RCM RELIABILITY CENTERED MAINTENANCE

RCM defined:- "*Reliability Centered Maintenance is a process used to determine what must be done to ensure that any physical asset continues to do whatever is users want it do in its present operating context*". RCM came about in the 1960s / 70s from the civil aircraft industry. Later John Moubray came out with his concept of RCM II specially designed to use in other industries. It is a logical, structured process used to determine the optimal failure management strategies for any physical asset system.

- Shall we allow the function of the asset to run to failure?
- Do we inspect the function of the asset periodically?
- Should we monitor the condition of the function of the asset?
- What if we developed a planned discard, restore or replace schedule for the function of the asset?

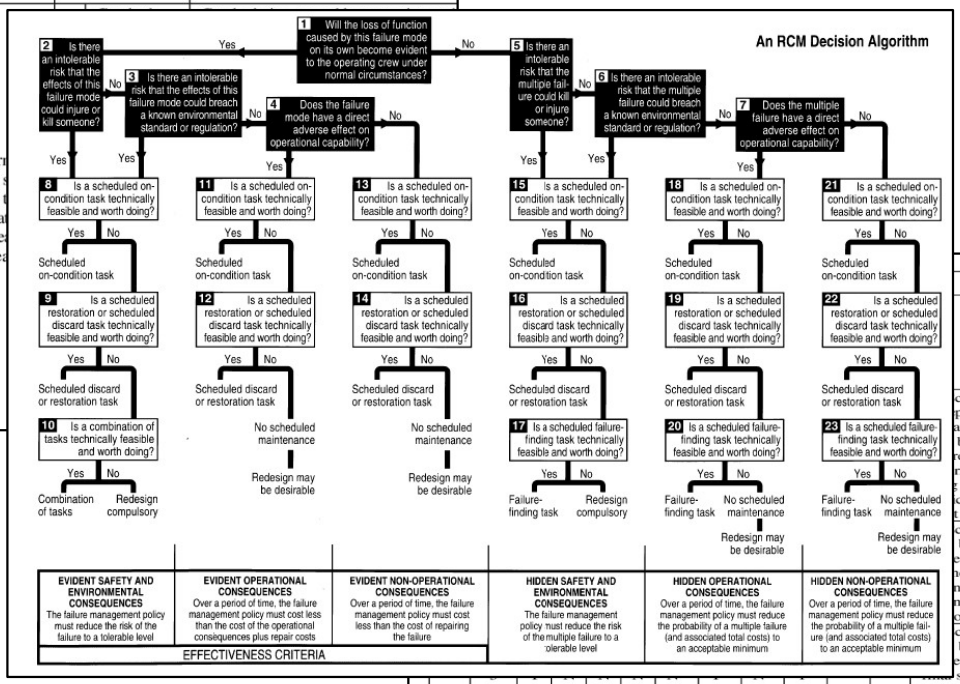
To answer these questions above with how do we manage the functional risks of a physical asset we first ask and answer the seven questions below.

1. What are the functions and associated performance standards of the asset in its present operating context?
2. In what ways does it fail to fulfill its functions?
3. What causes each functional failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What can be done to predict or prevent each failure?
7. What should be done if a suitable proactive task cannot be found?

From these questions we record their answers using two forms and one reference document diagram for the analysis in determining what pro-active tasks actions to take or as the case might be no pro-active tasks no actions to take and they are:

- RCM Information Work Sheet
- RCM Decision Diagram
- RCM Decision Work Sheet

RCM II Information Worksheet	Sistem : UNIT PEMBANGKIT LISTRIK TENAGA UAP	*Unit 4 UP Gresik*	
		1	*SUPERHEATER*
Function	*Function Failure*	*Failure Mode*	*Failure Effect*
1 Transform saturated steam to super heated steam that is exhausted from the high pressure steam drum	1 Fail to transfor saturated steam to s heated steam in t primary superhea secondary superhe and final superhea part.		



											Proposed Task	Can be Done by
											cheduled Discard task placing inlet drain ary superheated pipe. by doing finding e task by checking the rial composition by spectrometer as a ctive maintenance	Engineering mechanic
											cheduled Restoration by fixing the inler er drain valve in the ndary superheated by ng leaked plug. Do ng falure buy checking ondition of the valve.	Engineering mechanic
											cheduled Restoration by fixing the inler er drain valve in the superheated by closing the leaked plug. Do finding failure activity by checking the valve condition.	Engineering mechanic
		4	Y	N	Y	N	N	Y	N	N	Do scheduled restoration task by cleaning using cathodic protection	Har Mekanik, Engineering

1. What are the functions and associated performance standards of the asset in its present operating context? **(Functions)**
2. In what ways does it fail to fulfill its functions? **(Functional Failures)**
3. What causes each functional failure? **(Failure Modes)**
4. What happens when each failure occurs? **(Failure Effects)**

Questions 1 – 4 Are answered by the operating context, failure modes, possible causes, consequences, severity and recorded using the RCM Information Work Sheet – Similar to a Failure Mode Effects Analysis Work Sheet

5. In what way does each failure matter? **(Failure Consequences)**

Questions 1 – 5 Are answered by using the RCM Decision Diagram and recorded on the RCM Decision Work Sheet – Similar to a Failure Mode Effects Criticality Analysis

6. What can be done to predict or prevent each failure? **(Proactive Maintenance Tasks & How Often)**

Questions 1 – 6 Are answered by using the RCM Decision Diagram and recorded on the RCM Decision Work Sheet – What maintenance tasks will be used ● Scheduled On-condition Tasks (interval based on detection window PF curve) ● Scheduled Restoration Tasks (interval based on useful life on wear out age) ● Scheduled Discard Tasks (based on useful safe life) ● Scheduled Failure Finding Tasks based on hidden failure risk MTBF)

7. What should be done if a suitable proactive task cannot be found? **(Default Strategies)**

Questions 1 – 7 Are answered and recorded using the RCM Decision Diagram and recorded on the RCM Decision Work Sheet – What default actions are to be taken for failure modes that cannot be predicted or prevented ● Compulsory Redesign (modify the device where its failure is evident under normal operation by the crew) ● Failure Find Tasks (entail periodically checking hidden functions for protective devices and function to see it they are in a failed state) ● Standard Work (change the an operating procedure to mitigate the failure mode) ● Training (train or re-train affected and authorized personnel to mitigate the failure mode) ● No Schedule Maintenance (run to failure providing the failure mode consequence and severity will not kill or injure anyone or pose a biological hazard, violate any known environmental laws, cause property damage negatively harm company societal reputation or have intolerable, financial impacts to the organization)

RCM II Information Worksheet	Sistem : UNIT PEMBANGKIT LISTRIK TENAGA UAP	*Unit 4 UP Gresik*	
		1 *SUPERHEATER*	
Function	*Function Failure*	*Failure Mode*	*Failure Effect*
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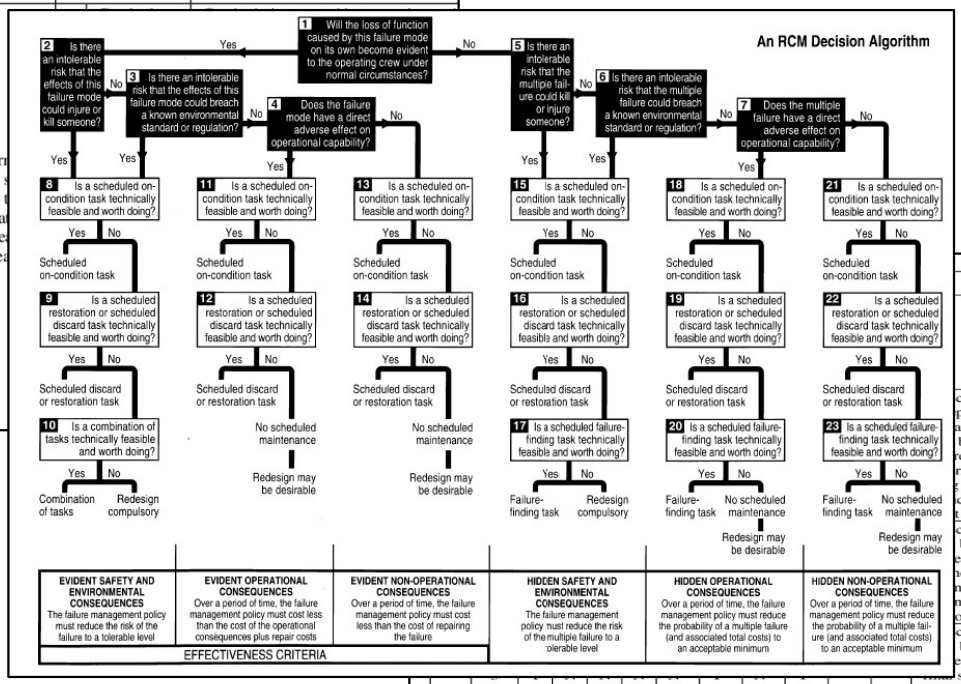

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		4	Y	N	Y	N	N	Y	N	N	Do scheduled restoration task by cleaning using cathodic protection	Har Mekanik, Engineering

RCM consists of seven steps:

Step 1: Functions: Record what the asset does (as opposed to what it is) including required standards of performance

Step 2: Functional Failure: Document the ways in which the asset can fail to fulfill its Functions

Step 3: Failure Modes: Identify what causes each Functional Failure

Step 4: Failure Effects: Detail what happens if nothing were done to predict or prevent each Failure Mode

Step 5: Failure Consequences: Determine how each Failure Mode matters. That is, identify one of four Consequences: Safety, Environmental, Operational, or Non-Operational

Step 6: Proactive Maintenance and Intervals: Analyze the Failure Mode to determine if a Scheduled Replacement, Scheduled Restoration, or a Condition Based Maintenance task is technically appropriate and worth doing

Step 7: Default Strategies: Here's where we go far beyond maintenance. When organizations take full advantage of RCM's powerful principles, non-maintenance solutions can be identified including (but certainly not limited to) things like: Equipment redesigns, new or modifications to operating procedures, updates or additions to technical publications, new or modifications to training programs, supply changes, and even troubleshooting procedures. Solutions like these have provided tremendous benefits to organizations all over the world.

CONDITIONING MONITORING TECHNOLOGIES & TECHNIQUES

Conditioning monitoring technologies and techniques are really no more than highly sensitive versions of human senses. In the same way as the human senses react to symptoms of a potential failure (noise, smells, etc.), so conditioning monitoring technologies and techniques are designed to detect specific symptoms (vibration, temperature, etc.) For the sake of simplicity, these technologies and techniques are classified according to the symptom (or potential failure effects) which they monitor, as follows:

- **Dynamic effects**. Dynamic effects monitoring detects potential failures (especially those associated with rotating element equipment) which cause abnormal amounts of energy to be emitted in the form of waves such as vibration, pules and acoustic effects.

- **Particle effects**. Particle effects monitoring detects potential failure which cause discrete particles of different sizes and shapes to be released in the environment in which the item or component is operating.

- **Chemical effects**. Chemical effects monitoring detects potential failures which cause traceable quantities of chemicals elements to be released into the environment.

- **Physical effects**. Physical effects monitoring encompasses changes in the physical appearance or structure of the equipment which can be detected directly and the associated monitoring techniques detect potential wear and dimensional changes

- **Temperature effects**. Temperature effects monitoring techniques looks for potential failures which cause a rise in the temperature of the equipment itself (as opposed to a rise in temperature of the material being processed by the equipment).

- **Electrical effects**. Electrical effects monitoring techniques look for changes in electrical voltage, current, resistance, conductivity dielectric strength and potential differences.

An enormous variety of technologies and techniques has been developed and more are appearing all the time, so it is not possible to produce an exhaustive list of all the technologies and techniques at any one time. So much has changed just with my own involvement in industrial maintenance engineering in the past 30 years. I am going to provide a very brief summary of the 96 of the technologies and techniques currently available. Some of these technologies and techniques are well known and well established, while others are in their infancy or still under development. However, whether or not any of these technologies and techniques are technically feasible and worth doing in any context should be assessed with the same rigor as any other on-conditioning tasks as conditioning is technically feasible for no more than 20% of failure modes and worth doing in less than half these cases.

DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.01 BROAD BAND VIBRATION ANALYSIS

Conditions Monitored: Changes in vibrational characteristics caused by fatigue wear imbalance misalignment mechanical looseness turbulence etc.

Applications: Shafts, gearboxes, belt drives, compressors, engines, Roller bearings, journal bearings, electric motors, pumps turbines, etc.

P-F Interval: Limited warning of failure.

Operation: A broadband vibration system consists primarily of two parts a transducer which is mounted on the point of measurement to convert mechanical vibrations into an electrical signal and a measuring and indicating device called a vibration meter, which is calibrated in vibrational units. Monitors the overall reading of the vibration signature which is simply the root mean square bracket RMS] value of the broadband signal. In its simple value and is suited primarily to a single sinusoidal wave rather than a complex wave. Such meters have a constant frequency response over the range of 20 hertz to 1000 hertz.

Specialized Skills / Training / Experience Required: To use the equipment and record the vibration a semi-skilled worker.

Advantages: Can be very effective in detecting a major imbalance or rotating equipment. Use by inexperienced personnel. Cheap and compact. Can be portable or permanently installed. Memorial data login. Interpretation and appraisals can be based upon published condition acceptability criteria such as VDI 2056 from Germany.

Disadvantages: The broadband signal provides little information about the nature of the fault. In initial Spectra,, spectral peaks are much lower and contribute very little to the overall broadband signature. When these spectral peaks do grow the equipment is normally in an advanced state of deterioration. Difficult to set alarm levels. Lacks sensitivity.

DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.02 OCTIVE BAND ANALYSIS

Conditions Monitored: As for broadband vibration.

Applications: Rotating elements.

P-F Interval: Days to weeks depending on application.

Operation: Fixed continuous octave and fractional octave filters divide the frequency spectrum into a series of bands of interest which have a constant width with plotted logarithmically. The average output from each filter is measured successively and the values are displayed by a meter or plotted on a recorder.

Specialized Skills / Training / Experience Required: To operate the equipment and interpret results requires a suitably trained technician.

Advantages: Simple to use when the measurement parameters have been previously determined by an engineer Portable relatively inexpensive. Good detection abilities using fractional octave filters. Recorder provides a permanent record.

Disadvantages: Limited information for diagnostic purposes. Logistically ability also limited by logarithmic frequency scale. Registry long analysis time.

DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.03 CONSTANT BANDWIDTH ANALYSIS

Conditions Monitored: Changes in vibrational characteristics caused by fatigue, wear, imbalance, misalignment mechanical looseness and turbulence and it to identify multiple harmonics and side bands.

Applications: Shafts, gearboxes, belt drives, compressors, engines, roller bearings, journal bearings, electric motors, pumps, turbines, and development diagnostic and experimental work open brackets (especially on gearboxes).

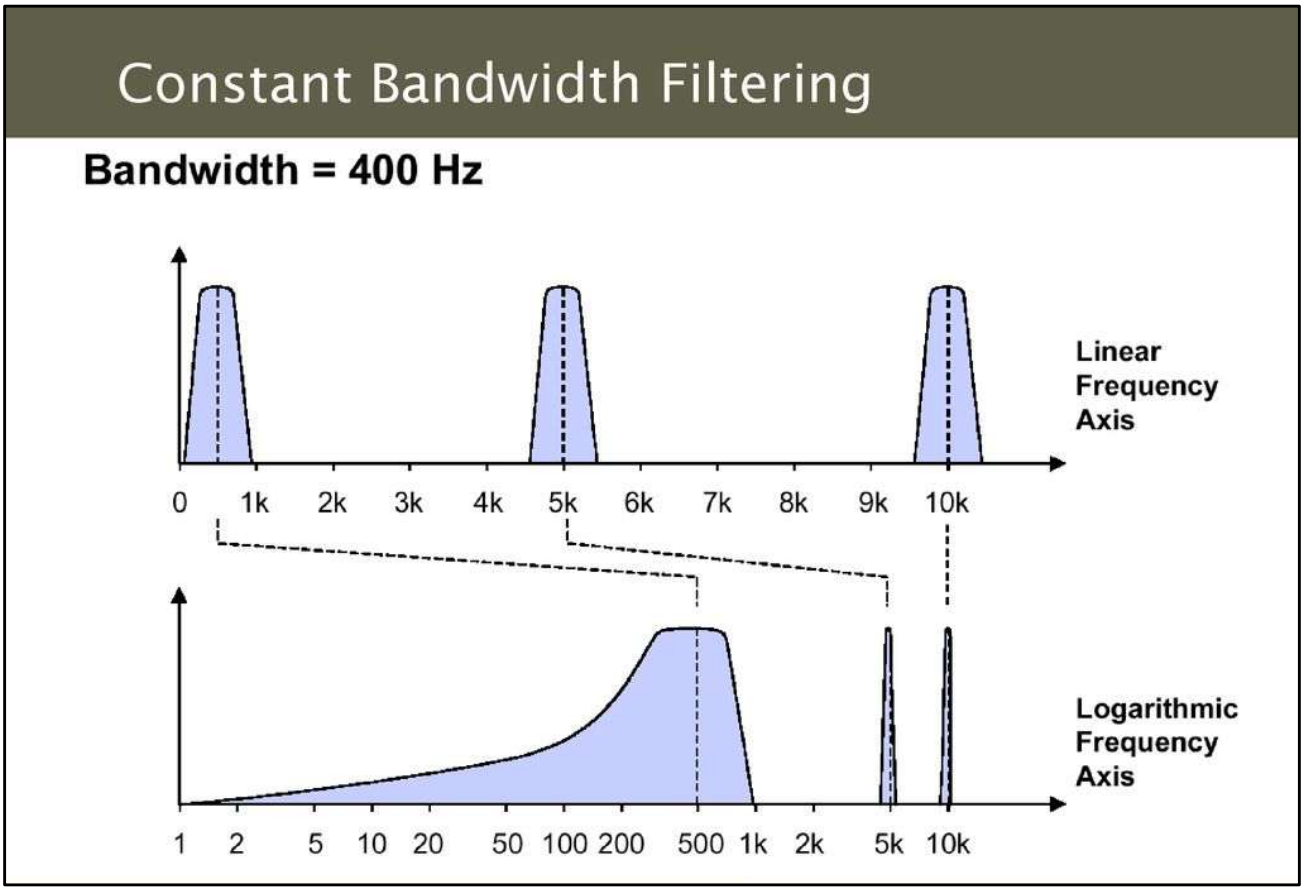
P-F Interval: Usually several weeks to months.

Operation: An accelerometer detects the vibration and converts it into an electrical signal which is amplified, subjected to a constant bandwidth filter and then fed into an analyzer. The constant bandwidths are between 3.16 Hertz and 1000 Hertz and the frequency range is from 2 hertz to 200 hertz. Both linear and logarithmic frequency sweeps may be selected but linear is chosen when identifying harmonics. In order to analyze the peaks in more detail bandwidths and frequency ranges can be changed to suit requirements.

Specialized Skills / Training / Experience Required: Operate the equipment, a suitably trained skilled worker. To interpret the results, an experienced technician is required.

Advantages: Simple to use when measurement parameters have been set. Good for large frequency ranges and for detailed investigations at high frequencies. Identifies multiple harmonics and side bands which occur at constant frequency intervals. Equipment is portable.

Disadvantages: Relatively long analysis time. In depth understanding of the machine harmonics and side bands required to interpret the results.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.04 CONSTANT PERCENTAGE BANDWIDTH ANALYSIS

Conditions Monitored: Shock and vibration.

Applications: Shafts, gearboxes, belt dryers, compressors, Engines, roller bearings, journal bearings, electric motors, pumps, turbines, etc.

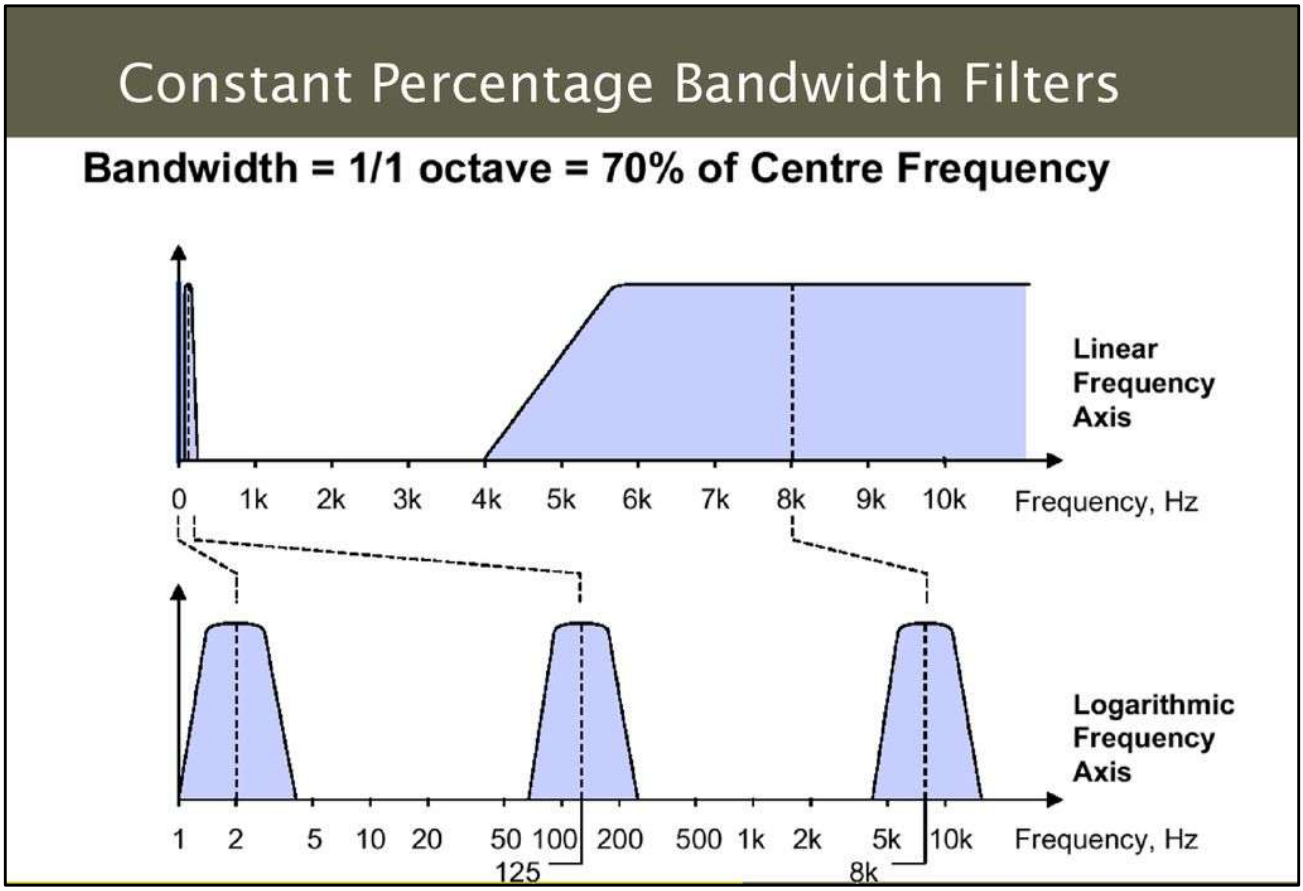
P-F Interval: Usually several weeks to months.

Operation: High resolution narrow bandwidth frequency analysis is performed by sweeping through the desired frequency range (2 hertz to 20 kilohertz) Which separates closely spaced frequencies or harmonics. A constant percentage filter bandwidth as narrow as 1% allows very fine resolution analysis. Continuous sweeps through the frequency range can be made in real time.

Specialized Skills / Training / Experience Required: To operate the equipment as suitably trained skilled worker, to interpret the results and experienced technician is required.

Advantages: Analysis can be done in real time and is therefore faster than FFT analysis and does not suffer from certain pitfalls caused by the batch nature of FFT, such a loss of data by windowing. CPB Spectra are very good for rapid fault detection. Equipment is portable.

Disadvantages: Highly skilled technician required to interpret results.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.05 REAL TIME ANALYSIS

Conditions Monitored: Acoustic and vibrational signals, measurement and analysis of shock and transient signals.

Applications: Rotating machines, shafts, gearboxes etc.

P-F Interval: Several weeks to months.

Operation: A signal is recorded on magnetic tape and playback through a real time analyzer. The signal is sampled and transformed into the frequency domain. A constant bandwidth spectrum is produced measured at 400 equally space frequency intervals across a frequency range selectable from 0 to 10 Hertz to zero to 20 kilohertz. A high-resolution mode can be selected and the scan can also be adjusted to give a slow-motion analysis, allowing any changes in the bandwidth spectrum to be observed as the time window is stepped along.

Specialized Skills / Training / Experience Required: To operate the equipment interpret the results requires an experienced engineer.

Advantages: Analysis or frequency bands over the entire analysis range simultaneously, instantaneously graphical display of analyze spectrum is continuously updated, no need to wait for level recorder readout, suited to analysis of short duration signals such as transient vibration and shock XY records provide permanent records.

Disadvantages: Equipment is not portable and very expensive. These high level of skill to operate. Offline analysis is required.

Note: Back in 2005 I started using these EFECTOR IFM VNB211 direct mount vibration sensor to all of the injection molding machine hydraulic pump when I was the Maintenance Manager for Alfmeier Corporation. Easy to install and use. All you did was hook it up the provided software via a laptop computer, locate the make and model of the bearing being used in the both the hydraulic pump and the motor drive, speed, temperature and some other parameters and download that information to the sensor and it would monitor it real time with a LED bar graph and when the bars started propagating into the red zone you plugged and analyzed the vibration spectrum signature to see what was going and you would take the appropriate action.

DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.06 TIME WAVEFORM ANALYSIS

Conditions Monitored: Chipped cracked broken gear teeth, pump cavitation, misalignment, mechanical looseness, eccentricity, etc.

Applications: Gearboxes, pumps, roller bearings, etc.

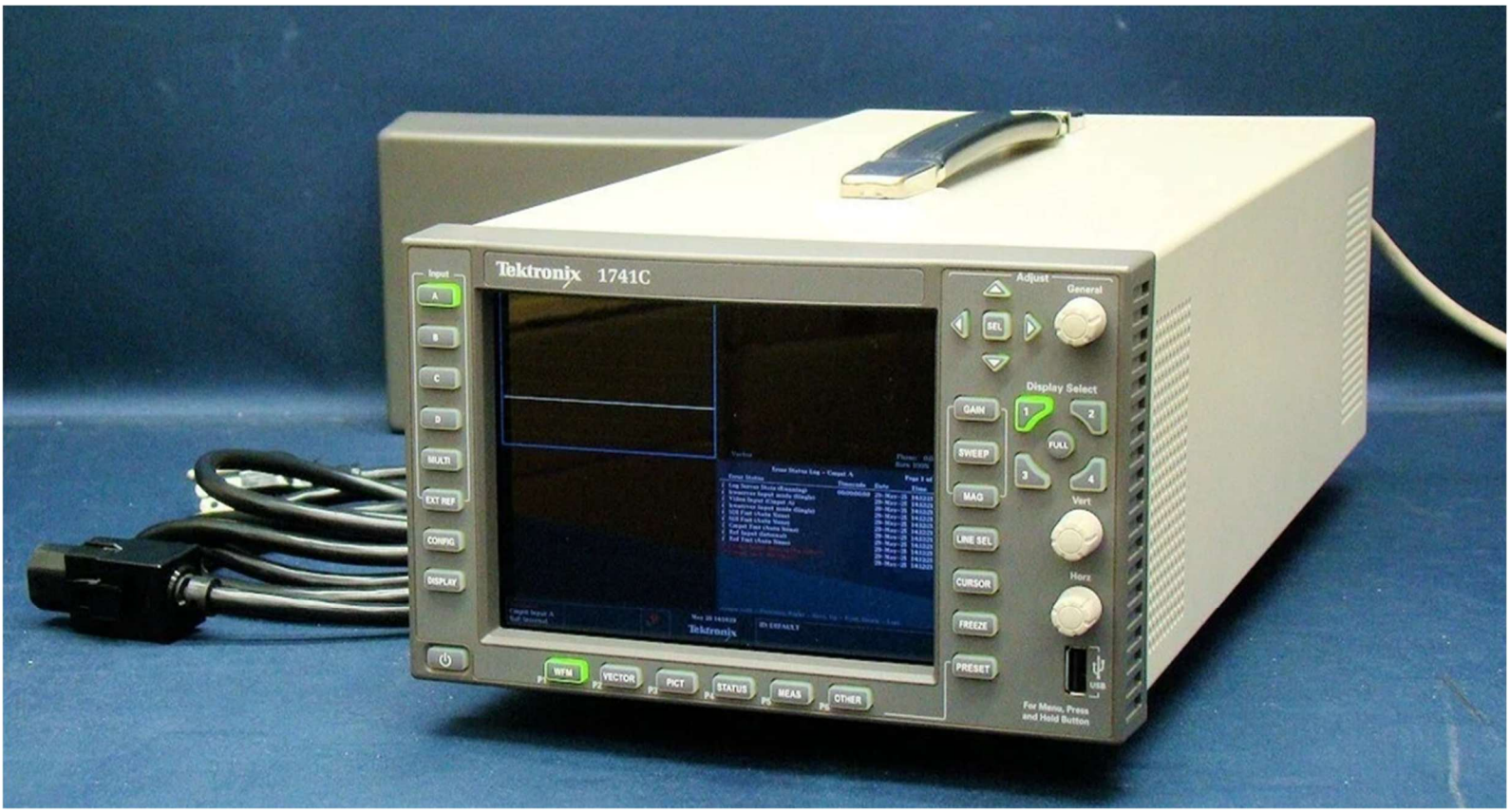
P-F Interval: Several weeks to months.

Operation: An oscilloscope is connected to a standard vibration analyzer or a real time analyzer. A vibration signal is applied to the oscilloscope vertical input. The vertical axis on the CRT is scaled in multitude amplitude and the horizon or access is scaled in such as seconds or milliseconds. The oscilloscope vertical gain is adjusted until the peak will peak to peak value of the waveform is displayed on the CRT corresponds to the amplitude reading on the vibration meter. When a machine is generating a signal frequency the time waveform is simply a sine wave with the reputation rate of the running speed of the equipment When the equipment generates more than one frequency, a complex composite waveform is generated. Additional frequencies can be generated in the form of pulse, transient, beat, modulation, etc.. Which add to the complexity of the waveform. To reduce the complexity of the waveform it is useful and even essential to use variable high pass low pass and bandpass filters.

Specialized Skills / Training / Experience Required: Needs considerable practice and experience to interpret complex waveforms.

Advantages: Good for looking at transient, low beats pulses, nonlinearities, sine waves, amplitude modulation, frequency modulation, instabilities, etc.. Often provides more information than frequency analysis. The waveform can be used to distinguish between Spectra resulting from impacts or random noise.

Disadvantages: Machines that generate multiple frequencies often generate noise which makes time wave forms so complex and confusing that they are difficult to break down into component parts. To examine a waveform which might have slow beats a longtime record is required.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.07 TIME SYNCHRONOUS AVERAGING ANALYSIS

Conditions Monitored: Wear fatigue, stress weighs emitted as a result of mechanical metal to metal impact in, micro-welding, etc.

Applications: Gearbox gear T, roller bearings, shafts, Banks of fans, rolls on a paper machine, rotated machines.

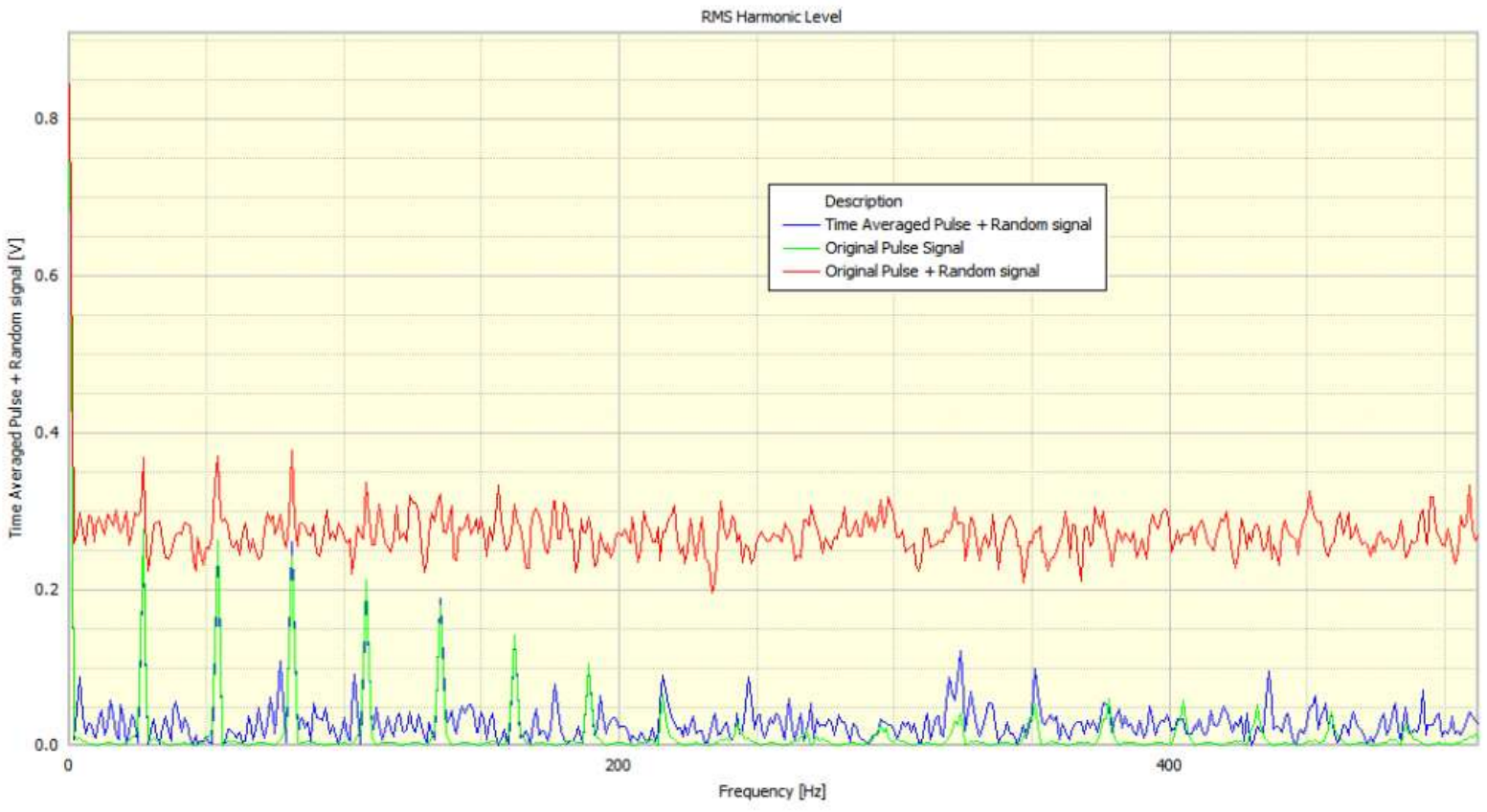
P-F Interval: Usually several weeks to months.

Operation: Most were taken mechanical systems produced a slightly varied signal with each revolution. (statistically there is term stochastic, in comparison with identically repeated signals which are deterministic). The closer the tolerances of slide in and roller parts, the less the vibration but nevertheless there is a vibration. And many systems, this difference can be put to can be so great than it mass any changes due to a developing fault. The presence of random noise can also confuse the signal. These problems can be overcome by performing a level check at precisely the same part of the rotation using a tachometer triggering pulse to initial data capture in a data collector. A number of cycles or time records are averaged together signals not related to the RPM of the shaft are averaged out, leaving a very real time wave representing the components related to a single turning speed. The average waveform can be examined directly, or a spectrum can be generated from it. It is devoid of random signals and will show whether one part of the cycle is changing more than the other.

Specialized Skills / Training / Experience Required: A suitably trained and experienced skilled worker. Considerable practice and experience to interpret the results.

Advantages: Gearboxes – specifically the individual gears –can be analyzed in detail. Very useful for analyzing equipment that has many components rotating at nearly the same speed.

Disadvantages: Care must be taken with machines with roller element bearings as the barren tones are not synchronous with the RPM and will average out.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.08 FREQUENCY ANALYSIS

Conditions Monitored: Changes in vibration characteristics caused by fatigue wear imbalance misalignment mechanical looseness turbulence, etc.

Applications: Shafts, gearboxes dried belts compressors engines roller bearings journal bearings, electric motors, pumps, turbines etc.

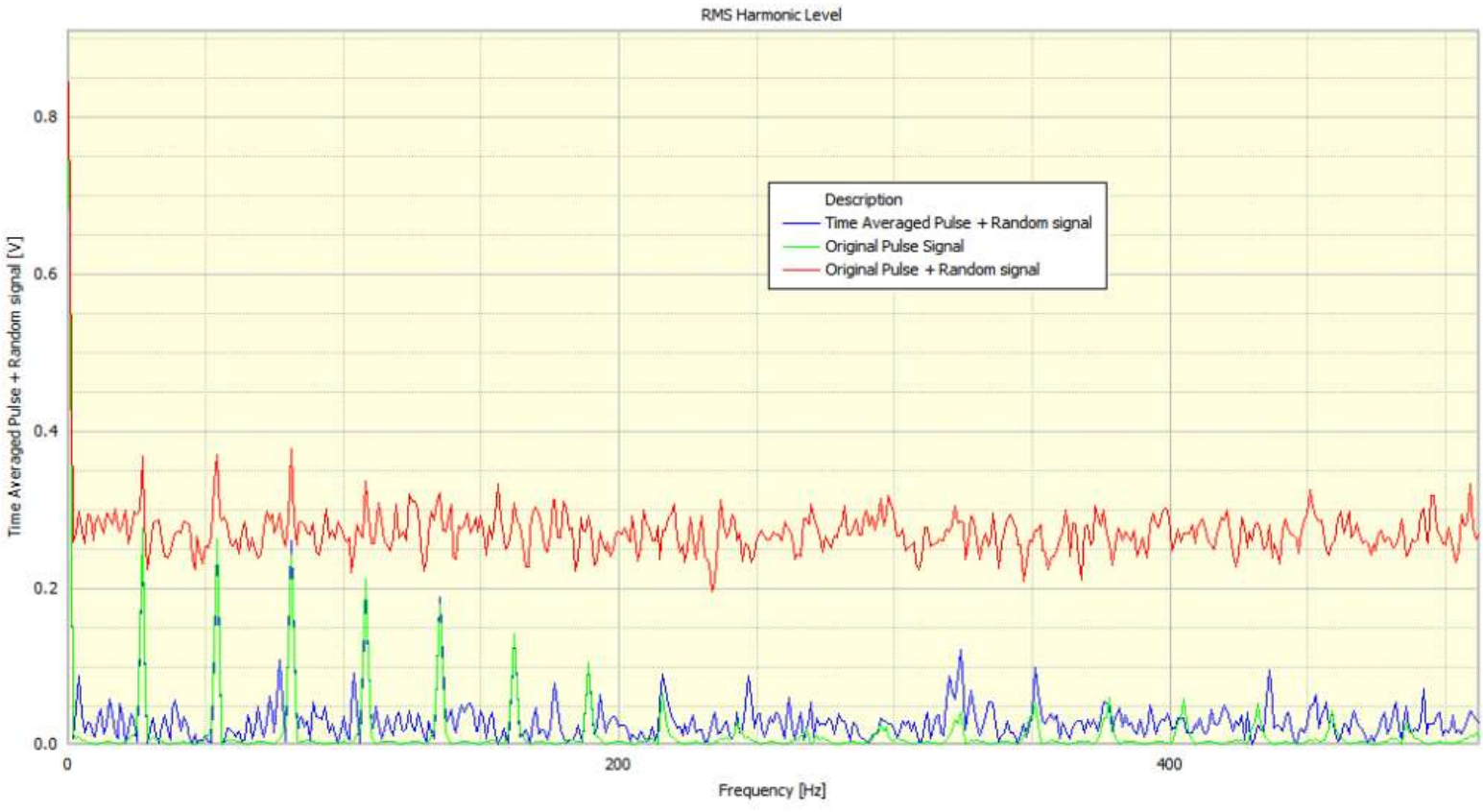
P-F Interval: Several weeks to months.

Operation: Data is collected from measurement points in the time domain and the transformed into the frequency domain using a Fast Fourier Transform (FFT) Algorithm, by either the data collector itself or a host computer. They require frequency range of the measurements is independent or dependent on the speed of the machine. Each machine width has its own moving parts will produce a spectrum of frequencies. A baseline spectrum of the machine is excellent condition is compared to an actual spectrum of the same machine running at the same speed and load. Any increases over the baseline of more than 1 standard deviation at any force in frequency can indicate a potential problem. One feature of frequency analysis is the 'waterfalls' are signatures taken at some point over an interval allowing the signature to be trended.

Specialized Skills / Training / Experience Required: I suitably trying to experience skilled Walker or technician requires considerable practice and experience to interpret the results.

Advantages: Data collecting equipment is portable and easy to use Expert software systems makes data interpretation easy. Using waterfall plots small changes in machine condition can be detected at an early age and stage.

Disadvantages: Spectra resulting from impacts and random noise can look similar.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.09 CEPSTRUM

Conditions Monitored: Wear causing in harmonics and side bands in vibration spectra.

Applications: Rolling element bearings, shafts, gears, gear mesh in, belt rotation, vein and blade pass frequencies of pumps and fans.

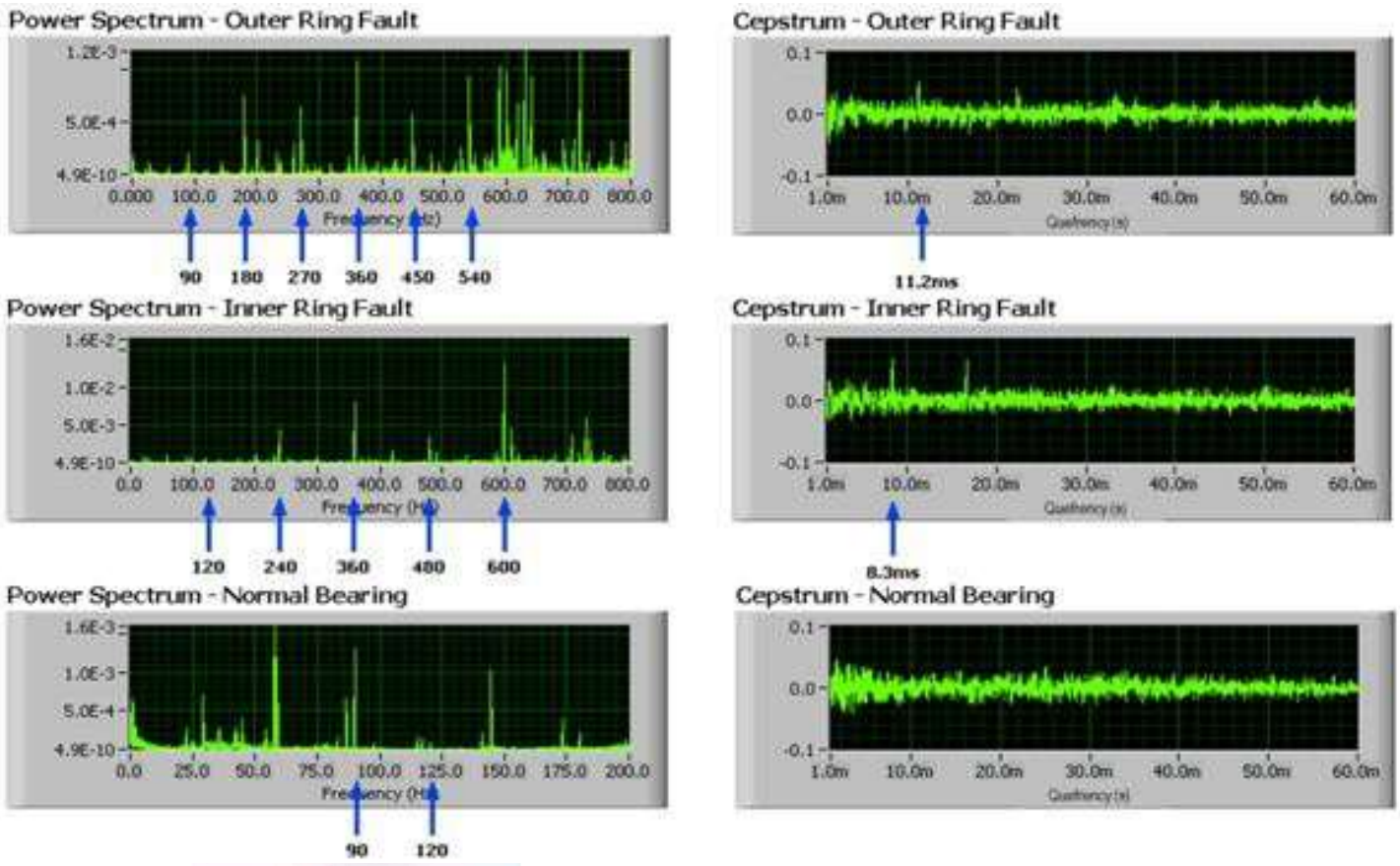
P-F Interval: Several weeks to months.

Operation: As the machine wearers, it develops non-linearities that cause harmonics of the primary force frequencies and some indifference (sideband) Frequencies appear in the vibration Spectra. Septum effectively separates the harmonics and sidebands present in the spectrum so they can be individually trended over time. In simple terms cepstrum could be defined as the FFT of the logarithmic spectrum obtained from FFT a spectrum of spectrum. All technical words in septum analyze are worst due to doubling up of the transform, i.e. spectrum becomes cepstrum, frequency becomes quefrency and harmonics become rahmonics.

Specialized Skills / Training / Experience Required: In depth understand of the machine behavior (harmonics and sidebands) and the expert software.

Advantages: Can analyze harmonics and sidebands that usually overlap in fairly complex machines. sidebands are easily to find in the Spectra of rolling element variance. Can be performed with some expert system software.

Disadvantages: Skill and experience needed to interpret harmonics and sidebands.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.10 AMPLITUDE DEMODULATION

Conditions Monitored: Barrington's Mass by noise, cracks in bare races eccentric or damaged gears, mechanical looseness.

Applications: Steam turbines, Barents and gearboxes, low speed rotating components of paper machines, reciprocating machines etc.

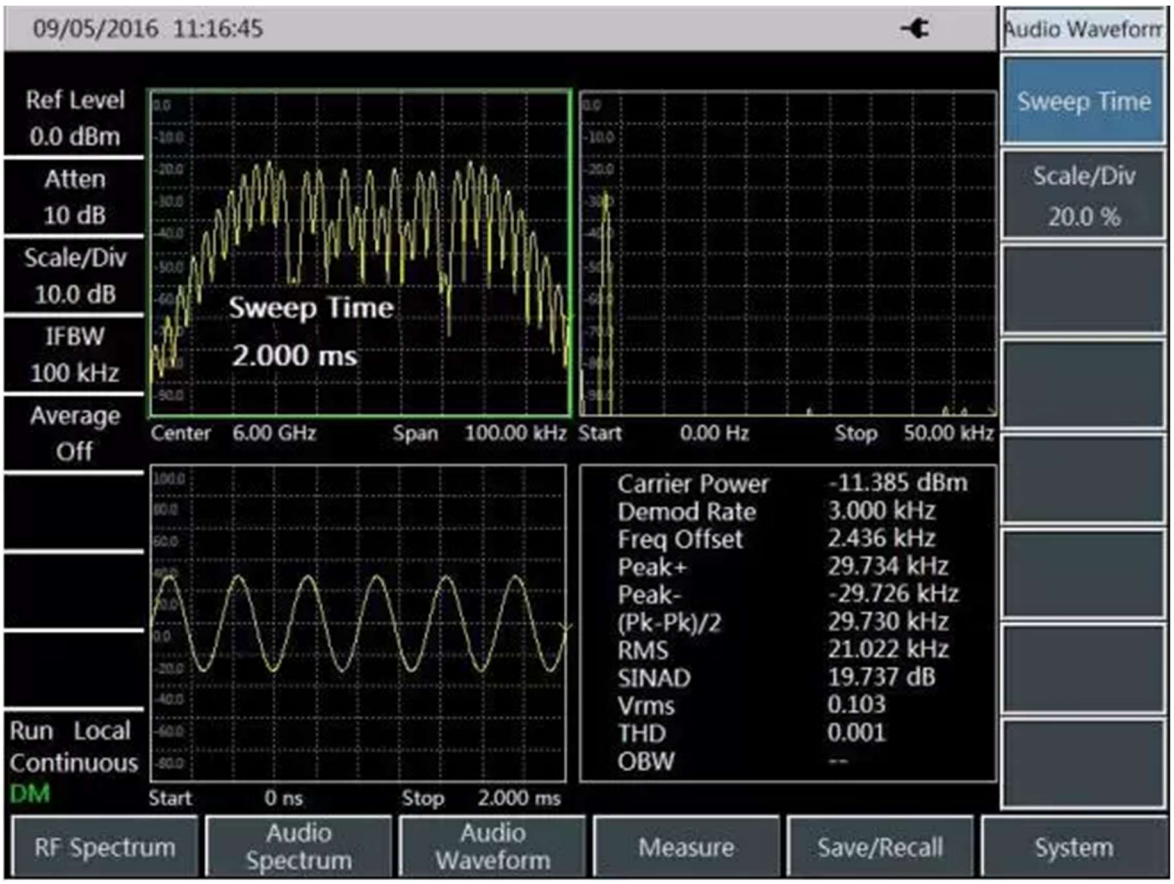
P-F Interval: Several weeks to months.

Operation: The acceleration and a lock signal (time domain) Subjective to high pass filtering and then amplitude demodulation. This is where a discreet frequency often called the carrier in the spectrum may be modulated by another frequency chord in modulator The resulting signal is then subjected to a low frequency range spectrum analysis The amplitude demodulation is performed in the data collector before the signal is digitalized.

Specialized Skills / Training / Experience Required: Soon to be trained and experienced technician.

Advantages: Early detection for barons and gearbox problems (specifically bearings completely masked by noise) can easily be detected and identified. Works well in low-speed applications such as paper machines.

Disadvantages: High skill and experience needed to understand and interpret the results Difficult to implement on slow speed bearings because the stress waves are short term transient events (less than a few milliseconds) So when the narrow pulse output from the demodulation circuit is passed through the final stage of signal conditioning (the low pass / antialiasing filter) a large fraction of the stress wave is filtered out, making fault detection less likely.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.11 PEAK VALUE (PEAK VUE) ANALYSIS

Conditions Monitored: Stress waves caused by metal-to-metal impacts or metal tearing, stress cracking or scuffing spalling and abrasive wear.

Applications: Anti friction bearings and gearbox shafts and gearing systems.

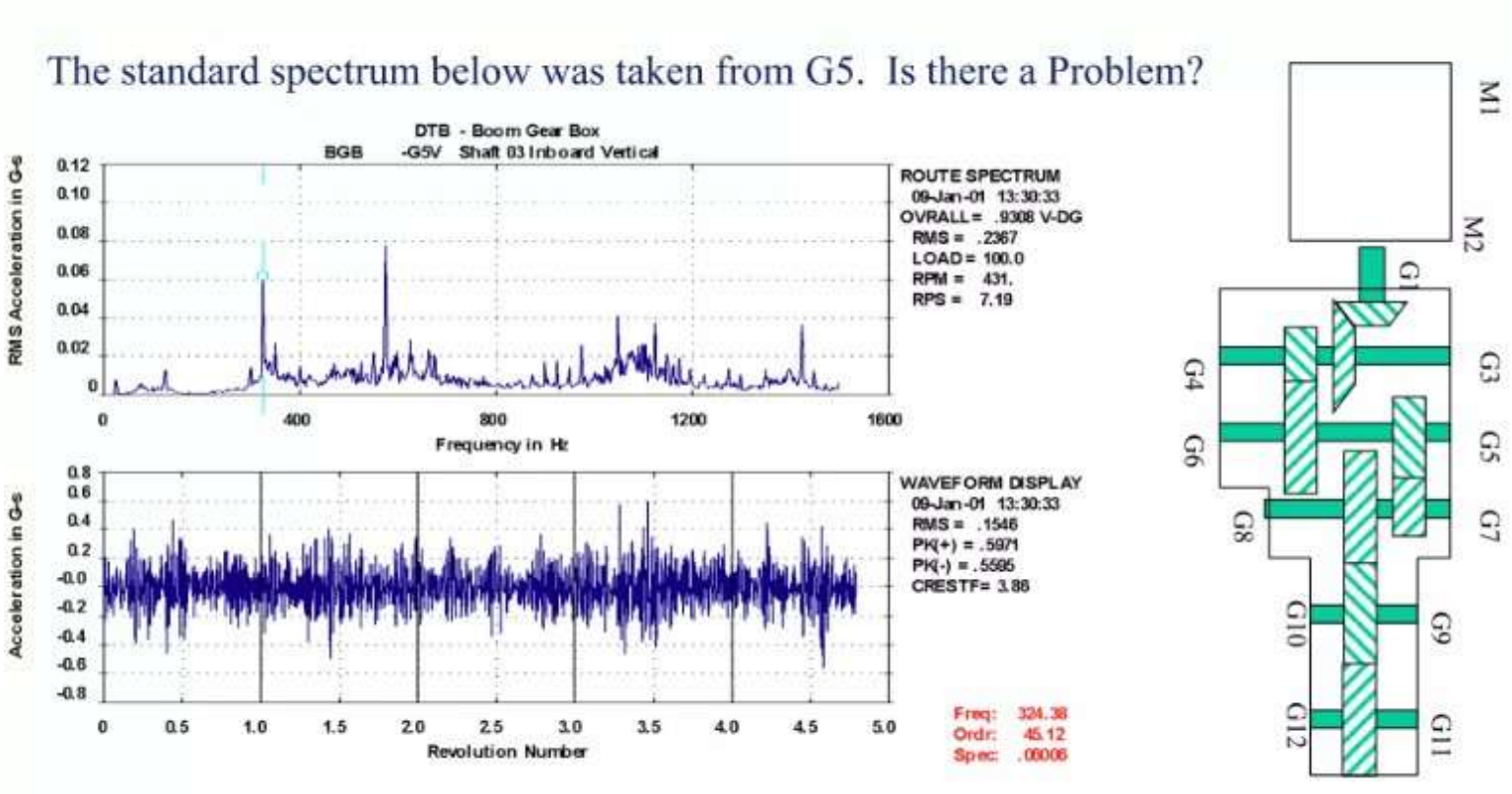
P-F Interval: Several weeks to months depending on the application.

Operation: Separates low energy faults such as those that occur in anti friction bearings and gears and enhances their signal causing the forces stand above the spectral noise floor. This makes them easier to recognize Peak view first separates the stress waves from the vibration waveform using the high pass filter. It is then conditioned to enhance its aptitude and pause with making it FFT friendly The conditioned waveform is then processed using an FFT to determine the frequency at which the stress wave occurs.

Specialized Skills / Training / Experience Required: Experience vibration technician required.

Advantages: Reveal some faults that may have gone undetected in their earlier stages on Which are buried in the noise floor (bottom) of the vibration spectrum. More consistent than demodulation. Outputs are independent of machine speeds and instrument F Max settings. Applicable to a broad range of frequencies, from very slow speed bearings to gear machine in excess of 1 kHz.

Disadvantages: High scale and the spring is required to interpret results.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.12 SPIKE ENERGY

Conditions Monitored: Dry running pumps karma cavitation, flow change, bearing loose fit, Bearing wear coals and metal to metal contact, surface flaws of gear teeth, high pressure steam or air flow, control valves noise, poor bearing lubrication.

Applications: Seal-less pumps used in the chemical and petrochemical industries, gearboxes, rolling element bearings, etc.

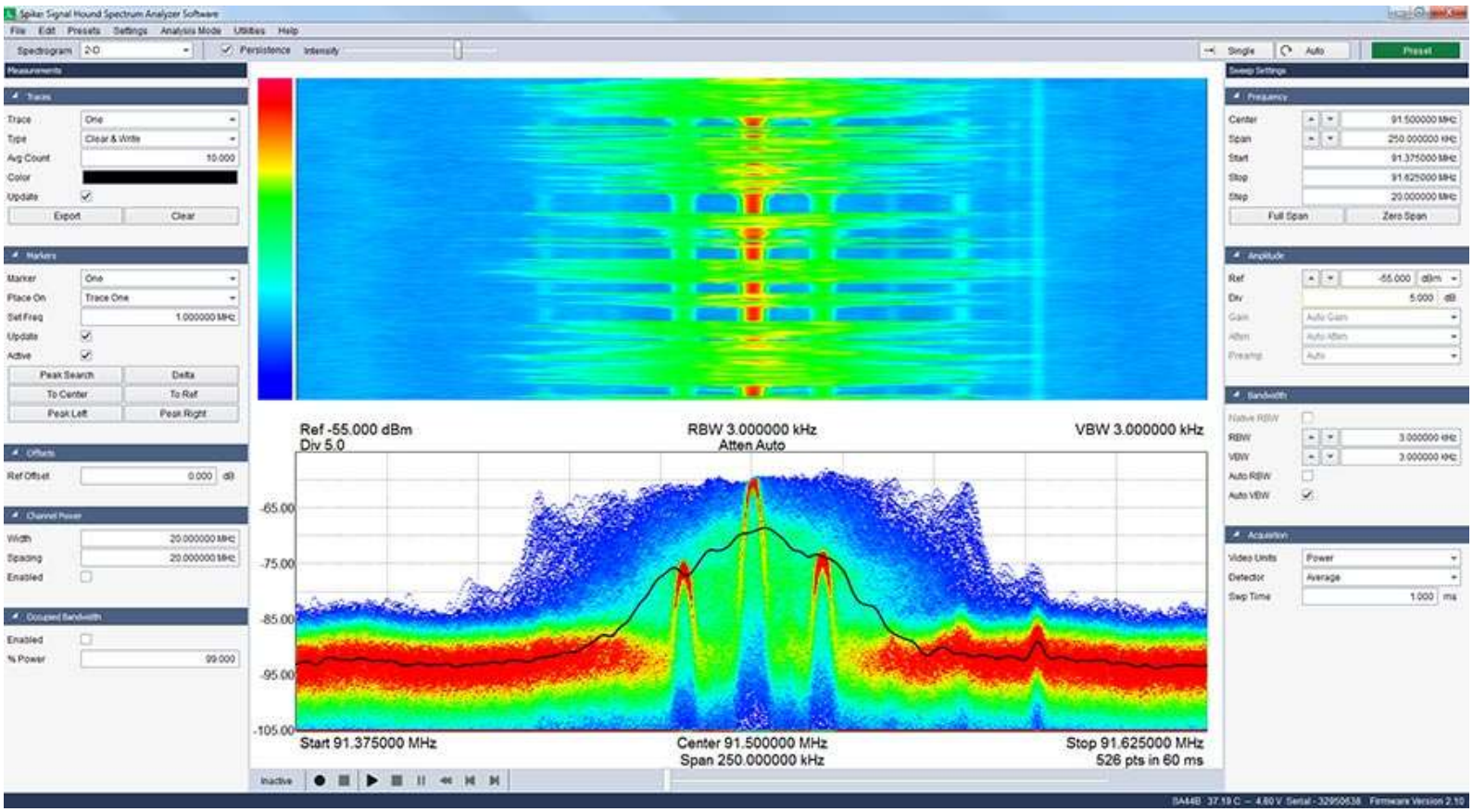
P-F Interval: Several weeks to months.

Operation: Some faults excite the natural frequencies of components and structures. The intention energy generated by reproductive transient mechanical inputs causes a signal to appear as. Of high energy and that frequency energy in the spectrum which can be measured by an accelerometer. A high frequency band pass filter is used to filter out the low frequency vibration signals. The high frequency signals pass through a peak-to-peak detector that detects and holds the peak-to-peak amplitudes of the signal. This is called enveloping and measurement results are expressed in 'gSE' units. Houses with large amplitudes and high repetition rates produce high overall high 'gSE' readings. The envelope signal can be subjected to a FFT analysis displaying a Spike Energy Spectrum. In the gSE spectrum, the fault frequency shows up as certain defect frequency and its harmonics.

Specialized Skills / Training / Experience Required: He suitably trained and experienced skilled worker. Practice and experience to interpret the results.

Advantages: Sensitive high frequency measurement parameters suited to the detection of seal-less pump problems which are often difficult to detect using conventional vibration sensors such as velocerometers meters and accelerometers.

Disadvantages: High skill and experience needed to interpret results.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.13 PROXIMITY ANALYSIS

Conditions Monitored: Misalignment oil swirl, rubs imbalance bent chassis resonance reciprocating forces, eccentric pulleys and gears, etc.

Applications: Shafts, motor assemblies, gearboxes, fans, couplings etc.

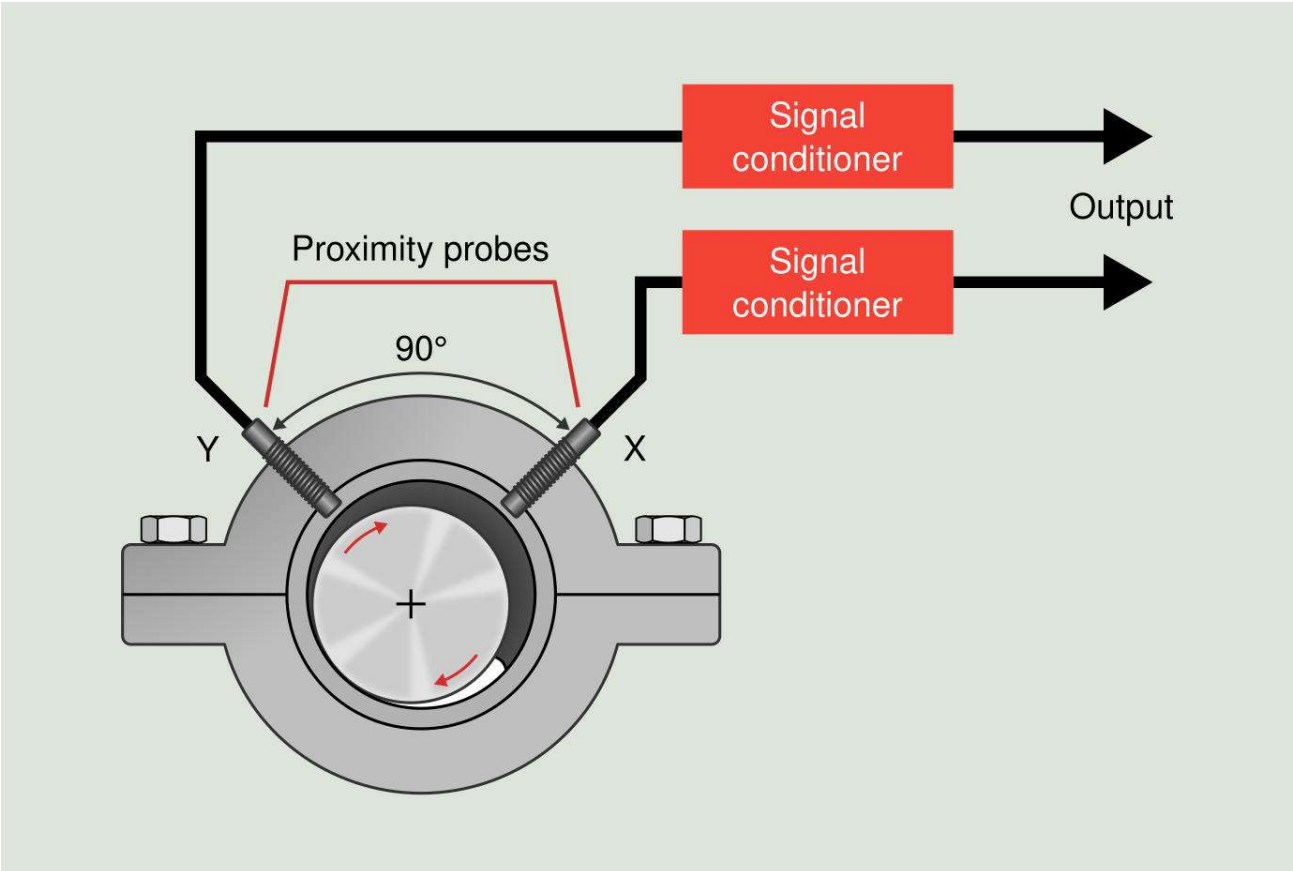
P-F Interval: Days to weeks.

Operation: In the basic mode a signal from our transducer operates as an ordinate against a time base. With a single impulse sinusoidal curves indicate imbalance bent shafts oil swirl misalignment adhesive bearing rubs. Two signals produce a polar diagram which provides more characteristic information than it XY diagram. More information can be obtained by introducing a phase indicator mark on the waveforms of an oscilloscope display. These marks are generated at the rate of 1 revolution by a pickup incorporated in the shaft speed tachometer.

Specialized Skills / Training / Experience Required: Suitably trained and experienced technician.

Advantages: Pinpoint's specific problems. Can be used for balancing. Portable very simple to use.

Disadvantages: PF interval is short. Long analysis time. Diagnostic ability limited.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.14 SHOCK PULSE MONITORING

Conditions Monitored: Surface deterioration and lack of lubrication caused a mechanical shockwaves. With data trending can identify incorrect baron installation or misalignment. Using the wrong type of lubricant, poor lubricant handling or dispensing practices or incorrect installation or maintenance of oil seals and packings, etc.

Applications: Rolling element bearings anti friction bearings pneumatic impact tools, and valves of internal combustion engines.

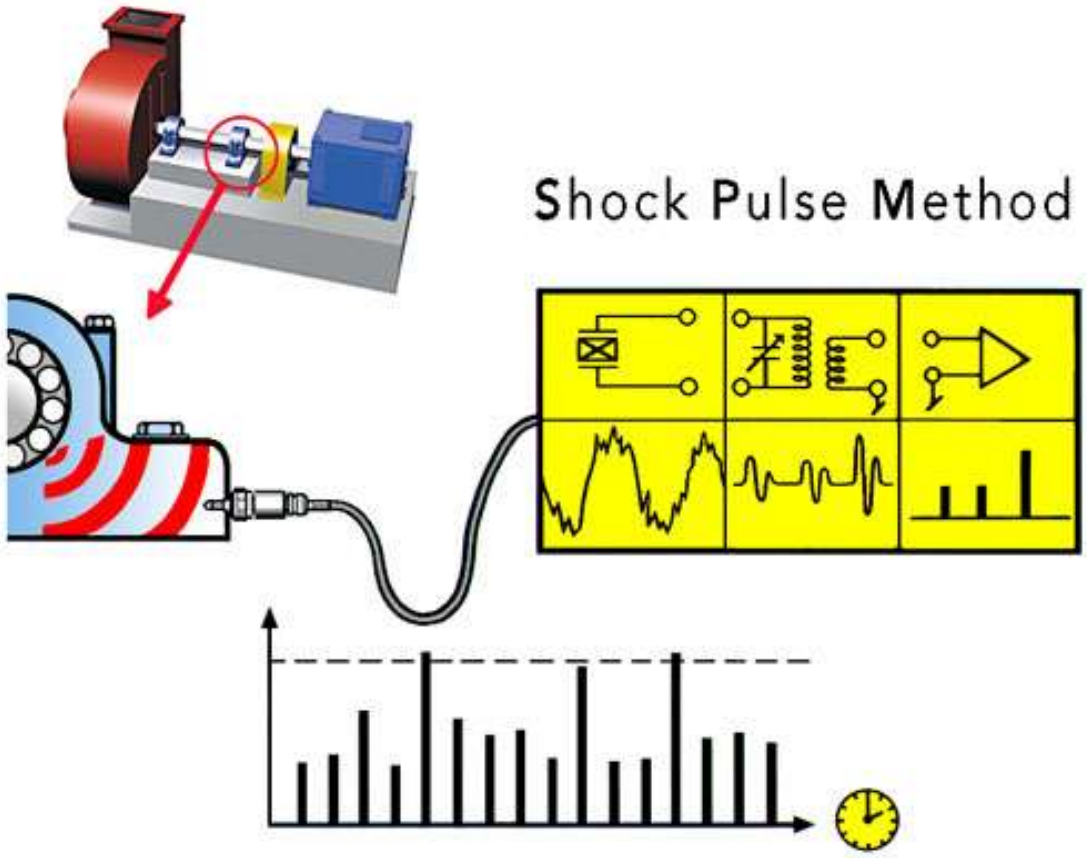
P-F Interval: Weeks to several months.

Operation: The type and size of the bearing is entered into the analyzer a piezoelectric accelerometer placed on a bearing housing and detects the mechanical impact of shock pulses, caused by the impact of two masses such as the rotational contact between the surface of the bowl or roller and the raceway. The magnitude of the shock pulses depends on the surface condition and the peripheral velocity of the bearing RPM and size. The pulses set up dampened oscillations in the transducer at its resonant frequency The transducer is tuned mechanically and electrically to resonate frequency at 32 kilohertz The peak magnitude of this oscillation is directly proportional to the impact velocity. As the bearing condition deteriorates from good to imminent failure short pulse measurements can increase up to 1000 times.

Specialized Skills / Training / Experience Required: I trained and suitably experienced technician.

Advantages: Relatively easy to operate.. Used on virtually any rolling element bearing. Bearing condition and lubrication status analyze within seconds. Shock pulses are not significantly influenced by background vibrations and noise. Identify subtle changes in bearing condition or lubrication which might not affect the differentiated by conventional vibration analysis.

Disadvantages: Needs accurate bearing size and speed information prior to taking measurement. Limited. to roller element bearings.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.15 ULTRASONIC ANALYSIS

Conditions Monitored: Changes in sound patterns sonic signatures caused by leaks, wear, fatigue or deterioration.

Applications: Leaks in pressure and vacuum systems i.e. boilers, heat exchangers, condensers, chillers, distillation columns vacuum furnaces, specialized gas systems. Baron wear or fatigue, steam traps, the valve and valve seat wear, pump cavitation Corner in switch gear, static discharge, the integrity of seals and gaskets in tanks, pipe systems and large walk-in boxes underground pipe or tanks leaks.

P-F Interval: Highly variable depending on the nature of the fault.

Operation: Ultrasound technology is concerned with high frequency sounds waves above human perception which is above 20 hertz to 20 kilohertz ranging from 20 kilohertz to 100 kilohertz. High frequency sound waves are extremely short and tend to be fairly directional, so it is easy to isolate these signals from background noises and detect their exact location. All operations and equipment and most leakage problems produced a broad range of sound. As subtle changes began to occur with deterioration in the nature of the airborne ultrasound allows these warning signals to be detected early. Ultrasonic transducers convert the ultrasound sensed by the instrument into the audible range where users can hear and recognize them through headphones. The ultrasonic monitoring equipment filters out surrounding noise and other unwanted frequencies. Ultrasonic readings may be displayed visually on AVDU or a moving coil meter as an audible signal on headphones or as traces on electronic monitor or computer.

Specialized Skills / Training / Experience Required: A suitably trained skilled worker.

Advantages: Quick and easy. Used in very noisy areas where headphone screen ambient noises microphones highly directional and enable the operator to detect a source of noise at long range.

Disadvantages: It does not indicate the size of leaks Underground tangs can only be tested under vacuum.

DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.16 KURTOSIS

Conditions Monitored: Shock pulses.

Applications: Rolling element bearings, anti friction bearings.

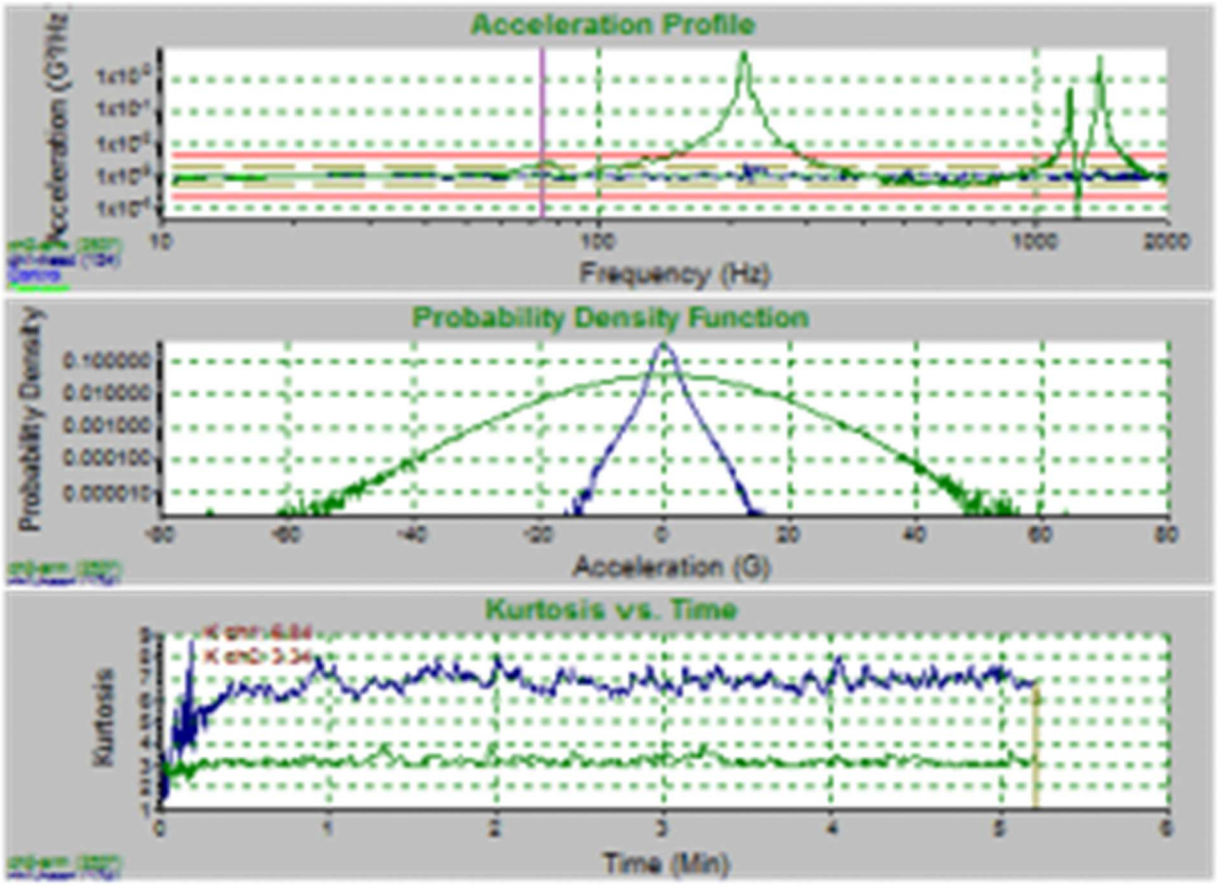
P-F Interval: Several weeks to months.

Operation: Restricted almost exclusively to barons where a few specific frequency ranges are examined (3-5 kHz, 5-10 kHz, 10-15 kHz). Kurtosis is a Statistical analysis of the time-based time domain signal and looks at the 4th moment of the spectral amplitude difference from the mean level. A normal distribution has a kurtosis (K) value of 3.

Specialized Skills / Training / Experience Required: A suitably trained semi-skilled worker.

Advantages: Applicable to any materials with a hard surface. Equipment portable. Simple to use.

Disadvantages: Limited application and significantly affected by impact noise from other sources. Considered by some users to be too sensitive.



DYNAMIC EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

1.17 ACOUSTIC EMISSION

Conditions Monitored: Placid defamation and crack formation caused by fatigue, stress and wear.

Applications: Metal materials used in structures plastic vessels, pipelines and underground mining excavations.

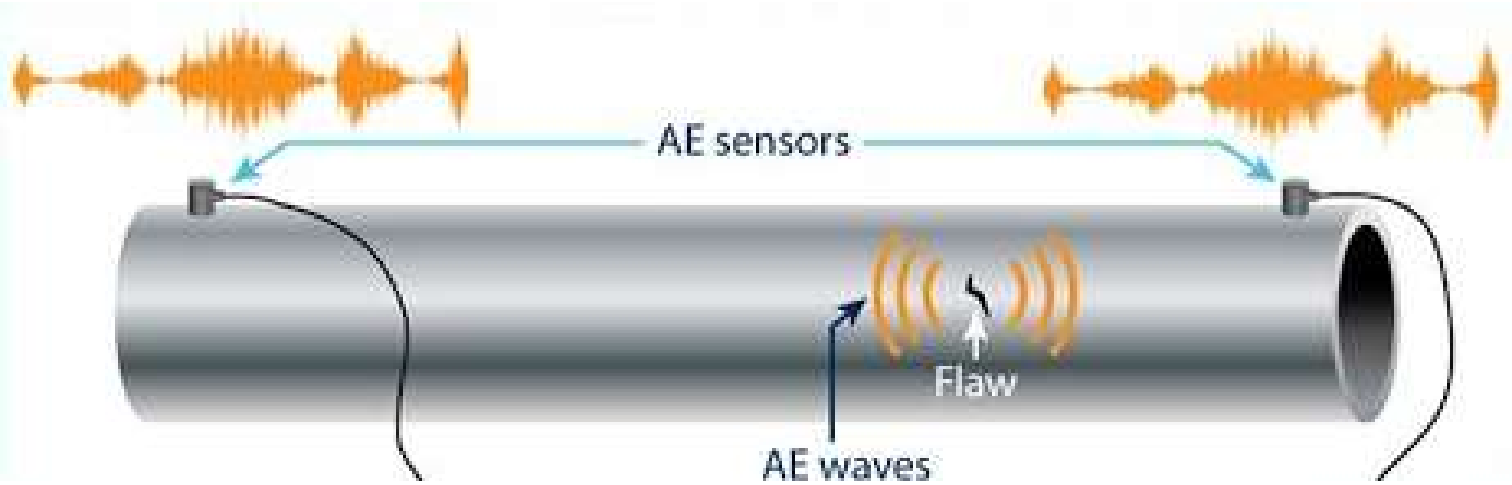
P-F Interval: Several weeks depending on the application.

Operation: Ottawa stress waves, due to crystallographic changes, are emitted from materials subjected to loads. These stress waves are picked up by a transducer and fed via an amplifier to a pulse analyzer then either to an X-ray recorder or to an oscilloscope The display signal is then evaluated.

Specialized Skills / Training / Experience Required: Requires specialized skills and training to identify and interpret results.

Advantages: A suitably trained experienced technician Remote detection of flaws. Covers entire structures. Measuring system set up very quickly. High sensitivity. Requires limited access to test materials and objects. Detects active flaws. Only relative loads are required. Can sometimes be used to forecast future loads.

Disadvantages: The structure has to be loaded. AE activity dependent on materials. Irrelevant electrical mechanical noise can interfere with measurements. Gives limited information on the type of flaw. Interpretation may be difficult. Not very good at detecting wear or corrosion.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.01 FERROGRAPHY

Conditions Monitored: Where, fatigue and corrosion particles.

Applications: Greece's, oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors, and hydraulic systems.

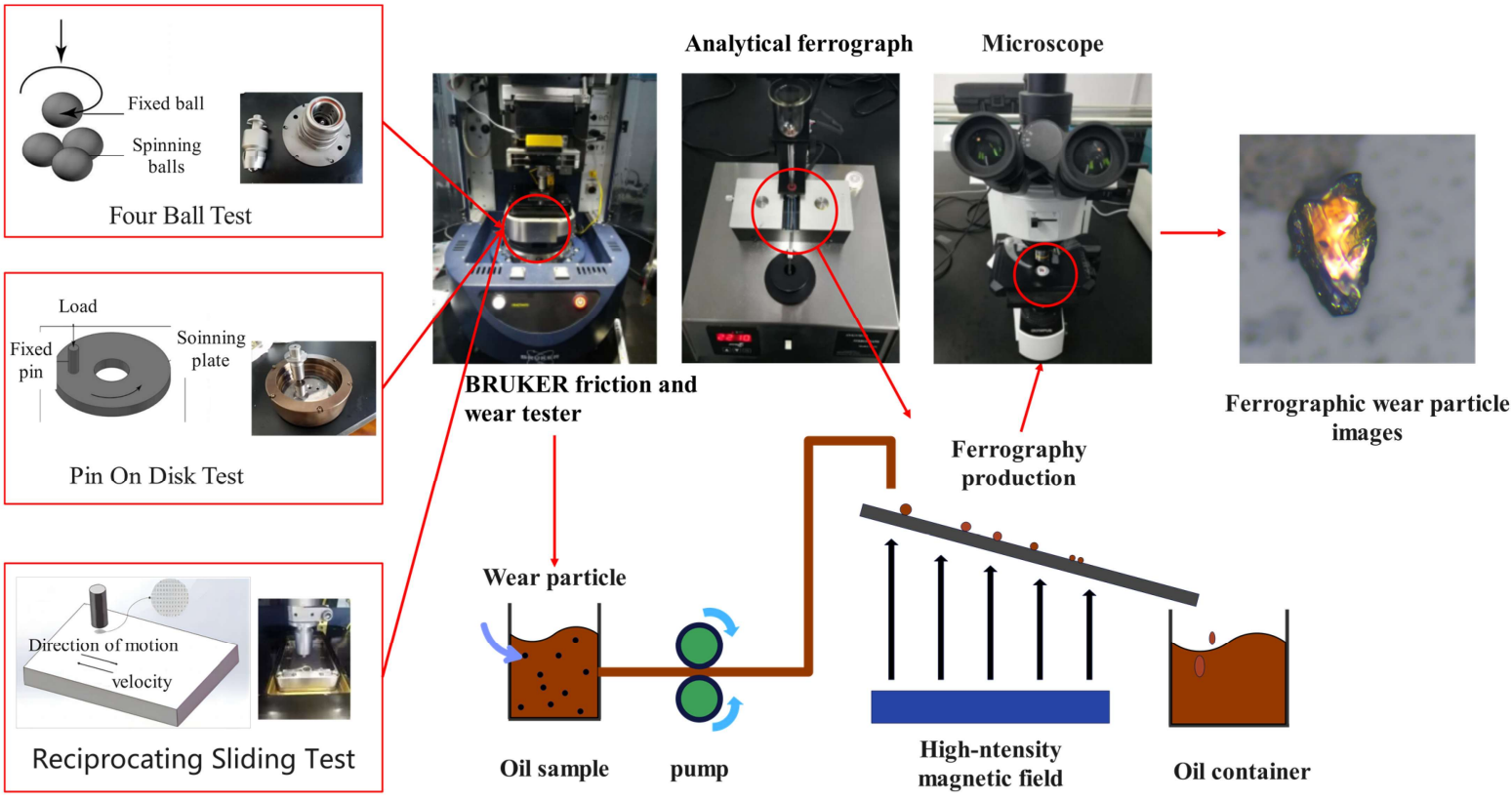
P-F Interval: Usually several months.

Operation: A representative sample is diluted with a fixer solvent tetrachloroethylene and then Passover an inclined glass slide under the influence of a graduated magnetic field. The particles are distributed along the length of the slide according to the size. Larger particles are deposited near the entry while fine particles are deposited near the exit of the slide this slide, known as a ferrogram, is treated so that the particles adhere to the surface when the oil is removed. Ferrous particles are separated magnetically and are distinguished by their alignment to the magnetic field lines, While non-magnetic and nonmetallic particles are distributed in a random fashion over the entire slide the total density of the particles Indicated type and extent of wear. Analysis is done by a technique known as biochemomatic microscopic examination. This uses both reflected and transmitted light sources which may be used simultaneously. Green, red and polarized filters are used also to distinguish the size, composition, shape and texture of both metallic and non-metallic particles. Electron microscope can also be used to determine particle shape and provide an indication of the cause of the failure.

Specialized Skills / Training / Experience Required: To draw a sample and operate the Ferrograph, a suitably trained semi-skilled worker. To analyze and interpret the results requires an experienced technician.

Advantages: More sensitive than emission spectrometry at the early stages of wear. Measures particles shape and sizes. Provides a permanent pictorial record.

Disadvantages: Not an on-line technique. Time consuming and needs some very expensive analytical support equipment. Measures generally only their ferromagnetic particles Requires an electron microscope for in depth analysis.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.02 ANALYTICAL FERROGRAPHY

Conditions Monitored: Wear, fatigue and corrosion particles.

Applications: Grease, oils used in diesel and gassing engines, gas turbines transmissions, gearboxes, compressors and hydraulic systems.

P-F Interval: Usually several months.

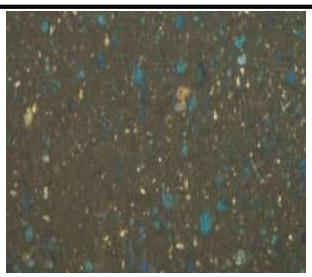
Operation: An analytical ferrograph is used to prepare a ferrogram as described under ferrography After the particles have been deposited on the ferrogram, a wash is used to flush away any remaining oil or water-based lubricant once the wash evaporates, the particles remain permanently attached to the substrate on the feral gram. A ferrogram scanner scans the ferrogram in less than 20 seconds and generates standard output values that correspond to the where mechanism. Various particles are graded by their types and shapes which reveal specific problems For example laminar metals (having a 'peeled look') long and thin) often indicate a problem with roller bearings. Red oxide typically are rust likely water contamination. The software then reports the wear levels and changes in condition of the component.

Specialized Skills / Training / Experience Required: To draw a sample and operate Ferrograph a suitably trained semi-skilled worker. To analyze and interpret the results, an experienced technician is required.

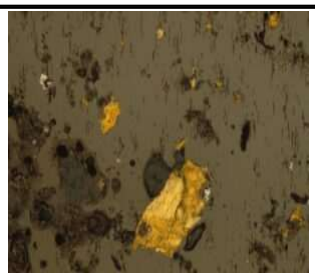
Advantages: Available in a wide range of on-line systems. In depth evaluation, Photographic recording and database management. Less affected by fluid opacity and water contamination than other techniques.

Disadvantages: Expensive equipment. Time consuming sample preparation and analysis. The need to dilute samples reduces the chance that the sample will actually be representative of actual wear.


Aluminum

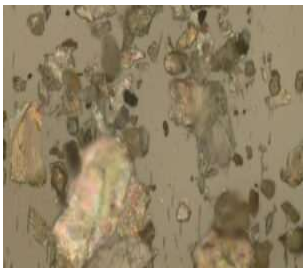

Normal Rubbing/Sliding Wear


ALUMINUM


Normal Rubbing/Sliding Wear

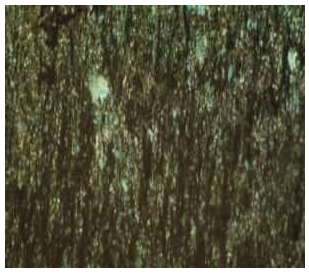

Cutting Wear

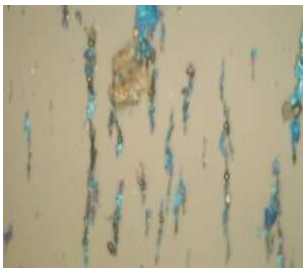

Aluminum


Dirt/Dust/Debris


Fibers/Cellulose

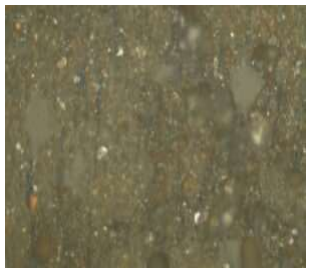

Laminar Wear


Organic Debris


Spheres


Severe Sliding Wear


Red Oxides (Rust)


Inorganic Debris

PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.03 DIRECT READING FERROGRAPH (DRF)

Conditions Monitored: Machine wear, fatigue and corrosion particles.

Applications: Oils used in diesel and gasoline engines, gas turbines, Transmissions, gearboxes, compressors and hydraulic systems.

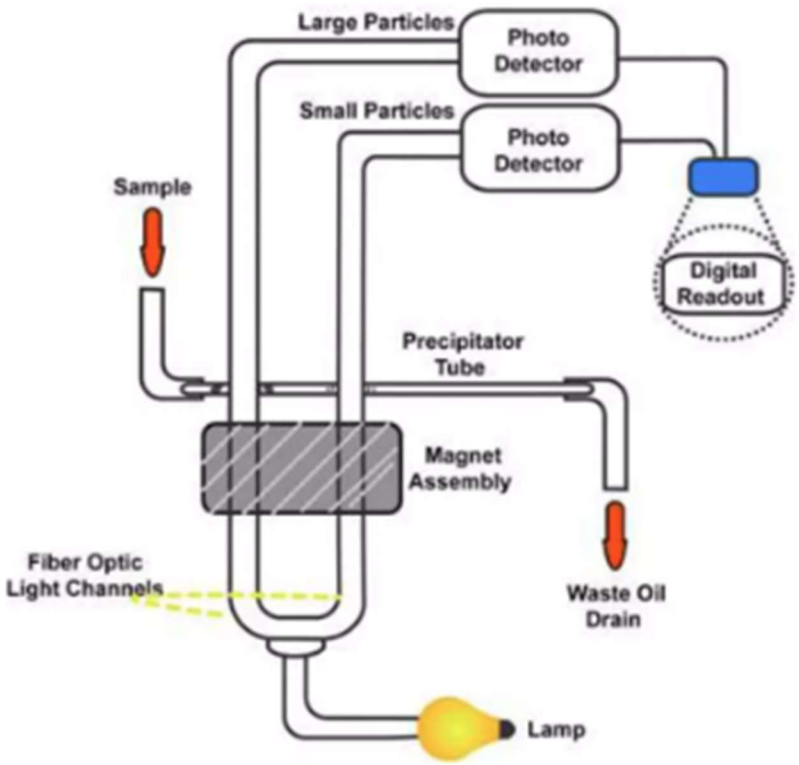
P-F Interval: Usually several months.

Operation: A DRF quantitatively measures the concentration of ferrous particles in a fluid sample by precipitating these particles into the bottom of a glass tube subjected to a strong magnetic field. Fiber optic bundles direct light through the glass tube at two positions corresponding to the location where large and small particles are deposited by the magnet. The light is reduced in relation to the number of particles deposited in the glass tube and this reduction is monitored and displayed electronically. Two sets of readings are obtained for large and small particles above and below 5 microns which is plotted on a graph.

Specialized Skills / Training / Experience Required: A suitably trained semi-skilled worker.

Advantages: Compact, portable, on-line technique, easy to operate. Less sensitive to fluid opacity and water contamination than some techniques.

Disadvantages: Measures only ferromagnetic particles Requires further analytical ferrographic analysis when readings are high.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.04 MESH OBSCURATION PARTICAL COUNTER (PRESSURE DIFFERENTIAL)

Conditions Monitored: Particles in lubricating in hydraulic oil systems caused by wear, fatigue, corrosion and contaminants.

Applications: Enclosed lubricating in hydraulic oil systems such as engines, gearboxes transmissions, compressors, etc.

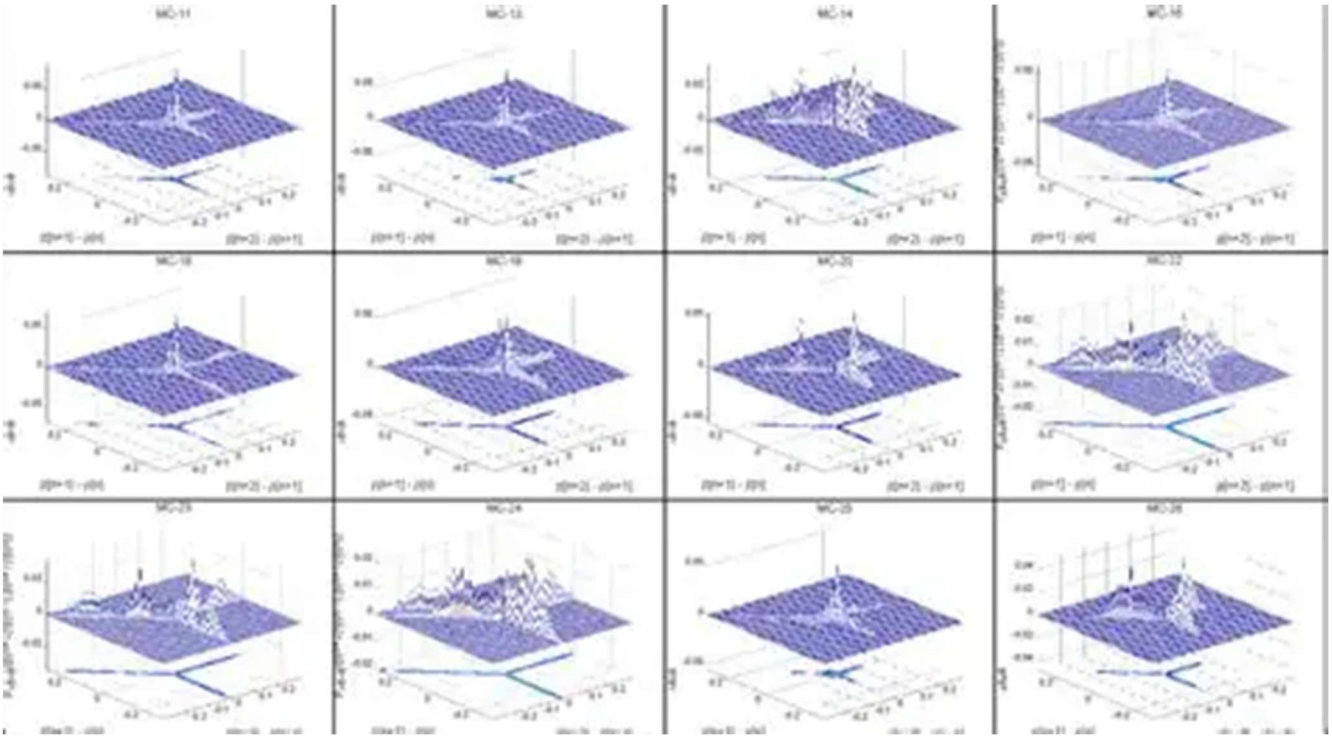
P-F Interval: Usually several weeks to months.

Operation: This instrument measures the differential pressure across three high precision 515 25 Micron screens, each with a known number of pores. As the oil passes through each screen, particles larger than the pores are trapped on the mesh surface, which reduces the open area of the screen and increases the pressure drop across the screen. Sensors measure the pressure change which is converted to reflect the number of particles larger than the screen size. This is converted in turn to an ISO 4406 Cleanliness Codes.

Specialized Skills / Training / Experience Required: To operate the portable unit requires a suitably trained semi-skilled worker. To interpret the results, a suitably trained experienced technician.

Advantages: No pre sample preparation is required. Equipment is portable and can be used in the field or in the laboratory An in-line version of the equipment can be used for real time continuous monitoring. Particle counts are calibrated to an ISO 4406 Cleanliness Standard. Most oils can be analyzed in a matter of minutes. Not affected by bubbles emulsions or dark oils that emit laser-based analyzers.

Disadvantages: Provides no indication of the chemical composition of particles only applicable to circulating oil systems. Equipment moderately expensive.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.05 PORE-BLOCKAGE (FLOW DECAY) TECHNIQUE

Conditions Monitored: Particles in lubricating and hydraulic oil caused by wear, fatigue, corrosion and contaminants.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors and hydraulic systems.

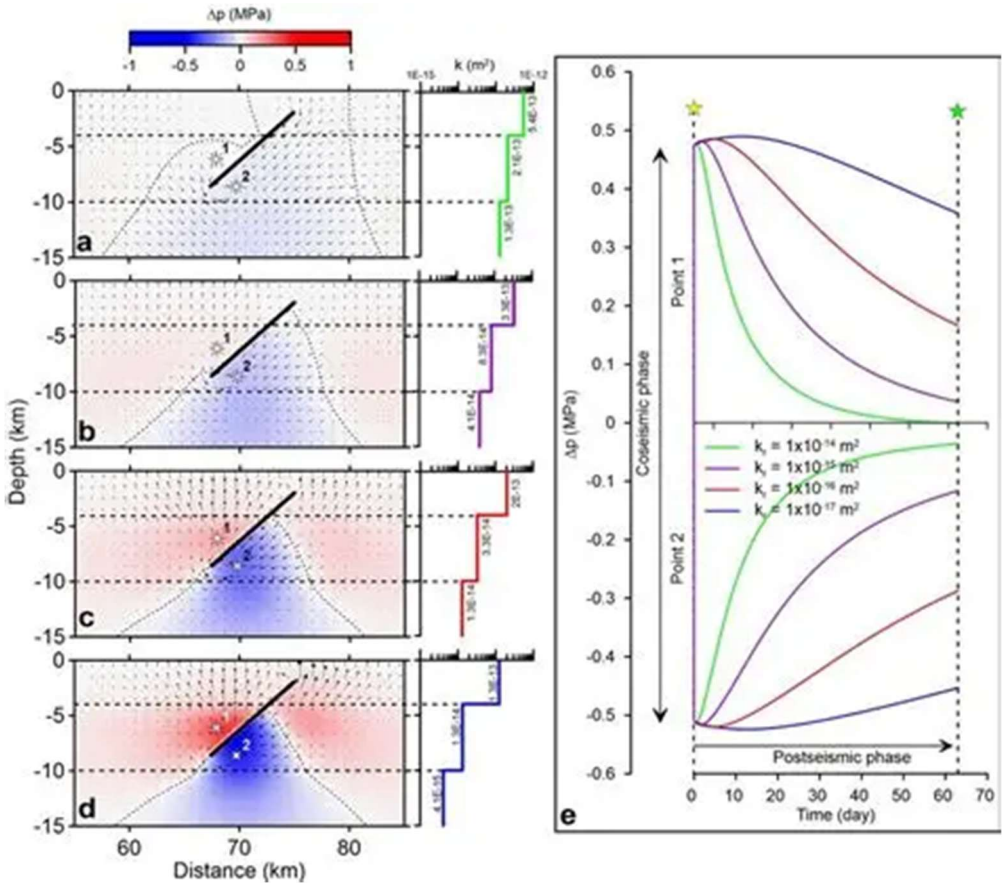
P-F Interval: Usually several weeks to months.

Operation: . A fluid sample is pressurized between 30 and 150 PSI can go as high as 3000 PSI and allowed to flow through a selected precision calibrated screen between 5, 10, and 15 Micron dependent on oil viscosity, in a sensor assembly. Particles larger than the screen start to accumulate, restricting the flow. Smaller particles gather around the bigger particles and restrict the flow even further The result is a flow decay time curve. The hand-held computer uses a mathematical program to convert the flow decay time curve to a particle size distribution. This is used to compare an ISO cleanliness code.

Specialized Skills / Training / Experience Required: To operate the portal equipment, a suitably trained skilled worker. To interpret the results, a suitably trained and experienced technician.

Advantages: No pre sample preparation needed. Equipment is portable and can be used in the field or in the laboratory An in-line version of the equipment can be used for continuous monitoring. Particle counts are calibrated to an ISO 4406 Cleanliness Standard. Most oils can be analyzed in a matter of minutes.

Disadvantages: Lacks the intensity and consistency of laser and fails to overcome reaction of many different wavelengths of light. Accuracy is dependent on fluid opacity, the number of translucent particles, air bubbles and water contamination. The counting size may also be very dependent on the orientation of long, thin or unusually shaped particles in the light beam. Resolutions limited to 5 microns particle range. Provides no information on the chemical composition of the contaminants.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.06 LIGHT EXTINCTION PARTICLE COUNTER

Conditions Monitored: Particles and lubricating in hydraulic oil caused by wear, fatigue, corrosion and contaminants.

Applications: Oils used in diesel gasoline engines gas turbines, transmissions, gearboxes, compressors and hydraulic systems.

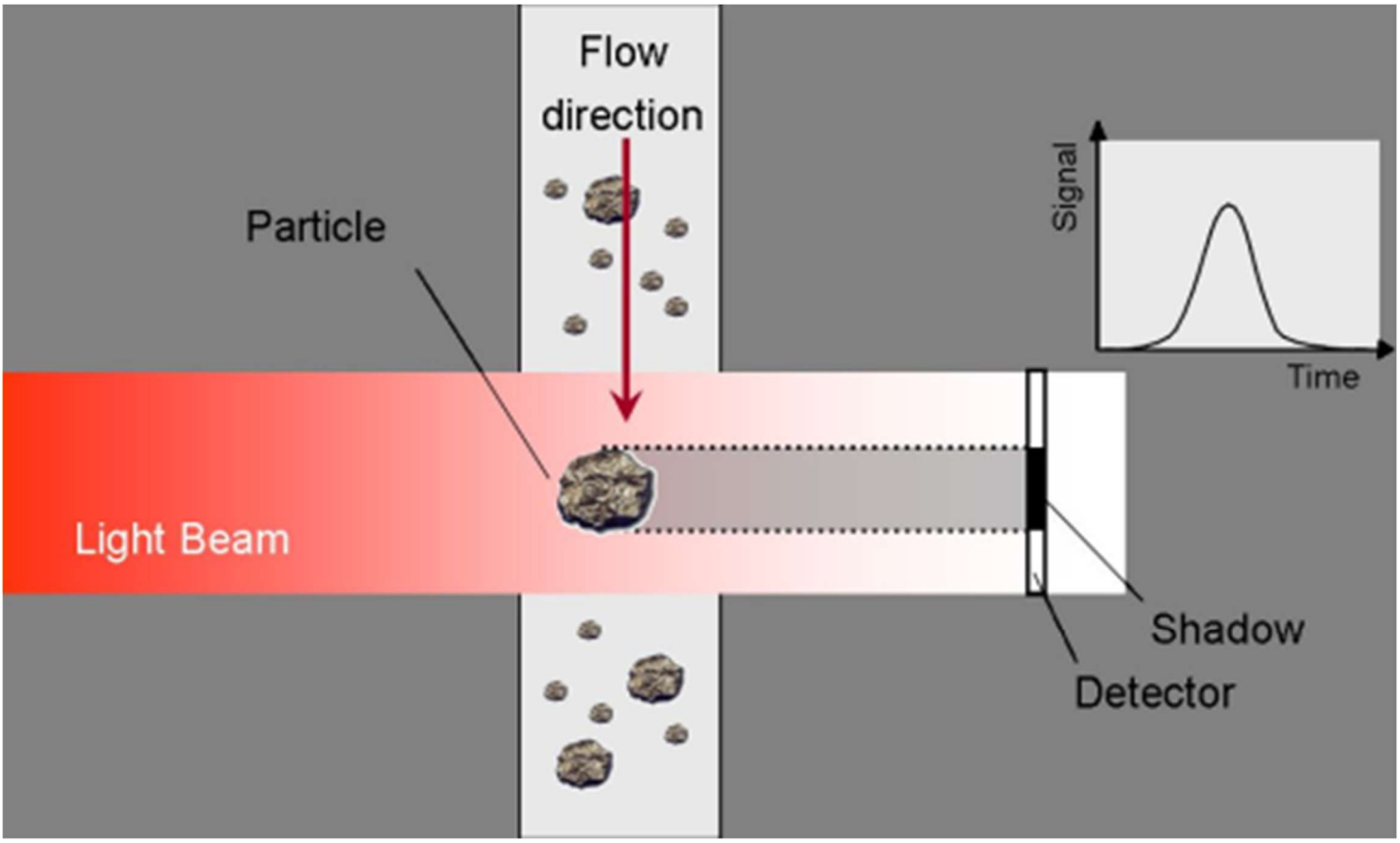
P-F Interval: Usually several weeks to months.

Operation: The light extinction particle counter consists of an incandescent light source, An object cell and a photo detector. The sample fluid moves through the object cell under controlled flow and volume conditions. When opaque particles in the fluid pass through the beam it blocks an amount of light proportional to the size of the particle. The number and size of the particles in the oil sample determine how much light is blocked or reflected and how much light passes through to the photodiode. The resultant change in the electrical signal at the photodiode is analyzed against a calibrated standard to calculate the number of particles in predetermined size ranges and displays the count. From this information a direct reading of the ISO cleanliness value is determined automatically.

Specialized Skills / Training / Experience Required: To operate the portal equipment, a suitably trained skilled worker is required.

Advantages: Considerably faster than visual graduated filtration. Test results available within minutes. Generally, the test is quite accurate and reproducible.

Disadvantages: Lacks the intensity and consistency of laser and failed to overcome reaction of many different wavelengths of light. Accuracy dependent on fluid opacity, the number of translucent particles, air bubbles and water contamination. The counting size may also vary depending on the orientation of long thin or unusually shaped particles in the light beam. Resolutions limited to 5 microns particle range. Provides no information on chemical composition of the contaminants.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.07 LIGHT SCATTERING PARTICLE COUNTER

Conditions Monitored: Ferromagnetic particles caused by wear and fatigue and lubricating and hydraulic oils caused by wear fatigue corrosion and contaminants.

Applications: Enclosed lubricating and hydraulic oil systems such as engines, gearboxes, transmissions, compressors etc.

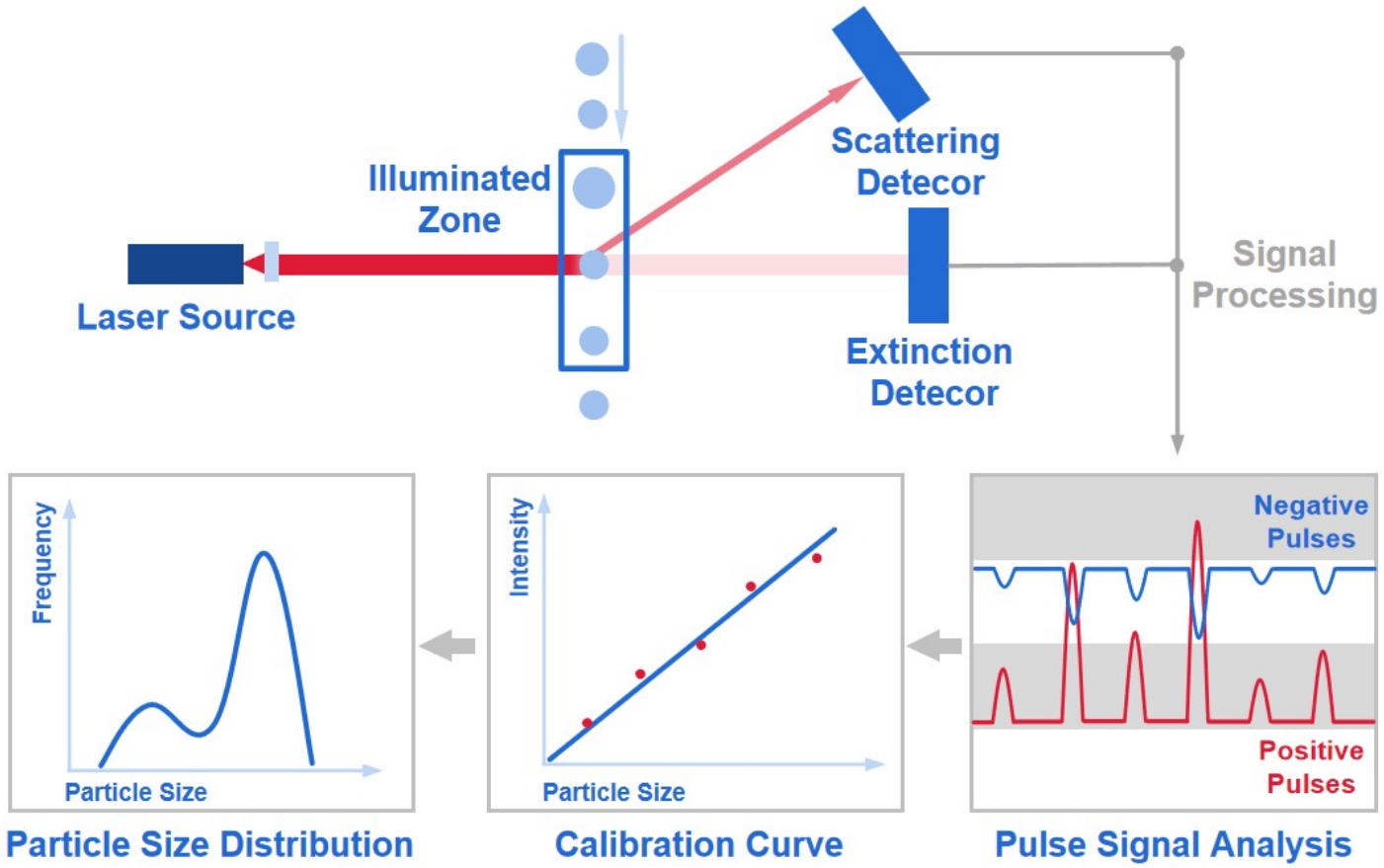
P-F Interval: Usually several weeks to months.

Operation: The light scattering particle counter consists of three primary components: a laser light source, An object cell and a photo diode. The sample fluid moves through the object cell under controlled flow and volume conditions. When opaque particles in the fluid pass through the beam, the scattering of light is measured and translated into a particle count. From this information a direct reading of the ISO cleanliness value is determined automatically.

Specialized Skills / Training / Experience Required: A soon to be trained skilled worker.

Advantages: Good performance in settings where conditions are controlled. High accuracy. Measures particles smaller as 2 microns. Faster than visual graded filtration, test results available within minutes. Generally, the test is quite accurate and reproducible. Continuous monitoring is possible.

Disadvantages: Accuracy depended on fluid opacity the number of translucent particles, air bubbles and water contamination. The counter size may also vary depending on the orientation of long, thin or unusually shaped particles in the light beam. Provides no information on a chemical composition of contaminants. Dilution is often required for high particle concentration to avoid coincidence error where several particles bunch together and appear as one large particle.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.08 REAL TIME FERROMAGNETIC SENSOR

Conditions Monitored: Feral magnetic particles caused by wear and fatigue.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors and hydraulic systems.

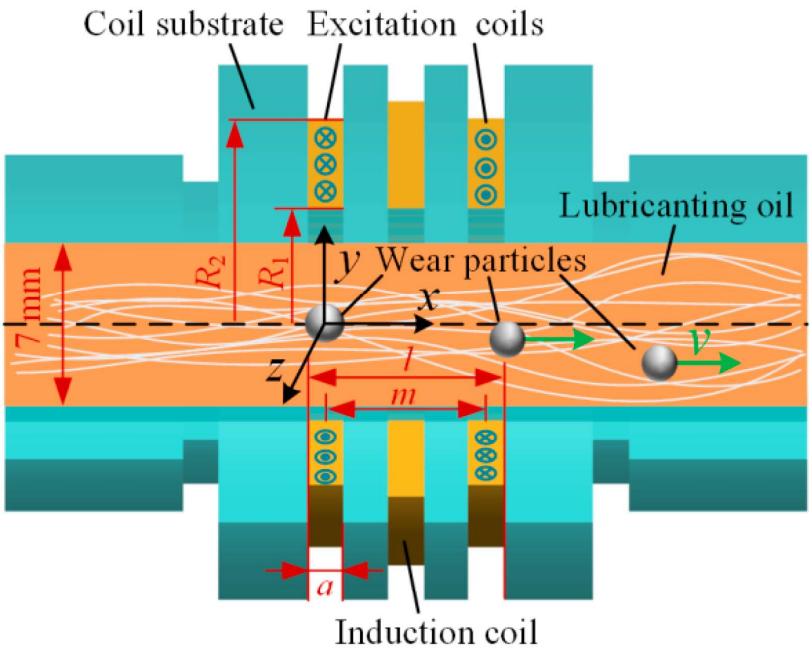
P-F Interval: Weeks to months.

Operation: An analog ferromagnetic sensor uses an inductive or magnetic principle to measure the quantity of ferrous particles passing the sensor. The sensor attracts the first particles with an electromagnet The particles collect around a sensing coil causing a change in an oscillator frequency. The frequency is calibrated to indicate the mass of ferrous particles collected. After a measurement has been taken the particles are released Measurements can be trended over time.

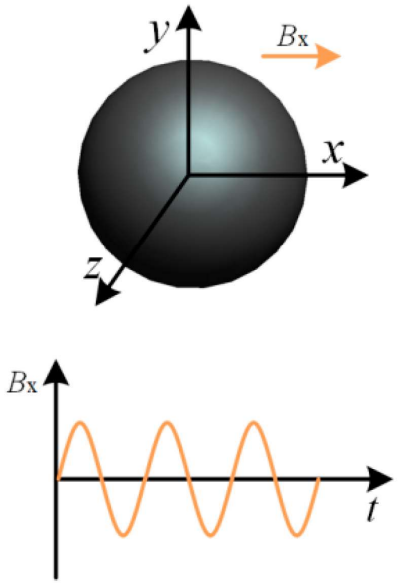
Specialized Skills / Training / Experience Required: Experience skilled worker or technician.

Advantages: On-line technique.

Disadvantages: Limited to collecting ferromagnetic particles only. Case mass of ferromagnetic particles only.



(a)



(b)

PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.09 ALL METAL DEBRIS SENSORS

Conditions Monitored: Ferris and non-ferrous particle was due to wear and fatigue.

Applications: Designed specifically for the protection of gas turbine bearings.

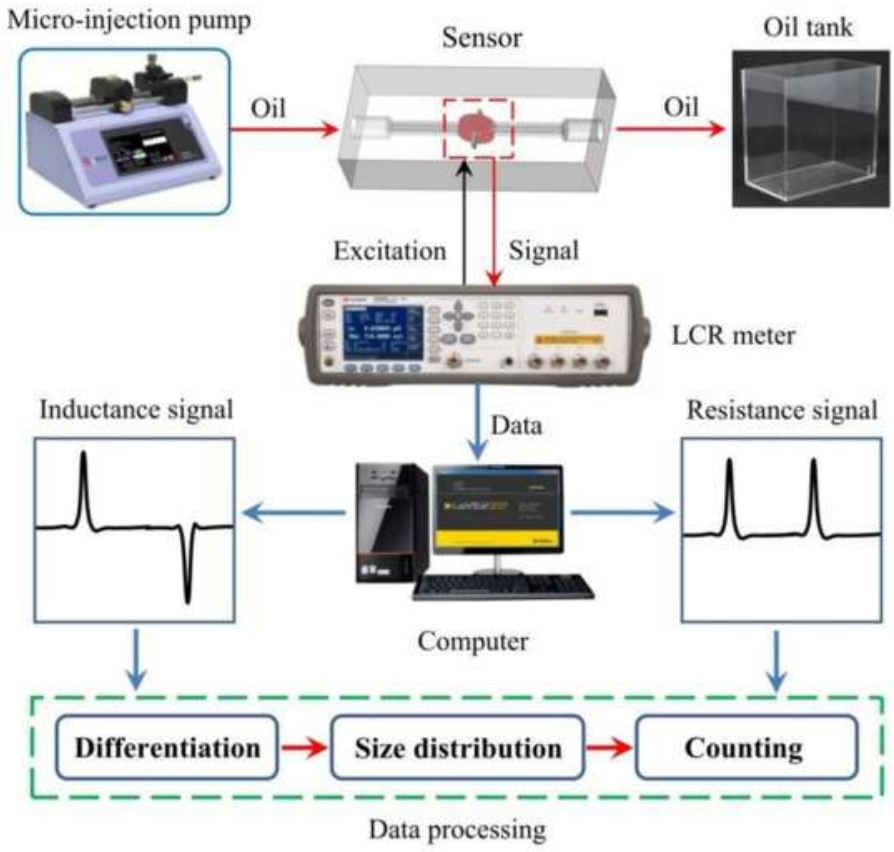
P-F Interval: Weeks to months.

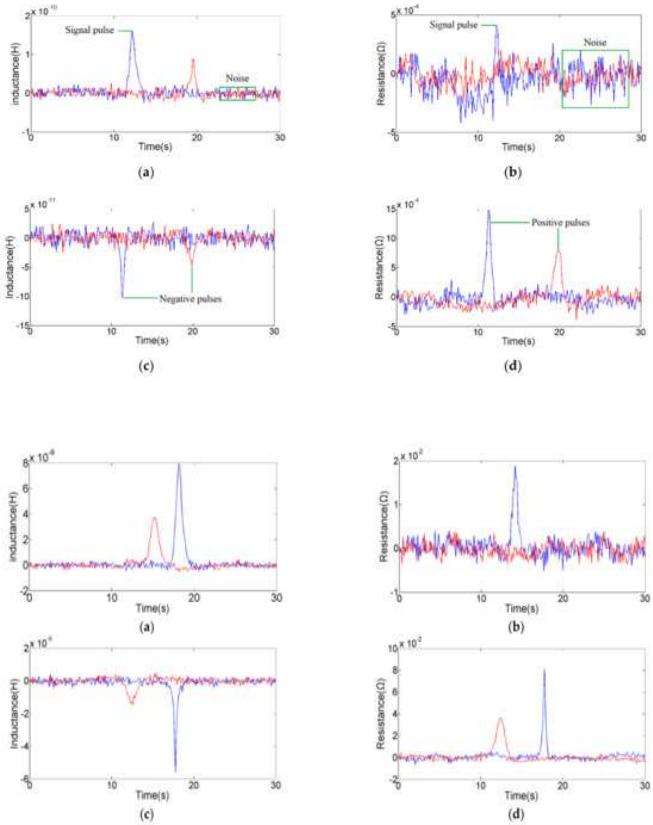
Operation: The sensor head consists of three coils wound around an insulating section of pipe. The outer stimulus coils are energized with an opposing high frequency signal. The sense coil middle is placed exactly at the null point between the stimulus coils. When a ferrous particle passes through the sensor, it disturbs the first field and then the 2nd, generating a readily detectable signature in the sense coil. A non-ferrous particle generates a unique and opposite signature. The sensor will detect and measure most of the severe wear particle range. These signatures are captured and stored as time domain plots and are used in real time to alert or advise operators, or to signal automatic processes from control systems.

Specialized Skills / Training / Experience Required: Experienced skilled worker or technician to trend results required.

Advantages: Detects and quantifies both ferrous and nonferrous wear metal particles. Low probability of false indication. Onboard sensors can capture and store the same domain plots of various damage modes which can be used for identification of where sources in near real time.

Disadvantages: Cannot determine chemical composition and size of particles.





PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.10 GRADED FILTRATION

Conditions Monitored: Particles in lubricating hydraulic oils caused by wear, fatigue, corrosion and contaminants.

Applications: Oils used in diesel and gasoline engines gas turbines transmissions gearboxes compressors and hydraulic systems.

P-F Interval: Usually several weeks to months.

Operation: A small amount of oil (100 ml) is diluted with passed through a series of standard filter discs. Each disk is then examined under a microscope and the particles are counted manually. The results are expressed as the number of parts in a particular size range Their statistical distribution is shown in the form of a graph. Analysis of the particles' distribution profiles indicate whether wear is normal or not.

Specialized Skills / Training / Experience Required: Sampling is required by a Laboratory Assistant. Examination of particle distribution profiles requires an experienced laboratory technician or engineer.

Advantages: Contaminants such as metal chips, pieces of seal material, or dirt can be identified visually. Relatively cheap

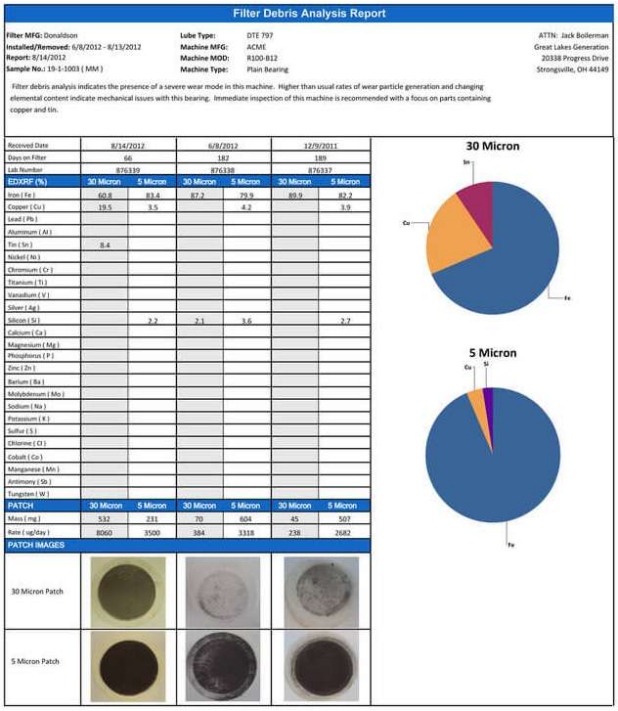
Disadvantages: Subjective because the operator has to determine visually the size of the particles, even though there are grid marks for reference through the microscope. Setting up and examining each filter disk sample takes several hours. Specialist skill required to interpret the test results. Identification of particle elements is difficult.

In this example, you can see how the particles measured at the given micron levels are assigned the specific code based on where that value falls in the table. For this example, the ISO code would be 20/17/13.

Table 1

	PARTICLES/ML	ISO CODE
>4 microns	9,721	20
>6 microns	1,254	17
>10 microns	326	
>14 microns	73	13
>21 microns	12	
>38 microns	5	
>70 microns	0	
>100 microns	0	

MORE THAN	UP TO AND INCLUDING	ISO CODE
(p/ml)	(p/ml)	
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8



Filter Debris Analysis Report

Filter MFG: Donaldson
Installed/Removed: 6/8/2012 - 8/13/2012
Report: 8/14/2012
Sample No.: 19-1-1003 (MM)

Lube Type: DTE 797
Machine MFG: ACME
Machine MOD: R100-B12
Machine Type: Plain Bearing

ATTN: Jack Boilerman
Great Lakes Generation
20338 Progress Drive
Strongsville, OH 44149

Filter debris analysis indicates the presence of a severe wear mode in this machine. Higher than usual rates of wear particle generation and changing elemental content indicate mechanical issues with this bearing. Immediate inspection of this machine is recommended with a focus on parts containing copper and tin.

	8/14/2012		6/8/2012		12/9/2011	
Days on Filter	66		182		189	
Lab Number	876339		876338		876337	
EDXRF (%)	30 Micron	5 Micron	30 Micron	5 Micron	30 Micron	5 Micron
Iron (Fe)	60.8	83.4	87.2	79.9	89.9	82.2
Copper (Cu)	19.5	3.5		4.2		3.9
Lead (Pb)						
Aluminum (Al)						
Tin (Sn)	8.4					
Nickel (Ni)						
Chromium (Cr)						
Titanium (Ti)						
Vanadium (V)						
Silver (Ag)						
Silicon (Si)		2.2	2.1	3.6		2.7
Calcium (Ca)						
Magnesium (Mg)						
Phosphorus (P)						
Zinc (Zn)						
Barium (Ba)						
Molybdenum (Mo)						
Sodium (Na)						
Potassium (K)						
Sulfur (S)						
Chlorine (Cl)						
Cobalt (Co)						
Manganese (Mn)						
Antimony (Sb)						
Tungsten (W)						
PATCH	30 Micron	5 Micron	30 Micron	5 Micron	30 Micron	5 Micron
Mass (mg)	532	231	70	604	45	507
Rate (ug/day)	8060	3500	384	3318	238	2682
PATCH IMAGES						
30 Micron Patch						
5 Micron Patch						

30 Micron

5 Micron

PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.11 MAGNETIC CHIP DETECTION

Conditions Monitored: Wear and fatigue.

Applications: Oils used in diesel and gasoline engines, gas turbines transmissions gearboxes compressors and hydraulic systems.

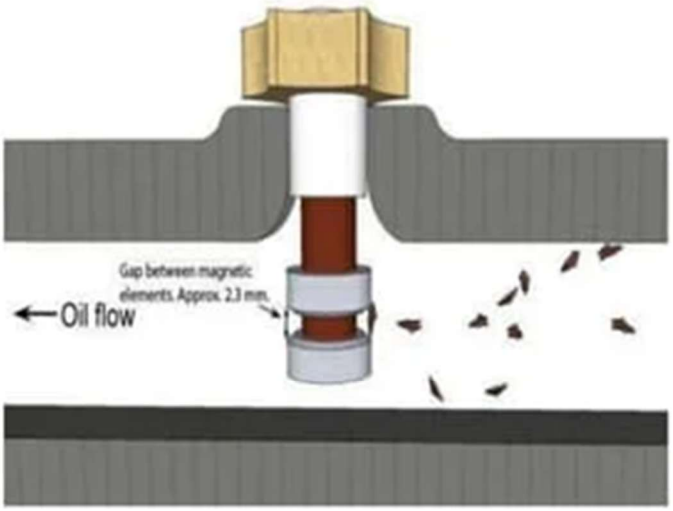
P-F Interval: Days to weeks.

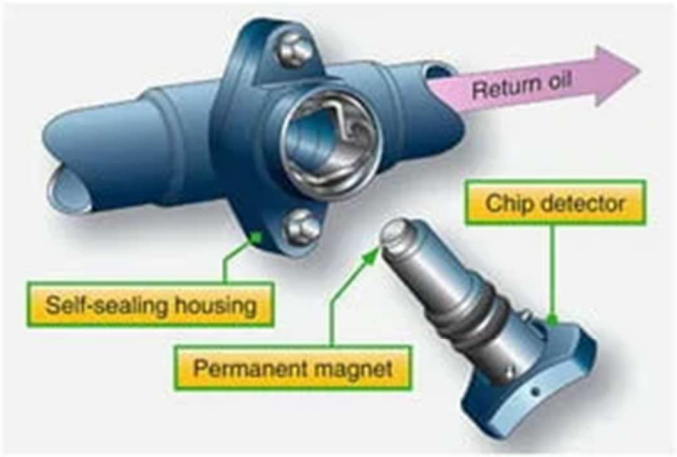
Operation: A magnetic plug is mounted in the lubrication system so that the magnetic probe is exposed to the circulating lubricant Find metal particles suspended in the oil and metal flakes from fatigue breakup are captured by the probe. The probe is removed regularly for microscopic examination of the returned particles. An increase particle size indicates imminent failure. The debris has different characteristics such as shape, color and texture depending on its source.

Specialized Skills / Training / Experience Required: To collect the sample requires a suitably trained semi-skilled worker. To analyze the debris requires a suitably trained and experienced technician.

Advantages: Cheap. Low powered microscope only required for the analysis of the debris. Some probes can be removed without loss of lubricant.

Disadvantages: Short PF interval. High skill required to interpret the debris.





PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.14 SEDIMENT (ASTM D-1698)

Conditions Monitored: Inorganic sediments from contamination, organic sediment from oil deterioration or contamination Soluble sludge from oil deterioration.

Applications: Petroleum based insulating oils and transformers Breakers and cables.

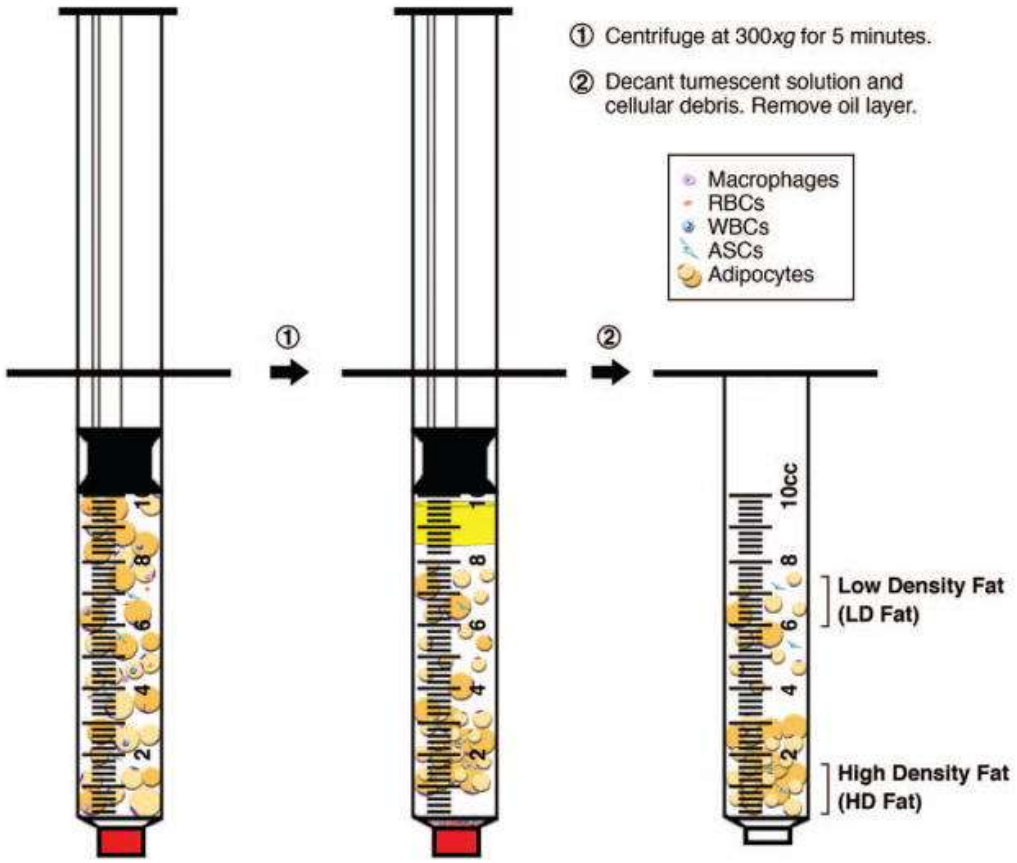
P-F Interval: Several weeks.

Operation: An oil sample is centrifuged to separate the sediment from the oil. The upper, sediment free portion is decanted and used to measure soluble sludge by dilution with pentane to precipitate pentane in insoluble and filtration through a filtering Crucible. The sediment is dislodged and filtered through a filtering Crucible. After drawing and waiting to obtain total sediment the Crucible is ignited at 500℃ and reweighted. Loss in weight is organic and the remainder is inorganic content of the sediment.

Specialized Skills / Training / Experience Required: Taking the sample requires an electrician for safety reasons. To conduct a test requires a suitably trained laboratory technician.

Advantages: Test is quick and easy. Transformer does not have to be taken offline to monitor the insulating fluid.

Disadvantages: Test suitable for low viscosity oils only, for example 5.7 to 13.0 cSt at 40℃ (104℉). Test has to be conducted in a laboratory. Pentane is mildly toxic and flammable.



PARTICLE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

2.15 LIDAR (LIGHT DETECTION AND RANGING)

Conditions Monitored: Presence of particles in the atmosphere.

Applications: Quality and dispersant of plumes of smoke from smokestacks.

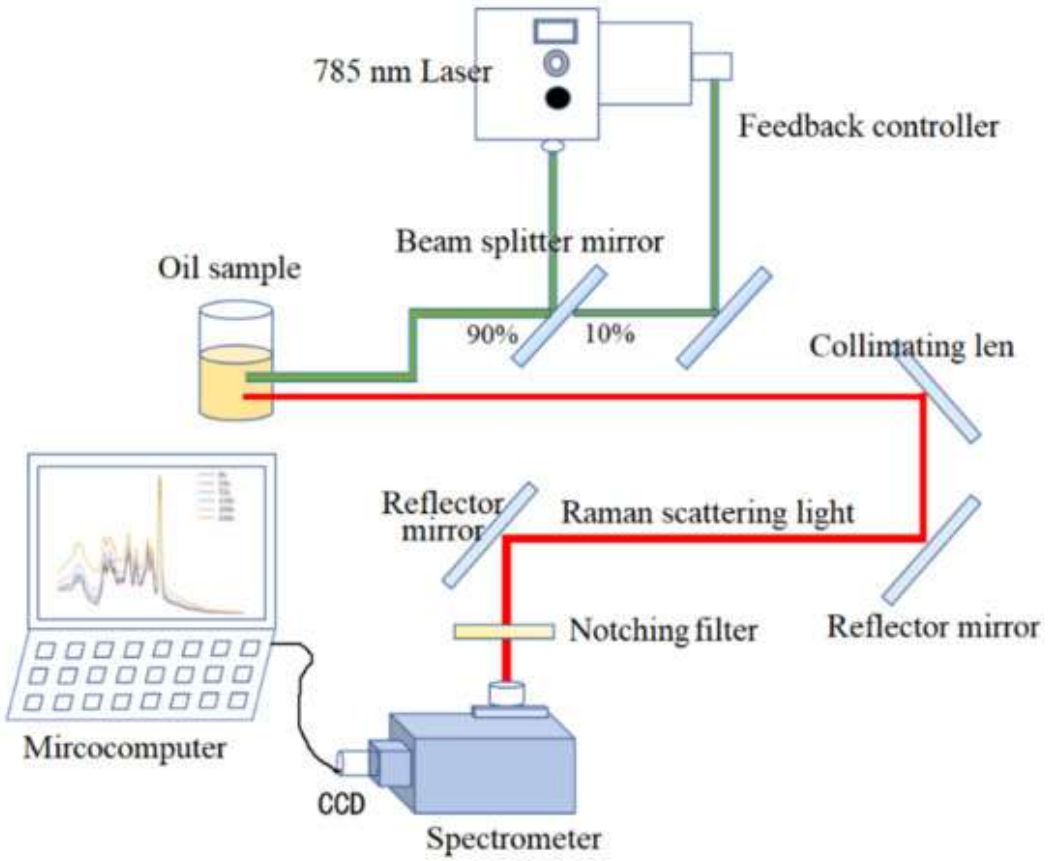
P-F Interval: Highly variable depending on the application.

Operation: Sing away form light is directed to the area under investigation. The quantity of particulate matter is assessed by measuring back scatter. Locations are determined by triangularization based on reasons taken from two points.

Specialized Skills / Training / Experience Required: An experienced engineer is required.

Advantages: A remote sensing technique which can cover large areas.

Disadvantages: Very expensive. A high level of skill.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON THE CHEMICAL DETECTION OF CONTAMINATES IN FLUIDS

The techniques described in this section of my predictive and detective techniques are used to detect elements in fluids usually lubricating oils which indicate that a potential failure has occurred elsewhere in the system, as opposed to incipient failure of the liquid lubricating oils is self. The elements most commonly detected by these techniques are listed below and can appear as a result of wear, leaks or corrosion.

- **Aluminum**. From Pistons, journal barons, shims, thrust washers, Accessory castings, bearing cages of planetary, pumps, gears gear pumps, etc.
- **Antimony**. From some barren alloys and grease compounds.
- **Chromium**. From the wear plated components such as shafts seals piston rings cylinder liners bearing cages and some bearings.
- **Copper**. From journal barons, thrust barons, Cam and rocker arm bearings piston pin bushings, gears, valves, clutches and turbocharger bearings. Present in brass or bronze alloys and often detected in conjunction with zinc in the former and in the latter.
- **Iron**. From cast cylinder liners, piston rings, pistons, camshaft, crankshafts, valve guides, anti friction bearing rollers and races, gears, shafts, Lube pumps and machinery structures, etc.
- **Lead**. From journal bearings and seals.
- **Magnesium**. From turbine accessory castings shafts and valves.
- **Manganese**. From valves and blowers.
- **Molybdenum**. From wear to plated upper piston rings in some diesel engines.
- **Nickel**. From valves, turbine plates, turbocharger cam plates and bearings.
- **Silver**. From locomotive engines, solder and needle bearings.

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON THE CHEMICAL DETECTION OF CONTAMINATES IN FLUIDS

The techniques described in this section of my predictive and detective techniques are used to detect elements in fluids usually lubricating oils which indicate that a potential failure has occurred elsewhere in the system, as opposed to incipient failure of the liquid lubricating oils is self. The elements most commonly detected by these techniques are listed below and can appear as a result of wear, leaks or corrosion.

- **Tin** From bearing alloys, brass, oil seals and solder.
- **Titanium**. Found in bearings hubs, turbine blades and compressor disks of gas turbine aircraft engines.
- **Zinc**. From brass components, neoprene seals.

Leaks: The following elements are associated with leaks.

- **Aluminum**. From atmosphere contamination.
- **Boron**. From coolant leaks in oil.
- **Calcium**. When found in fuel commerce generally indicates contamination by seawater.
- **Copper**. From oil cooler cores, coolant water in oil.
- **Magnesium**. From seawater contamination.
- **Phosphorus**. From Coolant Leaks in oil.
- **Potassium**. From Contamination by Seawater in oil.
- **Silicon**. From contamination by silica from induction systems or cleaning fluids.

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON THE CHEMICAL DETECTION OF CONTAMINATES IN FLUIDS

Leaks: The following elements are associated with leaks – cont.

- **Sodium**. From atmosphere contamination.

Corrosion: The following elements are associated with corrosion.

- **Aluminum**. From engine block corrosion.
- **Iron**. From corrosion in storage tanks and piping.
- **Manganese**. Sometimes found along with iron as a result of corrosion of steel.

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.01 ATOMIC EMISSION (AE) SPECTROSCOPY

Conditions Monitored: Wear metals such as iron, aluminum, chromium, copper, lead, tin, nickel, and silver. Oil additives containing boron zinc phosphorus calcium magnesium or barium. Extraneous contaminants such as silicon corrosion

Applications: Oils used in diesel and gasoline engines, gas turbines transmissions gearboxes compressors and hydraulic systems.

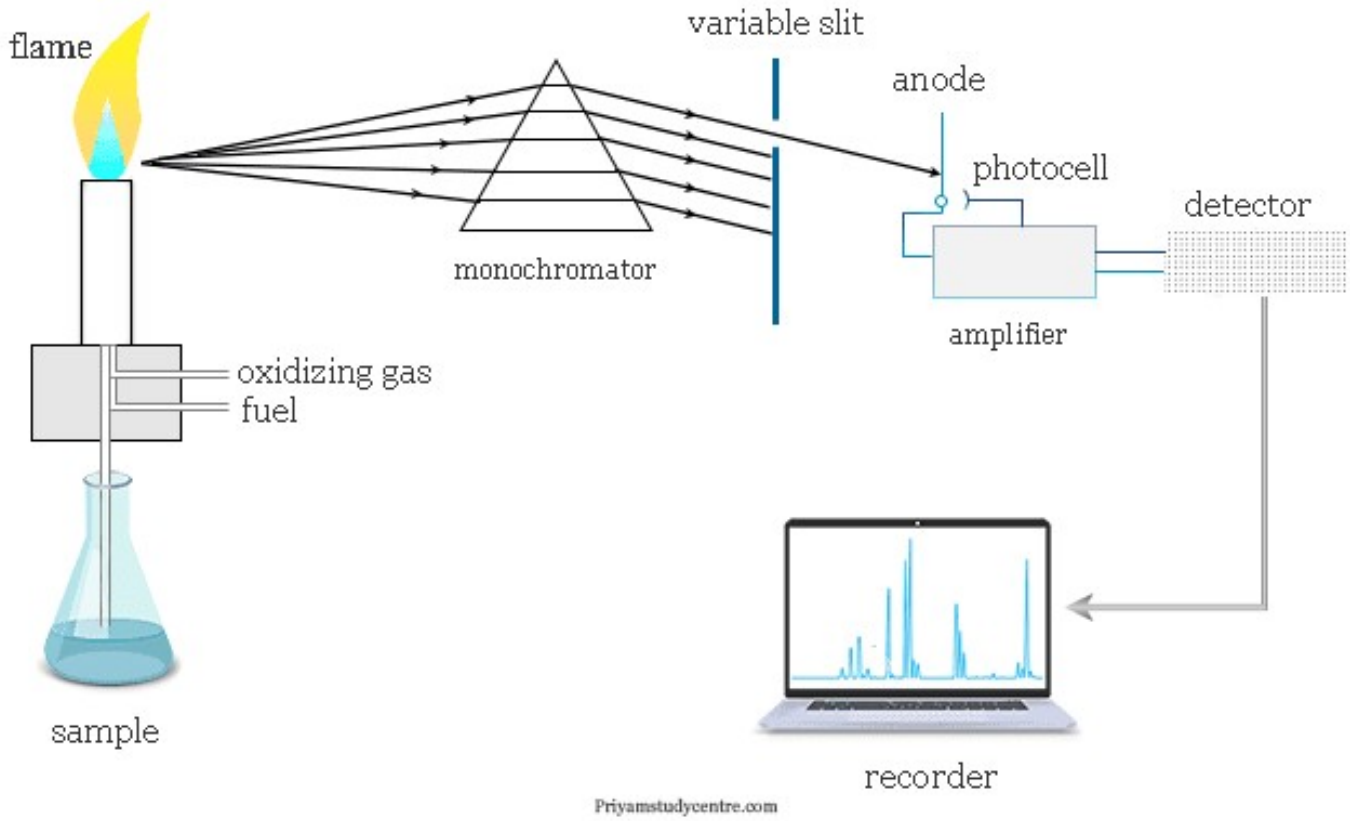
P-F Interval: Usually several weeks to months.

Operation: AE excites the wear metal elements in the sample by raising their Atomic Energy states in a high voltage (15kV) temperature source. The elements are atomized and emit their characteristic radiation. The resultant light energy passes through a slit to a diffraction grating which separates the individual mission lines from each element. The emission intensity at each characteristic wavelength of an element is proportional to the concentration of the element in that sample. A photomultiplier detector measures the intensity of each emission and transfers the value to a readout device usually a computer for additional processing and display. Standard curves are used to establish the relation between signal and element concentration values in parts per million.

Specialized Skills / Training / Experience Required: Skill to draw the sample, a suitably trained semis good worker to operate this spectrometer requires a suitably trained laboratory technician. To analyze the test results requires an experienced chemical analyst.

Advantages: And perform sequential or simultaneous measurements between 20 to 60 elements. Test takes just over one minute. Accurate within several PPM. Low cost.

Disadvantages: May fail to vaporize particles larger than 5 to 10 microns cannot determine the type of wear process that may be occurring.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.02 AE – ROTATING DISK ELECTRODE

Conditions Monitored: Trace levels of Ware materials extraneous contaminants and additive elements levels in lubricants, greases and fuels.

Applications: Enclosed lubricating systems in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors and hydraulic systems.

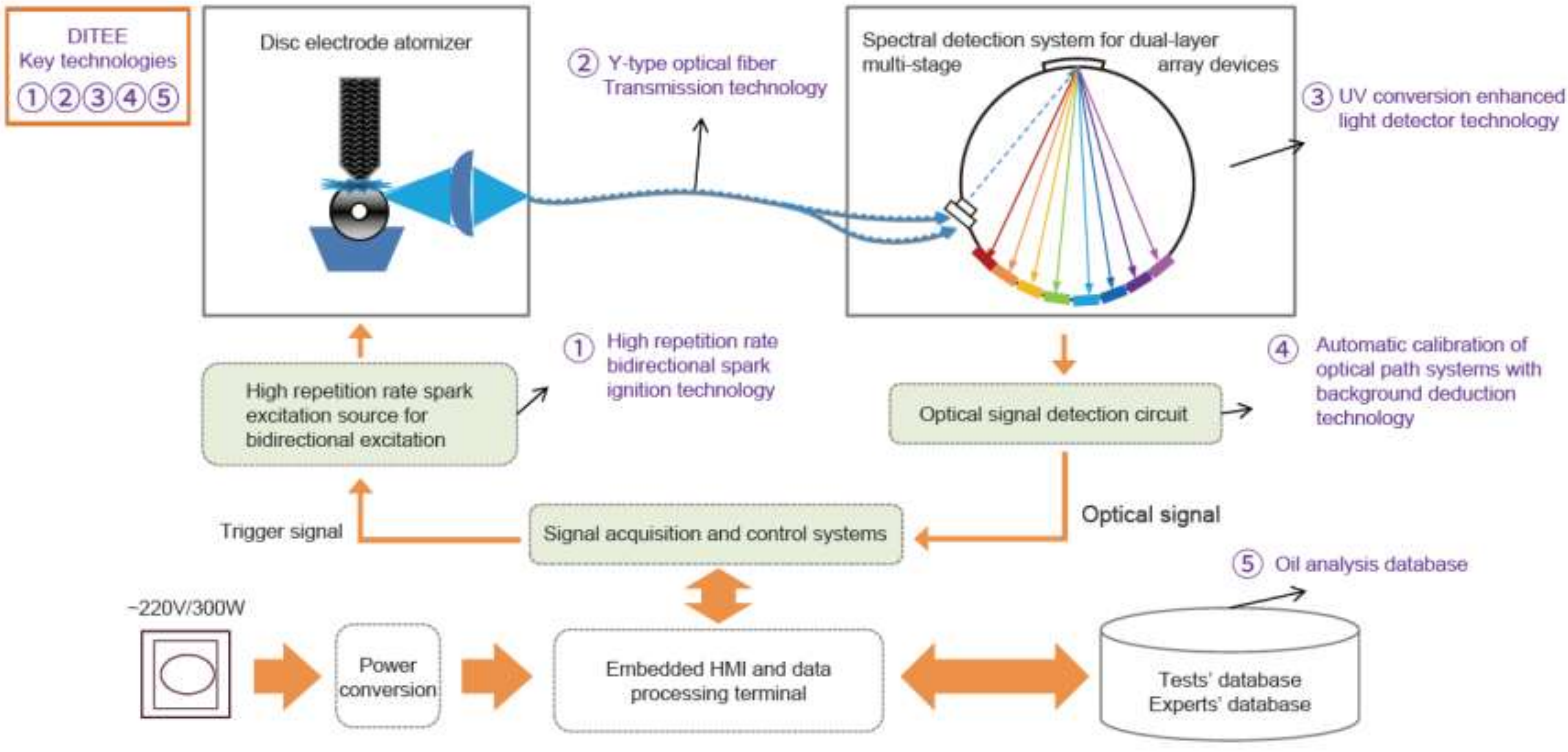
P-F Interval: Usually several weeks to months.

Operation: A rotating graphite disk is immersed into a sample vessel picking up a small sample of oil grease or fuel as it turns. The sample is introduced into a high temperature electric arc created in the gap between the disk electrode and the rod counter electrode This sample is completely fertilized, creating a plasma which emits light characteristic of the elements in the sample. The emission lines of each element are measured by an optical system and the results are displayed on a CRT and a printer in the parts per million PPM range.

Specialized Skills / Training / Experience Required: To draw the sample and to operate the machine requires a suitably trained technician. To analyze the test results requires a suit to be trained at laboratory technician.

Advantages: Simple to operate no pre sample preparation. Analytics takes about 30 seconds. Equipment is portable Up to 32 elements can be analyzed at the same time. No hazardous gasses are produced. High precision and good repeatability

Disadvantages: Can suffer from spectral interferences May fail to vaporize particles above 5 microns.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.03 AE – INDUCTIVELY COUPLED PLASMA (ICP)

Conditions Monitored: Wear materials from moving parts such as iron, aluminum, chromium, copper, lead, tin copper, nickel and silver. Oil additives containing boron, zinc phosphorus calcium magnesium or barium. Extraneous contaminants such as silicon Corrosion.

Applications: Four of using diesel and gasoline engines, gas turbines transmissions, gearboxes, compressors and hydraulic systems.

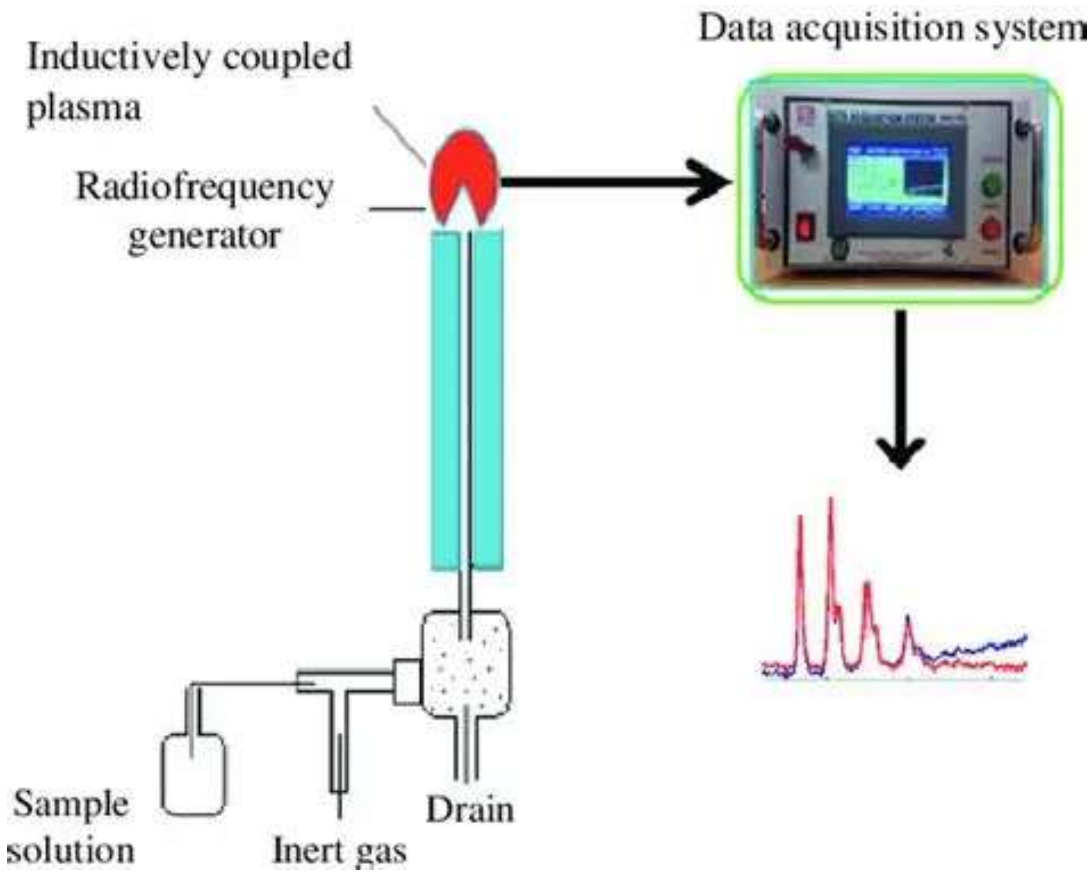
P-F Interval: Usually several weeks to months.

Operation: Argon gas is passed through a radio frequency induction coil and heated to a temperature of 8000 K to 10,000 K producing a plasma. The oil sample is diluted by a low viscosity solvent such as xylene or kerosene is nebulized and born by their argon gas carrier into the center of the plasma torch. The high temperature excites the metal atoms which radiate their characteristic emission lines. The lines are captured and measured by the optical system Instruments are available in simultaneous or sequential measurement modes. The sequential instrument uses a movable grating and a single photodetector. Multiple sequential burns are necessary to acquire all elements of interest.

Specialized Skills / Training / Experience Required: To draw the sample requires a suitably trained semi schooled worker to operate the spectrometer requires a suit to be trained technician. To analyze results requires an experienced technician.

Advantages: More accurate, reliable and repeatable than Rotary electrode method a large dynamic range permits single emission lines to be used for the measurement of a range of concentration levels. Provides parts per billion PPB sensitivity for compounds such as metal organics and where metal particles less than three microns in size. Fast and easy to operate. Need for operator to dilute samples manually prior to analysis.

Disadvantages: ICP spectrometer is more complex and expensive and has a higher operating cost than the Rotary disk spectrometer It uses hazardous chemicals thus generating higher waste costs. Where metal data generated by ICP were not correlated with data generated by other AE methods. May fail to vaporize particles above 5 microns.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.04 ATOMIC ABSORPTION (AA) SPECTROSCOPY

Conditions Monitored: Wear metals from moving parts such as iron, aluminum, chromium copper, lead, tin, nickel and silver. Oil additives containing boron, zinc phosphorus calcium magnesium or barium. Extraneous contaminants such as silicone. Corrosion.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes compressors and hydraulic systems.

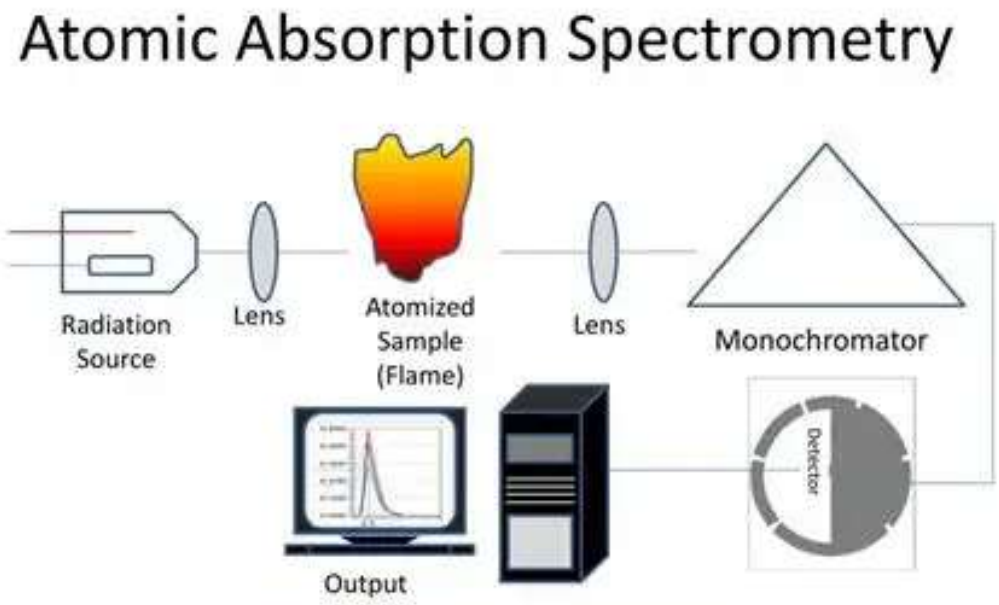
P-F Interval: Usually several weeks to months.

Operation: Works on the principle that every atom absorbs light of a specific wafer length. The oil sample is diluted and burned in an Acetylene flame or other atomizer hot enough to disassociate the sample into its constituent atoms. The flame is irradiated by a hollow cathode lamp at the characteristic wavelength of the desired metal. The higher the concentration of the metal, the higher the absorption of light. The degree of absorption is measured and converted into PPMS values for that metal by a readout computer graphite furnace spectrometer uses an electrically heated hollow cylinder to contain the sample and can be used for ultra low trace wear metal levels. This can increase measurement sensitivity from 100 to 1000 times over the settling flame method.

Specialized Skills / Training / Experience Required: To draw the sample requires a suitably trained semi-skilled worker to operate the spectrometer requires a suitably trained laboratory technician period to analyze the results requires an experience chemical analyst.

Advantages: Oil samples facilities for determining where metal concentrations used in oil analysis. High accuracy, precision and repeatability at a low cost. AA does not suffer from spectral interference.

Disadvantages: Samples require preparation. Analysis time is longer. Requires a flammable gas. May fail to vaporize particles above 5 microns.



Flame Atomic Absorption Spectrometry
AAS consist of two type: Flame AAS and Graphite-furnace AAS.

Please open this link :
http://www.cee.vt.edu/ewr/environmental/teach/smprimer/aa/aadiag.gif

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.05 X-RAY FLUORESCENCE SPECTROSCOPY

Conditions Monitored: Wear metals such as iron, aluminum, chromium, lead, tin copper, nickel and silver. All additives containing boron, phosphorus, zinc calcium magnesium, or barium. Contaminants such as silicon corrosion.

Applications: Oils used in diesel and gasoline engines, gas turbines transmissions gearboxes compressors and hydraulic systems.

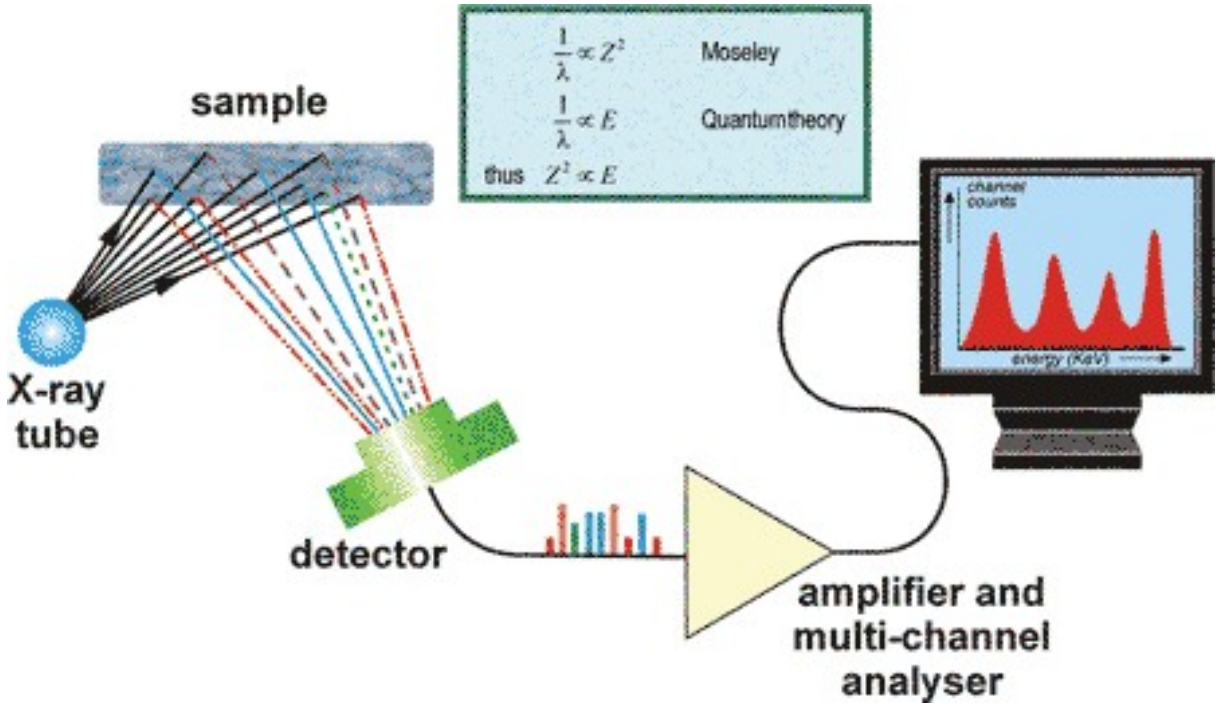
P-F Interval: Usually several months.

Operation: An oil sample is exposed to a high energy X-ray source which raises the energy level of the atoms in the sample. This causes the contaminants to emit characteristic secondary x-ray energy, except that the radiation measured is the characteristic fluorescence of the chemical elements in the sample which is converted into their respective elemental data by a multi channel signal analyzer.

Specialized Skills / Training / Experience Required: To draw a sample requires a suitably trained semi scored worker period to operate the equipment requires a suitably trained electrician or technician period to interpret the results requires an experienced engineer.

Advantages: Good accuracy precision and repeatability. Current software has simplified its operation and data interpretation. Covers a wide range of chemical elements and AA or AE. Can see any particle size.

Disadvantages: Requires a cryogenic cooled detector for comparable AE or AA detection limits longer analysis time. The analysis of lighter elements requires higher x-ray energies and hence increase precautionary measures in the lab.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.06 ENERGY DISPERSIVE X-RAY SPECTROMETRY

Conditions Monitored: Wear metals such as iron, aluminum, chromium lead tin copper, nickel and silver. Oil additive containing boron, phosphorus, zinc, calcium, magnesium or barium contaminants such as silicon. Corrosion.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors and hydraulic systems.

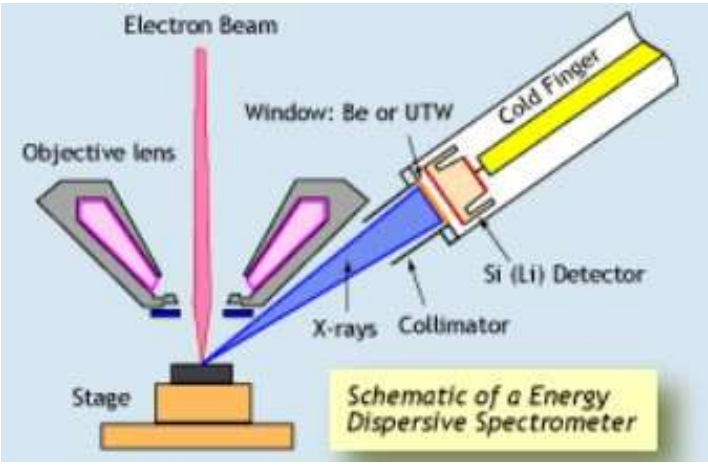
P-F Interval: Usually several months.

Operation: And Energy dispersive spectrometer EDS attachment to a scanning electron microscope SEM permits the detection of X rays produced by the impact of the electron beam on a sample, thereby allowing qualitative and quantitative analysis The electron beam of the SEM is used to excite the atoms in the surface of the solid. These excited atoms produce characteristic X rays which are readily detected. By utilizing the scanned feature of the SEM spatial distribution of the elements can be obtained.

Specialized Skills / Training / Experience Required: To draw the sample requires a suitably trained semi school worker period to do the test requires a suitably trained technician period to interpret the results requires an experienced engineer.

Advantages: Rapid identification of particles. Very fast elemental images and line scans.

Disadvantages: Not an on-line technique Requires expensive laboratory equipment. High degree of skill to interpret the results.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.07 DIELECTRIC STRENGTH (ASTM D-877 AND D-1816)

Conditions Monitored: The ability of insulating oil to withstand electric stress caused by conductive contaminants such as metallic cut insurance, fibers or free water.

Applications: Insulating oils in transformers, Breakers and cables.

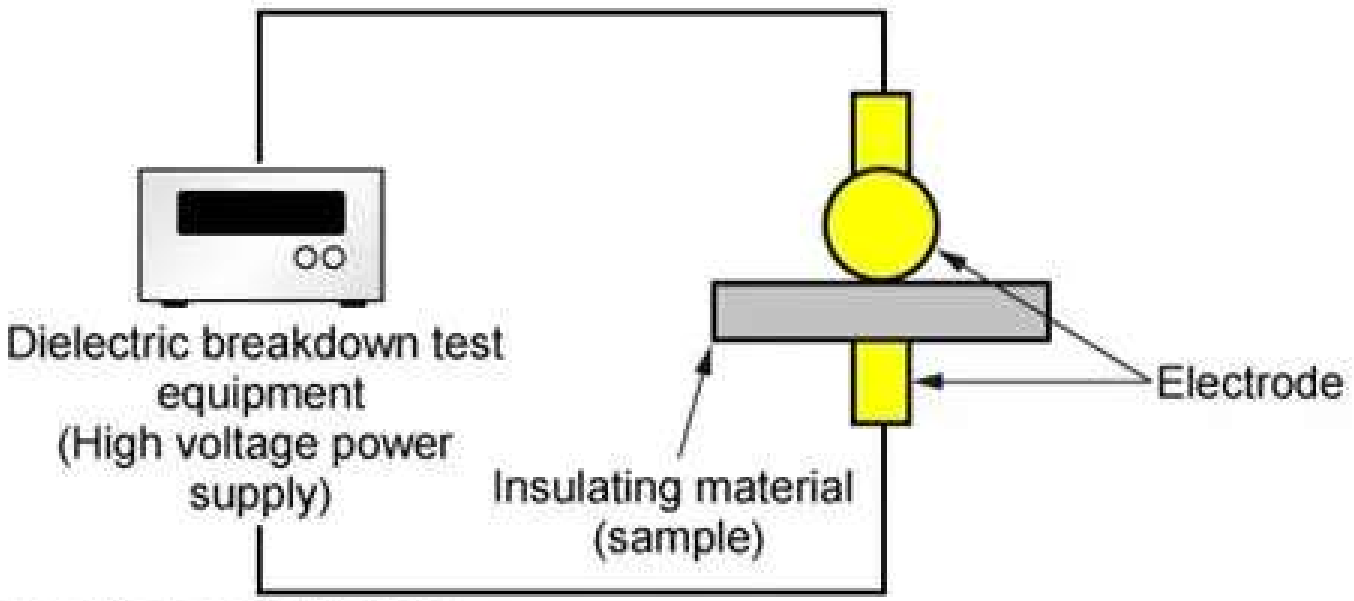
P-F Interval: Several months.

Operation: The sample container is inverted and swirled several times before filling the test cup The test cup is filled to the top of brass electrodes and an increase in voltage applied at a rate of 3 kV/s (D-877) or 5 kV/s (D-1816) to two electrodes spaced 2.54 mm (D-877) , 2 mm (D-1816) apart, until breakdown occurs. This value is recorded and trended. 5 break downs all made with One Cup filling at one minute intervals. The average of the five breakdowns is considered the dielectric breakdown voltage of the sample. High and medium voltage transformers should observe the following limits: >25kV for in service oil, >30 kV for new oil. D-877 test is used for rated voltages below 230 kV, D-1618 test used for voltages rated above 230kV.

Specialized Skills / Training / Experience Required: Taking a sample requires an electrician to conduct a test requires a suit to be trained laboratory technician.

Advantages: Quick test and simple. Transformer does not have to be taken offline to draw a sample. The good overall indicator of transformer condition.

Disadvantages: Test results dependent on sampling technique. Test sensitive to ambient temperature and humidity. Some risk involving and handling PCBs. Uses hazardous materials and equipment. Not an on-line technique.



Source: Matsusada Precision

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.08 INTERFACIAL TENSION (ASTM-D-971)

Conditions Monitored: Presence of hydrophilic compounds (a compound soluble in water which attracts water to its surface).

Applications: Petroleum based insulating oils in transformers, Breakers and cables.

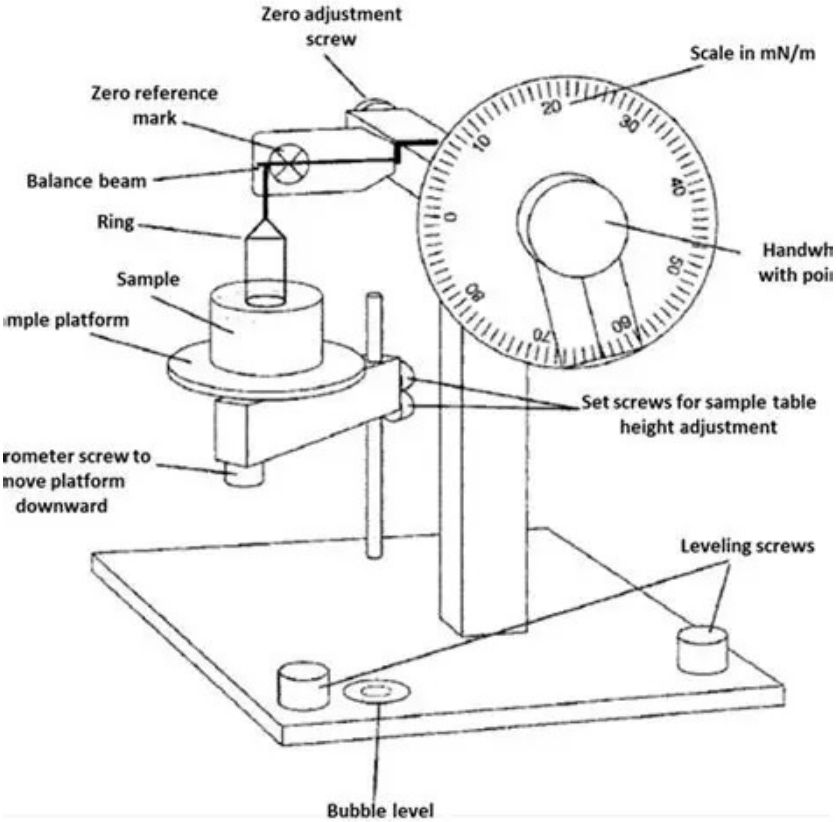
P-F Interval: Months.

Operation: . Interfacial tension is determined by measuring the force needed to detach a planar ring of platinum wire from the interface between a sample of oil and distilled water. After zeroing the device known as a tensiometer, the platinum ring is emerged in the water to a depth of 5mm. A filtered oil sample is poured on the water to a depth of 10mm. The oil water surface is aged for about 30 seconds, then the container is lowered until the film ruptures. The interfacial tension is then calculated. High and medium voltages transformers should not exceed >27 dynes/cm for in-service oil and >40 dynes/cm for new oil.

Specialized Skills / Training / Experience Required: Taken the oil sample requires an electrician period to conduct the test requires a suitably trained laboratory technician.

Advantages: Reliable indication of compounds soluble in water. Test takes about one minute Transformer does not have to be taken offline to monitor insulating oil.

Disadvantages: Tests depended on sampling technique. Hazardous and flammable materials are used to conduct a test. Not an on-line technique. Requires laboratory equipment.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.09 DIAL (DIFFERENTIAL ABSORPTION LIDAR)

Conditions Monitored: The chemical composition and dispersal of gasses in the atmosphere.

Applications: Gasses emitted by smoke stacks and leaks in tanks or pipelines.

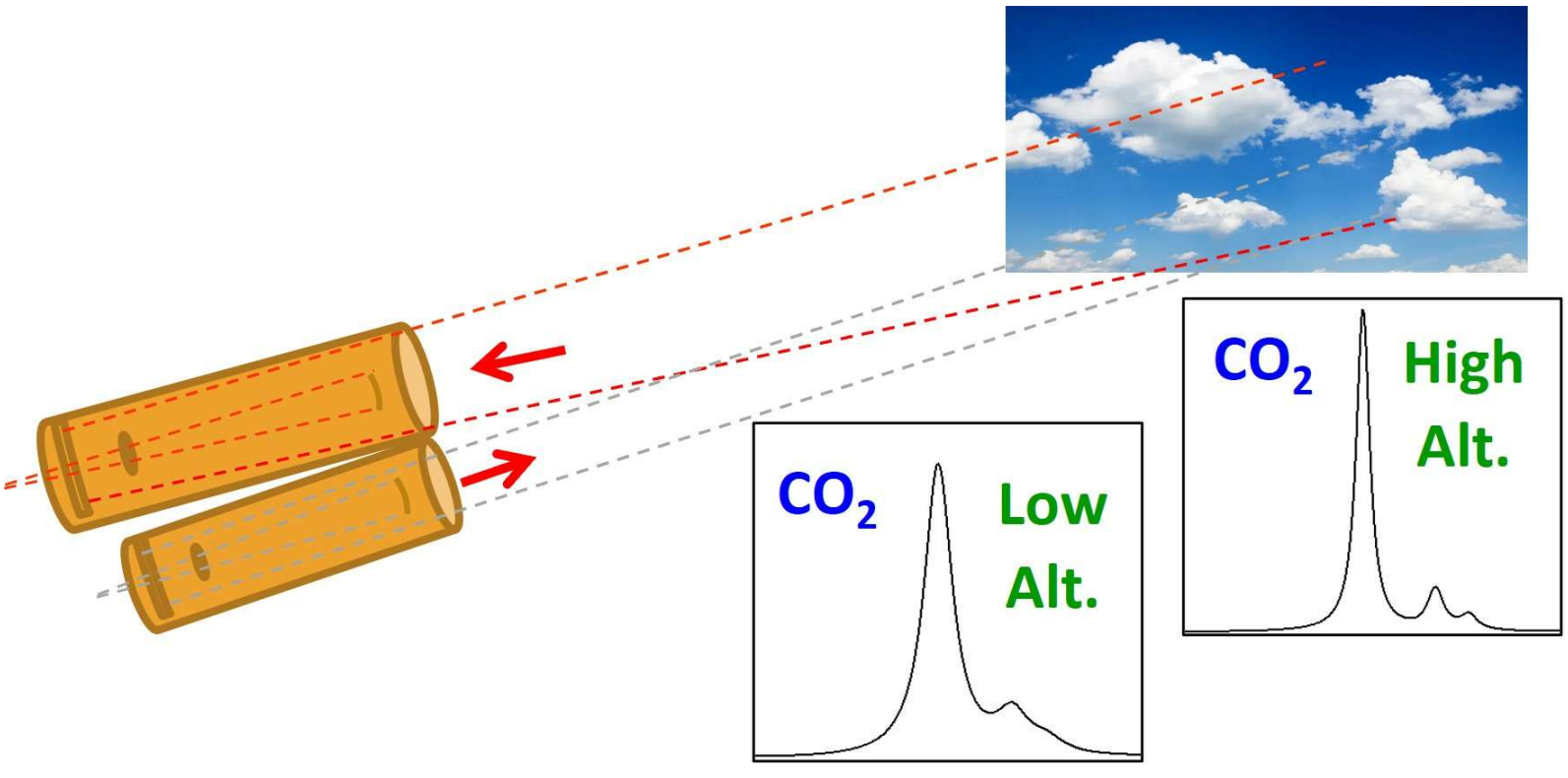
P-F Interval: Minutes to months depending on the application.

Operation: Similar to LIDAR, except that two differential wavelengths are used. One wavelength is set to correspond to a given gas so one wavelength is absorbed and the other is reflected. The quantity of gas present is determined by measuring the amount of light reflected. The location of the gas can be determined by triangularization based on readings taken from two points.

Specialized Skills / Training / Experience Required: Requires an experienced engineer.

Advantages: Can cover large areas.

Disadvantages: Must be calibrated for individual gasses. Very expensive and unlikely to be economic for a single site. Operating the equipment requires high level skill.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON THE CHEMICAL MEASUREMENT OF FLUID PROPERTIES

The techniques described in this section are used to detect incipient failure of the fluids themselves. They apply to fuels, lubricating oils and or gasses They are used mainly to analyze the properties of the base fluid and or the presence condition of additives although some also detect contaminants The elements most commonly detected by these techniques are listed below.

- **Antimony**. From grease compounds.
- **Arsenic**. From anti corrosion or biocide agents.
- **Barium**. From detergent, dispersant and antioxidant additives for fuels and oils.
- **Boron**. From anti corrosive additives for engine coolants and as an anti knock agent in fuels.
- **Calcium**. From detergent and Oregon dispersant additives.
- **Chromium**. From Antioxidant in jet fuels.
- **Cobalt**. From natural trace levels in crude oils.
- **Copper**. From natural trace levels in crude oil and lubricant additives.
- **Iron**. From natural trace levels in crude oil.
- **Lead**. Anti wear additives in some lubricants, sometimes added to fuel as anti knock agent.
- **Magnesium**. I'm detergent and ore dispersant additives.
- **Molybdenum**. From natural trace levels include oils and as an anti friction additives in some lubricants.
- **Nickle**. From natural choice levels in food oils usually in conjunction with vanadium.

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON THE CHEMICAL MEASUREMENT OF FLUID PROPERTIES – CONT.

- **Phosphorus**. Some natural trace levels in crude oils and as an anti wear additives and some lubricants.
- **Potassium**. From natural trace levels in crude oils.
- **Selenium**. From natural taste levels in some crude oils and coal.
- **Silicon**. From anti foment agents in some oils.
- **Sulphur**. From natural trace levels in crude oil and some fuels. Used as an anti corrosion agent in gear lubricants and as an antioxidants in lubricating oils.
- **Vanadium**. Natural trace levels and some crude oils.
- **Zinc**. Found naturally in some crude oils found as an anti wear additive in automotive lubricants and as an antioxidant in marine lubricants.

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.10 FOURIER TRANSFORM INTRARED (FT-IR) SPECTROSCOPY

Conditions Monitored: Deterioration oxidization water content and depletion of anti wear additives in mineral oils and synthetic lubricants.

Applications: Duplicating oils from combustion engines hydraulic systems etc.

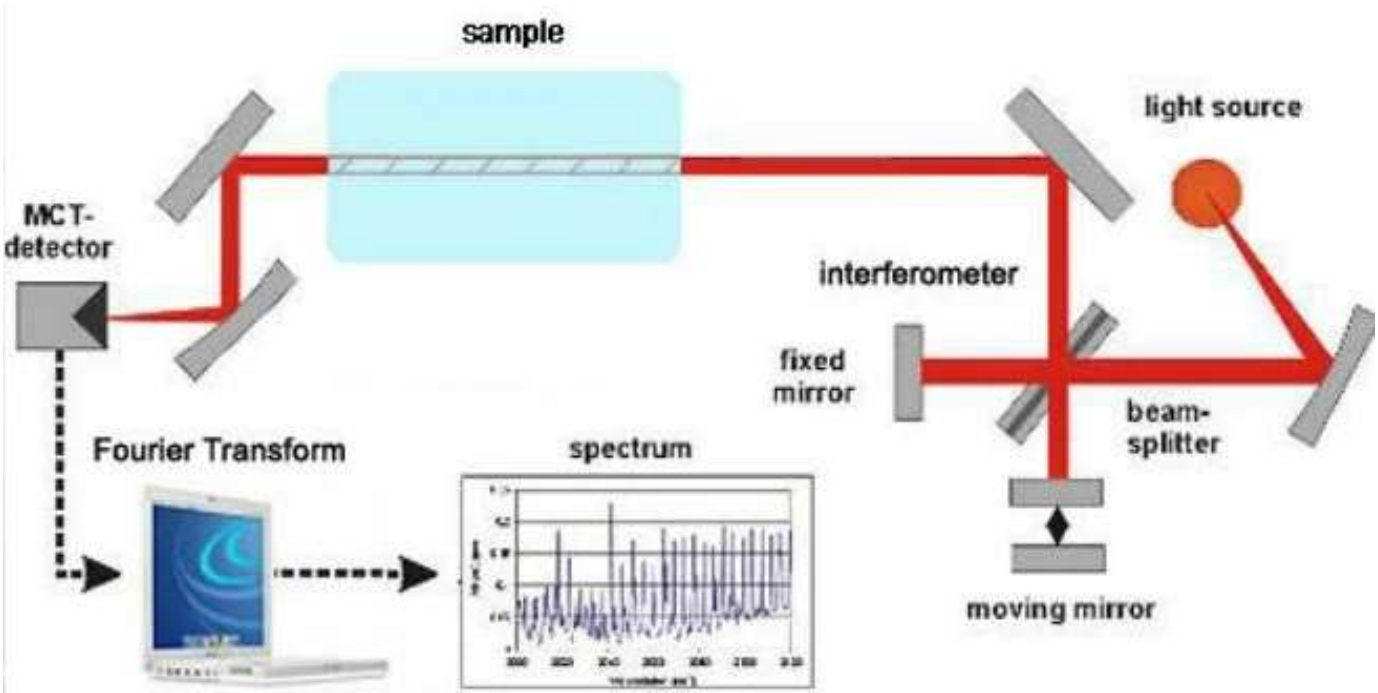
P-F Interval: Usually several weeks to months.

Operation: . Like atomic absorption spectrometry, FT IR measures absorbent light energy at specific wavelengths to determine the level of the elements in a sample. Uses a low power broadband infrared beam converted into a uniform pattern of constructive and destructive interference by A Michaelson Interferometer. The interference pattern is passed through a sample where it is altered by the characteristic absorbance levels of the elements of the oil and contaminants. The altered interference pattern enters a detector where it is converted into an audible frequency electronic signal, then converted into individual wavelengths amplitude data by a Fourier Transform. The absorbance of the oil, additives and contaminants at their respective wavelengths is measured, generating a scalar spectrum often called a 'fingerprint'. The sample fingerprint is compared with an unused oil sample fingerprint using intelligent software.

Specialized Skills / Training / Experience Required: To draw the sample requires a suitably trained semi-skilled worker. To operate the spectrometer requires a suitably trained laboratory technician period to analyze the test results requires an experienced chemical analyst.

Advantages: It does not use dangerous chemicals. Lower energy levels do not alter the molecular structure of the components in the sample, unlike AA. Data can be converted into ASTM equivalent parameters. Good repeatability. Total acid number TAN or total base number TBN data can be synthesized from FT-IR data.

Disadvantages: Uses flammable solvent for cleaning. Different manufacturers of FT-IR equipment use different data extraction algorithms for oil condition parameters and contaminants. Only sensitive to 1000 PPM water contamination.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.11 INFRARED SPECTROSCOPY

Conditions Monitored: The presence of gasses such as hydrogen sulfur hexafluoride nitrogen methane carbon monoxide and ethylene. Fluid degradation.

Applications: As for gas chromatography.

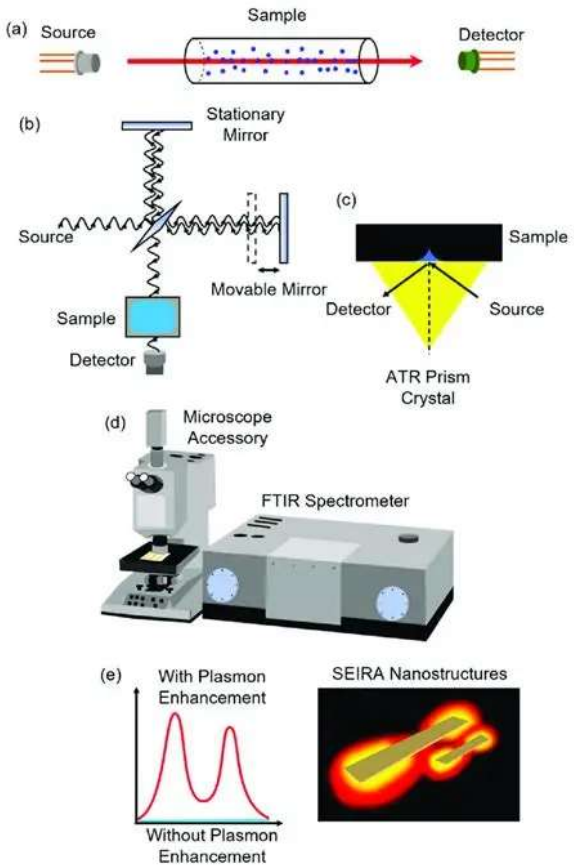
P-F Interval: Highly dependent on the application.

Operation: The atoms of a molecular vibrate about their equilibrium positions with different but precisely determinable frequencies. A sample, placed in a beam of infrared light, absorbs these characteristic frequencies. The absorption bands, plotted against wavelength, specifying the infrared spectrum. The position of the absorption points on the wavelengths scale is a qualitative characteristic and conclusions can be drawn from the intensity of the absorption bands.

Specialized Skills / Training / Experience Required: To operate a preset infrared spectrometer requires a trained laboratory assistant to interpret and evaluate the results requires an experienced laboratory technician.

Advantages: Rapid Analysis. High sensitivity. Can be operated by laboratory assistant when equipment is preset graphs provide a permanent record.

Disadvantages: Considerable experience and skill needed to analyze results. Laboratory based equipment. Wide range of applications required to justify the cost of the equipment.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.12 GAS CHROMATOGRAPHY

Conditions Monitored: Gasses emitted as a result of faults. There are over 200 gasses present in electrical insulating oils of which nine are of interest. In ascending order of criticality, these are nitrogen, oxygen, Carbon dioxide carbon monoxide methane Ethane Ethylene hydrogen and Acetylene. Large amounts of CO and CO^2 indicate overheating in the widens. CO, CO^2 and methane indicates hot spots in the insulation. Hydrogen ethane and methane indicate corona discharge. Methane is a sign of internal arching.

Applications: Nuclear power systems turbine generators sulfur hexafluoride or nitrogen sealed systems transformer oils. Breakers etc.

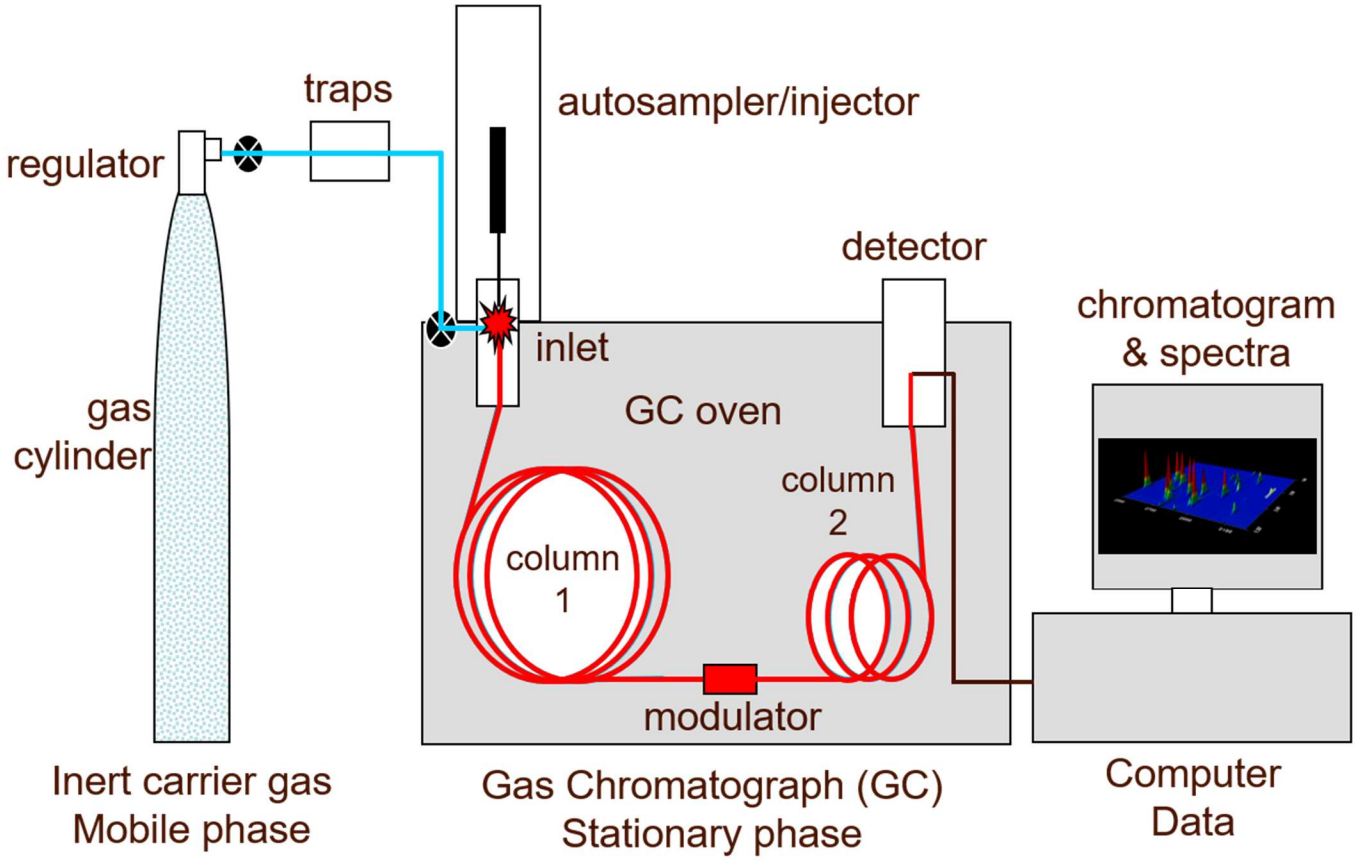
P-F Interval: Holly verbal depended on the nature of the fault.

Operation: A gas sample is injected through a silicon rubber spectrum injection port maintained at a temperature higher than the boiling point of the least volatile element in the sample. A carrier gas usually an inert gas such as helium, argon or nitrogen sweeps the vaporized sample out of the port into a separation column located in a thermostatically controlled oven. Elements with a wide range of boiling points are separated by starting at a low oven temperature and rising the temperature over time to elute the high temperature elements. The separation column contains absorbing materials such as diatomaceous earth to separate the gasses Gasses emerging from the column flow over a detector which can be directed into a mass spectrometer or Fourier Transform infrared spectrometer to record a spectrum as eluded from the column. Different detectors are used for different separation applications.

Specialized Skills / Training / Experience Required: Taking this sample requires an electrician period to conduct a test requires a suitably trained laboratory technician period to trend and analyze the result requires an electrical engineer.

Advantages: High sensitivity detection 1 part per 1000 million by volume. Once the equipment has been set up it can be operated by a laboratory assistant.

Disadvantages: A sensitive analysis are difficult to obtain. In large systems any fault gasses may be rapidly diluted. Considerable skill needed to interpret the results. Equipment is not portable. Wide range of applications required to justify purchase. Not widely used in maintenance.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.13 ULTRA-VIOLET AND VISIBLE ABSORPTION SPECTROSCOPY

Conditions Monitored: Changes in oil properties such as alkalinity, acidity, insoluble.

Applications: Oils used in diesel and gasoline engines gas turbines transmissions, gearboxes, compressors and hydraulic systems.

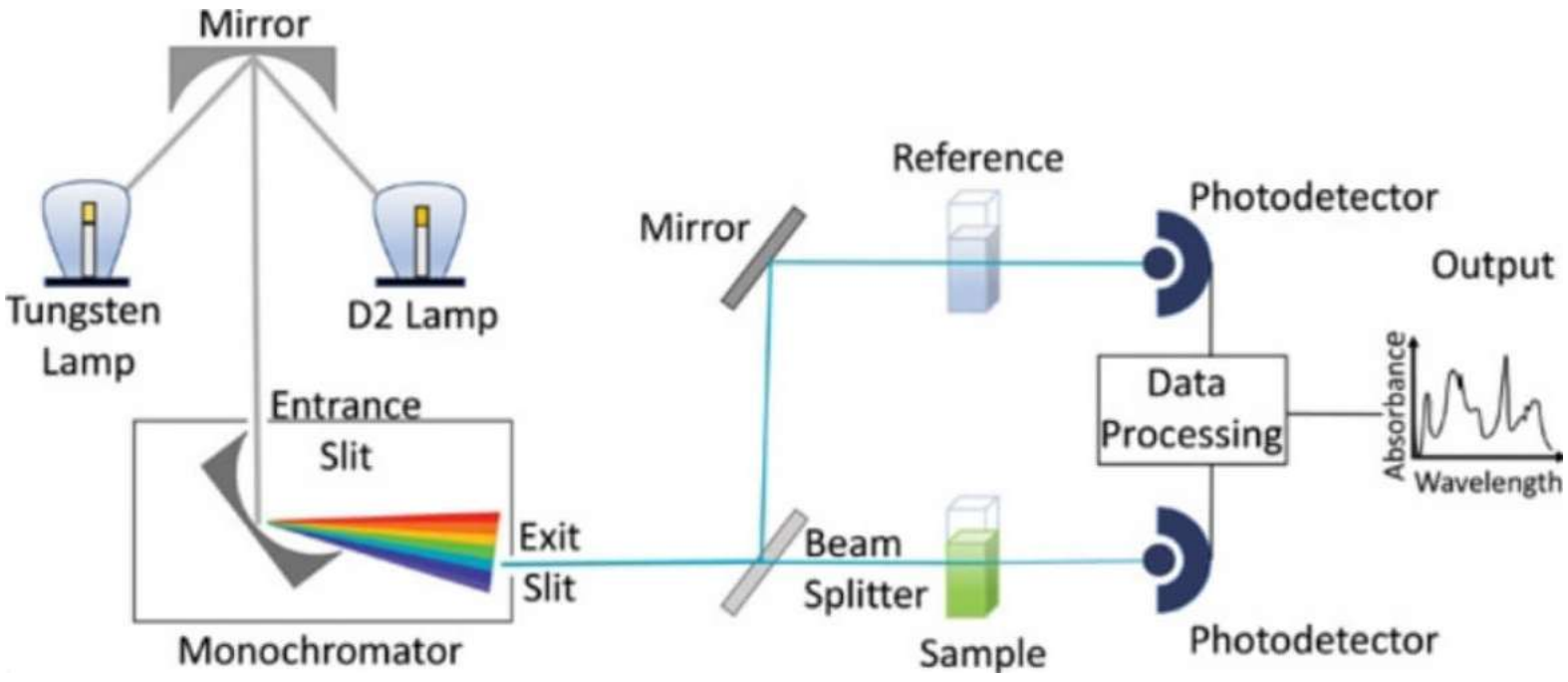
P-F Interval: Several months.

Operation: An oil sample is subjected to intense ultraviolet light come out usually from a hydrogen or deuterium lamp or to visible light from a tungsten lamp. Ultraviolet and visible light are energetic enough to promote the outer electrons of the sample element to higher energy levels, causing light at specific wavelengths to be absorbed. The absorption can be monitored using a wavelength separator such as a prism or a great in monochromator. The amount of light absorbed is related to the concentration of each element Quantitative measurements can be made by scanning the spectrum or at a single wavelength.

Specialized Skills / Training / Experience Required: A trained and experienced laboratory technician is required.

Advantages: . Useful for quantitative measurements.

Disadvantages: . The ultraviolet invisible Spectra have broad features that are limited use for sample identification considerable skill and experience needed to analyze the results. Equipment is laboratory based and is expensive.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.14 THIN-LAYER ACTIVATION

Conditions Monitored: Wear.

Applications: Oils used in diesel gasoline engines, gas turbines, transmissions, gearboxes compressors and hydraulic systems.

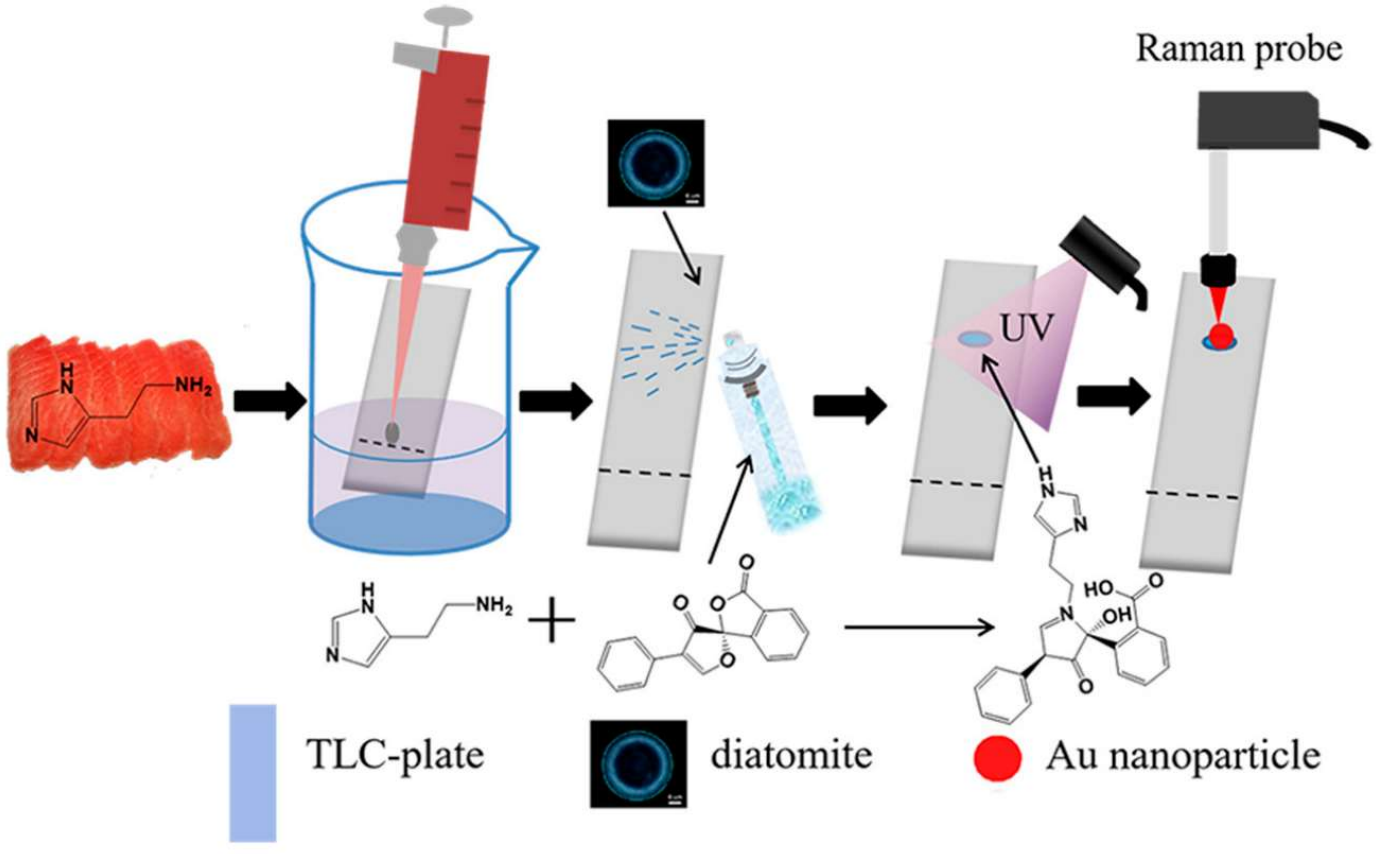
P-F Interval: Several months.

Operation: A thin layer of atoms in the surface of the material to be monitored is made radioactive by bombarding it with a beam of charged particles. Among Trans systems are calibrated to take radioactive decay into account. Material losses up to 1 um can be measured up to four years after activation.

Specialized Skills / Training / Experience Required: To take reading requires a suitably trained semi-skilled worker.

Advantages: Where can be measured during normal plant operation even with substantial intervening material.

Disadvantages: Compounds have to be removed to be activated unless coupons can be used. Reactivation is required every four years.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.15 SCANNING ELECTRON MICROSCOPY (SEM)

Conditions Monitored: Fractured surfaces for the presence of unusual elements.

Applications: Any surface types thin films and interfaces found in rural semiconductors, finished semiconductors, metal and steel surfaces medical devices, ceramics, polymers, etc.

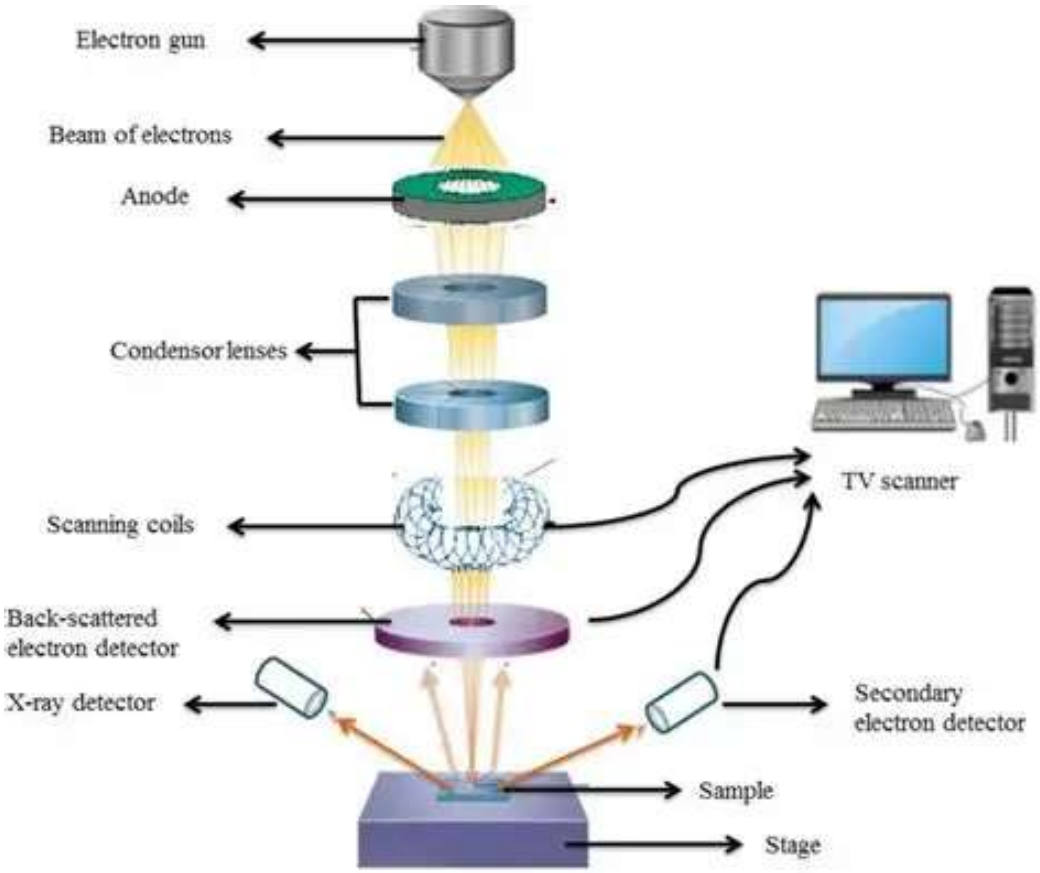
P-F Interval: Application dependent.

Operation: A focused beam of electrons is rastered across a sample surface. This causes a secondary electron current to be emitted from the sample which varies according to the angle of incidence of the beam into the sample. The secondary electron intensity is used to vary the brightness of the cathode ray tube which is synchronous with the raster scan, yielding a topographical image of the sample surface. Different detectors can be used to provide other information. For instance, a backscattered electron detector provides average atomic number information, while an auxiliary energy dispersive X-ray detector can identify elements such as boron and uranium.

Specialized Skills / Training / Experience Required: Skill laboratory Technician.

Advantages: A resolution with sample preparation. Launch depth of field allows use with rough samples. Rapid qualitative analysis of particles and small areas coupled with an energy dispersant X-ray detector.

Disadvantages: More of a diagnostic technique to determine what causes of failures.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.16 SCANNING AUGER ELECTRON SPECTROSCOPY

Conditions Monitored: Fractured surfaces for the presence of unusual elements, elemental mapping of fine particles corrosion and oxidization scales.

Applications: Any surface types thin films and interfaces found in raw and finished semiconductors, metal and steel surfaces medical devices, ceramic polymers.

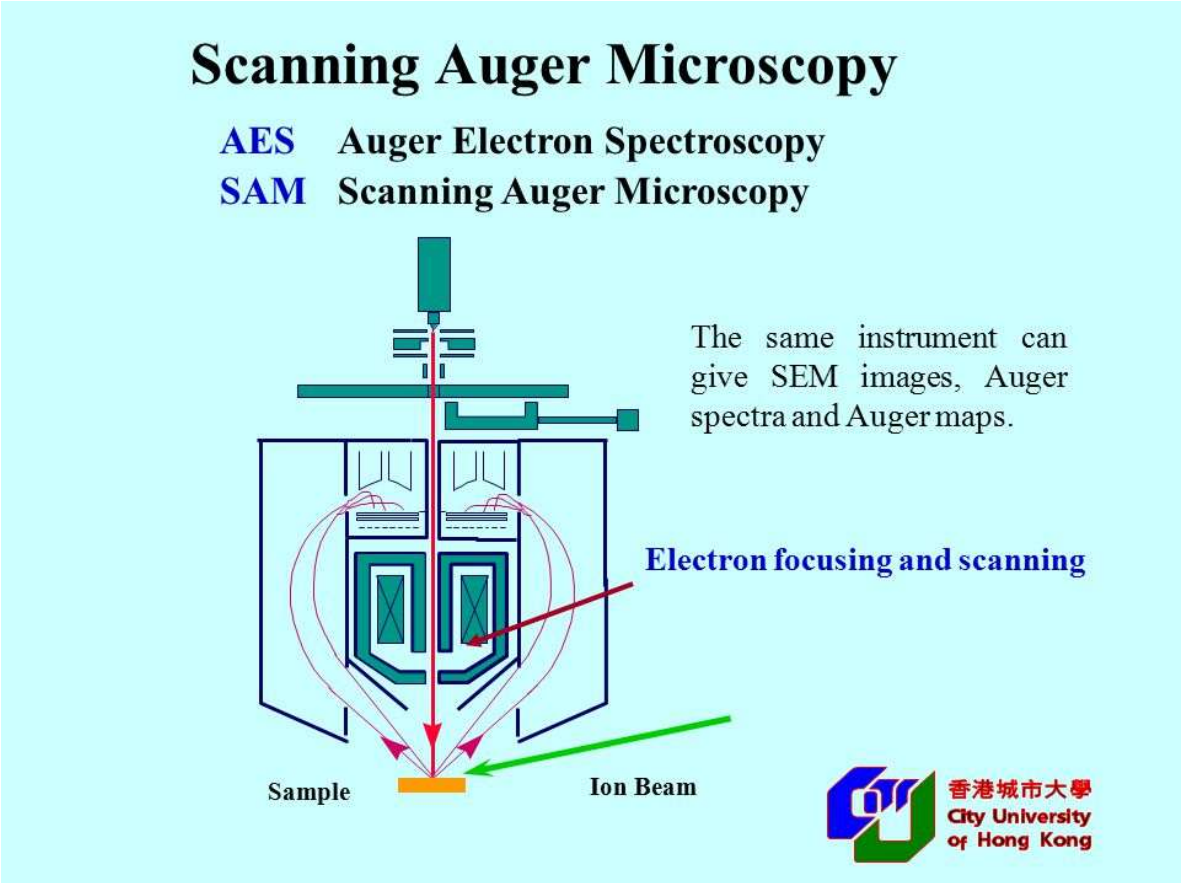
P-F Interval: Application dependent.

Operation: . A finely focused electron beam irradiates the sample and creates a core hole by injecting a core electron from a sample atom. The resulting ion then Dee excites one electron from an upper level fills the core hole and a 3rd electron the Auger electron is emitted to conserve energy. This electron has a kinetic energy characteristic of emitting atom which allows elements to be identified to adapter between 2 and 20 atomic layers.

Specialized Skills / Training / Experience Required: A suitably trained technician.

Advantages: . Structures do not have to be evacuated for inspection unless this technique reveals a real need to do so.

Disadvantages: Does not measure the extent or precise location of corrosion. Ground must be moist.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.17 ELECTRO-CHEMICAL CORROSION MONITORING

Conditions Monitored: Corrosion of material embedded in concrete.

Applications: Steal pylons, gantries, etc.

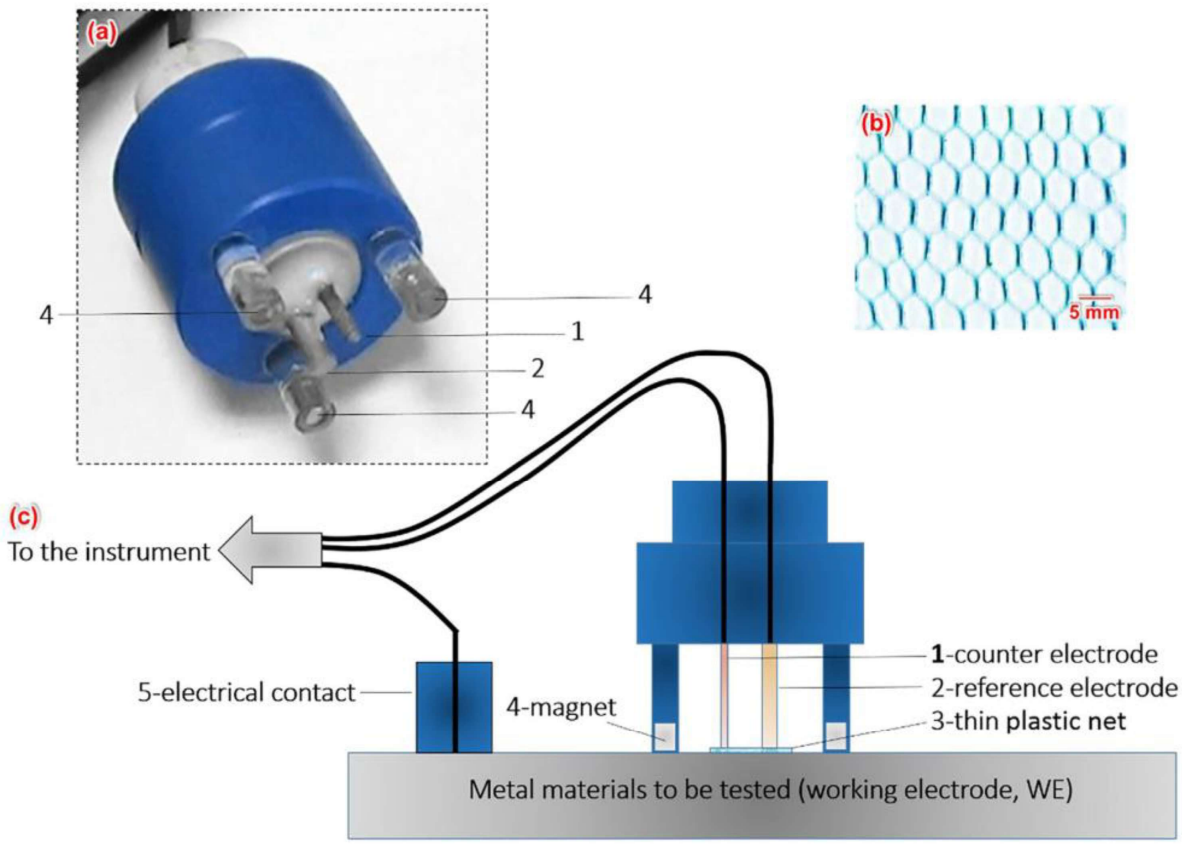
P-F Interval: Months.

Operation: Small currents are passed between the structure and a probe inserted in the ground nearby. These currents affect the potential of the structure at any point where corrosion is taking place. The changes in the potential are measured by a half cell in contrast with the ground and close to the structure. The degree of corrosion is directly related to the current required to displace the leg potential. High currents indicate the need for a physical inspection.

Specialized Skills / Training / Experience Required: A suitably trained technician.

Advantages: Structures do not have to be evacuated for inspection unless this technique reveals the need to do so.

Disadvantages: It does not measure the extent or precise location of corrosion. Ground must be moist.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.18 EXHAUST EMISSION ANALYZERS (FOUR-GAS ANALYSIS)

Conditions Monitored: Combustion efficiency by measuring the concentrations of oxygen, carbon monoxide, carbon dioxide, in hydrocarbons HC and exhaust emissions. Exhaust leaks.

Applications: Internal combustion engines.

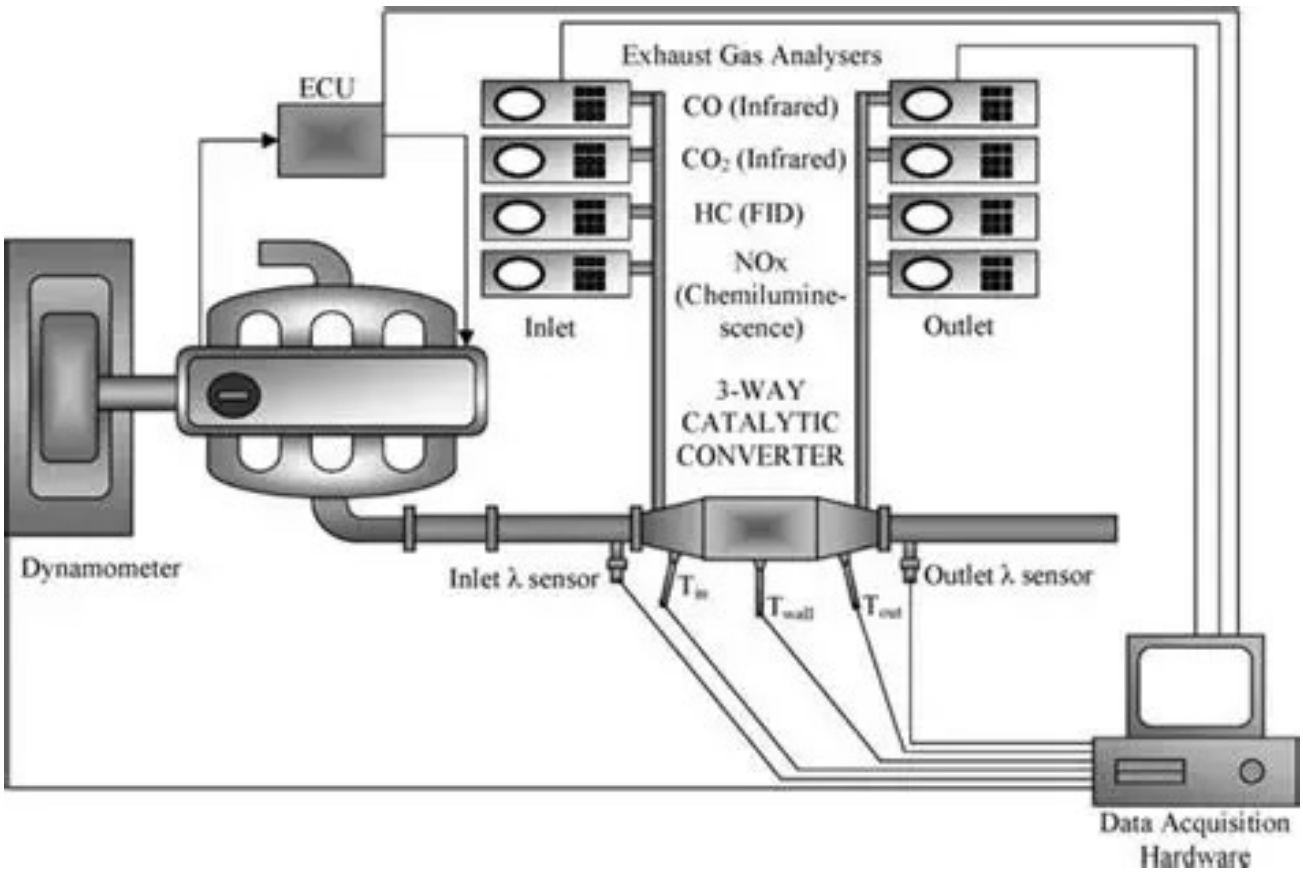
P-F Interval: Weeks to months.

Operation: A sampling probe is inserted into the exhaust pipe upstream of the catalytic converter. Dirt and oil are removed by a pre filter and moisture by a water separator. Gas sensors pick up the gas concentrations and regions are displayed as percentages (HC in parts million) High CO mean that the engine is running rich. High O_2 indicates a lean misfire or an exhaust leak. CO_2 is at its highest at the optimum air-fuel (AFR) and it drops when the AFR is too rich or too lean. High HC indicates misfires or incomplete combustion. 'Lambda' readings are also calculated on most analyzers. Lambda is the name given to the ratio of the actual AFR over the ideal ratio of 14:1.7. The ideal Lambda reading is one, and leaner ratios are greater than one.

Specialized Skills / Training / Experience Required: Training experience automotive mechanic.

Advantages: Pinpoints in mission failures. Equipment is portable.

Disadvantages: Equipment needs to be taken offline to connect to the analyzer.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.19 COLOR INDICATOR TITRATION (ASTM D974)

Conditions Monitored: Lubricant deterioration by determining the levels of acidity and alkalinity in an oil sample.

Applications: Or using diesel and gasoline engines, gas turbines transmissions, gearboxes, compressors and hydraulic systems.

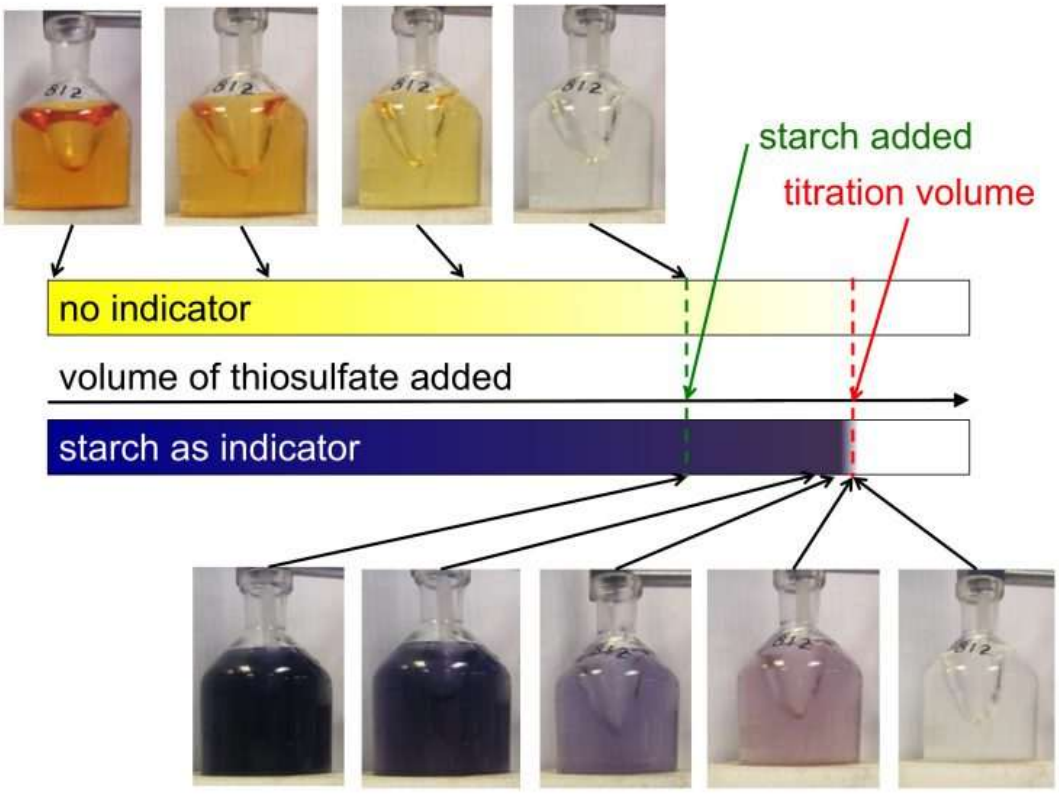
P-F Interval: Weeks to months.

Operation: The sample is dissolved into a mixture of toluene, isopropyl alcohol and water and titrated with an alcoholic base or acid solution to the end point indicated by a color change that the added naphthol benzene solution. The acidity or alkalinity is expressed in milligrams of potassium hydroxide needed to neutralize a gram of oil. The higher the acid or base number the greater the oil deterioration High and medium voltages transformers should be < 0.5mg KOH/gm for new oil and < 0.1mgKOH/gm for in service oil.

Specialized Skills / Training / Experience Required: Laboratory technician.

Advantage: Test accurate within 15%.

Disadvantages: It can only be used for petroleum-based oils. Poisonous, flammable, corrosive chemicals used in the test. Cannot be used for dark oils.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.20 POTENTIOMETRIC TITRATION TAN/TBN (ASTM D664)

Conditions Monitored: Lubricant deterioration by determining the level of acidity of Man oil sample.

Applications: Oil used in diesel gasoline engines, gas turbines, transmissions, gearboxes, compressors, hydraulic systems and transformers.

P-F Interval: Weeks to months.

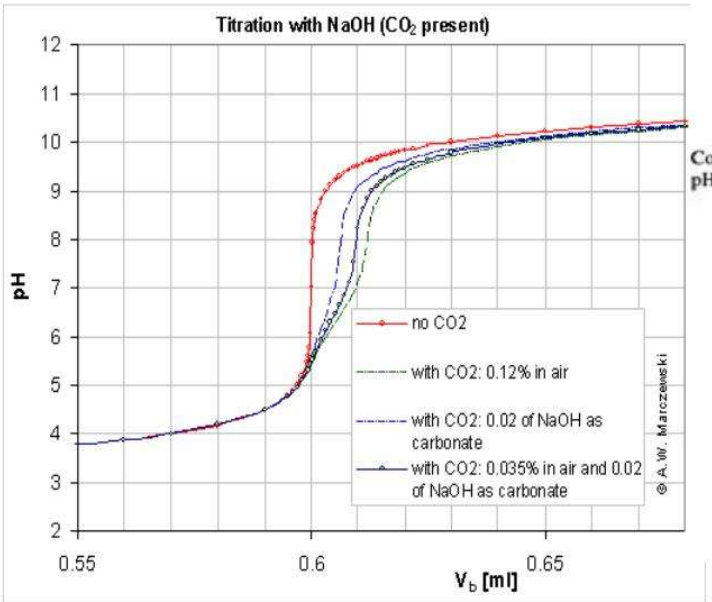
Operation: The sample is dissolved into a mixture of toluene isopropyl alcohol and water titrated well alcoholic potassium hydroxide The acidity is determined by measuring the change in electrical conductivity as the potassium hydroxide is added. The value is expressed as mgKOH/g. The higher the acid number, the greater the breakdown of the oil.

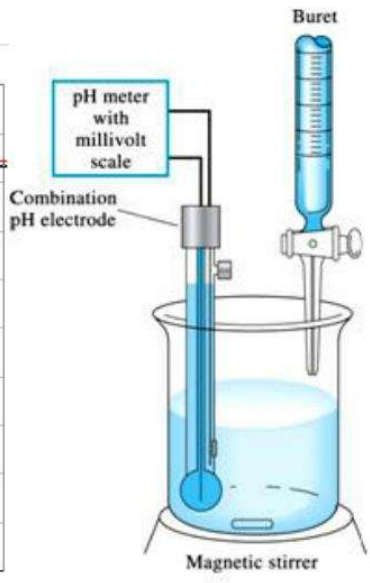
Specialized Skills / Training / Experience Required: Laboratory technician.

Advantages: Can we use for Oils that are too dark to use a color change indicator. Test is accurate within 4%.

Disadvantages: Can only be used for petroleum-based oils. Dangerous chemicals are used in the test.

Potentiometric titration





CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.21 POTENTIONMETRIC TITRATION (ASTM D2896)

Conditions Monitored: Lubricant deterioration by measuring alkalinity.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors, hydraulic systems and transformers.

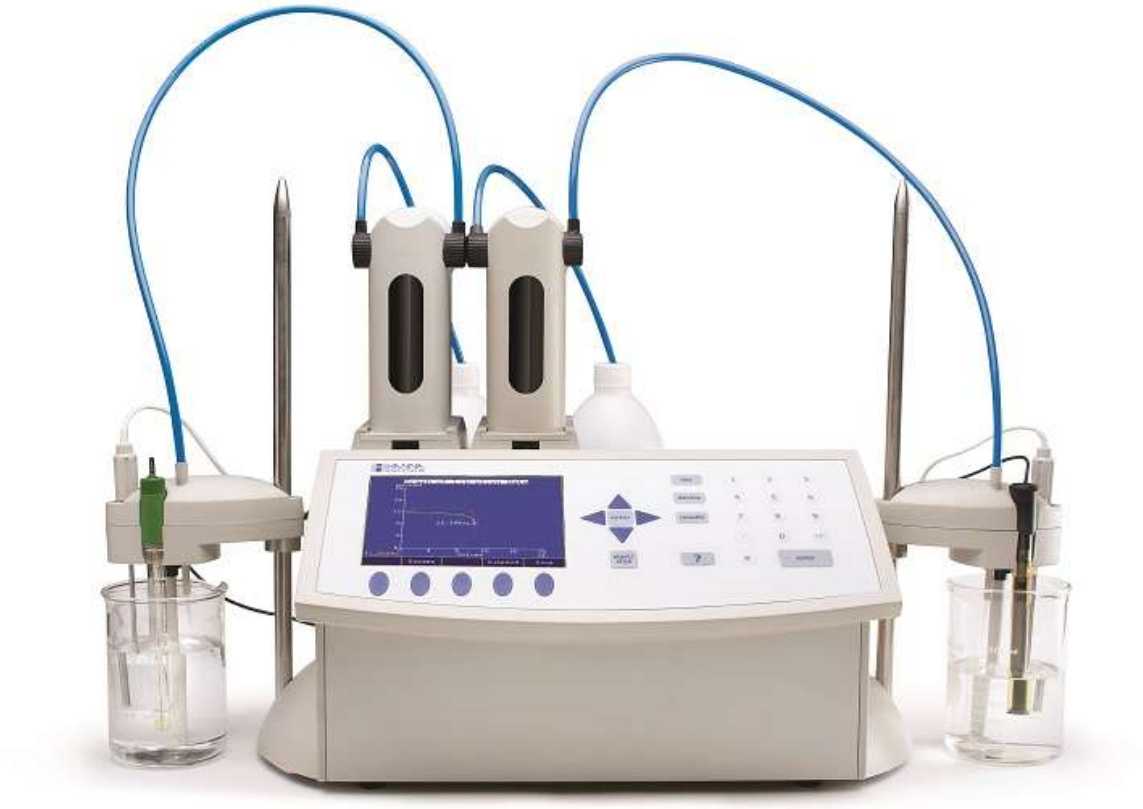
P-F Interval: Weeks to months.

Operation: Some pores dissolved into a mixture of titration solvent which is titrated with perchloric acid. The potential metric electrical conductivity readings are plotted against respective volumes of titrating solution. The alkalinity base number is calculated from the quantity of acid needed to titrate the solution express in milligrams of potassium hydroxide per gram equivalent(mgKOH/g) The test is a measure of an oils ability to neutralize corrosive acids formed during operation indicating its suitability for continued use.

Specialized Skills / Training / Experience Required: Laboratory technician.

Advantages: Can be used regardless of color of oil. Accurate to within 15%.

Disadvantages: Can only be used for petroleum-based oils. Dangerous chemicals used in the test.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.22 POWER FACTOR (ASTM D-924)

Conditions Monitored: Dielectric losses and insulating oils caused by contamination and oil deterioration.

Applications: Petroleum based insulating oils in transformers, Breakers and cables.

P-F Interval: Several weeks.

Operation: A thoroughly mixed sample is poured into a clean beaker and heated to 2°C Below desired test temperature. The cell is removed from the test chamber and filled with the heated sample. The inner electrode is inserted into the cell to gather with a mercury thermometer the electrical connections are then made to the cell. The sample is then electrically stressed by passing a voltage through the cell and the power factor is calculated. For high and medium voltage transformers the power factor limit should be less than 1% at 25°C.

Specialized Skills / Training / Experience Required: Taking the sample requires an electrician. To conduct the test requires a suitably trained laboratory technician.

Advantages: Test quick and relatively simple. Transformer does not have to be taken offline to monitor the insulating fluid.

Disadvantages: Uses hazards and materials and equipment. Test must be conducted in the laboratory and depends on sampling technique.

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON MOISTURE MONITORING

Water in oil rapidly reduces machinery and component life. For example, it can reduce roller element barren life by as much as 100 times It also interferes seriously with the lubrication properties of oil, for instance, a drop of water in 5 liters of oil at 85°C totally destroys zinc anti-ware additives. Water directly affects the oil itself in the following ways.

- It increases oxidization and in doing so forms slimes and resins.
- It increases conductivity which is especially undesirable in transformer oils.
- Reacts with antioxidants to form acids and precipitates salts.
- It reacts with zinc di-alkyl di-thio phosphate (ZDDP) anti-wear additives to form hydrogen sulfide and sulfuric acid.
- It promotes the growth of microbes.
- It changes the viscosity of the oil.
- It degrades viscosity improvers.

Water also affect other aspects of the system in the following ways.

- It rusts and corrodes metal surfaces.
- It jams vowels by forming ice crystals.
- It increases wear.
- It valves and orifices.
- It shortens the life of filters and it entrains more air, which effects bulk modius.

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.23 KARL FISCHER TITRATION TEST (ASTM D-1744)

Conditions Monitored: Water in oil.

Applications: Enclosed oil systems such as engines, gearboxes, transmissions, compressors hydraulic systems turbines transformers etc.

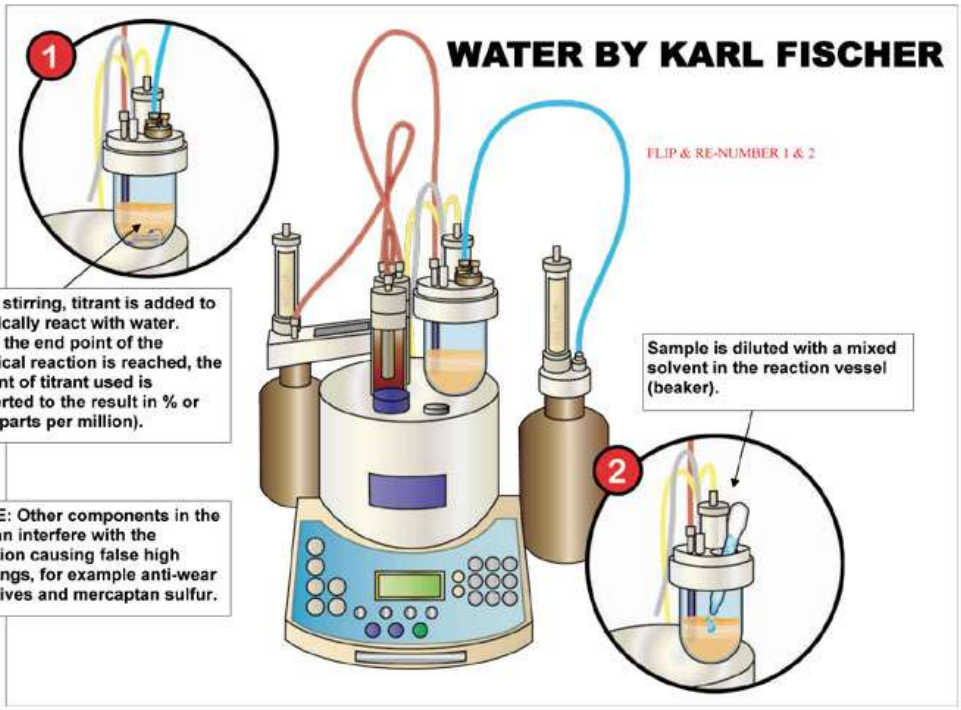
P-F Interval: Days to weeks

Operation: . A measured sample is reacted with a Carl Fischer reagent which contains iodine. When iodine is present, current will pass between two platinum electrodes. Moisture entrained in the sample reacts with the iodine, Perpetuating the test as long as water which has not reacted with the iodine remains. Once depleted, the electrodes are depolarized by the iodine and the test is complete. The corresponding potentiometric change is used to determine the titration endpoints and calculate the water concentration. The duration of the test indicates the water content. High and medium voltage transformers should not exceed 25 PPM at 20°C

Specialized Skills / Training / Experience Required: Laboratory technician.

Advantages: Accurate for small quantities of water parts per million. Accuracy within 10%. Test is relatively fast.

Disadvantages: Adequate samples for sensitive analysis are difficult to obtain. In a large system many folk gasses may be rapidly diluted. Considerable skill needed to interpret the results. Equipment is not portable. Wide range of applications required to justify purchase. Not widely used in the maintenance environment.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.24 MOISTURE MONITOR (VAPOR INDUCED SCINTILLATION)

Conditions Monitored: Water in oil.

Applications: Oil used in diesel gasoline engines, gas turbines transmissions, gearboxes, compressors, hydraulic systems and transformers.

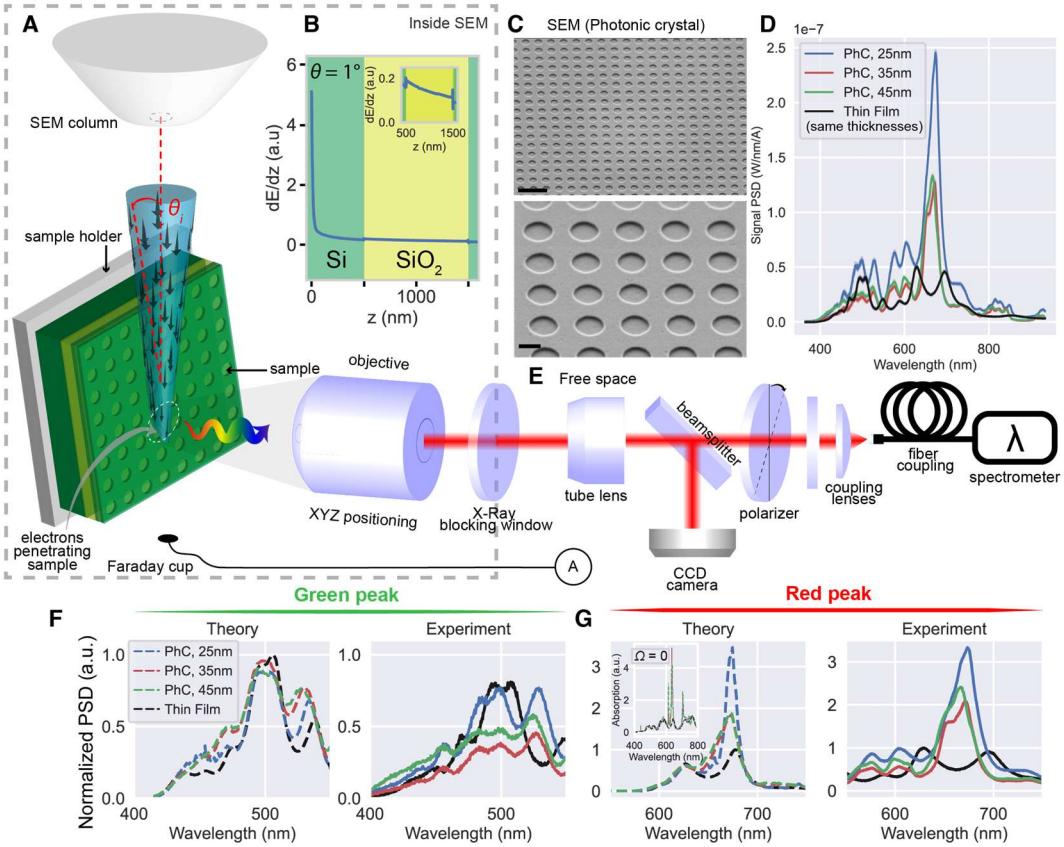
P-F Interval: Several weeks.

Operation: A probe with a miniature heathen element is submerged into an oil sample. During the test the heating element glows at a constant temperature, causing suspended moisture in the sample to vaporize and emitted distinctive acoustic signal known as cracking. And microphone mounted near the heat and element picks up this signal and electronically passes it to the data collector for analysis. The algorithm in the data collector is calibrated to convert signal threshold crossings per unit of time into moisture levels in PPM or a percentage. The unit is able to detect suspended moisture to as low as 25 PPM and as high as 10,000 PPM. A typical test takes 30 seconds.

Specialized Skills / Training / Experience Required: A trained semi schooled worker.

Advantages: No sample preparation needed. Quick and easy. Detects a wide range of concentrations. Requires only 70MILLILITERS of fluid to conduct the test. Contains no moving parts. Not affected by the fluid's viscosity camera color density contamination conductivity, or flow. Portable.

Disadvantages: Equipment is expensive.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.25 CRACKLE TEST (HUMAN SENSES)

Conditions Monitored: Water in oil.

Applications: Oils used in diesel gasoline engines, gas turbines transmissions, gearboxes, compressors, hydraulic systems and transformers.

P-F Interval: Days to weeks.

Operation: A few drops of oil or placed on a hot plate about 250°F If water is present, it quickly vaporizes and makes a popping sound.

Specialized Skills / Training / Experience Required: A trained semi-skilled workers required.

Advantages: Cheap quick and easy to use. Effective and economical.

Disadvantages: Moisture under 300 to 400 PPM cannot be easily heard crackling. Test is subjective from test to test and user to user. Does not qualify the amount of water present. Requires a choir area to hear the crackles. Danger of handling oil around a hot surface.

TEST RESULT	APPEARANCE	WATER CONTENT
No visible or audible change		No free or emulsified water
Very Small Bubbles (0.5 mm) produced and disappear quickly		0.05 - 0.1 % 500-1000 ppm
Bubbles +/- 2 mm, gather to centre, enlarge to 4mm, and disappear quickly.		0.1 - 0.2 % 1000-2000 ppm
Bubbles 2-3 mm produced growing to 4 mm, bubbling and audible crackling.		0.2% and more >2000 ppm

CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.26 CRACKLE TEST (AUDIO DETECTOR)

Conditions Monitored: Water in oil.

Applications: Oils used in diesel gasoline engines, gas turbines, transmissions, gearboxes, compressors, hydraulic systems and transformers.

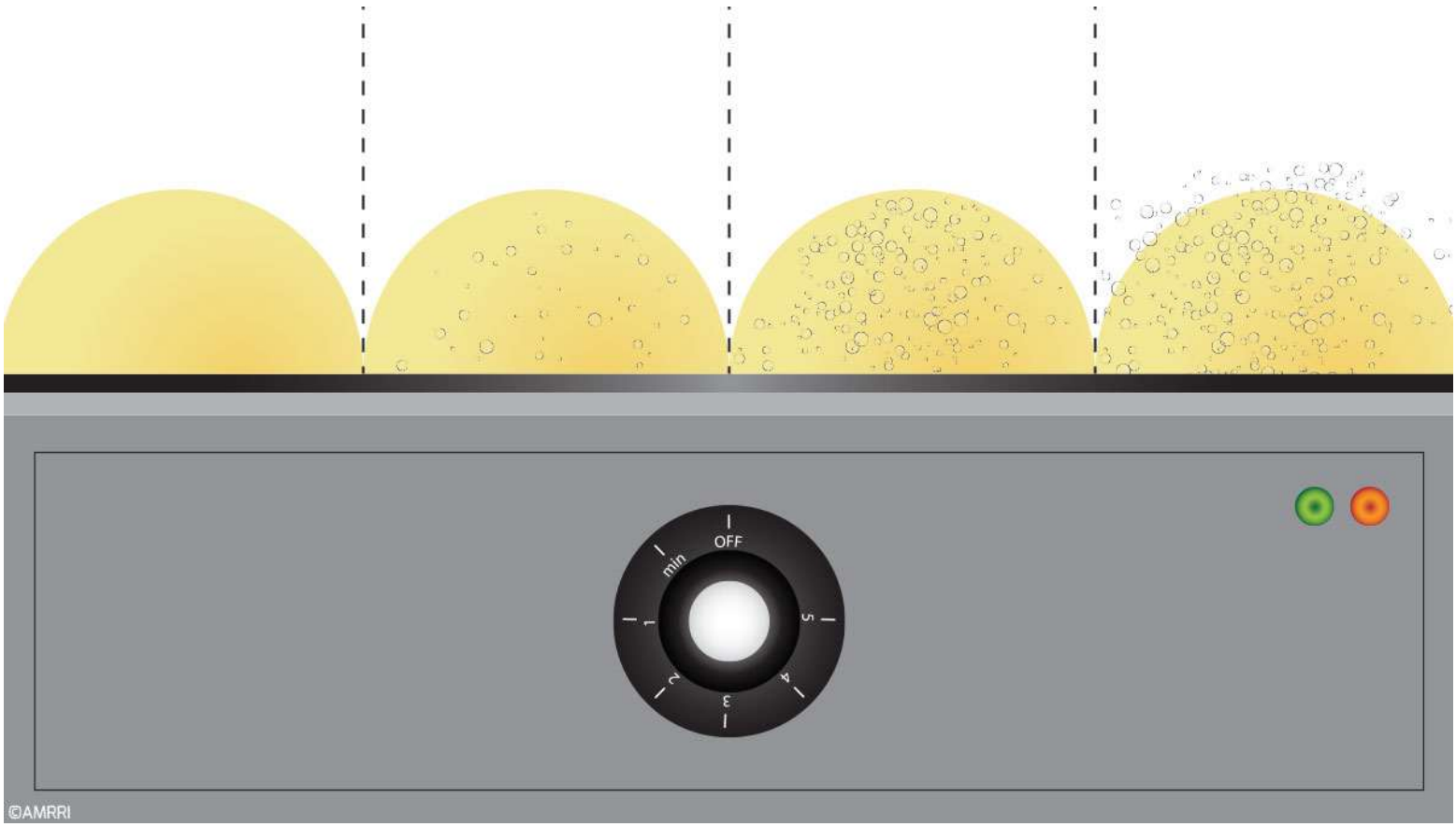
P-F Interval: Weeks.

Operation: A microphone is mounted adjacent to a hot plate near the heating element. A few drops of oil are placed on the hot plate about 250°F. If water is present, it quickly vaporizes and makes it crackling or popping sound. The microphone picks up the sound converts it into an electronic signal and passes it to a data collector for analysis. The algorithm and the data collector is calibrated to convert signal threshold crossings per unit of time into moisture levels in PPM or a percentage.

Specialized Skills / Training / Experience Required: A trained and experienced technician.

Advantages: Can detect moisture levels as low as 25 PPM and as high as 10,000 PPM. Test takes 30 seconds to complete. Easy to use.

Disadvantages: Danger of handling oil around a hot surface. Laboratory test.



CHEMICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

3.27 CLEAR AND BRIGHT TEST

Conditions Monitored: Water in oil.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors, hydraulic systems and transformers.

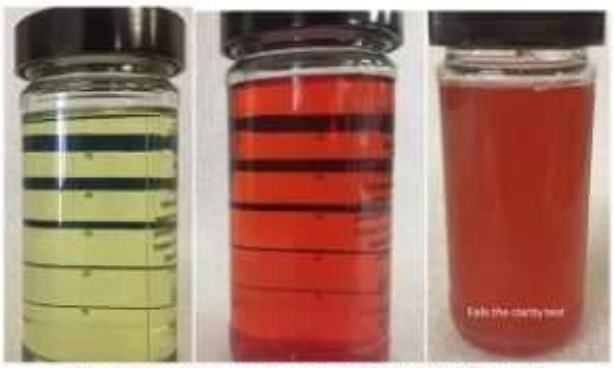
P-F Interval: Several days.

Operation: As Moshe becomes entrained in oil, the oil becomes visibly hazy in other words it is no longer clear and bright however note that some oils can dissolve significant amounts of water depending on its viscosity and the additive package and it still remains clear and bright. It is only when the oil reaches a more advanced stage of emulsification, where the oil and water combine that is no longer clear and bright.

Specialized Skills / Training / Experience Required: An experienced technician is required.

Advantages: No test equipment required. Cheap, quick, simple and economical.

Disadvantages: Oil color can bring error into the test. Subjective.



Two are clear and bright fuel ONE is not.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.01 LIQUID DYE PENETRANTS

Conditions Monitored: Surface discontinuities all cracks due to fatigue, where, surface shrinkage, grinding, heat treatment, corrosion, fatigue, Corrosion stress and hydrogen embrittlement

Applications:. Ferris and non-ferrous materials such as welds, machined surfaces, steel structures, shafts, boilers, plastic structures, Compressor receivers.

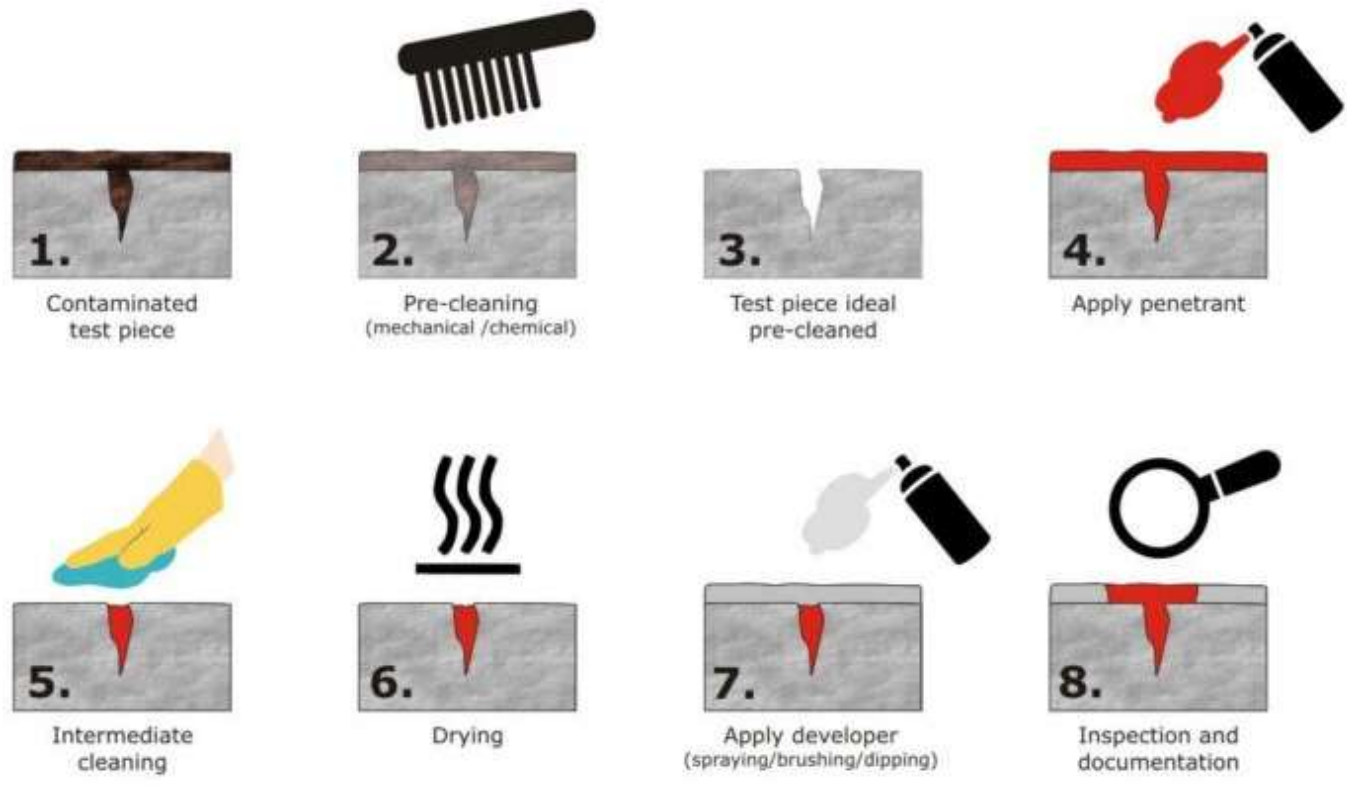
P-F Interval: Several days and several months, depended on the application.

Operation: Did liquid penetrant is applied to the test surface and sufficient time is allowed for penetration into surface discontinuities Excess surface penetrate is removed. A developer is applied which draws the penetrate from the discontinuity to the test surface where it is interpreted and evaluated. Liquid penetrates are categorized according to their type of dye visible dye, fluorescent or dual sensitivity penetrates and the processing required to remove them from the test surface whether it is water washable, post emulsification all solvent removed.

Specialized Skills / Training / Experience Required: To apply the penetrant requires a semi-skilled worker. Interpretation requires suitably experienced technician.

Advantages: Visible dye penetrant kits are very cheap, but the more expensive fluorescent kits are far more sensitive. Detect surface discontinuities on non first materials.

Disadvantages: Fluorescent penetrants require a darkened area for inspection. Hardly qualified personnel required to evaluate the results. Not on-line monitoring technique. Monitor surface brake and defects only. Cannot test materials with very porous surfaces.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.02 ELECTROSTATIC FLUOURESCENT PENETRANT

Conditions Monitored: As for liquid dye penetrants.

Applications: Ferrous and non-ferrous materials such as welds machines surfaces steel structures shafts boilers plastic structures compressor receivers.

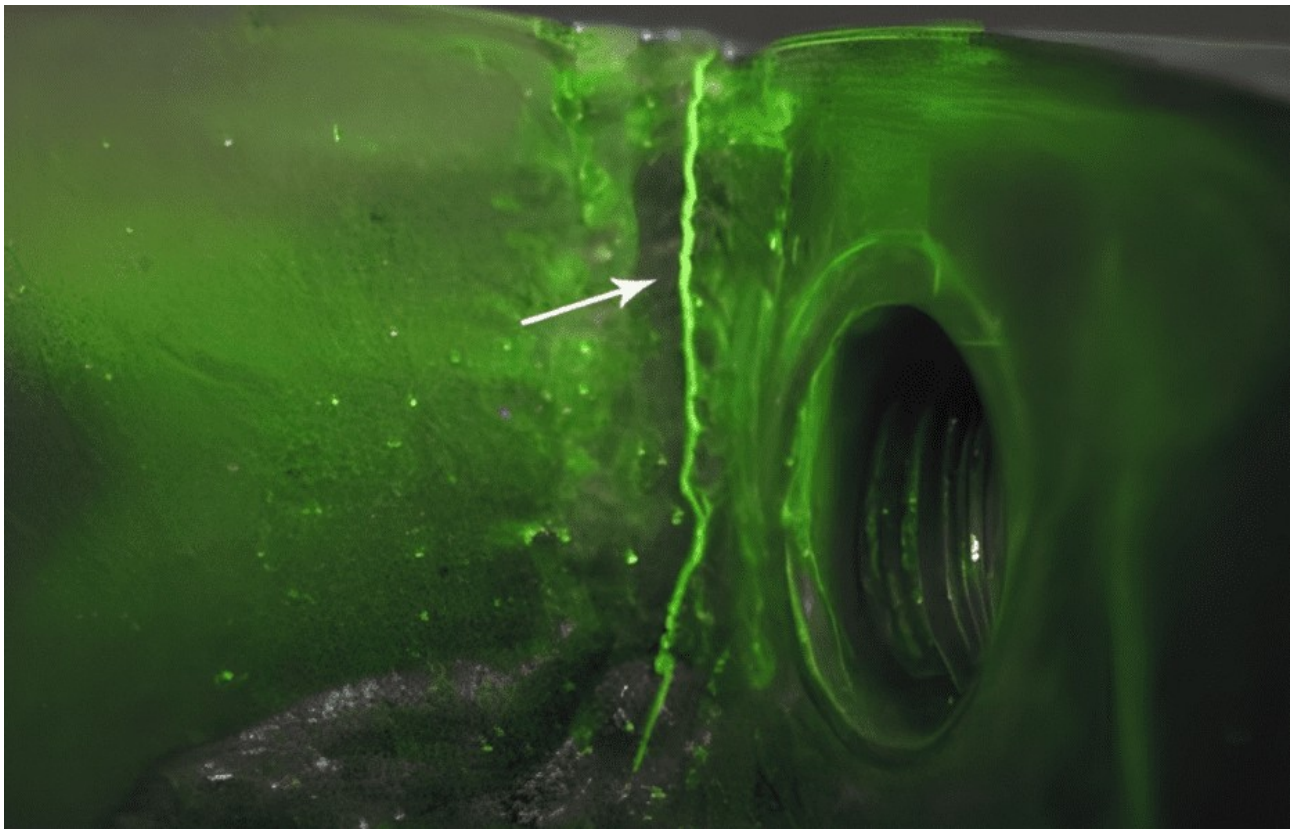
P-F Interval: Slightly longer than liquid dye penetrates.

Operation: As for liquid penetrant dyes, Except that opposing electrostatic polarity must be induced between the work piece and testing materials.

Specialized Skills / Training / Experience Required: Same as for dye penetrates.

Advantages: The polarity ensures more complete and even deposition of penetrant and developer than with ordinary penetrance which gives greater sensitivity.

Disadvantages: As for ordinary fluorescent penetrants.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.03 MAGNETIC PARTICLE INSPECTION

Conditions Monitored: Surface and near surface cracks and discontinuities caused by fatigue, wear, laminations, inclusions surface shrinkage, grinding, heat treatment, hydrogen embrittlement, laps, seams corrosion, fatigue and corrosion stress.

Applications: Ferromagnetic materials such as compressor receivers, welds machine surfaces shafts, steel structures, boilers, etc.

P-F Interval: Days to months depending on the application.

Operation: A test piece is magnetized and then sprayed with a solution containing a very fine iron particles over the area to be inspected. If a crack exists, the iron particles are attracted to the magnetic flux leaking from the area caused by the discontinuity and form an indication which is then interpreted and evaluated.

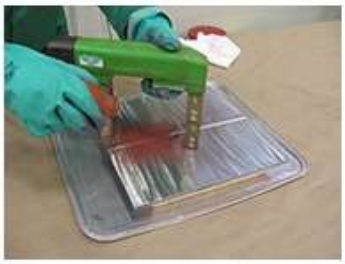
Specialized Skills / Training / Experience Required: A semi-skilled worker is required. Interpretation requires an experienced technician.

Advantages: Reliable and sensitive. Very widely used.

Disadvantages: The text only surface and near surface cracks period time consuming. Contaminates clean surfaces. Not an on-line monitoring technique.

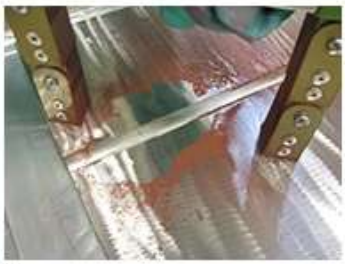
1.
Clean the surface to be examined. This may be accomplished using detergents, organic solvents, descaling solutions, paint removers, vapor degreasing, sand or grit blasting, or ultrasonic cleaning methods.

2.
Introduce a magnetic field into the part.



3.
Apply the ferromagnetic medium while the part is still magnetized.

4.
Remove excess ferromagnetic medium with a light air stream from a bulb, syringe, or other source of low-pressure dry air.



5.
Interpret and evaluate any indications to the applicable acceptance standard.

6.
Turn the yoke 90 degrees from the original position and repeat steps 2-5. Clean and demagnetize if necessary.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.04 STRIPPLE MAGNETIC FLIM

Conditions Monitored: Surface discontinuities to cracks caused by fatigue, wear surface shrinkage grinding heat treatment, hydrogen embrittlement, laminations, corrosion, fatigue corrosion stress, laps and seams.

Applications: Ferromagnetic metals such as compressor receivers, welds machine services shafts, gears, steel structures, boilers etc.

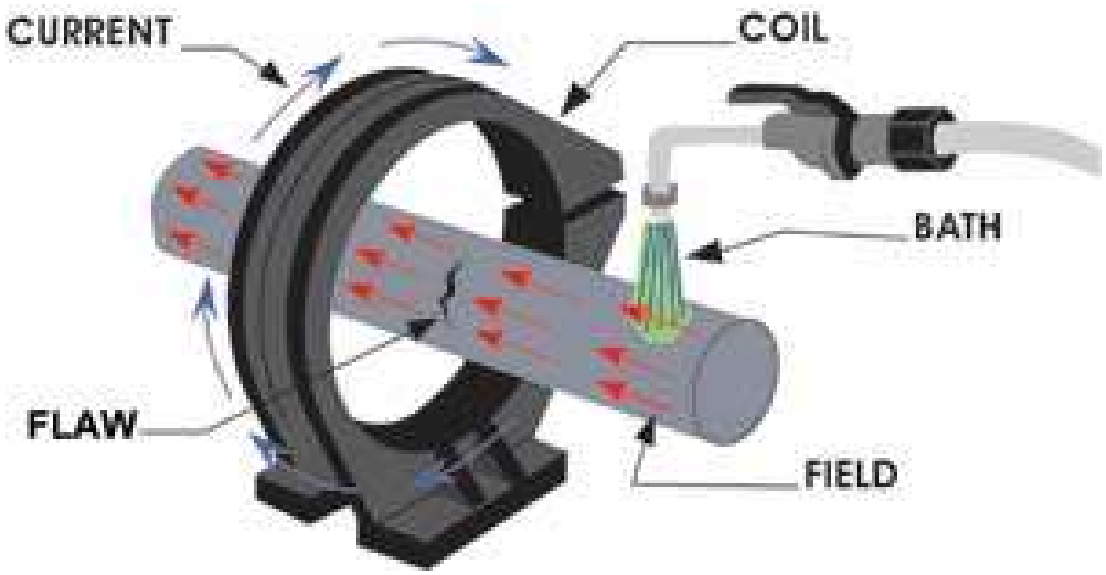
P-F Interval: Several weeks to months.

Operation: A self curing silicon rubber solution containing fine iron oxide particles is poured into or onto the area under inspection and a magnetic field is induced by a magnet. The magnetic particles in the solution migrate to cracks under the influence of the magnetic field. After curing, the rubber is removed as a plug from hose ore as a coating from surfaces. Cracks appear on the cured rubber as intense black lines. Investigation of small cracks may need a microscope.

Specialized Skills / Training / Experience Required: Application of solution requires a suitably trained semi-skilled worker Evaluation requires an experienced technician.

Advantages: Can be used on areas with limited visual access. Provides a record.

Disadvantages: Detects only surface cracks. Not an on-line technique.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.05 ULTRASONICS – PULSE ECHO TECHNIQUE

Conditions Monitored: Surface and surface discontinuities caused by fatigue, heat treatment, inclusions, lack of penetration and gas porosity in welds, lamination. The thickness of materials subject to wear and corrosion.

Applications: Ferrous and non-ferrous materials related to welds, steel structures, boilers, boiler tubes, plastic structures, shafts compressor receivers, etc.

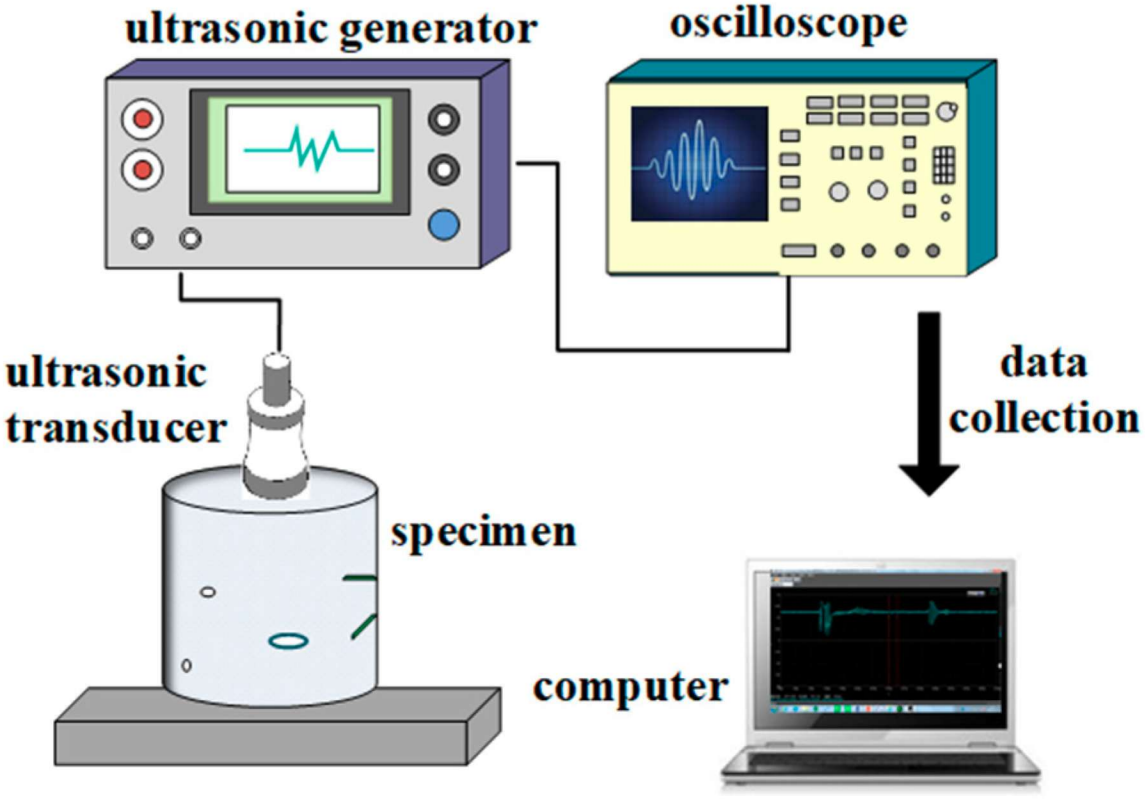
P-F Interval: Several weeks to several months.

Operation: A transmitter sends an ultrasonic pulse to the test surface. A receiver amplifier feeds the return pulse to an oscilloscope The echo is a combination of return pulses from the opposite side of the work piece and from any intervening discontinuity. The time elapsed between the initial and return signals and the relative height indicate the location and the severity of the discontinuity. A rough idea of the size and shape of the defect can be gained by triangularization.

Specialized Skills / Training / Experience Required: A suitably trained and experienced technician is required.

Advantages: Applicable to the majority of materials.

Disadvantages: Difficult to differentiate types of defects.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.06 ULTRASONICS – TRANSMISSION TECHNIQUE

Conditions Monitored: Same as for Pulse Echo Technique.

Applications: Same as for Pulse Echo Technique.

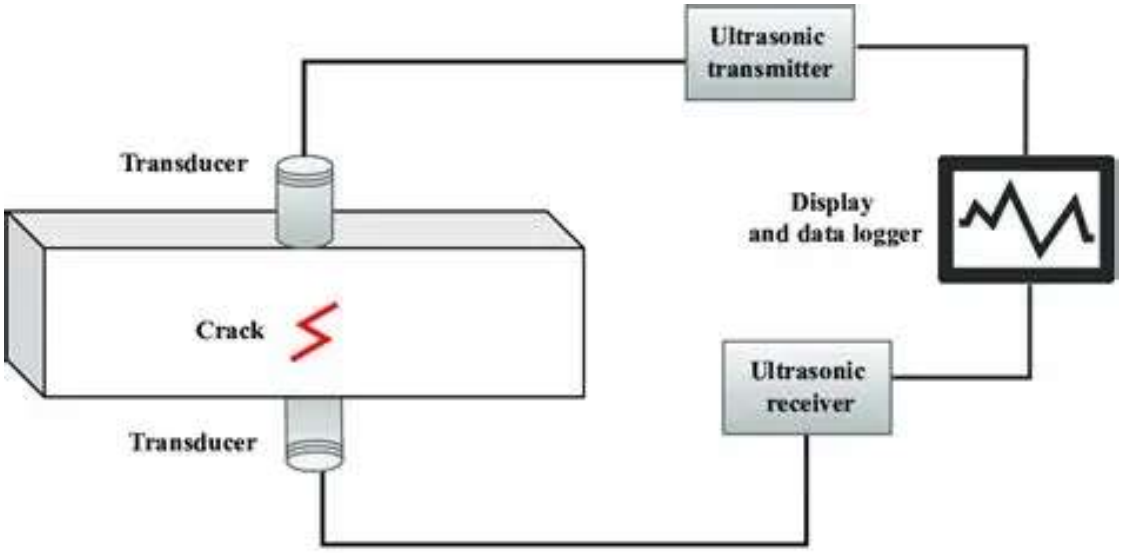
P-F Interval: Same as for Pulse Echo Technique.

Operation: A transmitter emits continuous waves from one transducer which are passed right through the test piece. Discontinuities reduce the amount of energy reaching the receiver and so their presence can be detected.

Specialized Skills / Training / Experience Required: Same as for pulse echo technique.

Advantages: Same as for Pulse Echo Technique.

Disadvantages: As for Pulse Echo Technique. Problems of modulation associated with standing ways cause false readings to be obtained.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.07 ULTRASONIC – RESONANCE TECHNIQUE

Conditions Monitored: Same as for Pulse Echo Technique. Also used for testing the bond strength between thin surfaces.

Applications: Same as for Pulse Echo Technique.

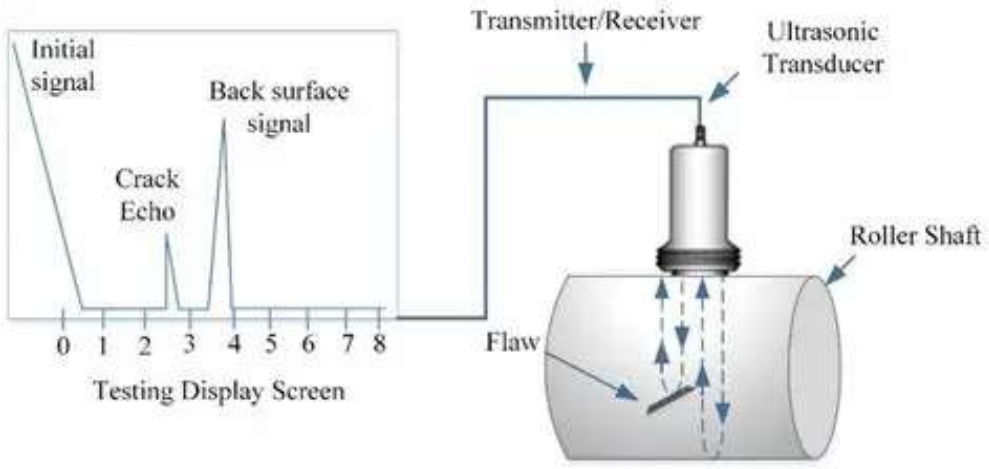
P-F Interval: Same as for Pulse Echo Technique.

Operation: A transmitter is moved over the test surface and the signal is observed. Resonance in the absence of discontinuities keeps the transmitted signal high. Discontinuites cause the transmitted signal to fade or disappear.

Specialized Skills / Training / Experience Required: Same as for Pulse Echo Technique.

Advantages: Same as for Pulse Echo Technique.

Disadvantages: Same as for Pulse Echo Technique.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.08 ULTRASONCICS – FREQUENCY MODULATION

Conditions Monitored: Same as for Pulse Echo Technique.

Applications: Same as for Pulse Echo Technique.

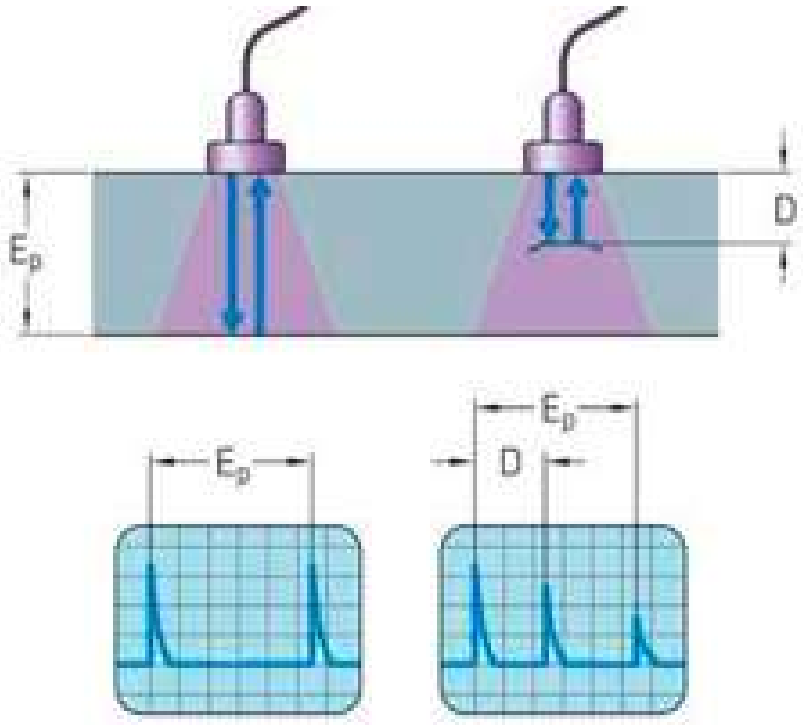
P-F Interval: Same as for Pulse Echo Technique.

Operation: A transducer is used to send ultrasonic waves continuously at changing radio frequencies. Echoes return at the initial frequency and interrupt the new changed frequency. By measuring the phase between frequencies, the location of the defect can be determined.

Specialized Skills / Training / Experience Required: Same as for Pulse Echo Technique.

Advantages: Same as for Pulse Echo Technique.

Disadvantages: Same as for Pulse Echo Technique.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.09 COUPON TESTING

Conditions Monitored: General and localized erosion and corrosion.

Applications: As for electrical resistance method, except paper mills.

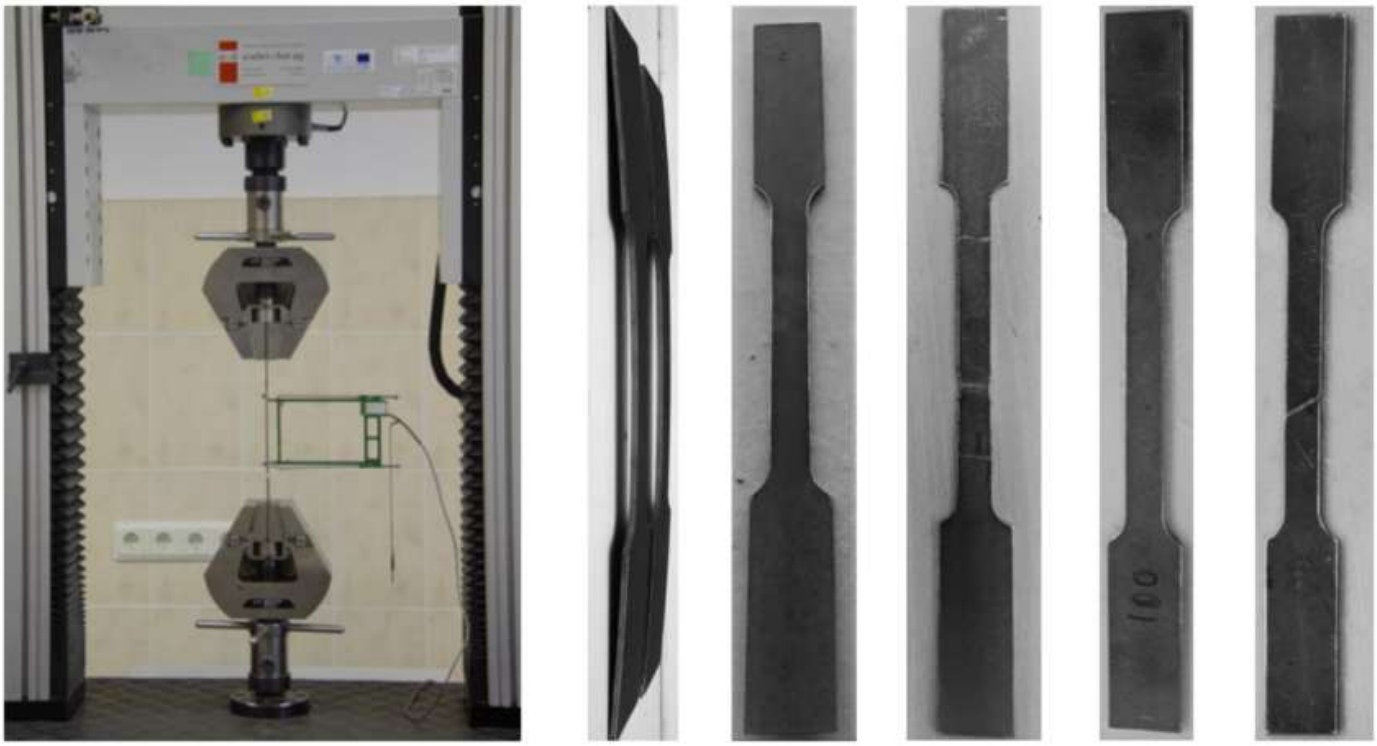
P-F Interval: Several months.

Operation: Coupons are usually produced from mild, low carbon steel or from a grade of material that duplicates the wall of a vessel or pipe. The coupons are carefully prepared, weighted and measured before exposure. After the coupons have been immersed in the process stream for a period of time (several weeks to several months) they are removed and checked for weight loss and pitting From these measurements, relative metal loss from the pipe wall can be calculated and pitting can be estimated.

Specialized Skills / Training / Experience Required: A suitably trained technician is required.

Advantages: Very satisfactory when corrosion is stead. Useful where electrical devices are prohibited. Fairly cheap. Indicates corrosion type. Very widely used.

Disadvantages: Long duration of exposure required. Response to dangerous corrosive conditions is slow. Use of coupons is labor intensive. Corrosion rate determination usually takes several weeks. Provides no allowance for unusual or temporary conditions. Coupons inadequate for pulp and paper industry.



(a) (b) (c) (d) (e) (f)

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.10 EDDY CURRENT TESTING

Conditions Monitored: Surface and subsurface discontinuities caused by wear, fatigue and stress. Detection of dimensional changes through wear, strain and corrosion. Determination of material hardness.

Applications: Ferrous materials used for boiler tubes, heat exchanger tubes hydraulic tubing hoist ropes railway lines, overhead conductors, etc.

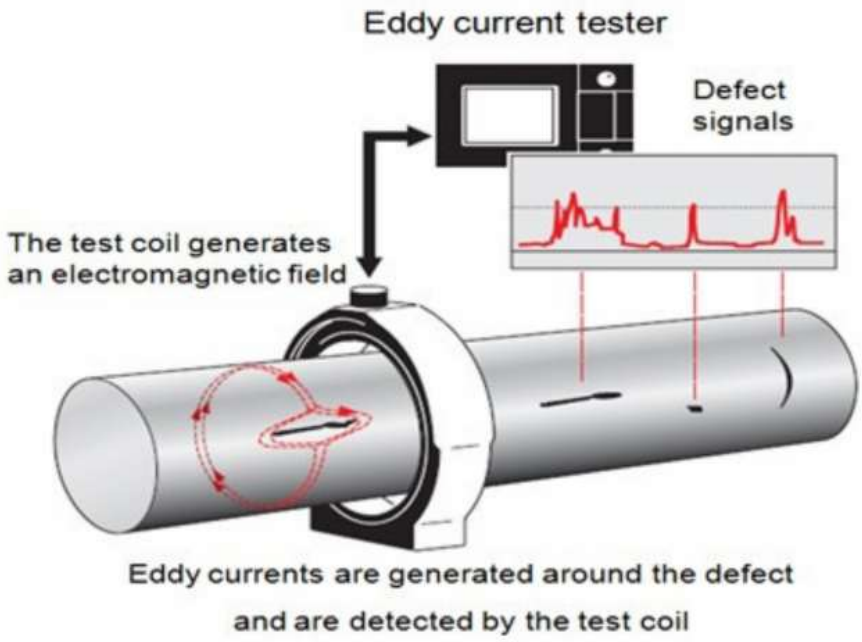
P-F Interval: Several weeks depending on the application.

Operation: A test coil carrying alternating current at 100 kHz to 4 MHZ induces Eddy currents in the part being inspected. Eddy currents detour around discontinuities, becoming compressed, delayed and weakened. The electrical reaction on the testicle is amplified and recorded on a CRT or a direct reading meter.

Specialized Skills / Training / Experience Required: Suitably trained or experienced technician is required.

Advantages: Applicable to a wide range of conducting materials. Can work out surface preparation. High defat detection sensitivity Strip chart recorder provides a permanent record.

Disadvantages: For response from non-ferrous materials.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.11 X-RAY RADIOGRAPHY

Conditions Monitored: Surface and subsurface discontinuities caused by stress, fatigue, inclusions, lack of penetration in welds gas porosity, Intergranular corrosion and stress corrosion. Semiconductor discontinuities such as loose wires.

Applications: Welds, steel structures plastic structures metallic wear components of engines, compressors, gearboxes, pumps shafts, etc.

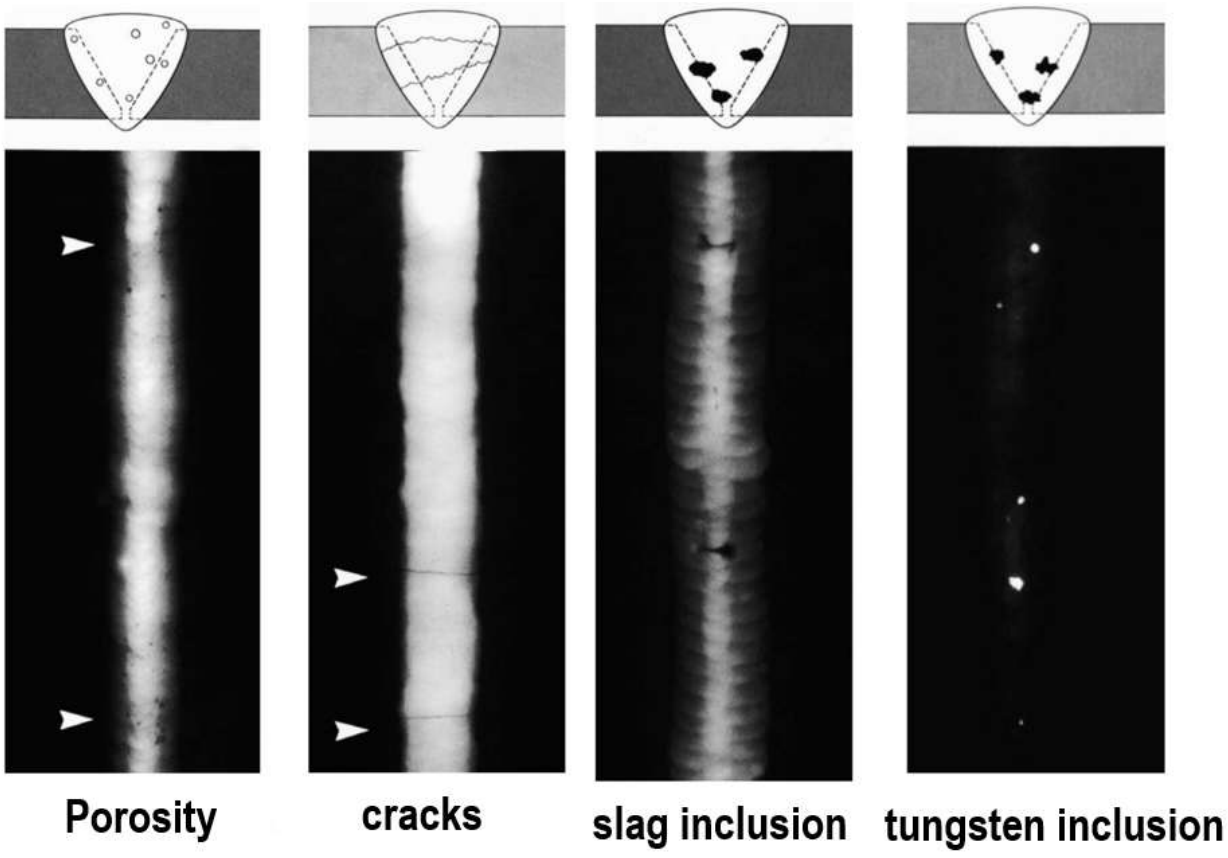
P-F Interval: Several months.

Operation: A radiograph is produced by passing x-rays or gamma rays through materials which are optically opaque. The absorption of the initial x-ray depends on thickness, nature of the material and intensity of the initial radiation. Film exposed to these rays becomes dark when it is developed, how dark it depends on the amount of radiation reach in it. The film is darkest where the object is thinnest. A crack inclusion or void is observed as a dark patch.

Specialized Skills / Training / Experience Required: Use of equipment requires a suitably trained and skilled technician Period to interpret the results requires a highly skilled technician or an engineer.

Advantages: Provides a permanent record. Detects defects in parts or structures not visually accessible. Most widely applied X-ray technique.

Disadvantages: Sensitivity often low for crack like defects. Two-sided access sometimes needed.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.12 X-RAY RADIOGRAPHIC FLOUROSCOPY

Conditions Monitored: Same as X-ray radiography.

Applications: Same as X-ray radiography.

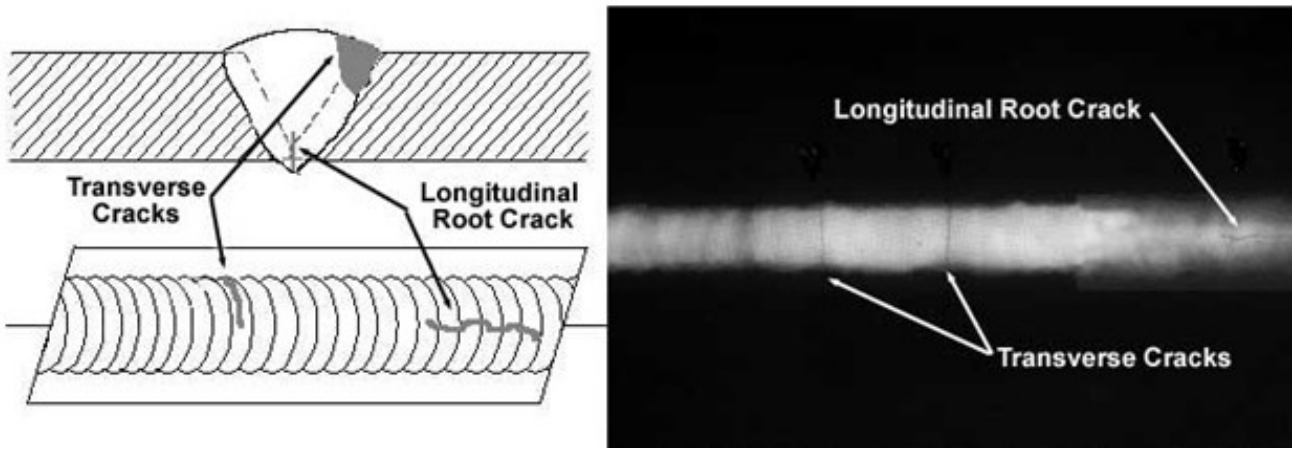
P-F Interval: Same as X-ray radiography.

Operation: The transmitter radiation produces a fluorescence of variant intensity on the coded screen instead of darker patches the brightness of the image is proportional to the intensity of the transmitted radiation.

Specialized Skills / Training / Experience Required: Same as X-ray radiography.

Advantages: Quick results. Scanning capability. Detects defects in parts or structures not visually accessible. Most widely applicable technique. Low cost.

Disadvantages: No record produced. Genuinely inferior image quality. Less sensitive than X-ray radiography.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.13 RIGID BORESCOPE

Conditions Monitored: Surface cracks and their orientation, oxide films, Weld defects, corrosion, wear, fatigue.

Applications: Internal visual inspection of narrow tubes, borers and chambers of engines pumps turbines compressors, boilers etcetera in automotive, Shipbuilding, aircraft, power generation, chemical and related industries.

P-F Interval: Several weeks depended on an application.

Operation: Light is channeled from an external light source along a flexible fiber cable to the bore scope. Very intense light 300 watts enables photographs to be taken.

Specialized Skills / Training / Experience Required: A suitably trained and experienced technician.

Advantages: Inspection done with clear illumination. Parts not visible to the naked eye can be photographed and magnified.

Disadvantages: Provide service inspection only. Resolution limited. Lens system relatively inflexible. Operators can suffer ‘optic eye’ during long inspections.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.14 COLD LIGHT RIGID PROBES

Conditions Monitored: Same as for Rigid Borescopes (also used in combustible and heat sensitive areas).

Applications: Same as for Rigid Borescopes.

P-F Interval: Same as for Rigid Borescopes.

Operation: High intensity white light is channeled from a cold light supply unit one hundred and fifty watts via a flexible fiber cable into a rigid bore scope. The probe contains a lens relay system sheathed by glass fibers which passes the light to the working tip. No light is wasted and no heat is emitted. Forward fore-oblique sideways and retro-viewing of these probes are available. Probe diameters range from 1.7 mm to 10 mm and lengths can be from 8cm to 133 cm. Parts not visible to the naked eye can be photographed and magnified or recorded by a miniature video camera.

Specialized Skills / Training / Experience Required: Same as for Rigid Borescopes.

Advantages: Same as for Rigid Borescopes. No heat is generated when cold light supply is used. Detailed inspection of surface finish is inaccessible to areas can be obtained without dismantling. Photographs provide permanent records. Equipment is portable With the use of the video camera endoscope technique inspection time is reduced to a quarter of the time required for direct viewing.

Disadvantages: Same as for Rigid Borescopes. Not an on-line technique.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.15 DEEP-PROBE ENDOSCOPE

Conditions Monitored: Same as for Rigid Borescopes (also used for inspections of pipework in boilers and heat exchangers).

Applications: Same as for Rigid Borescopes.

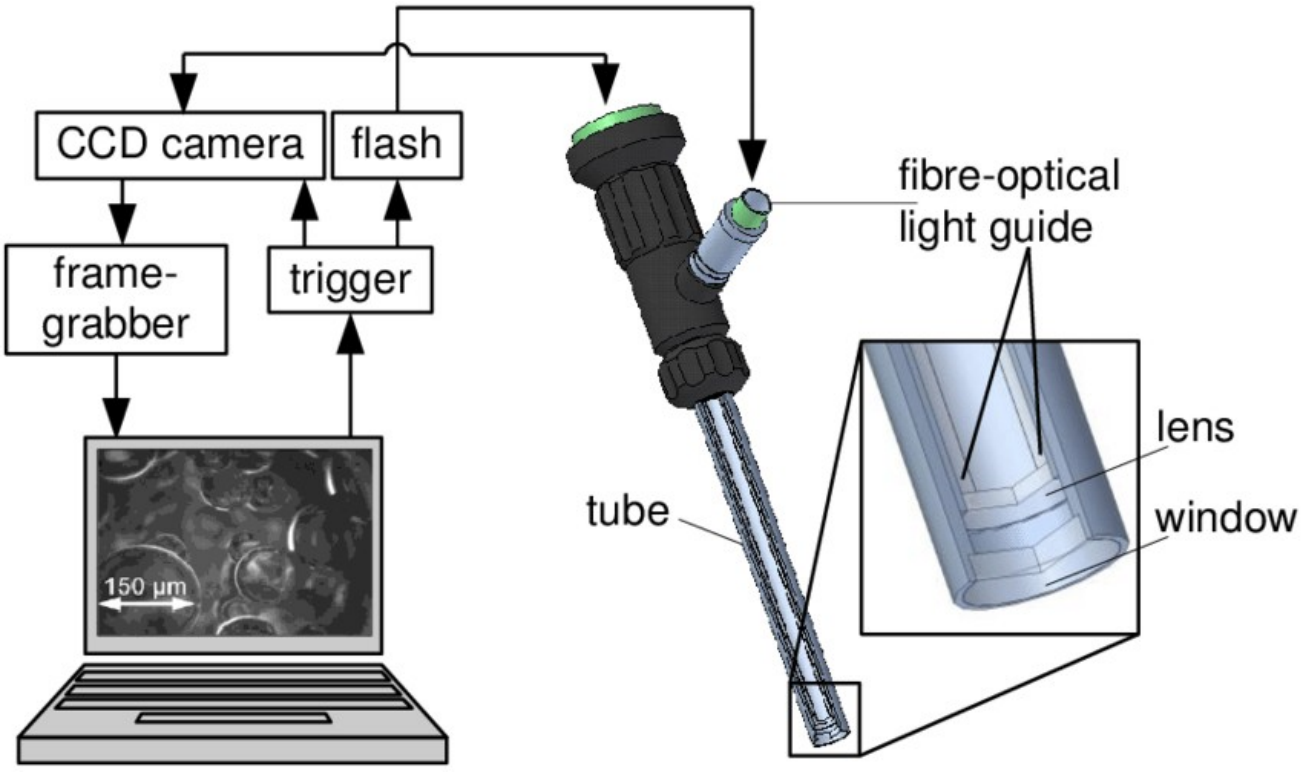
P-F Interval: Same as for Rigid Borescopes.

Operation: These are special modular endoscopes available in lengths of up to 21 meters. They are made of stainless steel and screwed together to provide a viewing system which can penetrate bores with severely restricted entry. Illumination is provided by a high intensity quartz halogen or LED light source

Specialized Skills / Training / Experience Required: Same as for Rigid Borescopes.

Advantages: Same as for Rigid Borescopes.

Disadvantages: Same as for Rigid Borescopes .



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.16 PAN-VIEW FIBERSCOPES

Conditions Monitored: Same as for Rigid Borescopes.

Applications: Same as for Rigid Borescopes.

P-F Interval: Same as for Rigid Borescopes.

Operation: White length high intensity from my code light supply unit is transmitted by total internal reflection through a flexible fiber cable into a fiberscope. The fiberscope contains optical fibers bundled together to form a flexible light pipes. The fiberscope has a remotely controllable prism built into its tip which can be made to forwards or sideways as required. The instrument can be inserted using forward viewing and can be stopped to take detailed sideways look at any passing defect by simply rotating a control knob built into this side of the eyepiece. Adapters can also be used to take photographs or mount TV or video viewers or silly cameras VHS an ultraviolet light of high intensity can also be used with fluorescent penetration to detect minute flaws in inaccessible areas.

Specialized Skills / Training / Experience Required: Same as for Rigid Borescopes.

Advantages: Same as for Cold Light Rigid Probes. Flexibility makes it more detailed inspections possible.

Disadvantages: Not an on-line monitoring technique. Provide surface inspections only. Resolution limited. Operators can suffer from ‘optic eye’ during prolonged inspections. Ultraviolet fiberscopes are expensive.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.17 ELECTRON FRACTOGRAPHY

Conditions Monitored: The growth of fatigue cracks.

Applications: Metallic components subject to cyclic stresses.

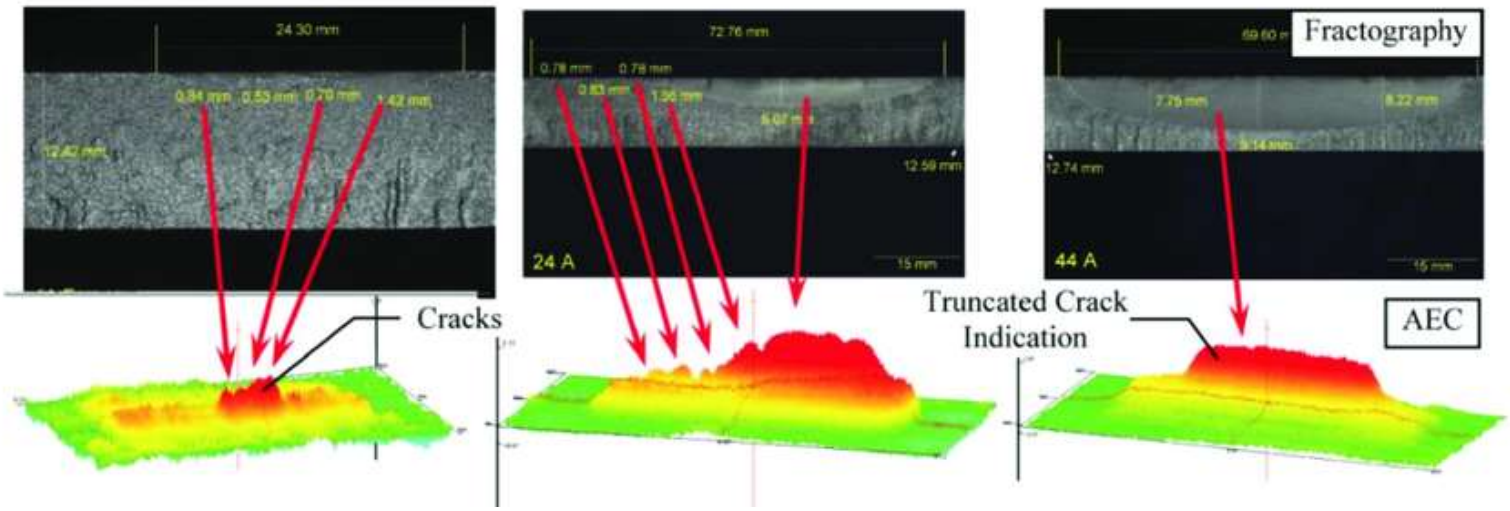
P-F Interval: Depends on the application.

Operation: Every fracture has its own fingerprint in that the history of the fracture progress is imprinted on the fracture surface. By studying a replica of the fracture with an electron microscope it is possible to establish the causes and circumstances of failure.

Specialized Skills / Training / Experience Required: Replica of the fracture surface requires a suitably trained technician. Analysis and reading requires an experienced engineer.

Advantages: Failure can be analyzed with a high degree of certainty. No damage caused to fracture surface when replica is made.

Disadvantages: Electron microscope is expensive. High degree of specialization required to read the results. Not an on-line monitoring technique. Inaccessible components must be dismantled.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.18 COLOR (ASTM D-1524)

Conditions Monitored: Oil color and condition.

Applications: Petroleum based insulating oils in transformers, breakers and cables.

P-F Interval: Weeks to months.

Operation: A test tube is filled with the oil sample and placed next to the color comparator. Color is compared by revolving the color standard disk until a color match is made with the sample. The figure seen in the upper opening in the front cover gives the direct reading. Through high and medium voltage transformers the color limit should not exceed 3.0 on the ASTM D152 color scale.

Specialized Skills / Training / Experience Required: An experienced electrician is required.

Advantages: Provide rapid field screening of test samples for further testing. Transformer does not have to be taken offline to monitor the insulating oil.

Disadvantages: Depends on sampling technique. Can be affected by sunlight.

Color comparator number	Color	Oil condition
< 7	Pale yellow	Good oil
7 - 10	Yellow	Proposition A oil
10 - 11	Bright Yellow	Service-aged oil
11 - 14	Amber	Marginal condition
14 - 15	Brown	Bad condition
16 - 18	Dark brown	Severe condition (reclaimed oil)
> 18	Black	Extreme condition (scrap oil)

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.19 OIL APPEARANCE

Conditions Monitored: Oil oxidization, water contamination, Wire metal particles and particulate contamination.

Applications: Lubricating oils.

P-F Interval: Days to weeks.

Operation: Perhaps the simplest of all tasks. appearance can provide distinct indications of oil condition and contamination. Most industrial oils are gold colored liquids that are bright and free of suspended solids when new. Greece's, coolants and fuels also have a distinct appearance prior to use. A hazy or clouded appearance often indicates water contamination, while graduated darkness often occurs as in oil oxidization in service. Particles as small as 40 microns can be seen by the unaided eye, Providing an indication of large particulate accumulation contamination.

Specialized Skills / Training / Experience Required: A trained semi-skilled worker.

Advantages: Test is simple, quick and cheap. No test equipment is required.

Disadvantages: Subjective. Particles less than 40 microns cannot be seen by the unaided eye. Particle concentration levels and source of contamination cannot be determined. Test dependent on sampling technique.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.20 OIL COLOR

Conditions Monitored: Oil oxidization.

Applications: Lubricating oils.

P-F Interval: Days to weeks.

Operation: Most oils have a bland or nondescript odor when new and develop a more pungent or burned odor as they oxidize in service. An unusual odor may indicate contamination such as fuel dilution. Often, the stronger the older, the greater the level of oxidization or contamination. This technique is also limited by the subjective nature of the observation. Some people have a more sensitive sense of smell and react differently to strong odors. In addition, the vapors can collect in close reservoirs or storage tanks and give off a strong odor when the tank is first opened. These concentrated vapors may therefore suggest higher levels of contamination or oxidization normally exist.

Specialized Skills / Training / Experience Required: Experienced semi-skilled worker.

Advantages: Quick, easy and cheap. No equipment is required.

Disadvantages: Test is subjective.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.21 STRAIN GAUGES (MECHANICAL TALE-TALE GAUGE 3 AXIS MONITORING)

Conditions Monitored: Crack propagation.

Applications: Many large civil structures such as bridges, tunnels, dams and the load bearing elements of large buildings.

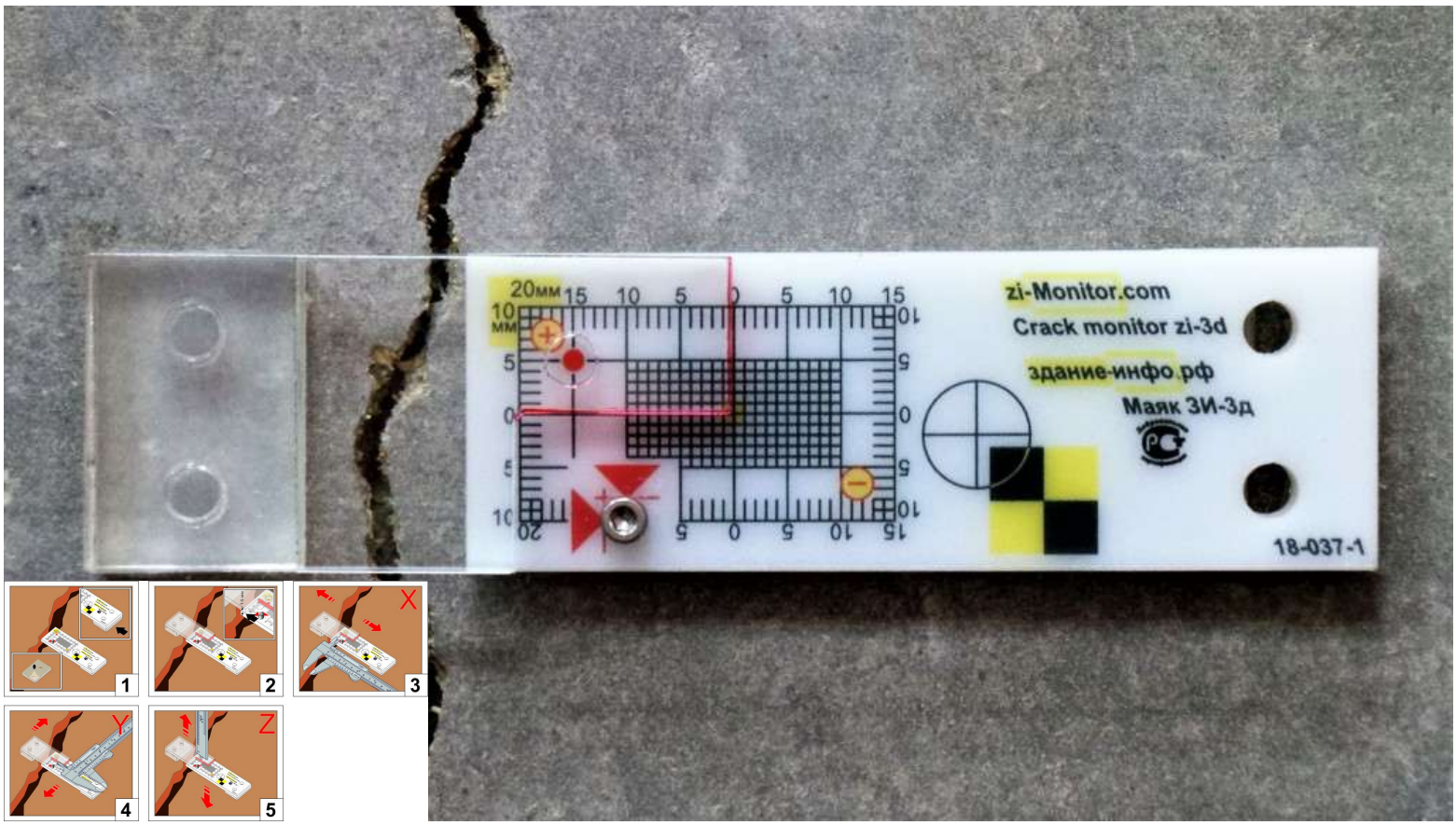
P-F Interval: Months to months.

Operation: A tell-tale or mechanical crack gauge uses 2 plates laid over each other with a marked-out measurement grid on one side and a precise cross-hair mark on the other. Each plate is secured either side of the crack, over time, if the crack moves the plates will move over each other. The cross-hair which starts at 0 mm will indicate the direction and magnitude of movement. Tell-tale gauges are very useful because they can illustrate movement and can show if the crack is getting bigger or smaller in a certain direction.

Specialized Skills / Training / Experience Required: Operation of the equipment requires a suitably trained technician Interpretation of the results require the structural engineer.

Advantages: Readily attached to almost any surface.

Disadvantages: The strain Gage must be compatible with both the material under test and the environment in which it is operating in.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.22 STRAIN GAUGES (ELECTRICAL / ELECTRONIC)

Conditions Monitored: Strain forces.

Applications: Large civil structures such as bridges, tunnels, dams and the load bearing elements of large buildings.

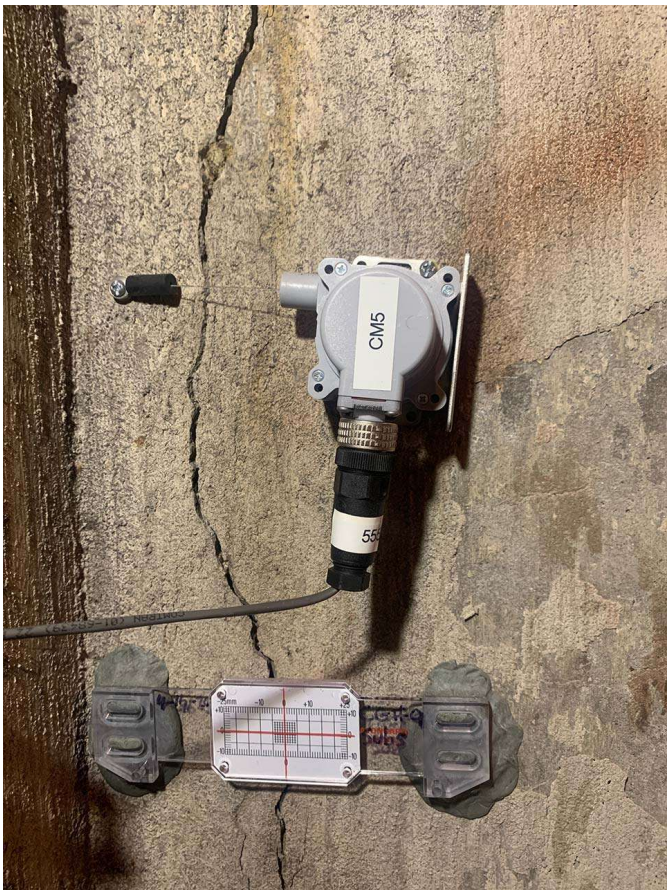
P-F Interval: Months to months.

Operation: Resistance wire, foil and semiconductor strain gages work on the principle that when an electrical conductor is stretched its electrical resistance increases. By bonding the conductor to provide intimate mechanical contact with the surface under test, any strain on that service will be reflected in a change of the resistance in the strain Gage. Sensitive indicating or recording equipment is needed to monitor the strains in most structures.

Specialized Skills / Training / Experience Required: Operation of the equipment requires a suitably trained technician Interpretation of the results require the structural engineer.

Advantages: Readily attached to almost any surface.

Disadvantages: The strain Gage must be compatible with both the material under test and the environment in which it is operating in.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON VISCOSITY MONITORING

Viscosity is an important physical property of lubricating fluids. It is essential in providing the critical clearances between moving and sliding surfaces. Improper viscosity is an early indicator of general lubrication failures. Viscosity changes may also be a warning sign of many potential failure conditions. An increase in viscosity can cause sluggish valve control, pump cavitation, reduce mechanical volumetric and energy efficiencies and increased temperature. A decrease in viscosity can cause increased internal and external leakage, increased temperature excessive wear due to poor lubrication and reduced control and precision.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.23 VISCOSITY MONITORING

Conditions Monitored: Viscosity changes caused by overheating, additive failure, mixed lubricants, fuel and glycol dilution oxidization, moisture and particulate contamination.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors, hydraulic systems and transformers. The diagram below shows a Petroleum Kinematic Viscometer Lubricating Oil Viscosity Testing Instrument.

P-F Interval: Several weeks to months.

Operation: A sensor is attached directly to a portable condition monitor which controls the test sequence and displays the results The sensor tests directly from the sample bottle and gives an on-the-spot viscosity results that can be saved into the PCM for later viewing. Results can be uploaded to a desktop personal computer for trending and graphing. The fluid temperature is measured using a digital temperature probe.

Specialized Skills / Training / Experience Required: A trained skilled technician is required.

Advantages: Fast reliable, on-site testing. Can be calibrated to ASTM viscosity standards. Measures absolute viscosity directly Kinematic viscosity can be determined by entrance specific gravity. Results can be displayed in SSU centipoise sentitroke or ISO viscosity grades and can be recorded at 40°C or 100°C.

Disadvantages: Equipment can be very expensive.

PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.24 FALLING BALL COMPARATOR

Conditions Monitored: Oil viscosity.

Applications: Oils used in diesel and gasoline engines, Gas turbines transmissions, gearboxes, compressors and hydraulic systems.

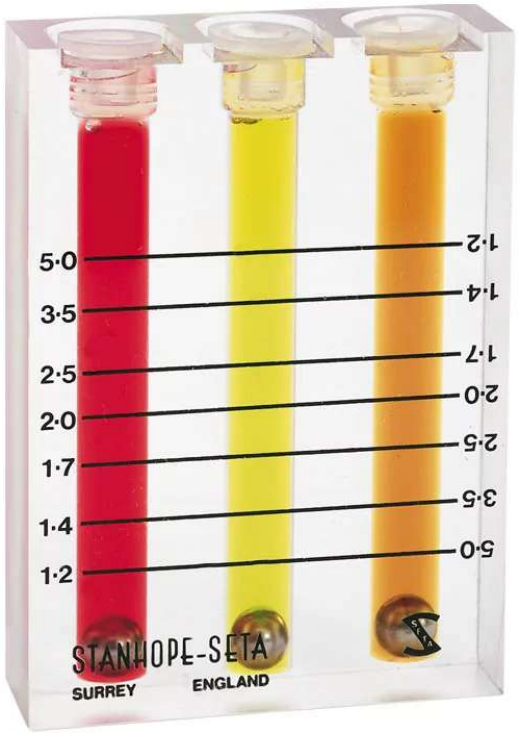
P-F Interval: Weeks to months.

Operation: An oil sample is compared to a reference oil. Identical balls are allowed to fall freely through the sample and the reference oil. The time required to fall a specific distance provides a comparison of viscosity. One kit provides a direct reading of the sample oil viscosity, while others require calculations.

Specialized Skills / Training / Experience Required: A trained laboratory technician.

Advantages: Simple and easy to use. Accurate to within 1% in most cases.

Disadvantages: Oil sample needs to be translucent enough to see the ball as it falls. Dark or oxidizers may be unsuitable. Not a fueled portable technique.



PHYSICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

4.25 KINEMATIC VISCOSITY (ASTM DE445)

Conditions Monitored: Oil viscosity.

Applications: Oils used in diesel and gasoline engines, gas turbines, transmissions, gearboxes, compressors and hydraulic systems.

P-F Interval: Weeks to months.

Operation: This test Resistance to Flow measures the time it takes for a given volume of oil to pass through a calibrated glass capillary This got a meter under a specified head of gravity at a given temperature usually 100°F or 38°C. The test can be used to monitor oil deterioration over time or to indicate the presence of contamination by fuel or other oils. The kinematic viscosity is the product over the time of flow and the calibration factor of the instrument. The dynamic viscosity is the product of the kinematic viscosity value and the density of the liquid.

Specialized Skills / Training / Experience Required: A trained laboratory technician.

Advantages: Can be used for both transparent and opaque oils. Good repeatability. Can be used for most lubricating oils.

Disadvantages: Flammable solvents are used in the test. Not a field technique.

TEMPERATURE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

A PRELIMINARY NOTE ON TEMPERATURE (THERMOGRATPHY) MONITORING

Thermography is the measurement of the radiation emitted from the surface of an object in real time, producing a visible image of the invisible infrared radiation It is based on the principle that all objects above absolute zero -273°F emit infrared radiation Thermal imaging systems are electronic cameras that make the radiation optically visible in an image of different colors or grayscales. These images can be recorded on conventional videotape or other electronic recording media.

TEMPERATURE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

5.01 INFRA-RED SCANNERS

Conditions Monitored: Electrical current, resistance relationships from loose, oxidized or corroded connections or malfunction of the component itself. Mechanical heat generated from friction caused by faulty bearings inadequate lubrication misalignment, misuse and normal wear and tear.

Applications: Electrical applications such as, power distribution and high tension lines transformers transformer bushings, capacitor bank connections, thyristor banks, disconnects, relays and circuit Breakers, meter and control connections circuit breaker contacts bus and fuse connections, fuse clips and stab connections, Molded case and air breakers, motor windings, thermal overloads Conductor fatigue generator windings generating Bush riggings generator feeders to primary exciters voltage regulators motor control centers. Mechanical applications such as boilers and refractories steam piping, heat exchanges, radiators, cooling towers, diesel engines, exhaust manifold, hydraulic systems, gas mains, bearings, bearing lubrication conveyor belts drive gears, drive belts couplings plastics, metals, gears, shafts, castings, Extrusions, turbine blades welds, buried steam lines steam traps, brick refractories, wall and roof insulation, ducting, rotating kilns, tire defects. Continuous process applications such as glass, paper, metal plastic and rubber manufacturing.

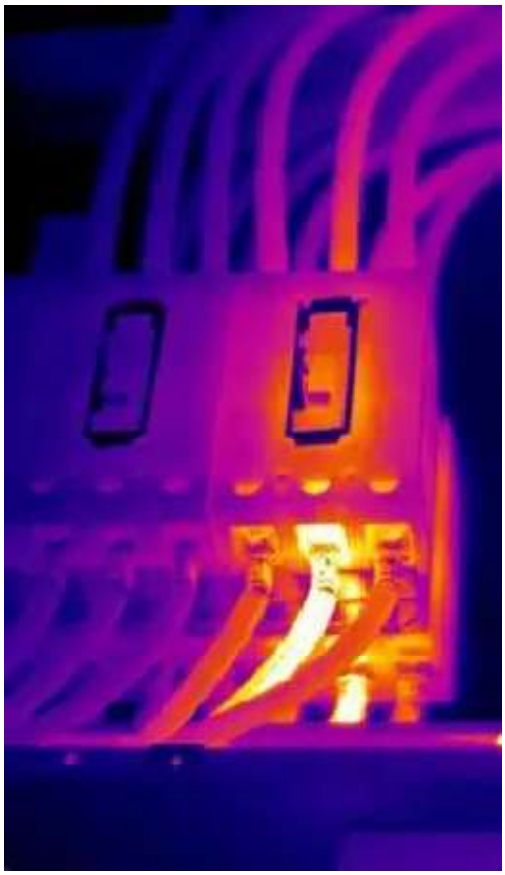
P-F Interval: A few days to several months depended on the application.

Operation: Infrared scanners employ sets of mirrors and Oregon prisons rotating at high speed and a calling mating lens to collect the radiation and deliver it to a few detectors. The detectors responded to their radiation by generating a current, the amount of current being proportional to the amount of radiation. This output is then processed by an on-board processor into a visible color image and presented on a viewfinder or monitor as a thermogram.

Specialized Skills / Training / Experience Required: It seemed to be trained and experienced technicians required.

Advantages: Non-contact, safe to view energize electrical systems. Stationary or movement processes without influencing the temperature of the object. Very sensitive, can see temperature differences as small as 0.1°F or less.

Disadvantages: Equipment can be expensive and can be cumbersome to move around However this technology is rapidly expanding to smaller handheld units Needs specialists to interpret the results.



TEMPERATURE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

5.02 FOCAL PLAN ARRAYS (FPS'S)

Conditions Monitored: Electrical applications such as current, resistance relationships from loose, oxidized or corroded connections, or malfunctioning of the component itself. Mechanical applications such as heat generated by friction caused by faulty bearings, inadequate lubrication, misalignment, misuse and normal wear and tear.

Applications: Electrical applications such as, power distribution and high tension lines transformers transformer bushings, capacitor bank connections, thyristor banks, disconnects, relays and circuit Breakers, meter and control connections circuit breaker contacts bus and fuse connections, fuse clips and stab connections, Molded case and air breakers, motor windings, thermal overloads Conductor fatigue generator windings generating Bush riggings generator feeders to primary exciters voltage regulators motor control centers. Mechanical applications such as boilers and refractories steam piping, heat exchanges, radiators, cooling towers, diesel engines, exhaust manifold, hydraulic systems, gas mains, bearings, bearing lubrication conveyor belts drive gears, drive belts couplings plastics, metals, gears, shafts, castings, Extrusions, turbine blades welds, buried steam lines steam traps, brick refractories, wall and roof insulation, ducting, rotating kilns, tire defects. Continuous process applications such as glass, paper, metal plastic and rubber manufacturing.

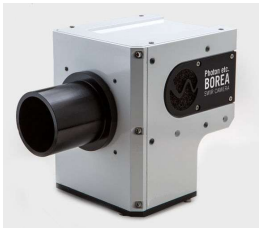
P-F Interval: A few days to several months depended on the application.

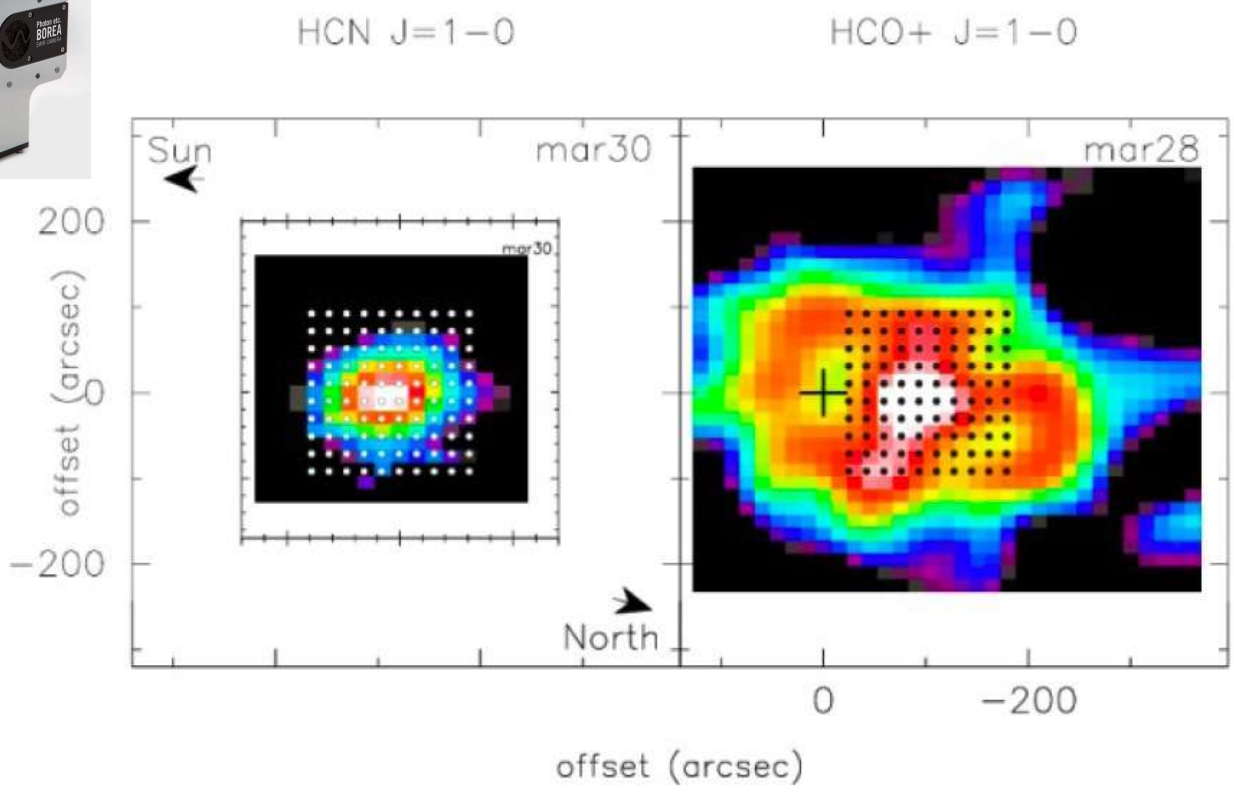
Operation: The lens and the FPA focuses the radiation onto a matrix of detectors which deliver spatial and thermal resolutions that were previously unknown. Each detector is composed of many small elements. The detectors convert their radiation into electrical energy, which is amplified and processed into a visible image presented on a viewfinder or monitor as a thermogram. FPAs have only one moving part.

Specialized Skills / Training / Experience Required: I seem to be trained and experienced technician.

Advantages: Holly versatile. Non-contact. Save the view energized electrical systems, stationary or moving processes without influencing the temperature of the object. Can see temperature differences as small as 0.1°F or less. Small and compact Radiometric.

Disadvantages: Equipment is more expensive than IR scanners. Need specialists to interpret the results.





TEMPERATURE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

5.03 FIBER LOOP THERMOMETRY

Conditions Monitored: Temperature variations caused by insulation deterioration leaks block cooling systems etc.

Applications: Pipelines, engines, transformer windings, power cables.

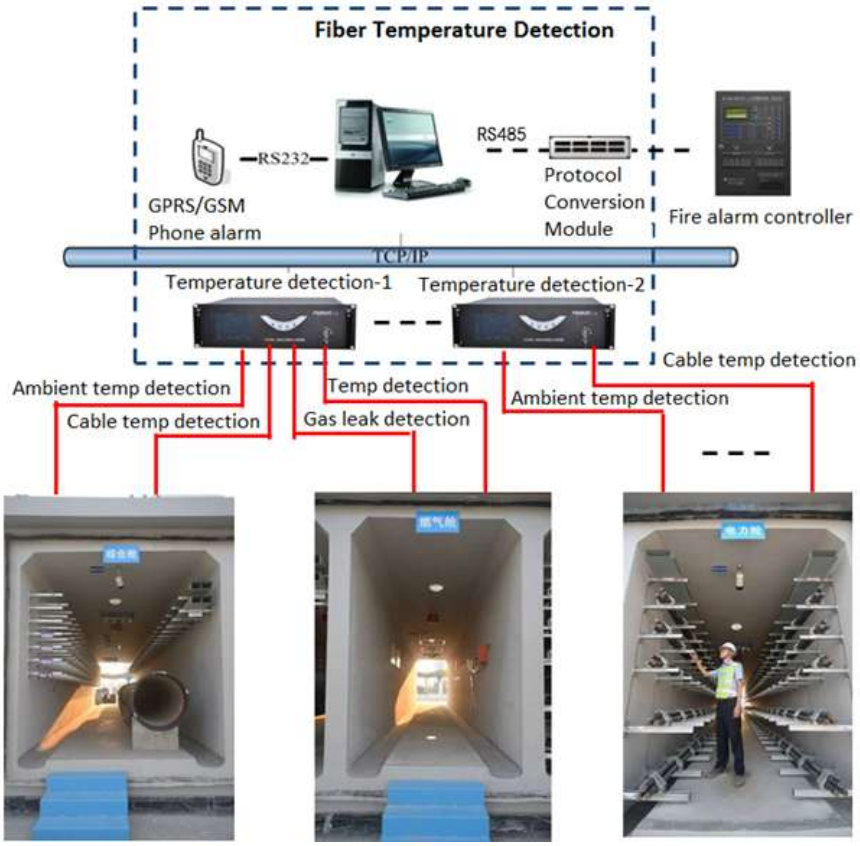
P-F Interval: Hours to months.

Operation: Light is passed down a fiber optic cable. A certain amount of backscatter is reflected back towards the light source and diminishes the strength of the outgoing signal. There is a direct mathematical relationship between the time it takes the light to travel down the fiber cable for a given distance, the amount of backscatter and the temperature of the cable. Their relationship can be determined the temperature at a given point along the cable.

Specialized Skills / Training / Experience Required: A suitably trained and experienced technician.

Advantages: Unaffected by the presence of electromagnetic interference. Operable in hazardous environments. Can reach inaccessible locations. Combines temperature sensing and data transmission in a single component. Continues functioning even if a cable break occurs. Accurate up to 4 km.

Disadvantages: Uneconomic in small installations.



TEMPERATURE EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

5.04 TEMPERATURE INDICATING PAINT

Conditions Monitored: Surface temperature.

Applications: Hotspots, insulation failure.

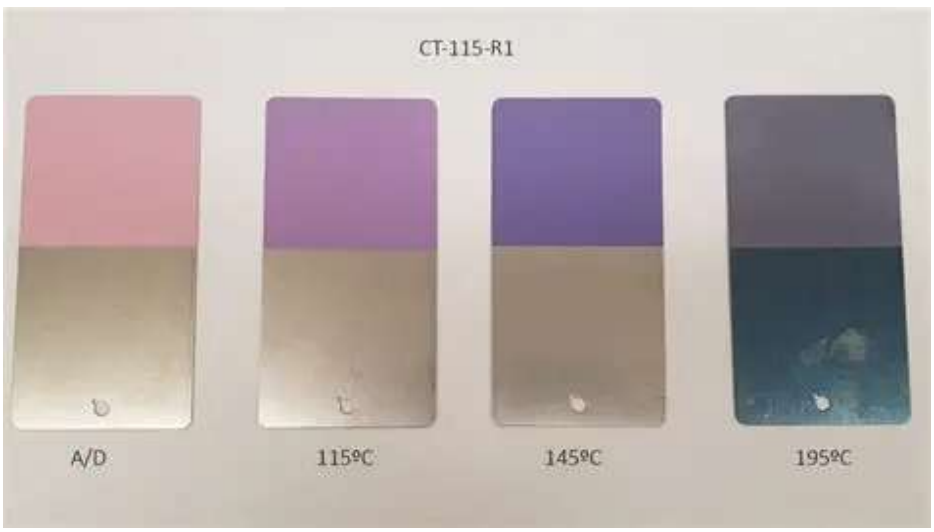
P-F Interval: Weeks to months depending on the application.

Operation: A silicon-based paint which changes color as the temperature rises. The color starts out green, changes to blue at 204°C and turns to white at 316°C. The colors do not change back again as the temperature drops.

Specialized Skills / Training / Experience Required: Very little training is required for observers.

Advantages: Simple. Permanent record at the highest temperature reached.

Disadvantages: Colors do not change back again Only use for at two fixed temperatures. Server slice of each code only one to two years, provided it does not change color in the interim.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.01 LINEAR POLARIZATION RESISTANCE (CORRATOR)

Conditions Monitored: Rate of corrosion in systems exposed to electrically conductive corrosive fluids.

Applications: Cooling water systems municipal water systems, nuclear power heat exchange waters, geothermal power generating systems, desalination plants and pulp and paper mills.

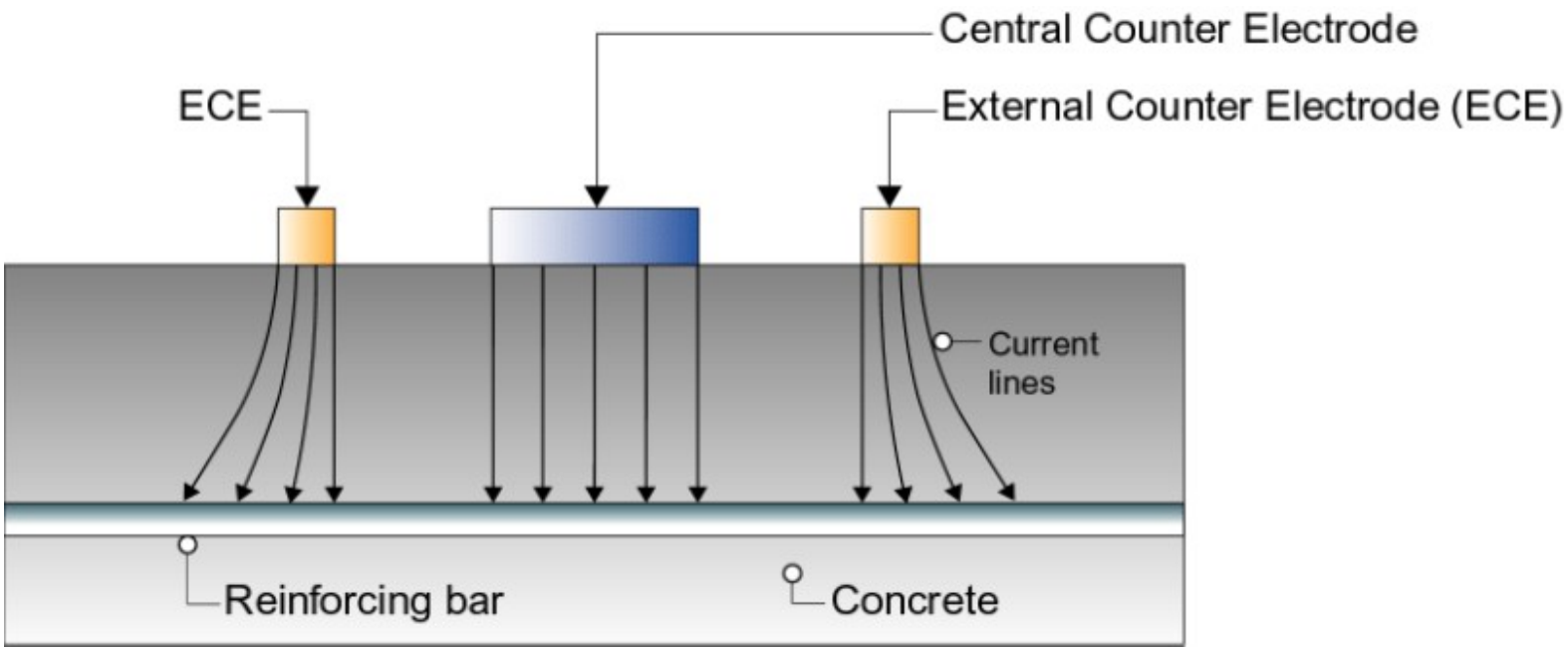
P-F Interval: Usually several months in most applications.

Operation: The electrochemical polarization is based on the fact that a small voteage is applied between a metal specimen and a corrosive solution produces a current. The ratio of applied voltage to current is inversely proportional to the corrosion rate, so this ratio provides a measure of the corrosion rate increase.

Specialized Skills / Training / Experience Required: A suitably trained technician.

Advantages: Provides a quick and direct indication of corrosion rate and pit in tendency. Measures corrosion as it occurs. Some instruments record the corrosion condition. Automatic and portable systems available. Sensitive to corrosion race as low as a fraction of a mil per year. Easy to interpret results.

Disadvantages: Portable equipment does not provide a permanent record. Readings must be adjusted when taken in high sensitivity corrosive media. Gives no information on total corrosion.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.02 ELECTRICAL RESISTANCE (CORRATOR)

Conditions Monitored: Integrated metal loss for example total corrosion.

Applications: Petroleum refineries process plants gas transmission plants, underground or undersea structures, Cathodic protection monitoring, abrasive slurry transport, water distribution systems, atmospheric corrosion, electrical generating plants, paper mills etc.

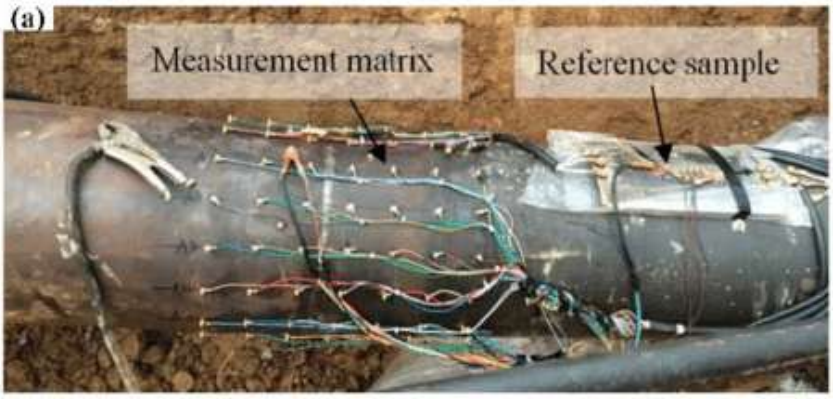
P-F Interval: Usually several months in most applications.

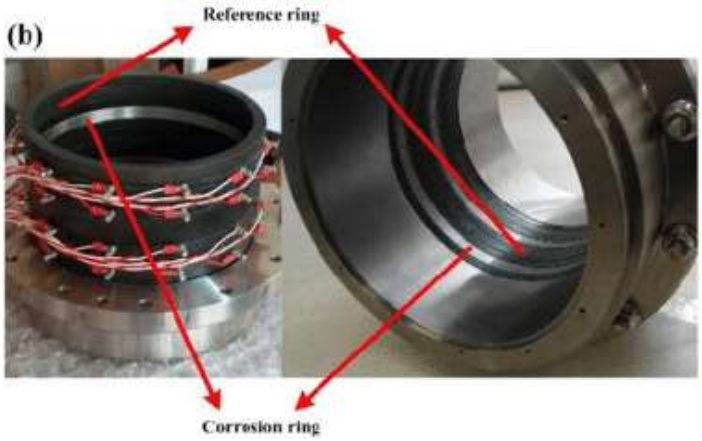
Operation: The system is composed of a probe and an instrument to read the probe The probe consists of a wire, strip or tube of the same metal as the plant being monitored. The electrical resistance of the probe, measured by a bridge circuit increases as the probe cross section decreases with corrosion. The increased resistance corresponds to total metal loss, which is easily converted to a corrosion rate.

Specialized Skills / Training / Experience Required: Same as Linear polarization method.

Advantages: When plotted against a timescale yields both corrosion rate and total metal loss. Can be used in any environment. Portable equipment available. On-line monitoring possible. In plant equipment provides permanent records. Interpretation normally easy.

Disadvantages: Indicate whether the corrosion rate at a particular time is high or low. Portable equipment provides no permanent record.





ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.03 POTENTIAL MONITORING

Conditions Monitored: Corrosion states active or passive such as stress corrosion cracking, pitting corrosion, selective phase corrosion, impingement attack etc.

Applications: Electrolyte environments such as chemical process plants, paper mills, electrical generating plants, pollution control plants, desalinization plants, etcetera. Best suited to stainless steel nickel-based alloys and titanium.

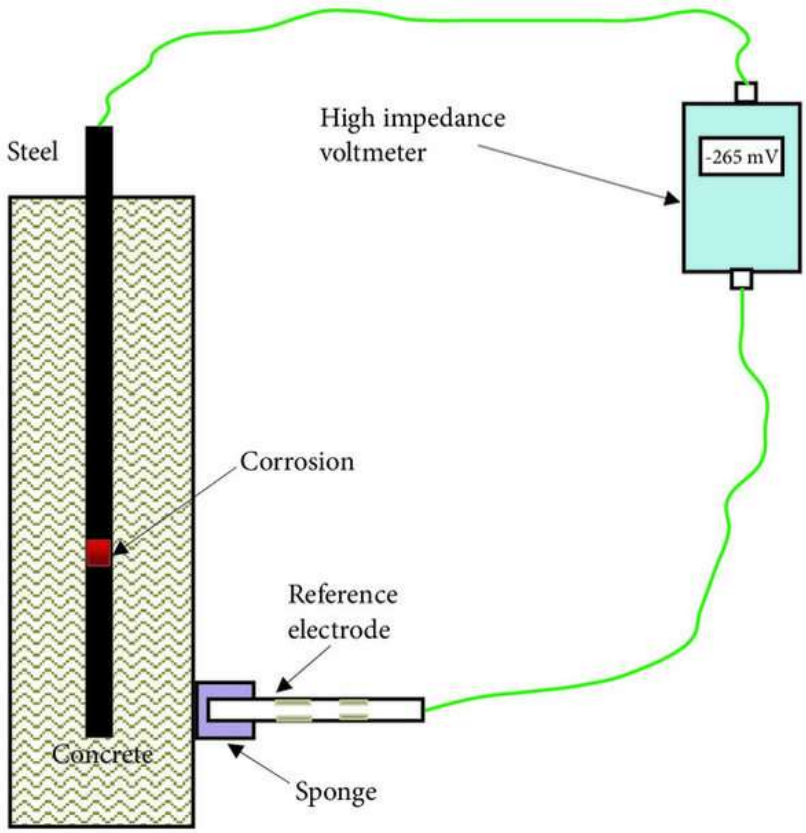
P-F Interval: Depends on the material and rate of corrosion.

Operation: This technique takes advantage of the fact that from the point of view of corrosion, a metal which is in a passive state of low corrosion rate has a noble corrosion potential, while the same metal in an active state higher corrosion rate has a much less noble potential. The potential changes one passivity breaks down, and measurements can be made using the voltmeter of about one mega ohm input and impedance to full scale deflection of 0.5 to 2 volts.

Specialized Skills / Training / Experience Required: Usually a trained technician but sometimes needs an experienced engineer.

Advantages: Monitors localized attack. Fast response to change.

Disadvantages: Small potential changes can be influenced by changes in temperature and acidity. Does not give a direct measurement of corrosion rate or total corrosion. Expert assistance may be required for interpretation.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.04 POWER FACTOR TESTING

Conditions Monitored: Power loss through the installation system caused by leakage to ground moisture and cables.

Applications: Electrical circuits, transformer windings high voltage transformer bushings, high and medium voltage cables.

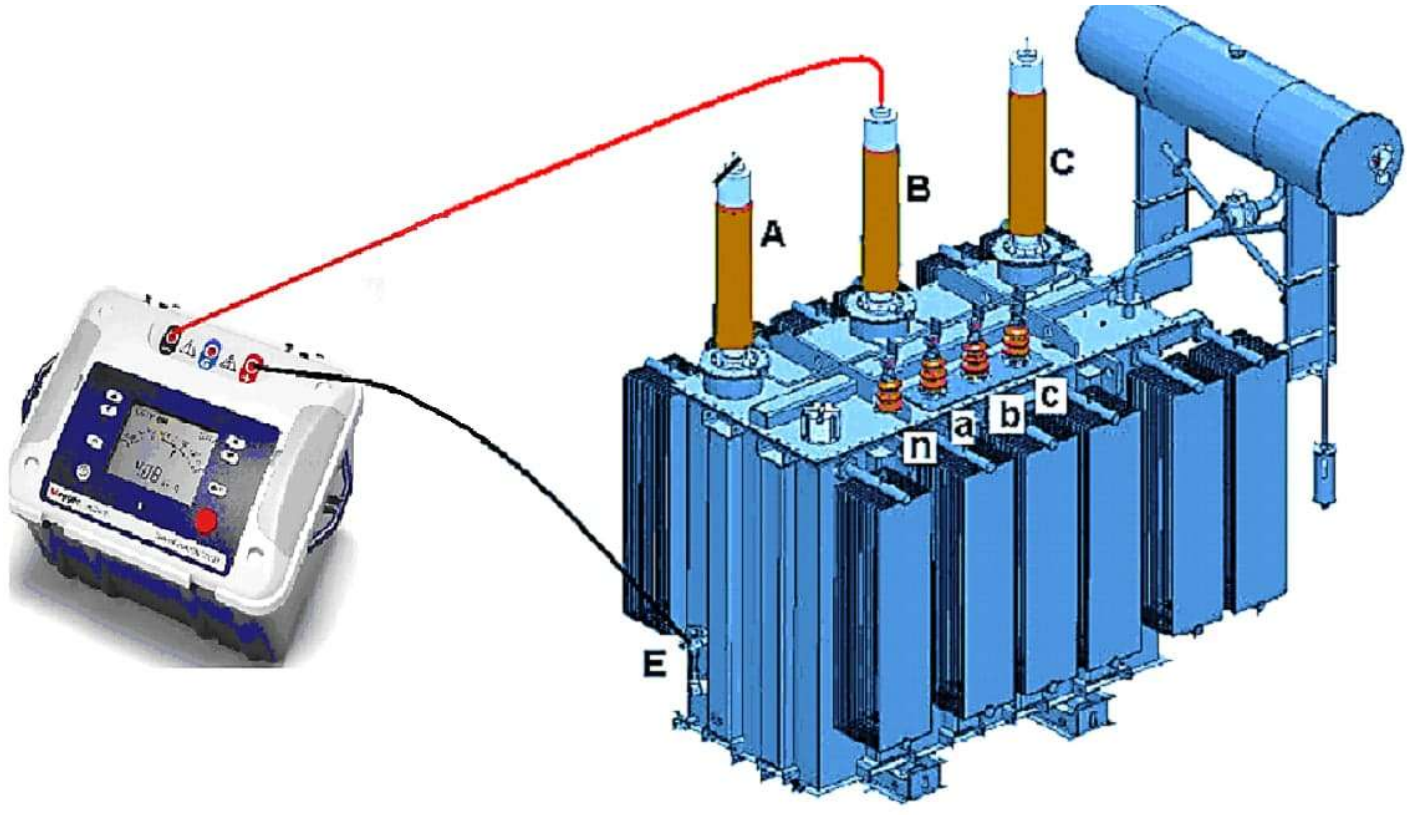
P-F Interval: Several months.

Operation: Power factor is circuit resistance divided by circuit impedance. A known voltage is applied to the wind and insulation and the resulting current is measured. The cosine of the angle between the voltage and current is called the power factor. The measured current squared times the installation resistance called the what loss. These values are measured and recorded when the installation system is first installed to establish a baseline. Subsequent tests results are compared to the initial readings. As the circuit impedance changes due to aging, moisture, contamination, insulation shorts or physical damage, the power factor raises. A newly filled oil transformer should have a power factor of under 0.5 percent and an in-service oil field transformer under 2%.

Specialized Skills / Training / Experience Required: Conducting the test requires the field technician. Analyzing the data requires an engineer.

Advantages: One of the best predictive tests.

Disadvantages: Not an on-line technique.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.05 MEGGERS AND OTHER VOLTAGE GENERATORS

Conditions Monitored: Insulation resistance.

Applications: Electrical circuits.

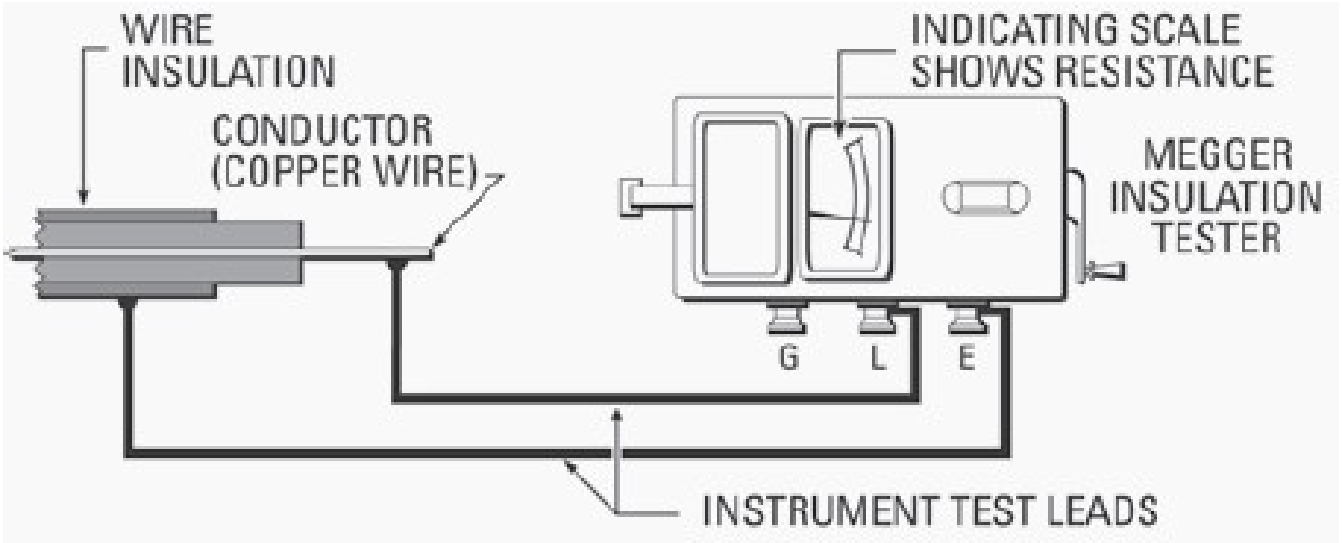
P-F Interval: Months to years.

Operation: A known DC 250 volts to 10 KV voltage is applied to the equipment under test, resulted in a hopefully small current flow If there is no current return to the test set from the equipment under test the current must be flowing to ground. The current flowing to ground is called leakage current. The insulation resistance can be calculated using Ohm's law.

Specialized Skills / Training / Experience Required: Technicians or Engineers.

Advantages: A simple and very well understood technique.

Disadvantages: Tests cannot be carried out on-line.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.06 BREAKER TIMING TESTING

Conditions Monitored: Breaker contact travel speed wipe and bounce.

Applications: High and medium voltage circuit Breakers.

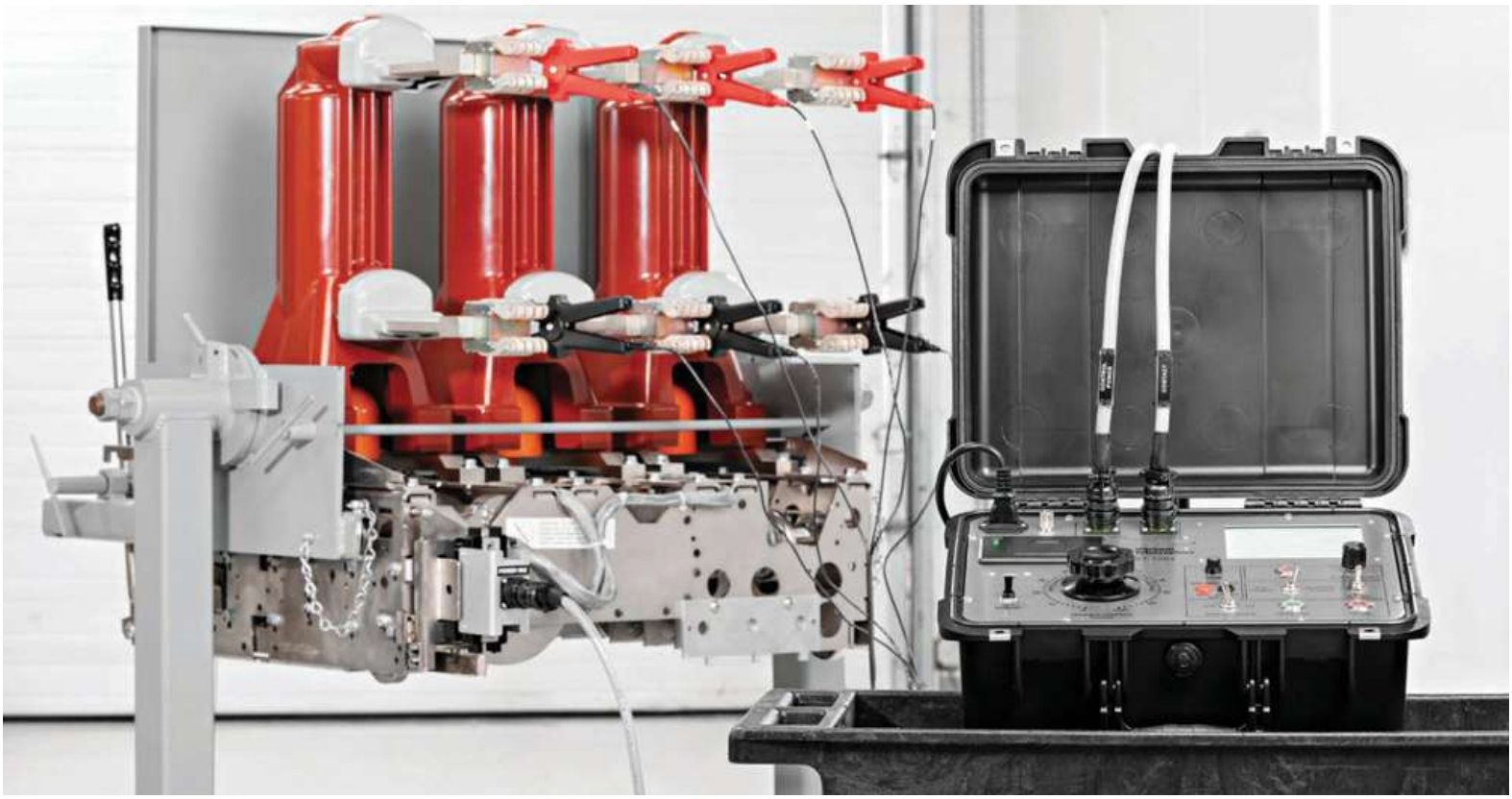
P-F Interval: Weeks to months.

Operation: A transducer is mechanically attached to the breaker mechanism, then electrically connected to a timing set. The breaker circuit is then operated through its entire cycle of opening and closing. The test set measures contact travel, speed, wipe and bounce. These results are compared to the last Test and to the manufacturer's recommendations. Trend in this information indicates whether adjustment to the breaker is necessary.

Specialized Skills / Training / Experience Required: Conducting the test requires field technicians. Analyzing the data requires an engineer.

Advantages: High and medium voltage Breakers can benefit from this test.

Disadvantages: Not an on-line technique. Not applicable to molded case Breakers and or low voltage Breakers.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.07 BREAKER CONTACT RESISTANCE TEST

Conditions Monitored: Breaker contact wear and deterioration.

Applications: Circuit breakers.

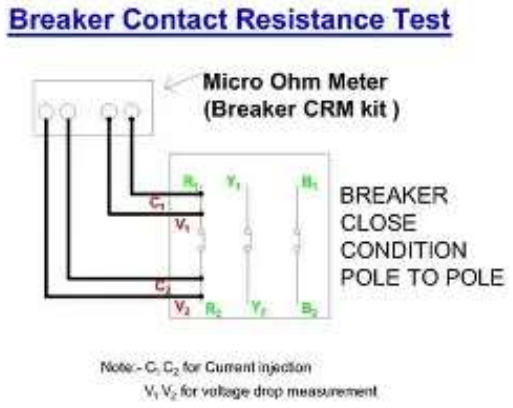
P-F Interval: Several weeks.

Operation: A DC current usually 10 or 100 amps is applied to the contacts the voltage across the contacts is measured and the resistance can be calculated using Ohm's law. Resistances of about 200 micro ohms are normal, although manufacturers routinely publish their own design limits. This value is trended overtime to assess deterioration. Maximum limits can be obtained from manufacturers.

Specialized Skills / Training / Experience Required: Conducting the test requires field technician. Analyzing the data requires an engineer.

Advantages: Resistance values can be trended over time to detect potential failures before the breaker contacts deteriorate significantly.

Disadvantages: Not an on-line technique. Normal resistance meter cannot be used due to the resistance being in the order of micro ohms. Not recognized as a true predictive technique.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.08 MOTOR CIRCUIT ANALYSIS (MCA)

Conditions Monitored: Changes in conductor path resistance caused by loose or corroded connections, loss of copper turns in the stator. Face to face inductance caused by magnetic interaction between stator and rotor. Stator inductance affected by road deposition, rotor porosity and eccentricity state of turn coil and phase shorten. Winding cleanliness and resistance to ground.

Applications: electric motors DC, AC inductions, synchronous and wound rotor.

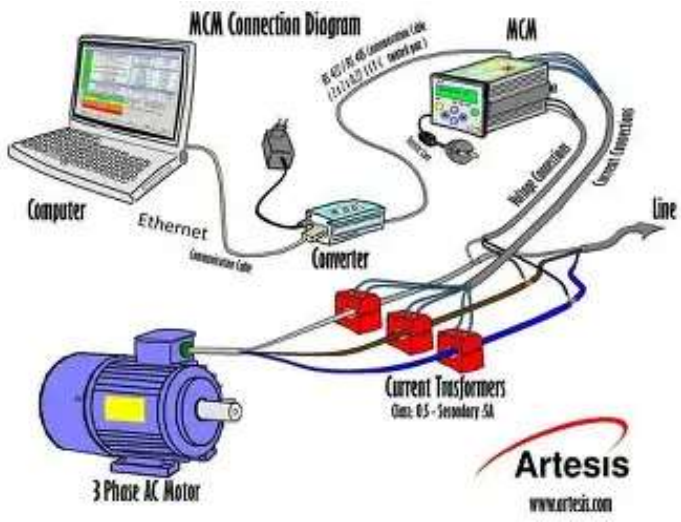
P-F Interval: Several weeks to months depending on the application.

Operation: A number of tests are taken together to give a complete picture of the motor circuit condition. Algorithms and rules are used to measure the severity of any defects which may present. The test applies a low DC and AC voltage resistance to ground test uses 500 to 1000 volts DC at the motor control center Power bus to measure the following, resistance to ground, circuit resistance face to face, capacitance to ground come up inductance phase to phase rotor influence, DC bar to bar and polarization index dielectric absorption in the conductor path at a motor circuit the resistance of each phase is measured and compared to other phases. Readings are usually lower for large motor circuits and higher for smaller motors. Unequal resistance in any part of the circuit unbalances the voltage in the phases, which in turn causes significant heating of the motor windings. Inductive imbalance is also measured. This indicates imbalance magnetic fields and unequal current flows in the windings and is most often associated with stator windings but can be influenced by the stator iron and rotors. The increased capacitance values are normally associated with the motor when the void between the stator and the motor case becomes dirty and or damp the capacitive effect between the conductor path inside the insulation and the outer skin that the insulation is increased. AC current passes across this natural capacitance and then the ground via The Dirty, wet connections to the rotor motor casing.

Specialized Skills / Training / Experience Required: Conducting the test requires a Field Technician. Analyzing the data requires an engineer.

Advantages: Tassel down at low voltages and minimum current test signals which are non-destructive. Lightweight importable equipment can be used in the field. Tests can be done at the MCC requiring no break in motor connections.

Disadvantages: Not an on-line technique. Motor circuit must be non energized.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.09 ELECTRICAL SURGE COMPARSION

Conditions Monitored: Turn to turn and face to face installation deterioration and reversal or open circuit in the connection of one or more coils or coil groups.

Applications: Induction or synchronous motors, DC armatures synchronous field poles.

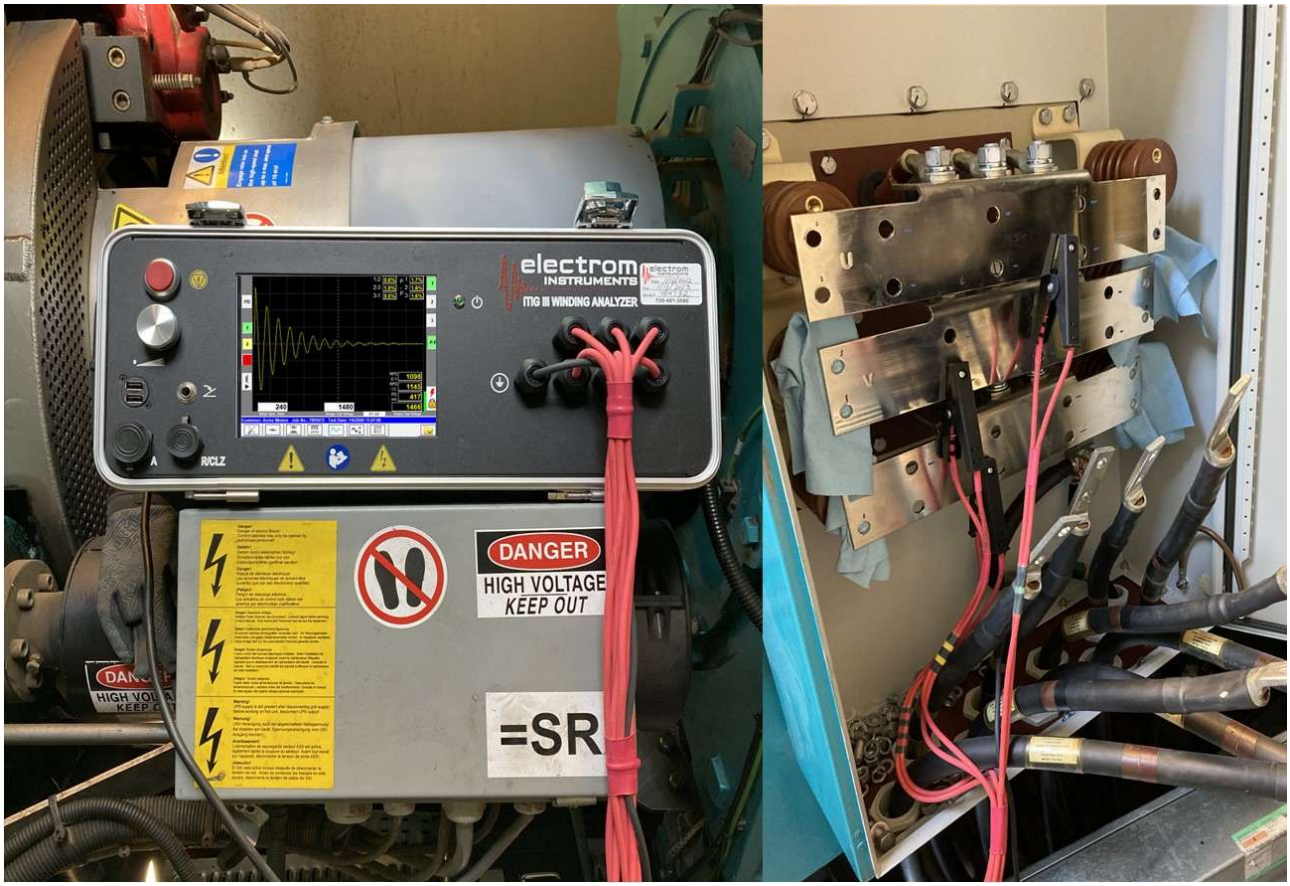
P-F Interval: Weeks to months, dependent on motorcycle frequency and starts under load condition.

Operation: A transient surge is applied at high frequency to two separate but equal parts of the winding. The resulting vote is waveforms reflected from each part are displayed on an oscilloscope. If both windings are identical, each waveform is exactly superimposed on the other, so a single trace appears on the screen. If one of the two winding segments contains a short circuit or a reverse or open coil, the waveforms are visibly different. If this problem is found, it is necessary to establish which segment is at fault This can be done by comparing each segment to a 3rd segment and note in which combination produces the waveform deflections generally, shorted or missing turns cause fairly small differences in waveform amplitude. Misconnections such as coil reversal or interface shorts tend to cause large differences or irregularities in waveform shape. With this method it is also often possible to determine the voltage at which turn to turn or face to face conduction begins. If this shorten is near operating voltage, then the motor has a serious installation fault and should be replaced as soon as possible. If shorten is not detected up to twice the operating vote is plus 1000 votes the winding is considered good and the motor can be returned to service.

Specialized Skills / Training / Experience Required: A trained and experienced test operator.

Advantages: Portable. Turn to turn and face to face shorten often occurs before deterioration of ground war insulation given a longer PF intervals. Most equipment can also perform high potential tests.

Disadvantages: Quite complex and expensive. Cannot evaluate one coil by itself. Requires careful repetition to determine the location and severity of a fault.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.10 MOTOR CURRENT SIGNATURE ANALYSIS

Conditions Monitored: Broken rotor barns or short in rings high resistance between bars and rings, uneven rotor stator air gaps rotor misposition, Deteriorated or shorted rotor or stater core lamination.

Applications: AC or DC motors.

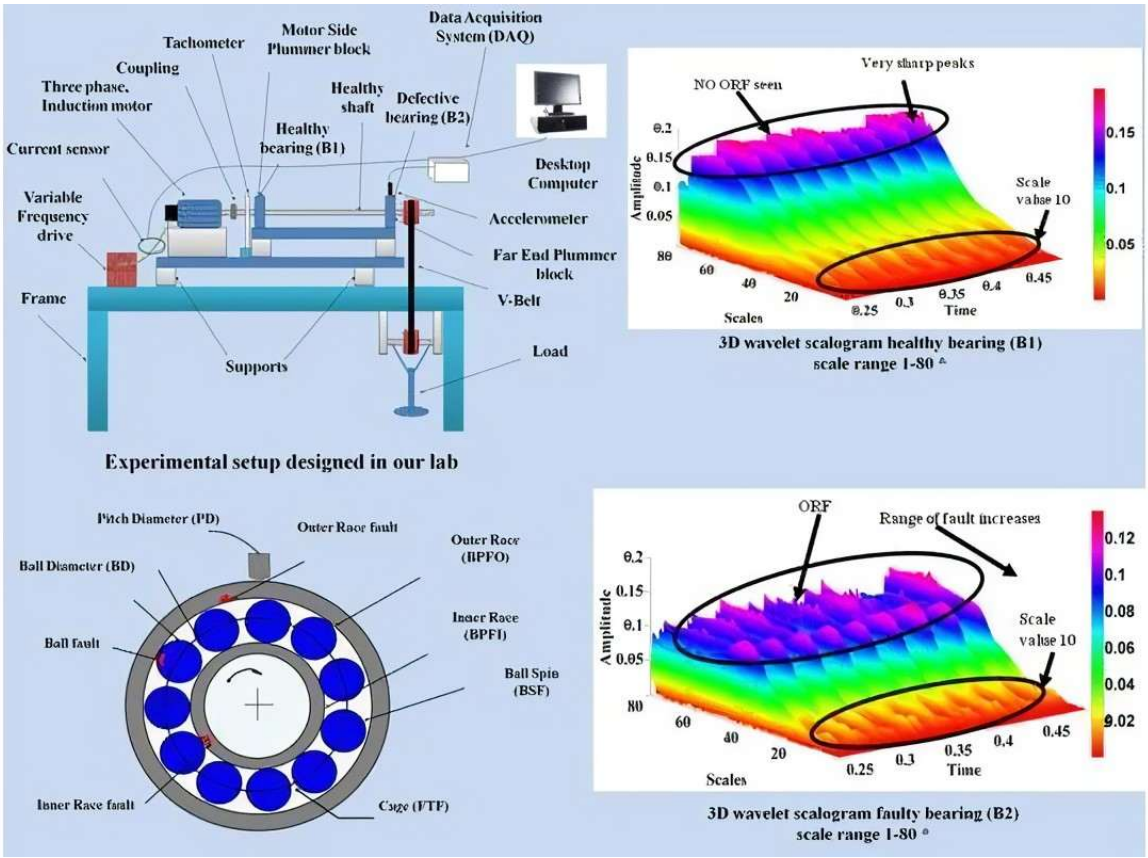
P-F Interval: Several weeks to months.

Operation: This technique is based on the principle that an electric motor driving and mechanical load acts as an efficient, continuously available transducer. The motor senses mechanical load variation and converts them into an electric current variations which are transmitted along the motor power cables These current variations current karma they were very small in relation to the average current drawn by the election motor coma can be monitored and recorded at A convenient location away from the operating equipment. Analysis of the variations provides an indication of machine condition, which may be trended over time to provide a warning of deterioration or process alteration. The test is done by placing a single split draw current transformer probe on one of the power leads at the motor Control Center or starter cabinet. The raw waveform signal is amplified, filtered and further processed to obtain a measurement of the instantaneous load variations within the drivetrain and the ultimate load. In general, the current in the three phases should not differ by more than 3 per cent. If the variation exceeds 3% for any phase, stator problems could exist. The amplitudes at line frequency can also be compared with the process frequency immediately to the left of line frequency A significant difference in amplitude between these two frequencies indicates a cracked or broken rotor bar, and rain, or slip rain, or resistance joint problems.

Specialized Skills / Training / Experience Required: Do clamp current transformer one of the phases of a 3-phase power line requires an experienced electrician period to conduct a test and interpret results requires a technician with an understanding of electric motors.

Advantages: On-line measurements can be taken without breaking any electrical connections. No electrical connections are required which reduces the hazard of electrical shocks. Readings can be taken remotely and safely on large, high speed or otherwise hazardous machines.

Disadvantages: Complex due to relatively subject nature of interpreting the spectra.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.11 POWER SIGNATURE ANALYSIS

Conditions Monitored: Rotors, broken bars, cracked or broken end rings, Bad cage joints, motor bent rotors, stators, short lamination, eccentricity, single phasing Comm phase current and voltage balance, resistive and inductive imbalance, torque variations, wear or deterioration of machine clearances, flow or machine output restrictions, machinery alignment, machinery efficiencies.

Applications: AC induction motors synchronous motors, compressors pumps and motor operated valves.

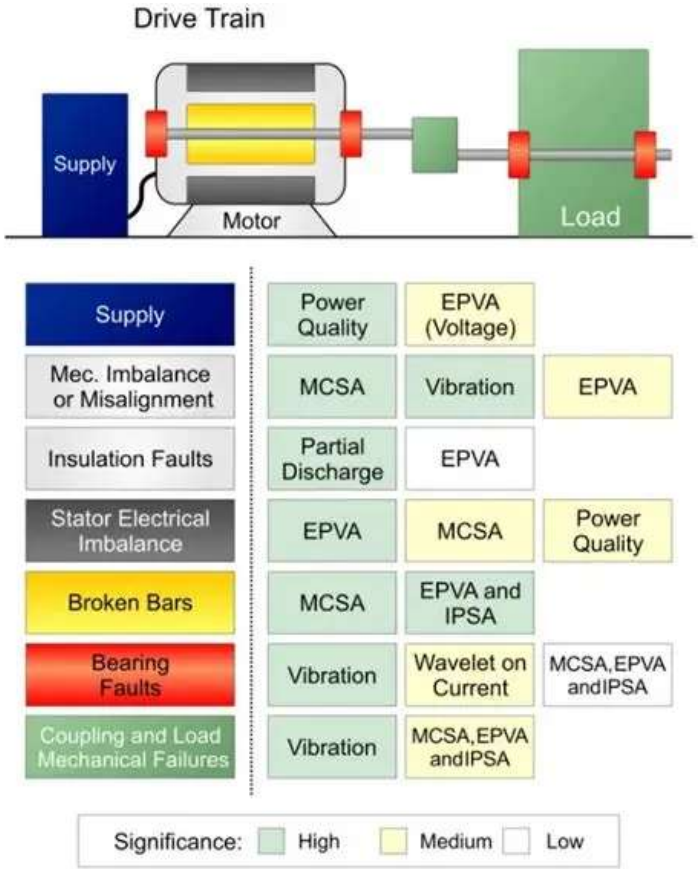
P-F Interval: Several weeks to months.

Operation: Probes are attached to motor feed lines either at their Motor Control Center MMC at the breaker box or locally at the motor to gather electric current and voltage signals while the motor is running. A signal conditioning unit conditions and filters analog signals sensed from the feed lines. Data files are compiled and analyzed using application-based software tools Fast Foyer Transform to plot variables such as total real power, total reactive power and total power factor. Analysis of the plots enables the motor and overall system performance to be evaluated in detail. The plots can also be compared to baseline fingerprints to detect deviations.

Specialized Skills / Training / Experience Required: To attach probes to murder requires an electrician period to conduct a test and interpret the results requires an experienced technician.

Advantages: Tests can be done without shutting down the equipment. One of the few techniques that enable broken rotor barns to be detected under load. Allows equipment efficiencies to be determined.

Disadvantages: Skewing care required when connecting probes to the live motor speed lines. Interpreting an analysis the data takes some practice and an understanding of electric motors and the driven equipment is necessary. Limited number of industry wide applications for comparison. Equipment is expensive.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.12 PARTIAL DISCHARGE

Conditions Monitored: Installation breakdown.

Applications: All types of medium voltage electrical equipment including switched gears, bus ducts, transformers, arrestors bushings, Switches, motor starters, Potheads motors, generators, cable terminations cable splices and the cables themselves Distribution systems and equipment > 2000 Volts AC.

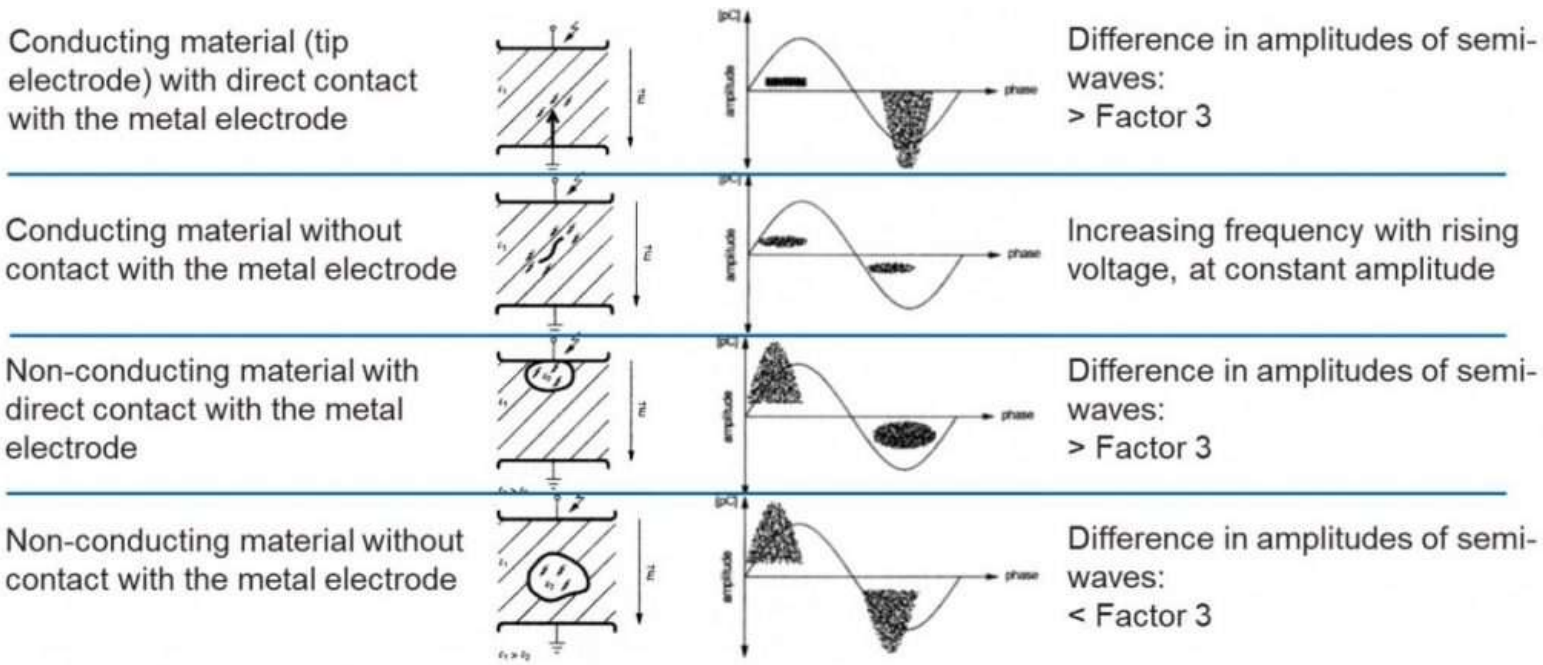
P-F Interval: Several weeks to months voltage levels, the shape of the void, ambient temperature, system losses or influence how quickly the insulation fails.

Operation: A partial discharge of PD occurs in a small void, crack, or irregularity in an insulation system causes an electric field build up. Sensors are used to pick up the PD. On switch gear, the sensor is connected between the grounded side of the meter and CT circuit. On cables, the sensors connected around the ground wire that connects the cable shield or placed around the insulated conductor. On motors, sensors are placed on a motor frame or around the ground connection or around the insulation motor lead in analysis in the data three issues are considered. 1. the number of pulses per second and the magnitude of the pulse field strength and pickle coulombs. 2. The power of the pulses intensity. 3. Their rates of change overtime of the power trend analysis.

Specialized Skills / Training / Experience Required: Experienced Electrical Technician

Advantages: last quick and more informed decisions. Can be applied to any type of electrical equipment.

Disadvantages: Current available on-line technology cannot locate the exact source of the PD while the equipment is energized. One single data point provides little or no information. Several data points are needed to trend the information. No current standards available on maximum acceptable levels of PD activity, except for cables. Expert knowledge and statistical analysis required to set PD thresholds Use special sensors offline to determine the exact location of PD activity.



Sources: J. Fuhr: Procedure for Identification and Localization of Dangerous PD Sources in Power Transformers; A. Küchler: Hochspannungstechnik, Grundlagen – Technologie – Anwendung, 3rd Edition

ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.13 HIGH POTENTIAL (HI-POT) TESTING

Conditions Monitored: Motor winding ground war insulation deterioration.

Applications: AC and DC motors.

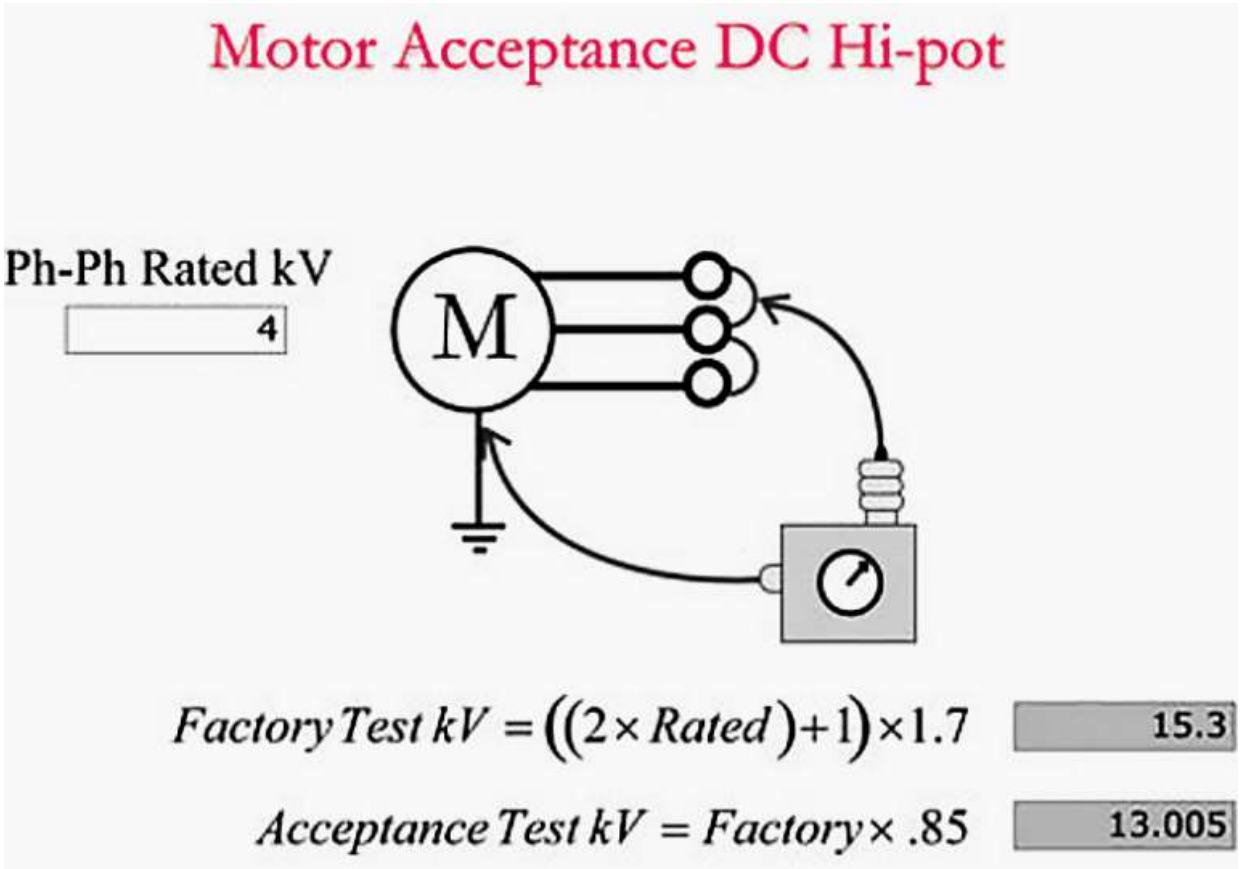
P-F Interval: Several weeks.

Operation: High DC voltage is applied to the state of windings in graduated steps or ramps up to a limit, usually twice the line voltage. Test voltages are usually derived from the IE standard 95. At the first sign of the non-linearity in the test current or drop in insulation resistance with further voltage increase, the test voltage is recorded and the vote is removed in order to avoid complete insulation breakdown. If the insulation withstands the voters, it is considered to be safe and the motor can be returned to service. Any trend in voltage at which non-linearity and current drop or insulation resistance occurs can be used to predict remain in life.

Specialized Skills / Training / Experience Required: An experienced electrical electrician.

Advantages: Tests normally correlate with surge comparison test.

Disadvantages: Motors have to be taken out of service to conduct tests. Testing potentially destructive.



ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.14 MAGNETIC FLUX ANALYSIS

Conditions Monitored: Broken motor bars unbalanced phases and anomalies in state of windings such as turn to turn, face to face and face to ground short circuits.

Applications: AC and DC motors.

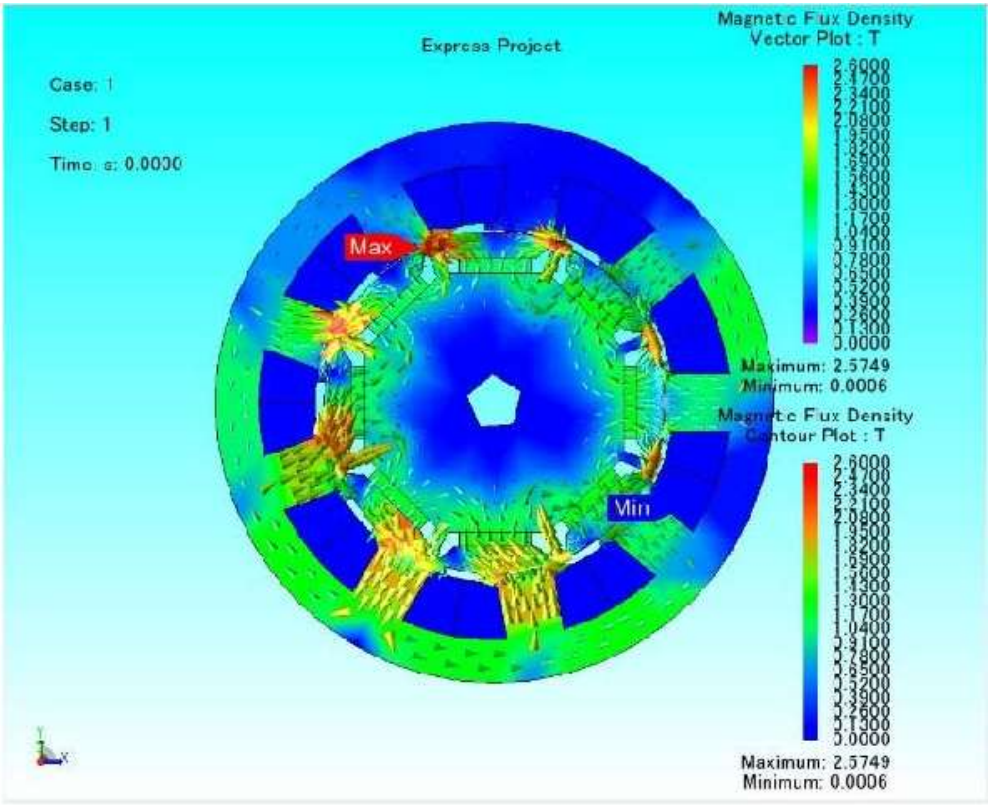
P-F Interval: Several weeks.

Operation: Coil sensor is placed at the center of the axial outbound end of this motor. (Consistent position of this sensor is essential for reliable and trending data). The signal received from the sensor is transformed into the frequency domain using an FFT analyzer A trend of certain magnetic flux frequencies will indicate electrical asymmetries associated with the motor and state of windings. Most of the peaks in the flux core spectrum occur at frequencies which have some relationship to running speed. Broken rotor bars increase the sideband activity around running speed. Unbalanced supply voltage which causes motor heating and eventually leads to premature deterioration of the state windings shows no change except around the peak occurring at line frequency + 1 X RPM. One of the first phones I warned in Will Encounter is Turn to Turn Shores which then migrate to phase to phase or phase the ground short circuits. A winding foe can be indicated around the 3 X running speed sideband of line frequency. Creation of this technique is used to detect turn to turn shorts by looking at the family of ‘slot pass’ frequencies from measurements taken with a flux coil. Flux measurements are taken as mentioned above and the resultant signature is analyzed at the slot pass frequencies. The principal slot pass frequency occurs at the product of the number of rotor bars and running speed The technique involves comparing Spectra over time to determine when changes occur.

Specialized Skills / Training / Experience Required: To record a spectrum requires an electrician or technician with an understanding of motors period to interpret the results requires an electrical engineer.

Advantages: One of the few techniques that can detect faults associative with electrical insulation of electric motors while the motor is on-line.

Disadvantages: High degree of skill and knowledge of election motor is required to interpret the results.



ig 11. BLDC’s Magnetic Flux Density Vector at Step 1

ELECTRICAL EFFECTS MONITORING TECHNOLOGIES & TECHNIQUES

6.15 BATTERY IMPEDANCE TEST

Conditions Monitored: Cell deterioration.

Applications: Emergency power and DC control power batteries.

P-F Interval: Several weeks.

Operation: As the battery ages and begins to lose capacity, its internal impedance rises. A battering impedance set injects an AC signal between the terminals of the battery. The resulting voltage is measured and the impedance calculated period two comparisons can be made. First, the impedance is compared with the last reading for that battery and this 2nd, the reading is compared with other batteries in the same bank. Each battery should be within 10% of the others and 5% of its own last reading. A region outside these values indicates a sale problem or capacity loss. There are no set guidelines and limits for this test. Each type style and configuration the battery has its own impedance, so it's important to take a baseline reading early in the battery's life.

Specialized Skills / Training / Experience Required: Field technician required.

Advantages: The last Test can be performed without moving the battery from service, as the AC signal is low level and 'rides' on top of the DC of the battery.

Disadvantages: Tests could take a long time Our large battery banks.

CONIDTIONING MONITORING TECHNOLOGIES & TECHNIQUES

A NOTE ON LEAKS

With the exception of ultrasonic leak detection, a topic which has not been covered in much detail in this RCM topic of on conditioning monitoring technologies and techniques is leaks, especially in underground storage tanks. This is because a publication which provides a comprehensive description of more than 36 different leak detection methods is already available. It is called ‘Underground Leak Detection Methods’ - A State-of-the-Art Review and is in the form of a report prepared in 1986 by Shahzad Niaki and John Broscious of the IT Corporation in Pittsburgh, PA and commissioned by the Hazardous Waste Engineering Research Laboratory, Edison, New Jersey. Copies of this report are available from the National Technical Information Service, a division of the United States Department of Commerce based in Springfield, VA, USA.