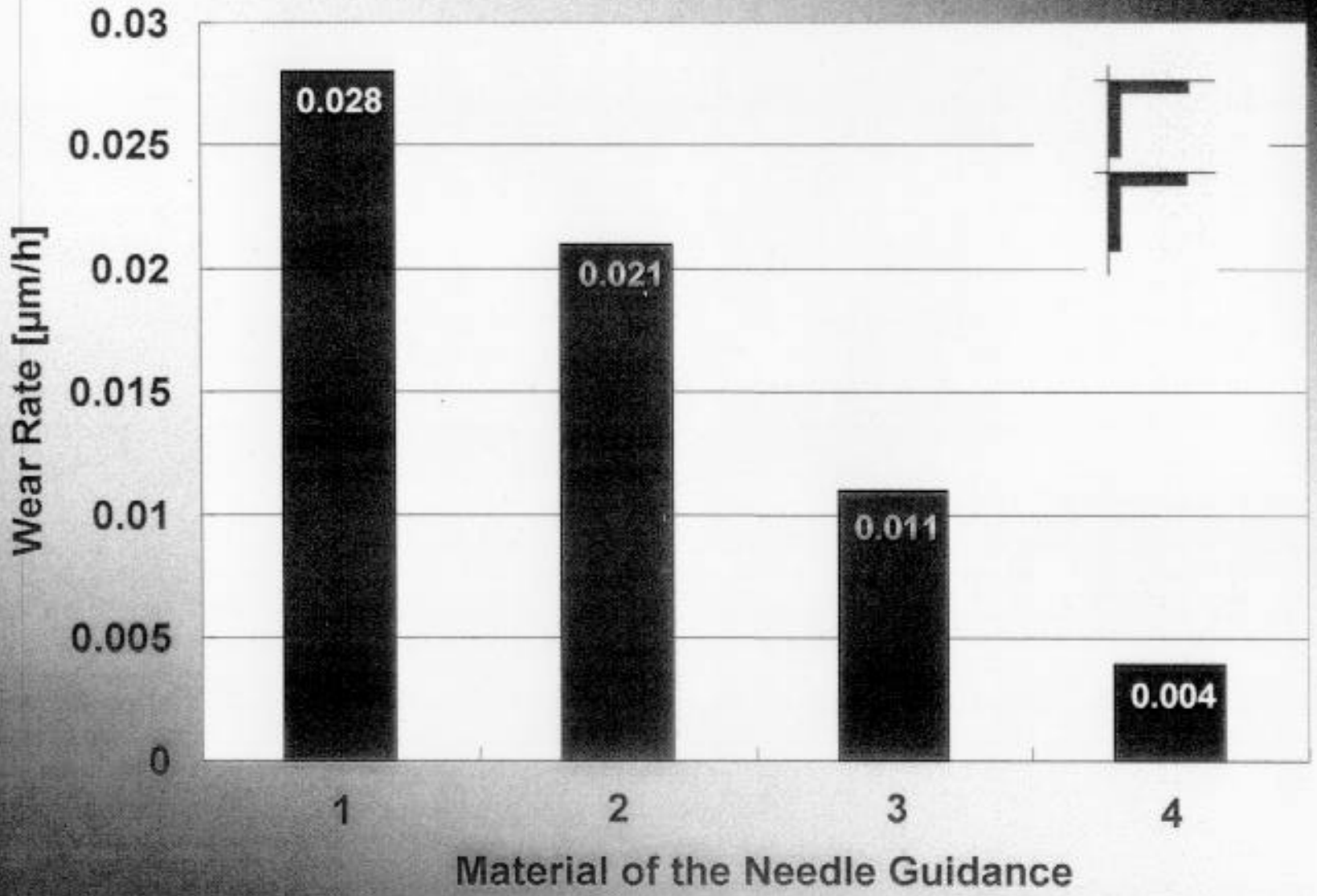


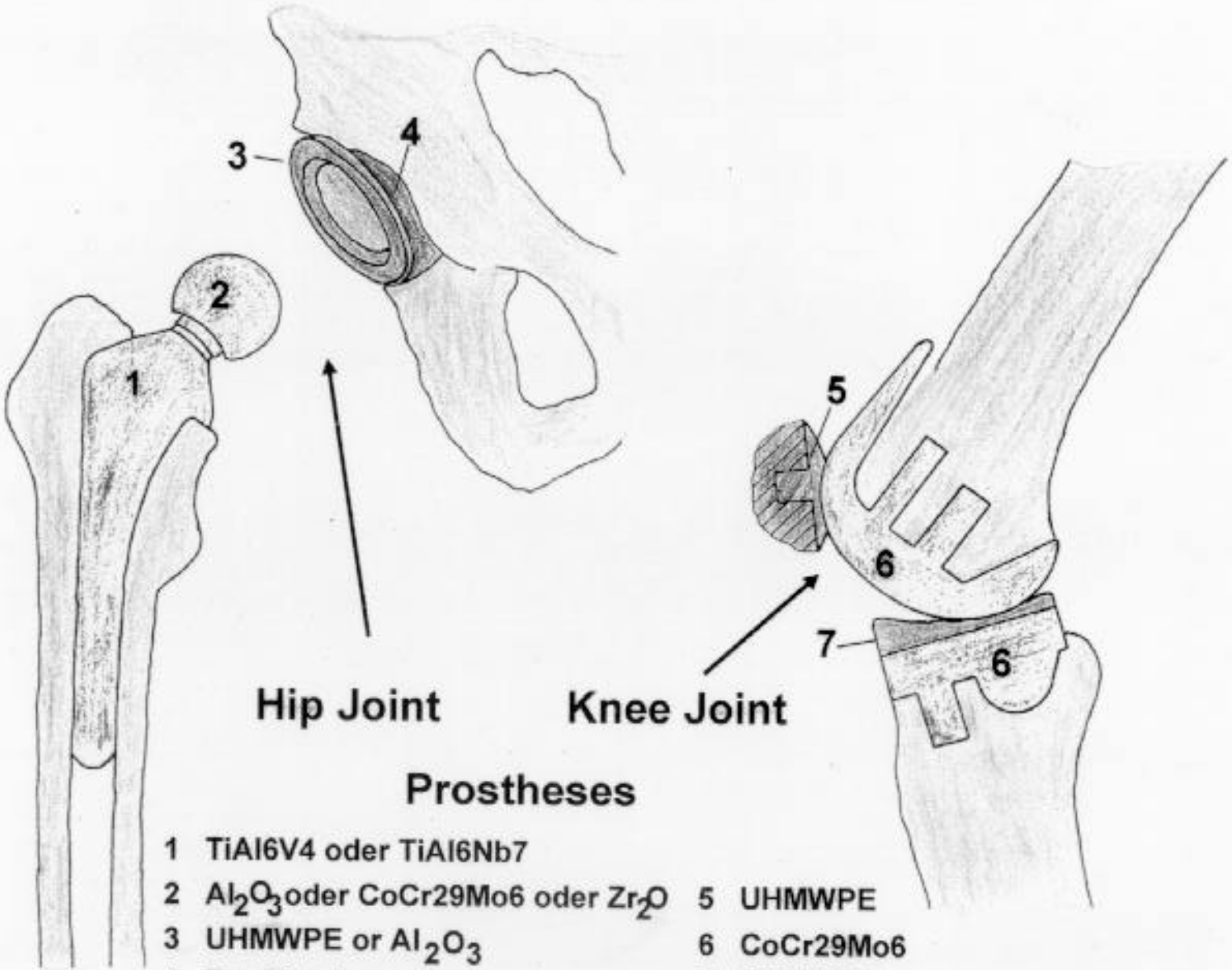

0.03
0.025
0.02
0.015
0.01
0.005
0
Wear Rate [µm/h]
0.028
0.021
0.011
0.004
1
2
3
4
Material of the Needle Guidance

The Main Features of RTM

- **High Sensitivity:** ***Wear Resolution up to 1/10 Microgram or several Nanometers***
  - **non-contacting**
  - **non-interacting**
  - **on line, continuous**
  - **selective**

Thin Layer Activation has been developed for

- all Industrial Iron and Steel Grades,
- Non-Ferrous Metals and Alloys,
- Hard Metals and
- the most usual Ceramics.



Prostheses

1 TiAl6V4 oder TiAl6Nb7
2 Al_2O_3 oder CoCr29Mo6 oder Zr_2O
3 UHMWPE or Al_2O_3
4 Pur Titanium
5 UHMWPE
6 CoCr29Mo6
7 UHMWPE.

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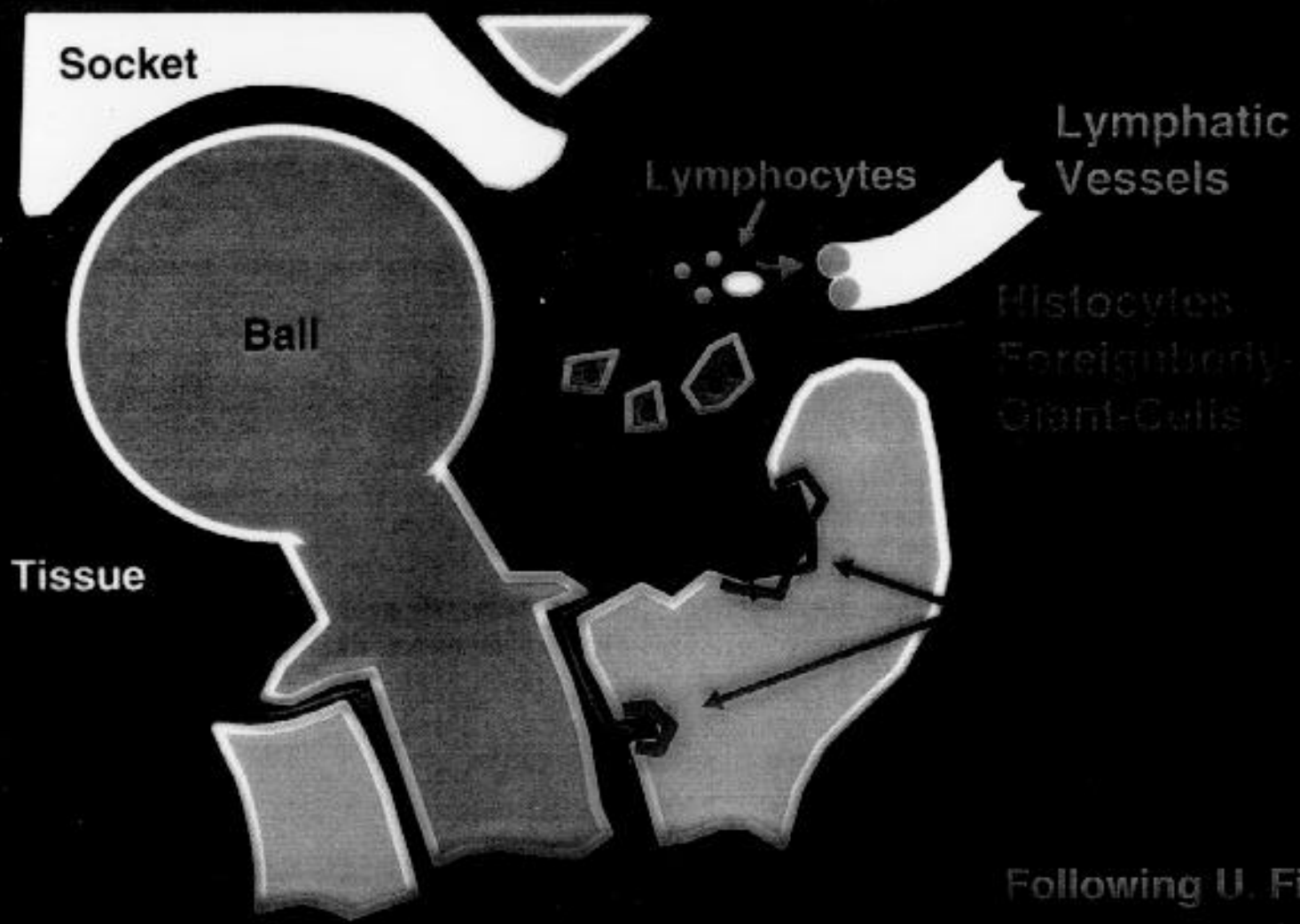
Aseptic Late Slackening of the Prosthesis



Following U. Fink

FZK

HZY/RTM

Be-7 Implantation of Endoprosthetic Materials

	Worldwide	Germany
Hip Joint Surgeries per Year for Endoprosthesis Implantations	600 000	100 000
Knee Joint Surgeries per Year for Endoprosth. Implantations	300 000	30 000

50% of all Surgeries are Replacement Implantations.

Target: **Prosthetic Components**

Dimensions: 50 - 100 mm **Material:** Polyethylen (PE)

Critical Area F: 1 - 5 cm^2 **Labelling Depth s:** 2 -3 µm

	^{7}Be	^{22}Na
Specific Activity (min.) [kBq/mg]	500	10
Total Activity (F=1cm^2, min.) [kBq]	100	2
Number of Particles	$6 \cdot 10^{11}$	$2 \cdot 10^{11}$

Beam:

Ø 5 - 10 mm

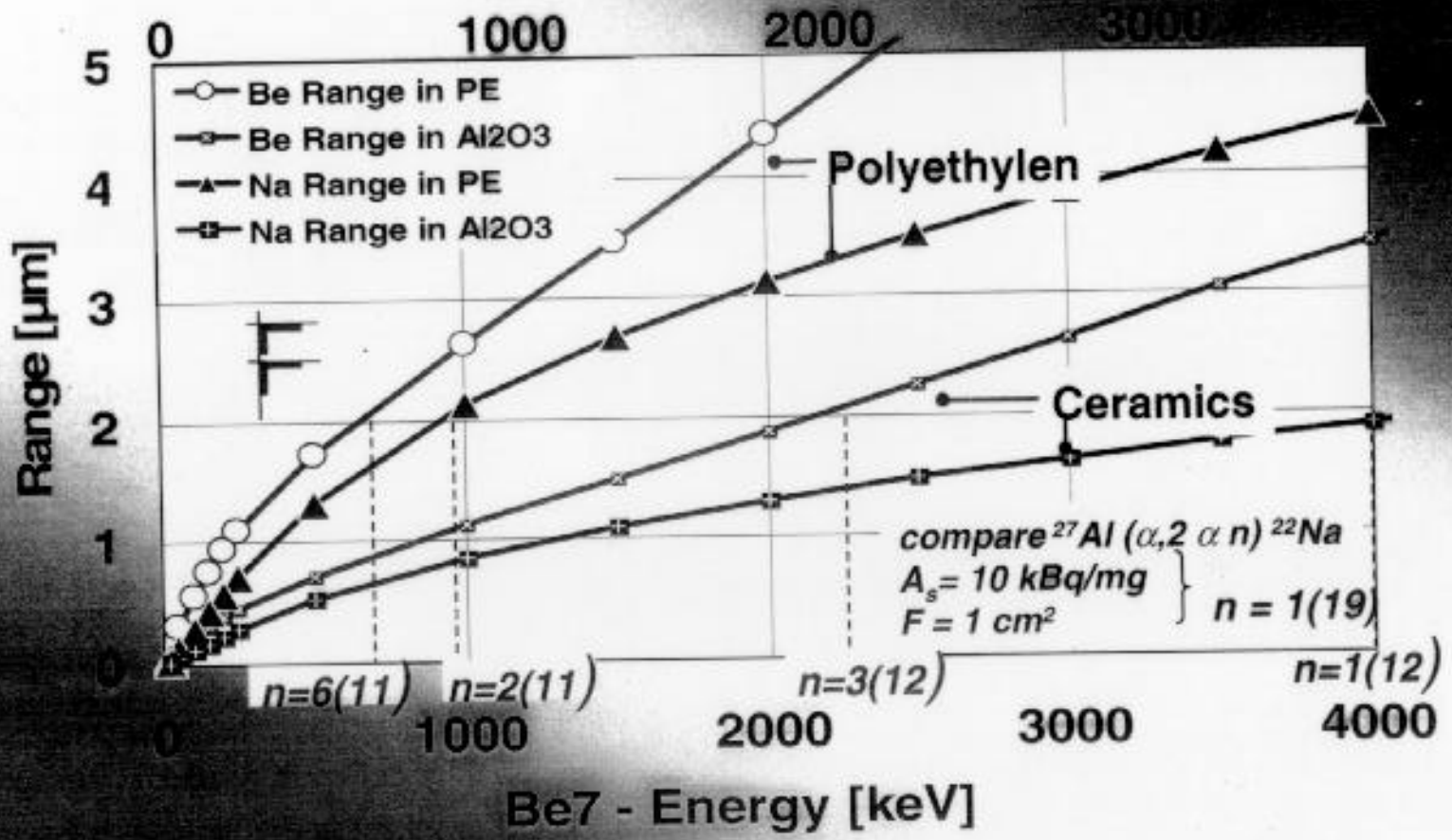
Energy [MeV]

1 for ^{7}Be in PE
3 for ^{7}Be in Al_2O_3
2 for ^{22}Na in PE
5 for ^{22}Na in Al_2O_3

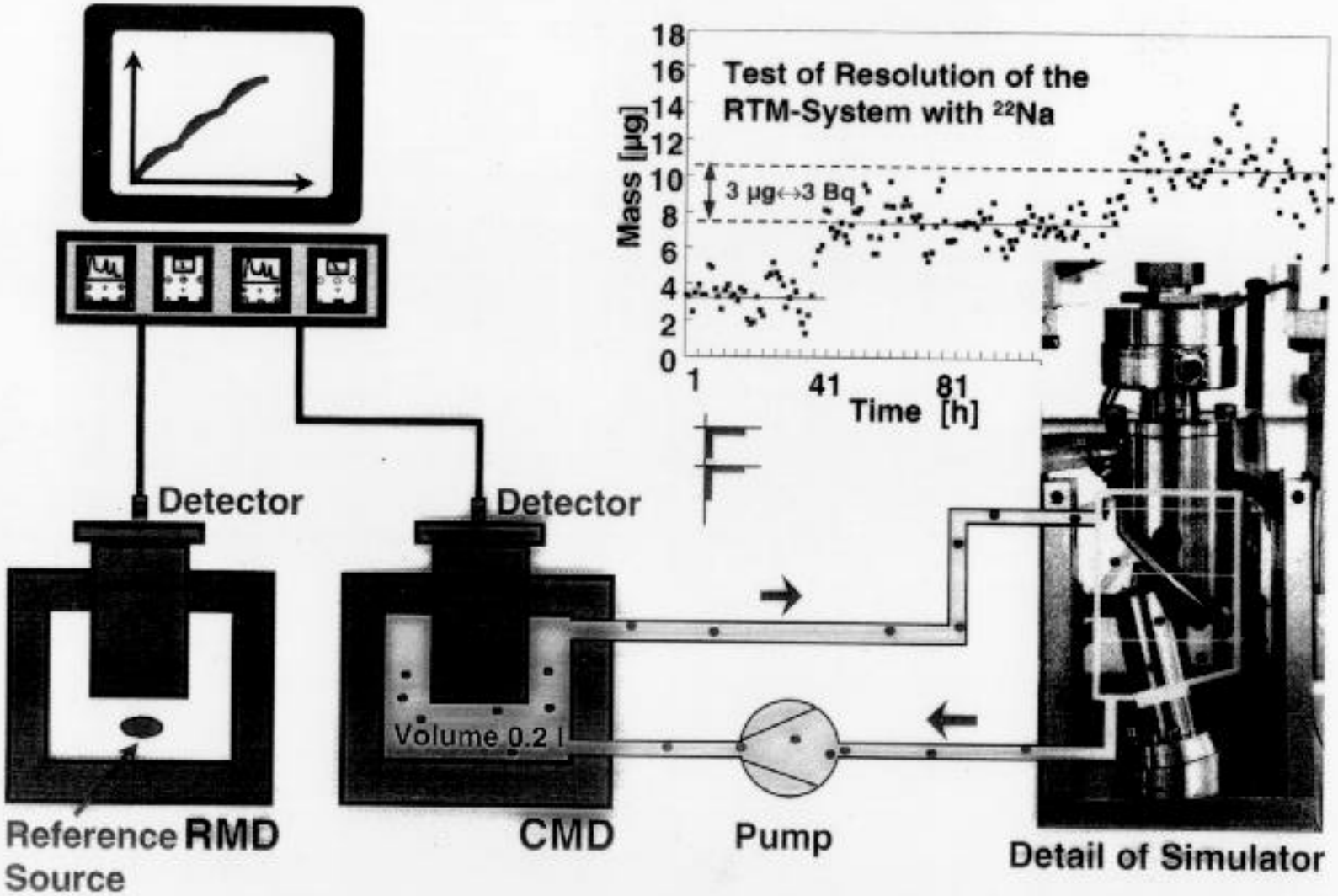
Energy Wobbling for Homogeneous Depth Distribution

Low Beam Contaminations are required

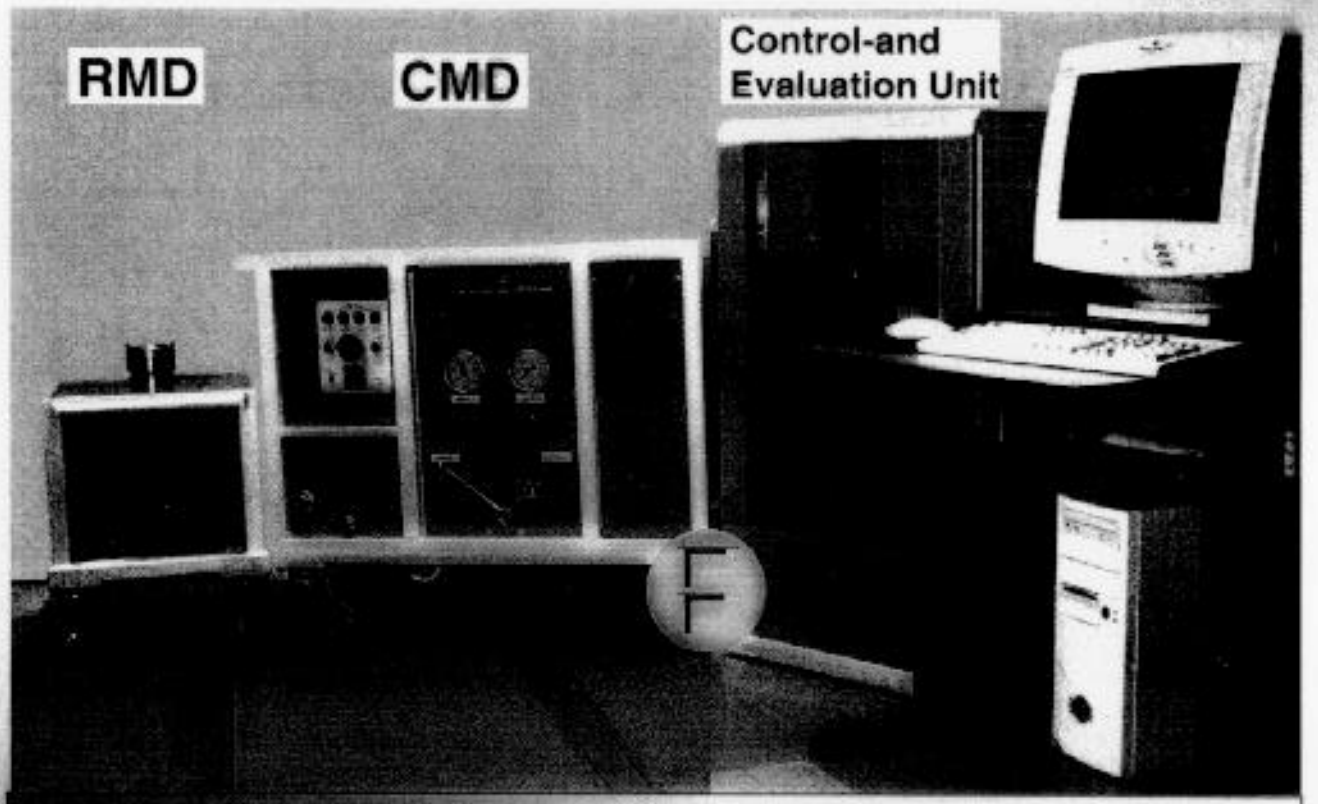
RIA Application to RTM
Calculated Ranges and Number of Radioactive Ions



RTM Measurement System for Prosthetics

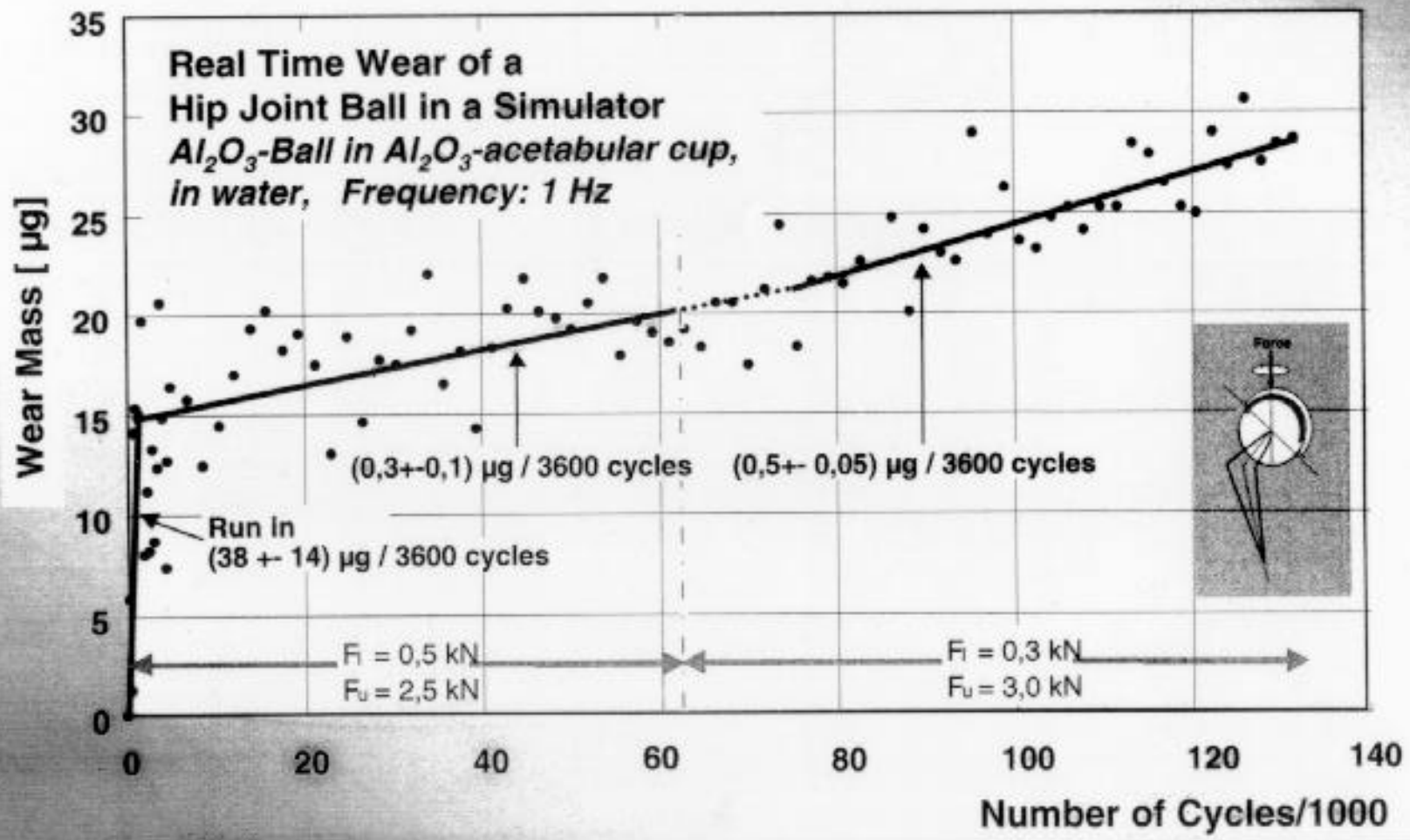


RTM Measurement System for Prosthetics



RTM Measuring System for Wear Diagnostics of Bone Joints with Concentration-Measuring-Device CMD and Reference-Measuring-Device RMD

First Real Time Wear Measurement of a Bone Joint Prosthesis



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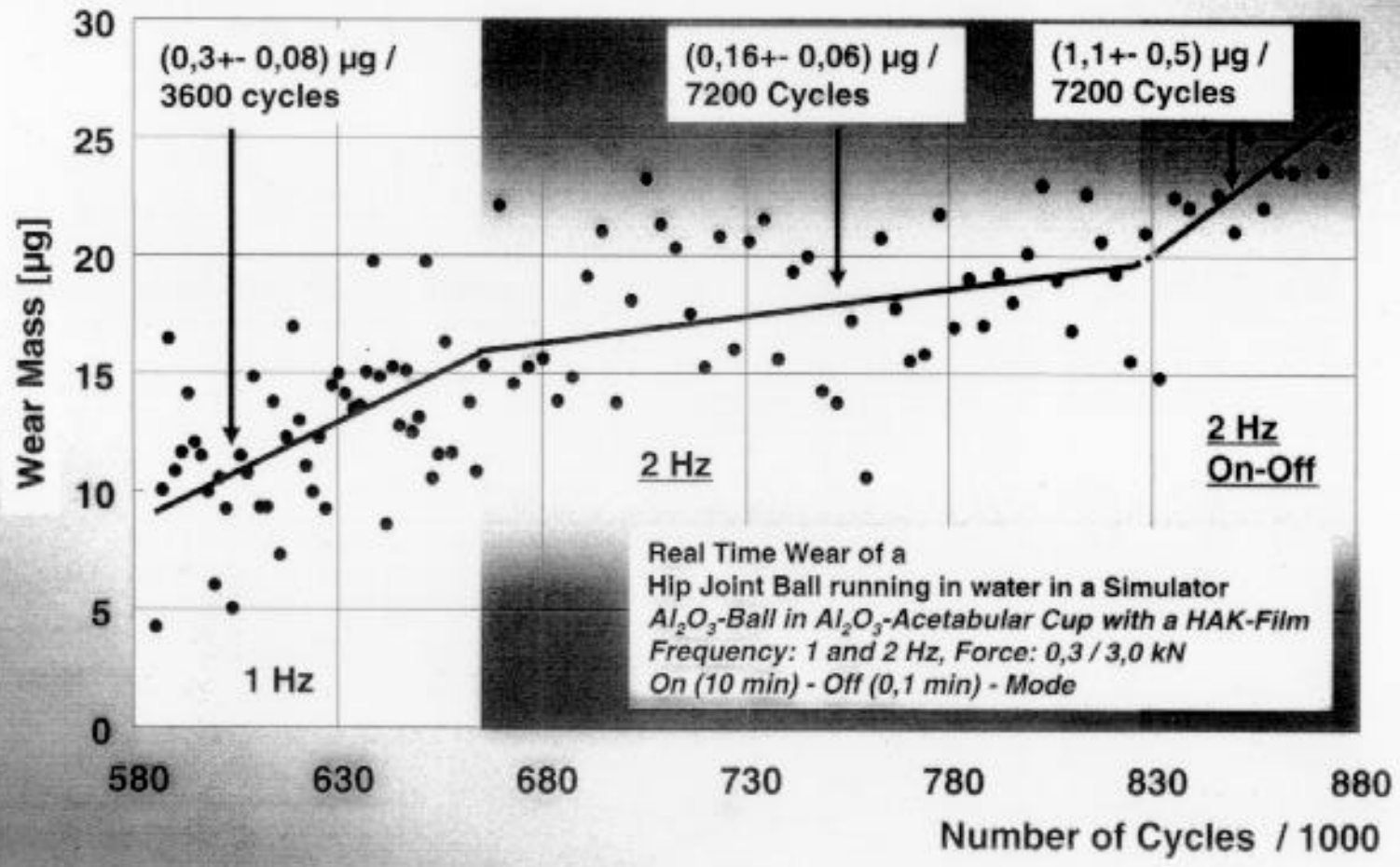

Areas of RIA Application

Prosthetics:
- **UHMWPE**
- **Ceramics as Al_2O_3, Zr_2O**

Mechanical Engineering:
- **Hard Coatings like**
  - **Diamond**
  - **TiC**
  - **TiN**
- **Plastic Material** ***for Shaft Sealings, Gears, Belts*** **a.o.**
- **Ceramics as Al_2O_3, Zr_2O, Si_3N_4, SiC**