U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Chapter 12

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EDG PERFORMANCE MONITORING AND MAINTENANCE

HRTD
Human Resources
Training & Development

Learning Objectives

Upon completing this lesson, students will better understand EDG reliability monitoring and maintenance, including:

1. The difference between Prescriptive (periodic) and Predictive (condition-based) EDG maintenance, and how licensees have benefited from the trend to a Predictive approach.

2. An overview of key regulatory requirements for maintenance, including the "NRC Maintenance Rule."

3. Monitoring, trending, and analysis of key EDG parameters, including specific engine and support system values during runs, as well as the fuel oil, lubricating oil, cooling water, etc.

Learning Objectives (continued)

4. The importance of baseline data, parameter trending, competent analysis, and follow-up to assure effectiveness.
5. The necessity for observations before, during and after EDG runs, and also in conjunction with any maintenance done on (or even in the vicinity of) the EDG.
6. Some applications of EDG monitoring systems…including the human senses.
7. Information on the contribution of each EDG subsystem to the failure rate, and some observations regarding that.

EDG Maintenance: Prescriptive vs. Predictive

These two very different approaches to EDG maintenance will be discussed and their effectiveness for nuclear facilities compared.

Prescriptive (Calendar-Based) Method

One reason diesel engines were selected for on-site emergency power systems is their very long history of reliable service, mostly in continuous-duty applications (8000+ hours/yr)…

Published maintenance schedules designed for such service were inappropriate for nuclear service, where engines run infrequently.

Prescriptive maintenance schedules resulted in many unnecessary, intrusive inspections, disassembly for parts replacement, etc. that were costly, and took EDG's out of service. Each was a chance to make errors detrimental to engine reliability… "If IAB, DFI"

EDG Maintenance: Prescriptive vs. Predictive

Predictive (Condition-Based) Method

A much more effective approach based on equipment condition, as determined by comprehensive monitoring, trending, analysis…

It can head off failure by detecting early warning signs such as abnormal temperature, pressure, vibration, wear products, etc.

Typically includes a wide range of techniques: observation and logging of data, chemical analyses of fuel oil, lube oil, and cooling water, the use of engine analyzers, thermal (IR) scanning, etc.

Will increase EDG reliability, reduce unscheduled down-time, can reduce maintenance cost, and may prevent a costly plant outage.

Regulatory Criteria

A very brief overview of the principal documentation and its role:

10 CFR 50.65: "Requirements for Monitoring Effectiveness of Maintenance at Nuclear Power Plants." This is also known as the **"NRC Maintenance Rule,"** and requires licensees to monitor the performance of their structures, systems, and components against preset performance goals or criteria they establish, commensurate with safety significance. For EDG's, this document compliments licensee's FSAR, Tech Specs, other commitments to maintenance.

Reg Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants" provides NRC guidance for implementation of the "Maintenance Rule."

Regulatory Criteria (continued)

NRC Inspection Manual, Chapter 0609, Appendix K: "Maintenance Risk Assessment and Risk Management Significance Determination Process." Incorporates a method for evaluating licensee maintenance program effectiveness using the Significance Determination Process (SDP) plus Inspection Procedure 7111.13, "Maintenance Risk Assessment and Emergent Work Control."

NUMARC 93-01, Rev 1 (now NEI 1996a): Originally the Nuclear Management and Resource Council, now the Nuclear Energy Institute, "Industry Guideline for Monitoring Effectiveness of Maintenance at Nuclear Power Plants." Prepared to give more guidance on 10 CFR 50.65 "Maintenance Rule" implementation.

Monitoring and Trending Fundamentals

- Requires understanding of present diesel generator conditions for each parameter, including the optimum range or value and what represents unacceptable conditions.

- Requires systematic trending of parameters during successive EDG operating cycles or time periods.

- Deviation must trigger alert for investigation of the underlying cause, to determine action required to head off adverse trend.

- This methodology permits planned, need-based maintenance. It will not guarantee elimination of unplanned maintenance but can minimize such events.

Monitoring and Trending Fundamentals (cont)

- The preferred predictive monitoring applications are those that can be implemented with the engine in service.
- Information from monitoring techniques may overlap, giving different indications of the same condition(s). Integrated analysis of data can help confirm trends and identify problems.
- Effective application of complex engine analyzers is rather engine-specific and may be a work in progress. They can at least raise a flag that *change* has occurred.
- No one symptom / test / engine analyzer can tell the whole story. All parameter monitoring technology is useless unless the data is competently analyzed by individuals who have responsibility and authority to follow up results.

Monitoring Prerequisites

Equipment Calibration: Data from gauges, meters, or monitoring systems is useless unless their accuracy is verified. The licensee's equipment calibration system or service needs to be certified for compliance to ISO 170125 or MIL-STD-45662A (1985), "Calibration Systems Requirements," the successor document to MIL-C-45662.

Ambient Conditions Data: The temperature of engine intake air and cooling air or water (as applicable) can have a substantial engine performance impact. Atmospheric pressure, especially as determined by altitude, is also a significant factor. Even humidity can have a bearing on engine operation. Therefore, the ambient conditions are an important part of engine performance data and need to be a part of the monitoring program.

Fuel Oil Quality Monitoring

Diesel fuel characteristics can have a profound impact on engine performance, even engine life. Therefore, licensees are required to implement a fuel oil monitoring program complying with ASTM D-975, "Limiting Requirements for Diesel Fuel Oils."

Due primarily to differences in climate, diesel fuel specifications are plant-specific. The important fuel parameters to monitor are:

- **Flash point (°F)**: The lowest fuel oil temperature at which continuous vapor generation will sustain flame at a free surface exposed to an oxygen source in the presence of an ignition source. Fire protection codes encourage fuels with flash points of 65°C (150°F) or above.

Fuel Oil Quality Monitoring (continued)

- **Specific Gravity or API Gravity @ 60°F:** Relates the weight of fuel to water. Diesel fuels are lighter than water, with specific gravity's under 1.0. However, the API gravity index uses an inverse scale starting at 10.0 for water where the lighter diesel fuels have a higher API gravity number.

- **Pour point (°F):** This is the temperature of the fuel at which it ceases to flow.

- **Cloud point (°F):** The fuel temperature at which wax present in it will start to form crystals (giving a "cloudy" appearance). This characteristic can have a large impact on the performance of filters and injection equipment because the wax crystals will cause clogging/plugging in these components... **(IN 94-19, S.M. NOTE)**

Fuel Oil Quality Monitoring (continued)

- **Water and Sediment,** by centrifuge (% volume): This indicates fuel cleanliness. Water and sediment can impact operation of fuel injection components. Sediment can foul fuel filters and water promotes microbial growth (bio-fouling) in diesel fuel storage tanks. They can also cause microbiologically-induced corrosion (MIC), especially of steel pipe and tanks.

- **Color:** Ranges from dark-amber to light-golden. The fuel's natural color (darker or lighter) is of less concern than changes in color during shipping and storage (typically darkening), as that can indicate unstable fuel.

- **Carbon residue,** % by weight: Carbon depositing can foul injector tips , cylinder head exhaust valves, and piston rings.

Fuel Oil Quality Monitoring (continued)

- **Ash** (% by weight): Fuel ashes are non-combustible trace minerals and metals in fuels, such as silicon and vanadium. Most are undesirable, as they tend to have an abrasive or corrosive effect on engine components or result in formation of engine deposits. Vanadium is especially troublesome, as it forms Vanadium pentoxide, which can be highly corrosive.

- **Distillation temperatures,** (°F) at 90% and end points, at STP: This relates to the volatility or the vaporization tendency of fuel during distillation. In lighter diesel fuels, such as those used in diesels at nuclear facilities, the 90% distillation point is often used. Lighter, more volatile fuels tend to have lower ignition points, which can affect engine starting and running.

Fuel Oil Quality Monitoring (continued)

- **Viscosity** @ 100°F (Saybolt Universal Sec, SUS): This relates to flow characteristics of the oil. Oils with lower API gravity numbers tend to be more viscous (thicker).
- **Sulfur** *(%* by weight): Trace sulfur contaminates in the fuel can result in acid formation under engine post combustion conditions (i.e. in the presence of water vapor at the required temperature). Because sulfur serves as a lubricant, very low sulfur fuel have additives to provide lubricity. See Chapter 13 discussion of potential issues with **ultra-low sulfur fuel oil**.
- **Copper strip corrosion test** (comparative test): Predicts the copper corrosion characteristics of a fuel. Can be important for engines using copper gaskets/components in the fuel system.

Fuel Oil Quality Monitoring (continued)

- **Cetane number** ignition quality test (comparative-qualitative rating). *One of the more critical properties of fuels relating to smooth engine operation*. The comparison is between Cetane with a high ignition quality and Heptamethylonane with a low ignition quality. Can effect starting times and load acceptance response time. *Fuels with higher Cetane numbers provide more responsive start times and load acceptance*.

- **Heating value** (BTU per lb.). One of the more critical properties of fuel. Diesels are heat engines (they convert stored chemical energy into heat in the engine to produce work). Fuels with higher heating values per pound tend to be the lighter fuels, but the lighter fuels have lower specific/API gravities… (con't)

Fuel Oil Quality Monitoring (continued)

… *Although lighter fuels have a higher BTU content per pound, the net effect is that they have a lower BTU content per gallon*. Since diesel fuel storage and consumption are monitored in gallons, BTUs per gallon is the critical parameter.

Diesels used in nuclear applications frequently had their fuel consumption tests performed using fuel oil with an API gravity of 28. If operated on a lighter fuel (API gravity of 29 or above), they will have to burn more fuel to generate the equivalent heat required to produce the same power output. This would place into question the sufficiency of on-site fuel oil storage tanks for the EDG systems.

Fuel Oil Quality Monitoring (continued)

Here are the most important take-away points on fuel monitoring:

1. The time to determine the acceptability of fuel oil shipments is before they are off-loaded into on-site storage tanks. Proactive licensees will subject samples of delivered fuel to quality tests *before accepting or permitting the fuel to be off-loaded*.

2. A program should also be in place to periodically assess the quality of fuel oil in tanks, as it can be impacted by moisture (from condensation/infiltration), deterioration of the tank (leaks/rusting), aging, and microbial growth.

NOTE: Biodiesel is a particular concern that will be discussed in Chapter 13. It has the potential to cause a number of problems.

Lube Oil Analysis and Trending

Lube oil analysis can provide a good general indication of engine internal condition. Oil samples should be taken down-stream of supply pump, prior to the filter, with system at normal operating temp and pressure. Oil analysis will determine:

Lubrication oil condition: Oil properties which indicate condition and age include viscosity, oxidation, total base number/ total acid number (TBN/TAN), and additive concentrations.

Typical values for new oil of the type being used should be readily available from the oil supplier / producer. Alert and action values should be established regarding end-of-useful-life.

Lube Oil Analysis and Trending (continued)

Contamination: Contamination of lube oil is usually due to the operating environment. Contaminants monitored may include water, glycol, TBN/TAN changes, SO_x or NO_x level changes, fuel dilution, viscosity changes, and dirt (i.e. silicon, aluminum).

Engine internal component condition: Indications of engine mechanical condition/wear are based on metal "wear" particle concentrations in the oil. Typical engine wear metals of interest may include iron, copper, lead, tin, chromium, aluminum, and silver to name a few. The licensee should specify expected wear metals of concern to the lab performing lube oil sample tests to ensure they are included for analysis. Engine manufacturer data and experience are used to set alert and action values for each…

Lube Oil Analysis and Trending (continued)

Major engine problems have developed and been overlooked due to inappropriate alert limits or the fact that no alert limits had been set. Similarly, oversights have occurred when results were not reviewed in a timely manner by qualified and experienced personnel with the authority and responsibility to obtain action.

CASE EXAMPLE -- Crankcase Explosions: Engine failures occurred in which there were wear metal trend precursors that should have alerted the operators and enabled them to head off the problem. There were 13 crankcase explosion events in Cooper-Bessemer KSV engines that power EDG units at several nuclear power plants. This was documented by IN 92-78. Figures 12-1 and 12-2 are photographs of two pistons from an engine after an explosion…

Figure 12-1 Piston with Advanced Tin Smear

Tin removed from side of piston, exposing the base metal (dark area).
Some scoring of piston base metal, plus indication of sticking rings.
The direct result of inadequate lubrication (multiple underlying causes).
Figure, 12-2 shows this effect on another piston with more severe damage.

Figure 12-2 Failed Piston -- Tin Wiped Off

Essentially all tin removed from sides, exposing the base metal (dark area).
Scoring of piston base metal, entrapped rings, and evidence of blowby.
The direct result of inadequate lubrication (multiple underlying causes).

Lube Oil Analysis and Trending (continued)

The root cause of the Cooper KSV engine crankcase explosions was insufficient lubrication of surfaces between the piston and cylinder liner. However there were multiple contributing factors involved:

- Routine "fast start and load" tests
- Very cold intake combustion air
- Oil scraper ring near bottom of piston, designed to reduce oil consumption in continuous-duty commercial service.

Effective corrective actions were taken and no further explosions have been reported in these engines. However, an effective lube oil monitoring and analysis program would have prevented it in the first place, as would an effective oil mist monitoring system.

EDG / Support System Monitoring

Engine and support system parameter monitoring provides general indication of mechanical condition and combustion performance.

To obtain valid results, the EDG should be operated at repeatable baseline conditions with the monitored parameters stabilized prior to the collection of data.

Progressive or step changes in engine/support system parameter values should be analyzed to determine cause.

The slides which follow list parameters that should be monitored. Those with a round bullet point (•) are *required* by IEEE 387-1995, Table 4, previously discussed and included in Chapter 11. Others, identified with (➢), will assist engine/generator monitoring.

EDG/Support System Parameters to Monitor

Pressures:

- Lube Oil: Engine Inlet
- Lube Oil: Turbo Inlet
- Lube Oil: Engine, Filter Differential
- Lube Oil: Turbo, Filter Differential
- Lube Oil: Engine Header
- Crankcase (Positive/Negative)
- ➢ Fuel Oil (Pressure and Flow)
- ➢ Cylinder Combustion Air Inlet Manifold
- ➢ Cylinder Inlet Manifold Boost Pressure

EDG/Support System Parameters to Monitor

Temperatures:

- Lube Oil: Engine Inlet and Outlet
- Jacket Water: Engine Inlet, Outlet
- Exhaust: Each Power Cylinder
- Exhaust: Turbo Outlet
- Exhaust: Manifold (if applicable)
- ➢ Cylinder Combustion Air Inlet Manifold
- ➢ Engine Bearings
- ➢ Generator Stator

EDG/Support System Parameters to Monitor

Electrical:

- Frequency
- Power (KW)
- Reactive (KVAR)
- Current: Generator, All Phases
- Voltage: Generator, All Phases
- Current: Generator Field
- ➢ Voltage: -- Generator Field

EDG/Support System Parameters to Monitor

Levels:

- Jacket Water: Standpipe/Expansion Tank Level
- Engine Lube Oil Sump Level
- Generator Bearing Oil Reservoir Level

Other Parameters:

- Engine speed
- Fuel rack settings.
- All Alarmed Indications
- Engine bearing temperatures.
- Ambient conditions (temperature, etc)
- Engine hours (calendar time plot)

Engine Cooling Water Analysis

The primary concerns for engine cooling water systems are:

- Fouling and Scaling – These impair heat transfer
- Component corrosion – Can result in leakage or failure

Closed loop cooling water tests commonly include conductivity, Ph, chloride titration, microbiological growth (bacteria count), and antifreeze/additive concentrations.

Open loop cooling water sampling usually looks at total dissolved solids, Ph, salt hardness, and microbiological growth as a minimum.

Monitoring jacket water inlet and outlet temperatures can provide warning of a developing fouling/scaling issue.

Engine Exhaust Emissions Analysis

Emissions testing reveals info on combustion performance and can help identify an engine in need of closer monitoring/adjustments. Data must be collected under repeatable, comparable conditions.

Primary Combustion Byproducts:

Carbon Monoxide (CO) - Possible rich fuel/air equivalence or high temperature dissociation. A measure of combustion efficiency.

Unburned hydrocarbons (HC) - Possible crevice volume effect, flame quench, lubricating oil. Associated with engine condition and efficiency.

Particulate (soot) - Possible rich unburned fuel spray/fuel-core zone or lubricating oil.

Engine Exhaust Emissions Analysis (continued)

Secondary Byproducts Linked to the Combustion Process:

Nitrogen Oxides (NOx) - Usually from nitrogen reaction with high temperature burned gases. Largely related to the combustion temperature (i.e. thermal NOx), it can be associated with possible injection timing, spray pattern or air temperature issues.

Sulfur Oxides (SOx) - Usually associated with fuel sulfur content. Little value for monitoring engine performance, due to ULS fuel.

Increases in emission levels from baseline values can be caused by things such as timing changes, degraded fuel system performance or general engine/cylinder condition.

Use of "Engine Analyzers" for Monitoring

These can monitor cylinder pressures, temperatures, and vibration, integrating the resulting data with crankshaft angle and fuel rack position. Supplemental equipment can monitor lube oil parameters "on-line" (as the EDG runs), providing additional real-time data….

These systems trend the data and compared it to baseline. Such comprehensive, whole-engine monitoring is costly but gives EDG operators a potentially powerful tool to monitor the performance and health of engines as they run.

The US Navy has done work in this area using their Integrated Condition Assessment System (ICAS). Information on specific engine analyzers and engine monitoring equipment follows:

Use of "Engine Analyzers" (continued)

Phased Cylinder Pressure Type – This equipment provides info on individual cylinder pressure characteristics through engine cycles:

- Peak firing pressure spreads, deviation
- Peak firing pressure angle (phased cylinder pressure)
- Rate of cylinder pressure change
  (first derivative, psi/degree)
- Mean effective pressure
- Indicated horsepower
- Reference compression pressure
- Reference exhaust terminal pressure
- Reference intake terminal pressure

Use of "Engine Analyzers" (continued)

Average cylinder peak pressure and peak pressure spread are reliable indicators to monitor for engine deviation from baseline conditions. Cylinder peak pressure is an indication of stress and cylinders with *excessive* peak pressures may have been damaged.

NOTE: Matching peak firing pressures between cylinders within a predetermined band is the most accurate method of balancing an engine ("peak firing pressure balancing"). However, high cylinder peak pressure can occur for a variety of reasons and in some cases the cylinder with the highest peak pressure is not the cylinder with the highest load (although the anomaly still warrants correction).

See Figures 12-3 through 12-6 for Phased Cylinder Pressure data.

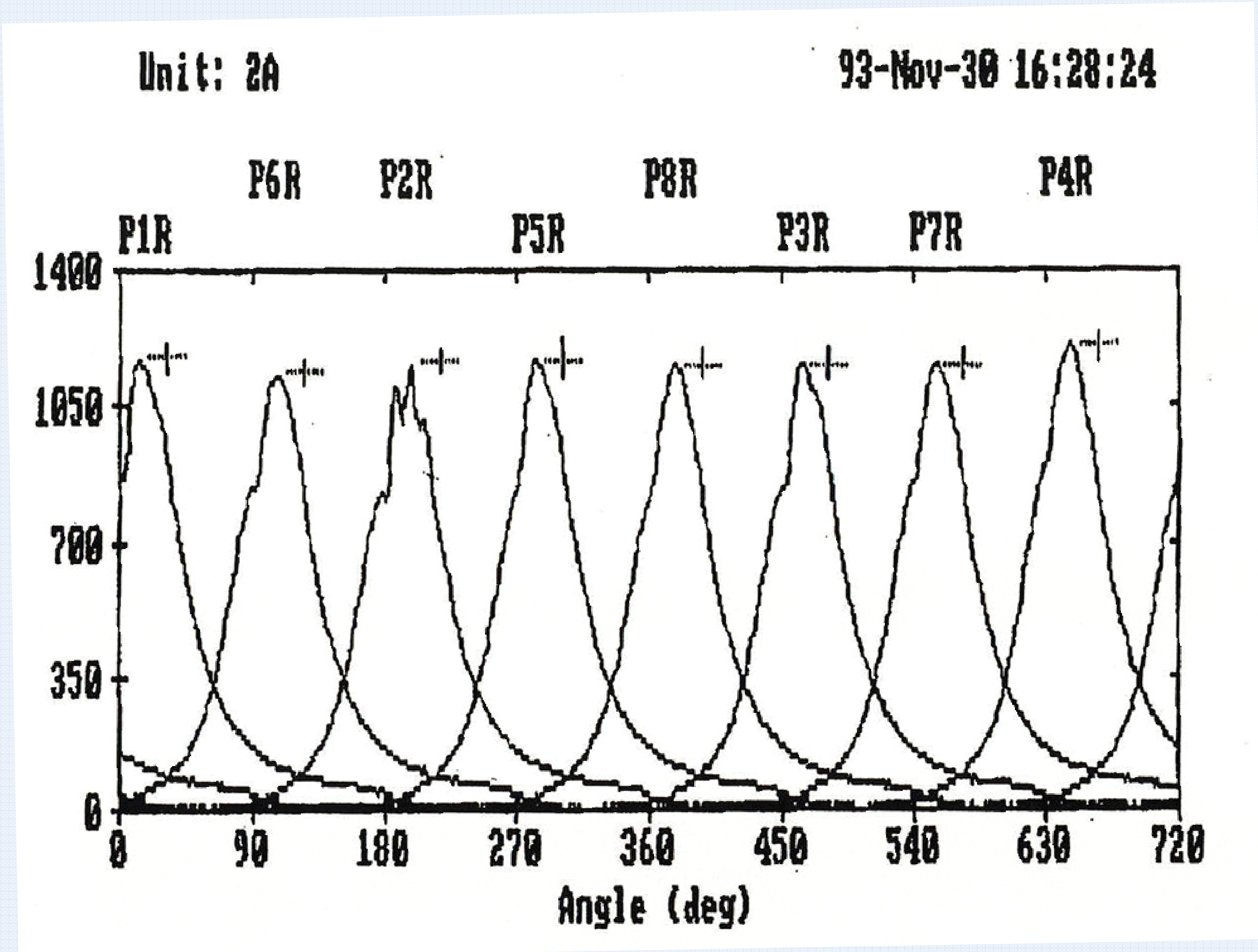


Figure 12-3 EDG Diagnostic Report – PFP vs. Crank Angle (Right Bank)

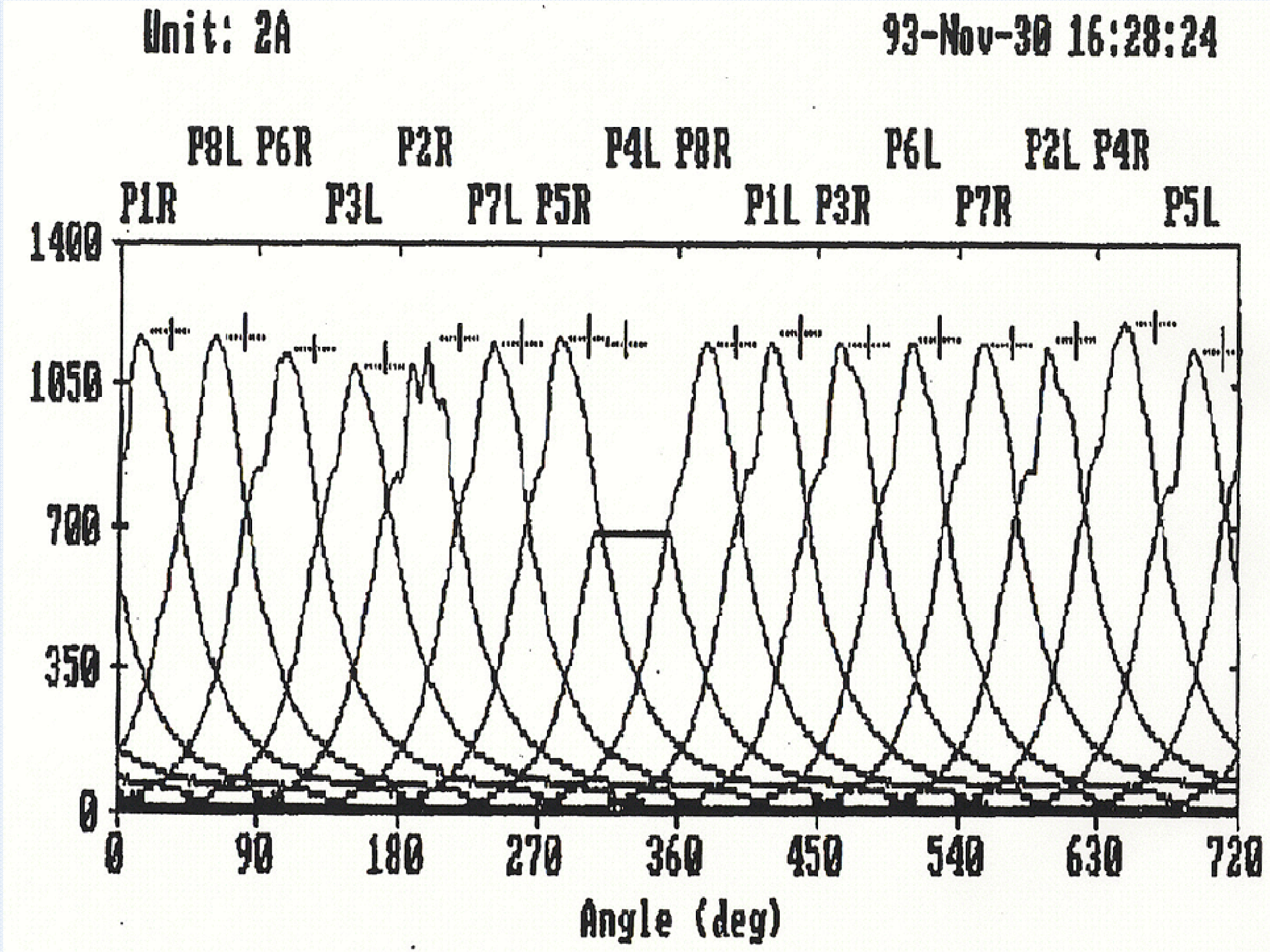


Figure 12-4 EDG Diagnostic Report – PFP vs. Crank Angle (16 Cylinders)

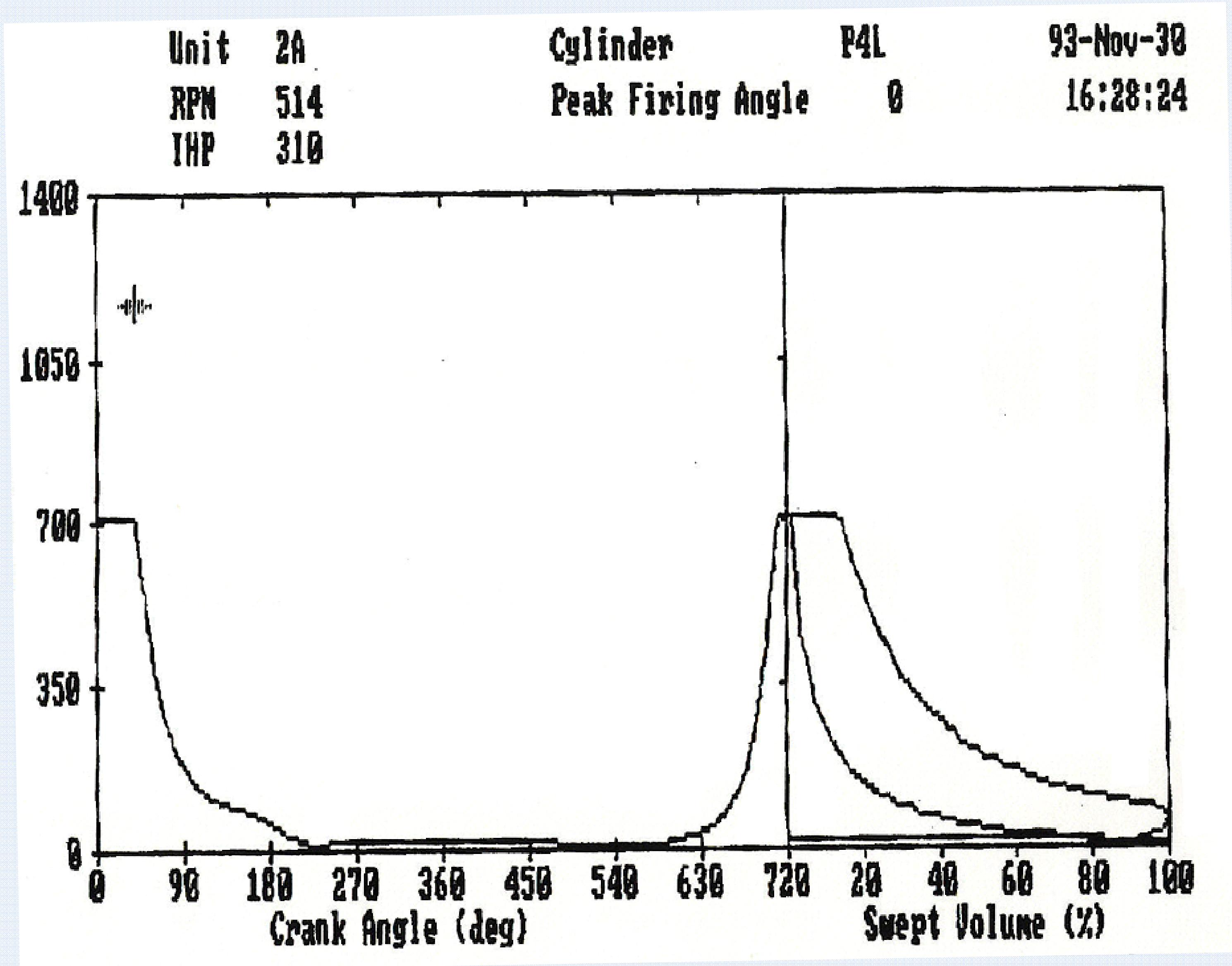


Figure 12-5 EDG Diagnostic Report – PFP vs. Crank Angle (& Swept Volume (4L)

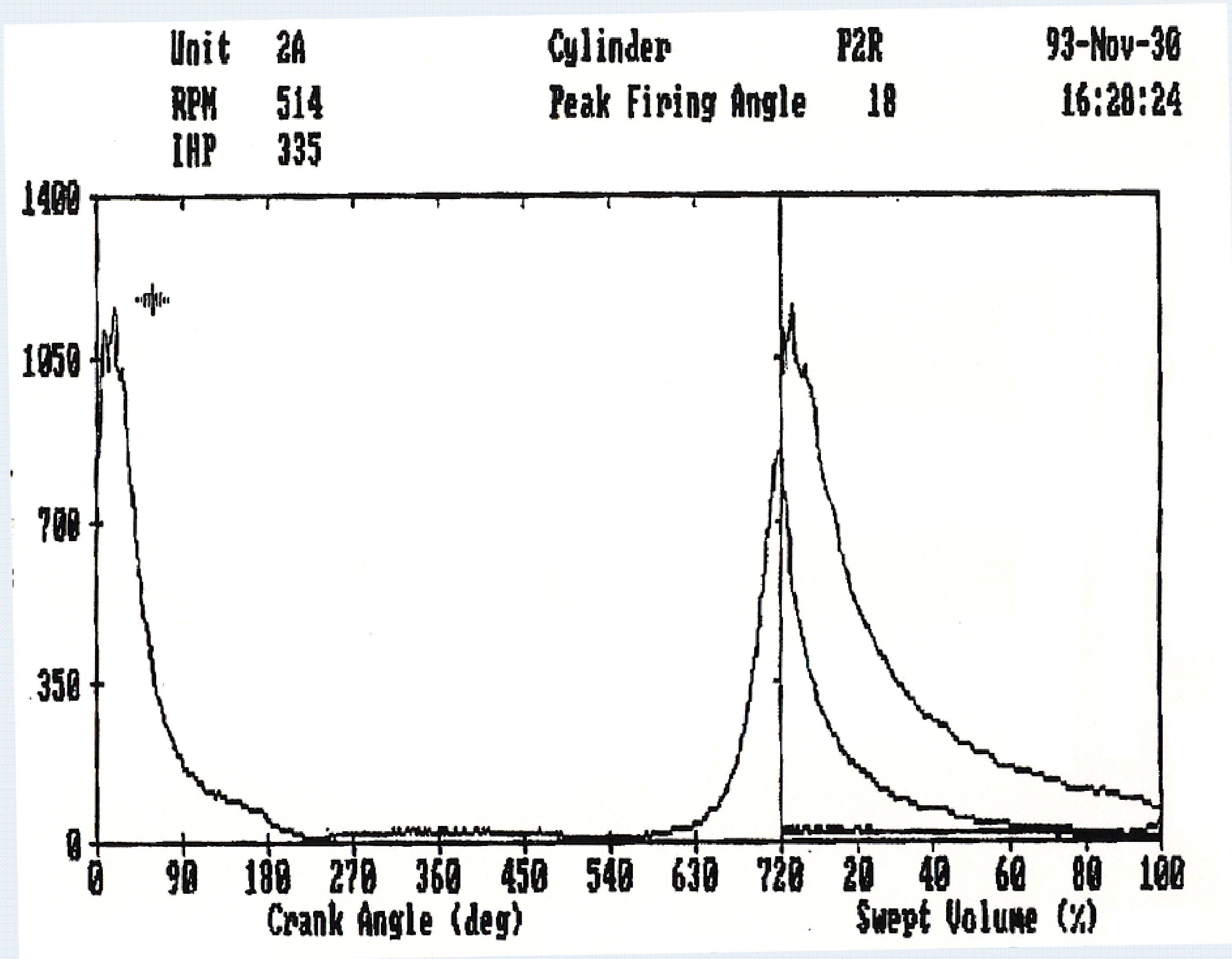


Figure 12-6 EDG Diagnostic Report – PFP vs. Crank Angle (& Swept Volume (2R)

Use of "Engine Analyzers" (continued)

Phased Engine Vibration (VT) and Ultrasonic (UT) Type – These monitor vibration and ultrasonic frequency anomalies pertaining to:

- Valve train condition
- Main bearing condition
- Piston to cylinder interaction
- Cylinder combustion characteristics
- Piston blow-by and cylinder-ring interaction
- Injector nozzle characteristics and injection pump status
- Magnitude and duration of the exhaust blow-down event
- Turbocharger and/or supercharger status, including bearing
- Piston pin, articulated pin, or connecting rod bearing condition

A Practical Cylinder Balancing Method

Engine balance is determined from temperatures and pressures occurring in each cylinder. Exhaust temperature is measured by pyrometers located just downstream of the cylinder exhaust ports. Cylinder pressures are measured using special gauges connected to cylinder test ports (passages to the combustion space)…

Although cylinder pressures are the *preferred means of balancing* an engine, cylinder temperatures are typically used to monitor cylinder balance during routine operation. As a "rule of thumb" a balanced engines will normally have:

- Exhaust temperature deviations < 150 °F on the average.
- Cylinder firing pressure deviations < 150 PSI on the average.

Crankcase Oil Mist Monitoring

Crankcase oil mist detection systems can warn of engine mechanical distress such as cylinder wall or piston scuffing, incipient bearing failure, etc. because those events create localized hot spots that cause lube oil to boil, producing oil mist.

- Normal crankcase oil mist concentration is typically < 2 mg/liter
- The lower explosive limit (LEL) for lube oil mist is ≈ 50 mg/liter
- Problems with early design systems have hindered acceptance
- Better instruments use signal processing to prevent false alarms at start-up and also provide calibrated oil mist concentrations
- Data is logged to assess trends and alert/alarm levels can be set
- Figures 12-7A, -7B illustrate one manufacturer's installed system

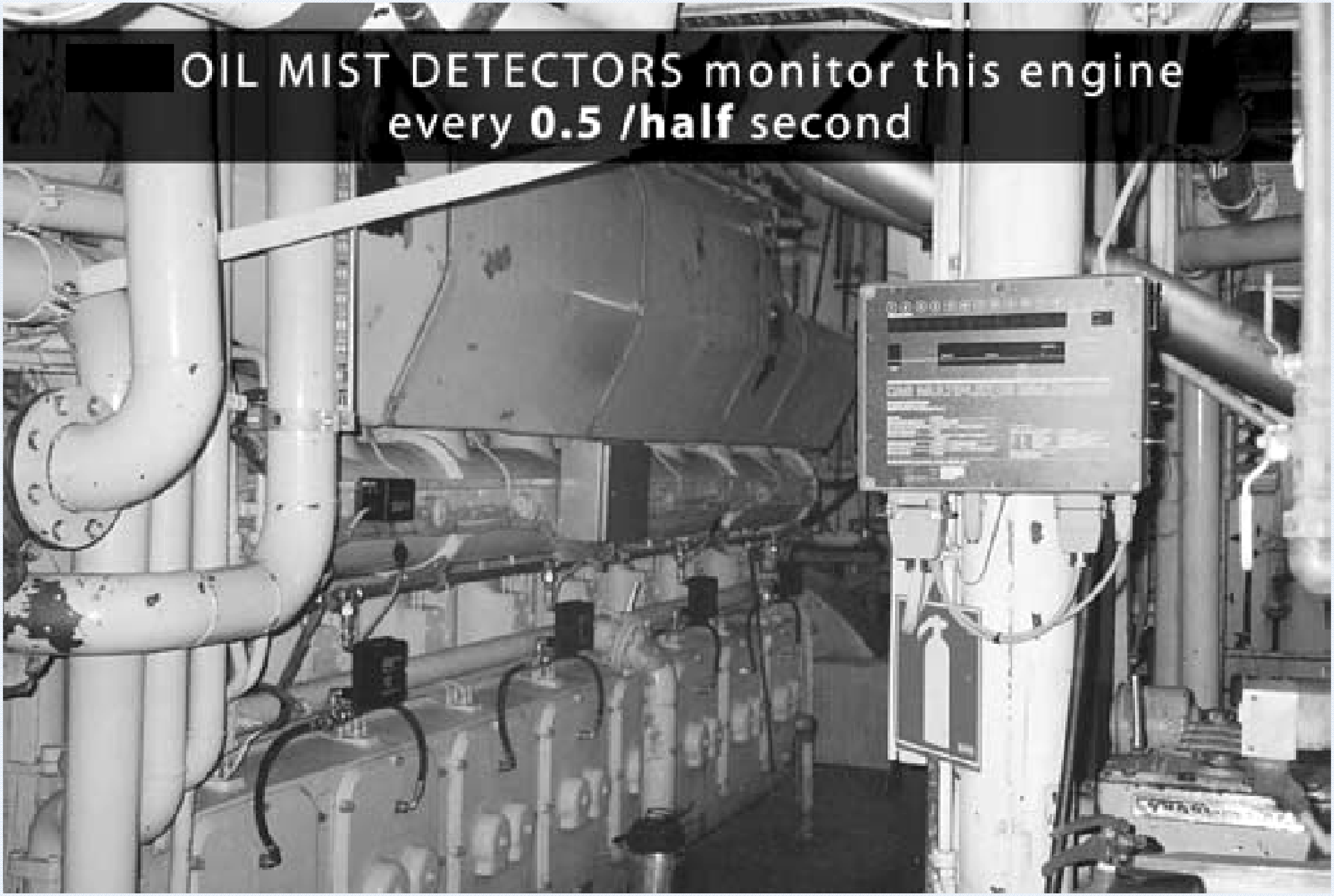


Figure 12-7A Crankcase Oil Mist Monitoring System

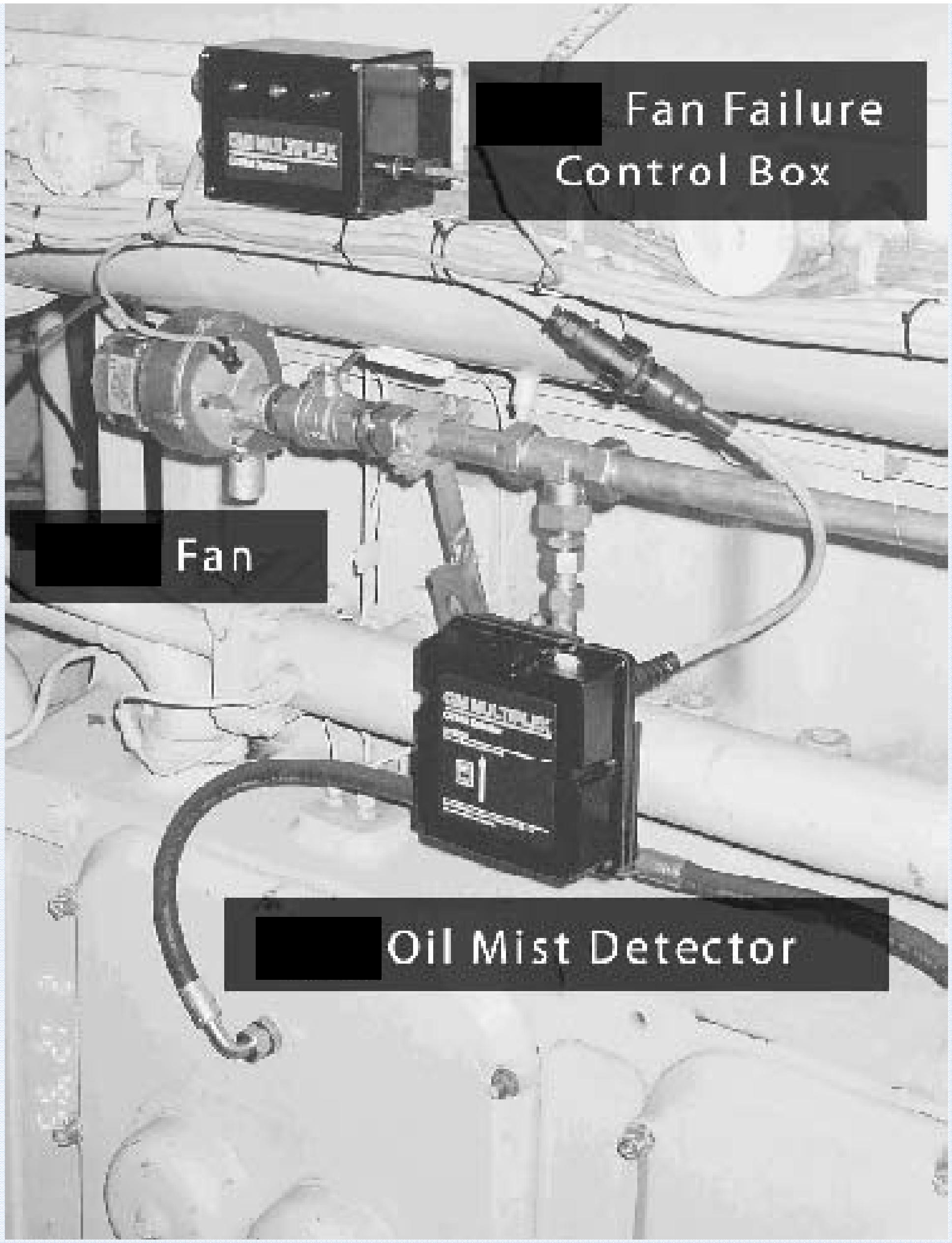


Figure 12-7B Crankcase Oil Mist Monitoring System

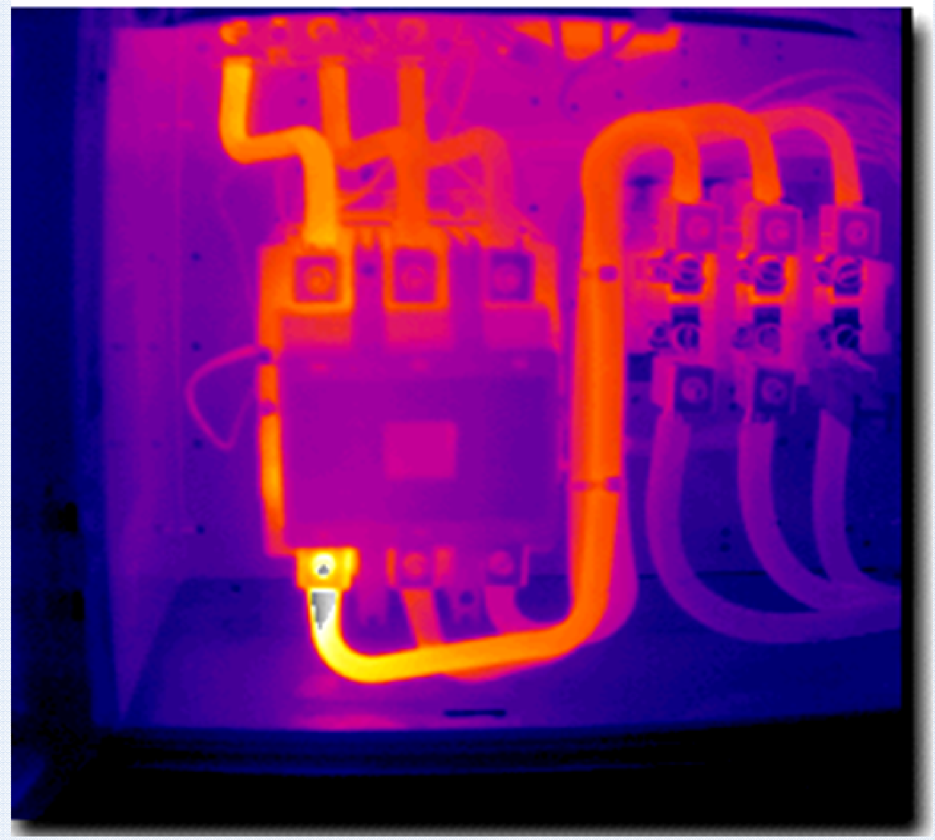
Infrared (IR) Scanning as a Monitoring Tool

Many operational anomalies and incipient failures in engines, generators, electrical systems, and support equipment result in pronounced temperature variations from the norm. Examples:

- Failing electrical termination at equipment or in switchgear
- An electric motor that is overloaded or has a failing bearing
- A generator winding or bearing in distress and overheating
- Engine cylinder misfiring, or large variations in cylinder loading
- Failing electrical transformer, overloaded electrical circuit

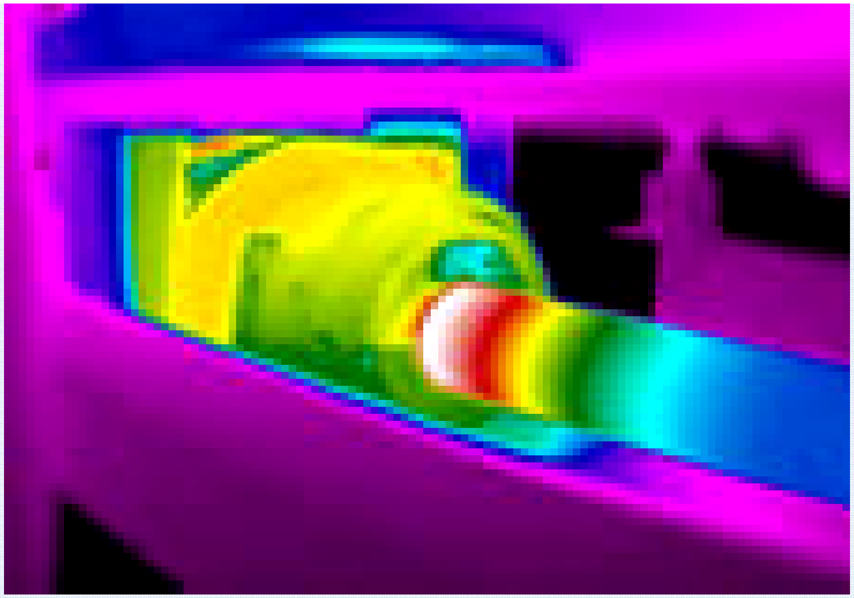
Portable equipment to record IR images of equipment is available, and can be a cost-effective tool. Take images at stabilized, steady-state conditions and compare to baseline data... Figures 12-9A, B

Ordinary Visual Inspection

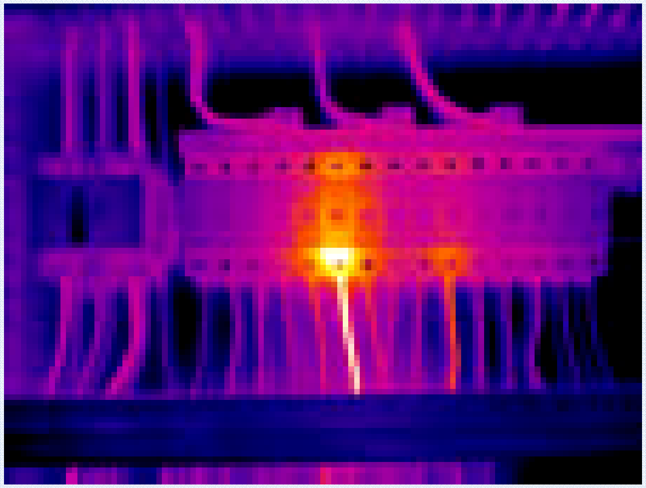


IR Thermograph of Same Equipment

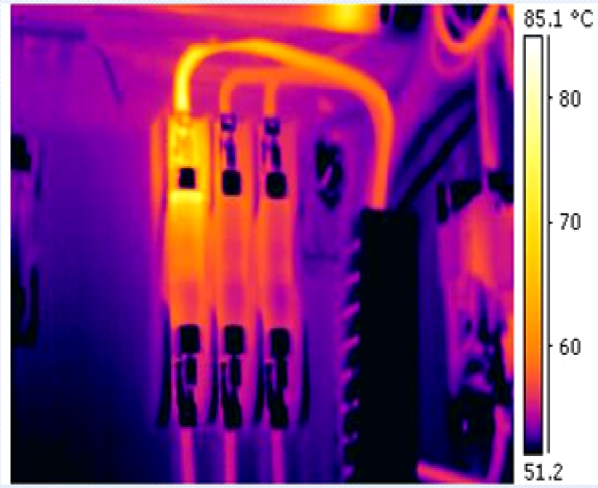
Figure 12-9A IR Thermograph of Impending Failure



Overheating
Bearing



Electrical Termination



One Leg of 3-Phase Fuse Block

Figure 12-9B IR Thermographs of Impending Failures

Monitoring by Human Senses

Visual observations and other human senses can be extremely effective in identifying equipment anomalies, often better than high-tech, high-cost systems. Examples include:

- Visual EDG inspection before run (preferably with a check list) to verify readiness for operation and look for any problems…
- Repeat after run. Make sure configured for emergency use.
- Non-Visual: Overheating transformer or motor will have odor, or may be unusually hot to touch. Unusual noises should also trigger action to determine what has *changed*...
- Human senses compliment technology-based EDG monitoring systems and are always involved in assessing their data.

Monitoring Summary

None of the described monitoring schemes or systems will provide complete, conclusive information on engine health/maintenance needs. However, integration and competent analysis of data from all sources will enhance EDG reliability. All successful predictive monitoring programs have:

- *Access* to monitored data collected under consistent and reproducible conditions, and compared to baseline data.
- *Data review* by experienced personnel who are knowledgeable of engine design details and operations.
- *Clear responsibility and authority* to obtain corrective action for all verified anomalies that have significant potential to impact EDG readiness, or reliability.

Selected Maintenance Topics

EMD Lube Oil Change (Adverse Consequences)

- Recommended oil had chlorinated additive, so unable to recycle
- User changed to oil used in rail service EMD engines. Wrist pin failures resulted because the types of service were so different.
- Additive was to keep oil on surfaces during long shutdowns and for extreme pressure service, both typical of nuclear EDG use.
- The substitute oil did not provide equivalent extreme pressure capabilities or the adherence qualities of the former oil.
- See IN 2002-22, "Degraded Bearing Surfaces in GM/EMD Emergency Diesel Generators," including consultant reports.

Selected Maintenance Topics

EDG Support Systems Major Contributors to Inoperability Events

- Most long-term studies show EDG engine-mechanical problems cause only 5% to 10% of failures, a testimony to the durability and reliability of diesels…
- Engine monitoring is still emphasized because such failures are often catastrophic and have huge cost impact.
- This statistic does support a more comprehensive approach to EDG reliability, one that puts more resources on assuring the operability of support systems.
- Figure 12-8 provides data on the failure rate of EDG sub-systems and is based on years of Licensee Event Reports (LERs).

System	Source			
	INEL	SwRI	U.S. Navy	NPRDS
I&C	30.1%	14.4%	0%	17.3%
Fuel Oil	24.9%	23.9%	24.6%	10.1%
Electrical	22.7%	20.8%	5.3%	0%
Cooling Water	7.6%	8.9%	19.3%	9.4%
Engine Mechanical	4.9%	10.3%	36.8%	4.6%
Lube Oil	4.5%	8%	7%	11.9%
Air Start	4.5%	13.8%	7%	46.9%
Ventilation	0.7%	0%	0%	0%

Idaho National Engineering Laboratory (INEL) data is for 353 LERs, 1987-1993.

Southwest Research Institute (SwRI) data is based on 689 LERs, 1968-1982.

US Navy data is skewed by piston-cylinder failures with one engine family, plus a high rate of cooling water problems. Their Instrumentation and Control data do not correlate with the other sources.

Nuclear Plant Reliability Data System (by Institute of Nuclear Power Operations) includes many EDG event reports not in NRC's LER system due to being a non-demand situation, therefore not reported.

Figure 12-8 EDG Failures by Responsible System

Selected Maintenance Topics

Post-Maintenance Inspections Critical

- Many EDG failures have been attributed to the lack of effective post-maintenance inspection after any work is done on the EDG, any of its support systems, or just in vicinity of the EDG. Examples will be discussed in Chapter 13…

Engine "Air Roll" or "Bar" Check

- Before any run following maintenance or a long period without being run, perform an "air roll" to verify freedom of movement. Cylinder test cocks open and fuel racks in "no fuel" position…
- Experience of licensee's has proven the worth of this procedure! Not a universal practice but recommended by manufacturers.

Selected Maintenance Topics

Engine Owner Groups – Discussed in the Student Manual

Long Term Aging Concerns

- Heightened by plant license extensions
- Some licensees still routinely perform fast start and load tests

Comprehensive EPRI Report on Diesel Engine Analyzers

- "Everything you wanted to know but were afraid to ask"
- Available for free download at their web site but hard to find…

http://my.epri.com/portal/server.pt?space=CommunityPage&cached=true&parentname=ObjMgr&parentid=2&control=SetCommunity&CommunityID=404&RaiseDocID=TR-107135&RaiseDocType=Abstract_id

END OF CHAPTER 12