Brüel & Kjær Vibro

Product Data

COMPASS™ Monitoring System – Type 3540

COMputerized **P**rediction, **A**nalysis & **S**afety **S**ystem — Version 6.x and higher

USES:

- Fully automatic and integrated system for the protective, predictive, and performance monitoring of rotating machinery
- Piston rod-drop monitoring of reciprocating machinery
- Complements existing monitoring systems with the addition of predictive/performance monitoring, high speed communications, centralised data storage, access and display at multiple locations
- Detailed, diagnostic analysis of machine faults

FEATURES:

- Powerful, comprehensive monitoring system for continuous (on-line) and intermittent (on-line and off-line) measurements with identical processing, analysis and display from a common database
- Modular system with flexibility to optimally meet individual applications, and which is easily expandable to meet growing requirements
- Adaptive Monitoring Strategy (AMS) maximises sensitivity by automatically adapting the monitoring system to different operating conditions
- Innovative data compression provides rapid access to significant values with 0.1s resolution within measurements spanning 30 years
- Digital Signal Processing (DSP) provides effective, detailed monitoring necessary for the earliest recognition of small changes, and allows rapid variations in monitoring strategy for specific operating modes, e.g. run-up, running, coast down
- Based on the most progressive industry standards for easy upgrading, flexibility, and all of the benefits of a multi--user, multi-tasking environment
- Total plantwide system integration with flexible interfacing solutions that include RS232, LAN, Modbus, and relay outputs
- Dial-up capability for remote monitoring
- Automatic self-testing gives high system reliability
- Versatile automatic monitoring functions, and user-friendly interface give high performance at low operational costs

*The **Type 3540 Computerized Prediction, Analysis and Safety System (COMPASS™)** provides optimized, cost effective monitoring to assure total machine protection and early recognition of faults.*
COMPASS is a complete system, consisting of – a versatile front-end with intrinsically safe transducers and components; one or more permanently installed Vibration Monitors (VMs), each with user-selected modules; locally or remotely placed master computers (CVMs) and slave terminals for setting up the system, and/or for trending, and for displaying plots and alarms; and finally, a host of software to make the system fit your application.
Detailed information on all the hardware and software components of COMPASS can be found in the respective product data sheets.

General Applications

The **COMputerized Prediction, Analysis and Safety System (COMPASS™)** is a state-of-the-art monitoring system that uses both vibration and process parameters to provide fully automatic, protective, predictive and/or performance monitoring on all types of rotating machinery found, for example, in the power, petrochemical, paper, steel, and heavy process industries. COMPASS incorporates the latest strategies for automatically monitoring the condition of your rotating machinery, alerting personnel and activating relays to protect machinery if any significant changes are detected. The COMPASS system also offers the analysis and diagnostic capabilities needed to plan the appropriate maintenance action long before a catastrophic failure occurs.

Integrated monitoring strategies
COMPASS is a total-monitoring, integrated solution that lends itself to automatic monitoring of machinery for three different kinds of monitoring strategies – *protective*, *predictive* and *performance*.

Protective Monitoring
Protective monitoring provides immediate recognition and response to changes in machine conditions, which could be hazardous to personnel and/or vital machinery.
Protective monitoring requires permanently installed transducers and is accomplished by continuously comparing easily measured values such as overall vibration against pre-set limits. In COMPASS, violation of an alarm limit can be set up to activate a relay for warning and/or automatic shutdown.

COMPASS conforms to all of the major requirements of API670 – considered 'the' standard for protective monitoring, specifically in the power and petrochemical industries.

Predictive Monitoring
Predictive monitoring consists of detailed analytical monitoring to gain the earliest warning of small changes in machine condition.
Predictive monitoring in COMPASS includes trend forecasting and detailed examination of components within complex spectra and cepstra to identify changes. Process variables can be incorporated for a complete assessment of total condition.
Predictive monitoring is advisable for machine elements such as gears, and rolling element bearings, where early symptoms of incipient flaws are hidden within complex vibration characteristics and thus require detailed analytical methods for early recognition.
Apart from the standard analysis and diagnosis tools, COMPASS also offers a machine diagnosis package that is *fully automatic*, receiving all of its measurement data from the monitoring system database at time intervals pre-set by the user.

Performance Monitoring
Performance parameters are used extensively in a wide range of industries (specifically in petrochemical, oil and gas, and power) to maximise efficiency and productivity, as well as to detect and diagnose specific machine faults. The performance monitoring capability offered by COMPASS provides a high level of accuracy and reliability because it is based on a collection of individual performance monitoring databases which are 'fine-tuned' to your specific gas turbines, compressors, pumps, etc., as a standard service.

Permanent/portable monitoring
COMPASS can use both permanent on-line (continuous/intermittent) and portable off-line (intermittent) measurements for predictive monitoring. Permanent on-line monitoring is advisable in applications where changes develop quickly, or where machine components are inaccessible or cannot be reached safely. Portable off-line monitoring is made with a 2526 Series Data Collector, and is effective in applications where changes develop slowly and machine components are readily accessible. A portable monitoring solution is the most cost effective way of monitoring a large number of measurement points on non-critical machinery.

Upgrading existing systems
Additional capabilities can be provided to existing systems by interfacing them to COMPASS. For example:

- Predictive monitoring can be added to *existing safety systems* for early fault detection.
- *Existing predictive monitoring systems* can benefit from the user-friendly interface and advanced alarm handling capabilities of COMPASS. Automatic expert diagnosis and performance monitoring are also available.
- *The information provided by existing turbine and compressor control systems* can be used by COMPASS to offer extended performance monitoring capability for both operational and machine condition monitoring purposes.

DCS integration
For effective total quality management, COMPASS can be easily integrated as part of a *Distributed Control System (DCS)* for applications such as process data acquisition for performance monitoring, maintenance management, statistical analysis, customised reports, special application monitoring, and many other data acquisition applications.

Multi-user & multi-tasking
With the trend towards plantwide system integration, COMPASS provides all of the benefits of a multi-user, multi-tasking environment including simultaneous data access for minimising the cost per operator, and distributed information and knowledge for work sharing and faster problem solving. COMPASS uses only the most progressive industry standards such as Ethernet (TCP/IP), UNIX, and X-window, and therefore builds on previous investments by connecting directly onto existing computer networks, and uses existing PCs to distribute data.

Remote monitoring
Due to safety, inaccessibility or simply economic considerations, it is not unusual for facilities today to be locally unmanned or distant from the control room. For example, in the offshore industry the trend is towards minimum facility, unmanned platforms. For these types of applications, COMPASS can employ a high-speed modem and a satellite link to monitor remote sites.

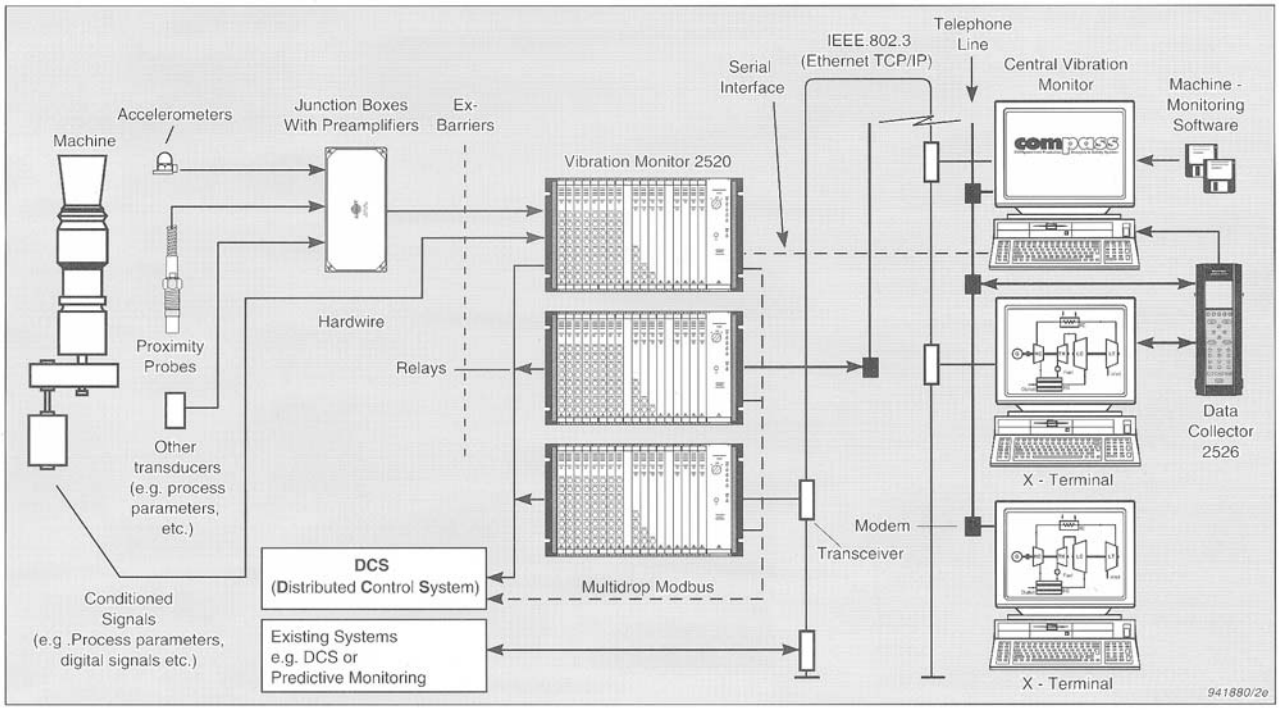

Fig 1. The COMPASS monitoring system. Protective, predictive, performance, permanent and/or portable monitoring can all be accommodated in a single system. COMPASS can also be readily integrated to a Distributed Control System. With a choice of communication methods, plantwide system distribution or remote monitoring is no problem

Monitoring Continuously or Intermittently?

Protective monitoring requires *continuous* measurements and comparison to provide the fast response time required for personnel and machine protection. Predictive and performance monitoring requires time to accomplish the detailed examination of complex characteristics and are thus performed *intermittently* at regular intervals. Both types of monitoring can be accomplished on-line from permanently installed transducers or off-line from information recorded with portable data collection instruments.

Continuous monitoring
Continuous monitoring measurements must be made at sufficiently frequent intervals to assure reliable detection of a potentially damaging change in condition so that a hazard to personnel and equipment can be avoided. The COMPASS input modules used for continuous monitoring can all respond to changes within 100ms.

Intermittent monitoring
The only difference between continuous and intermittent monitoring is the interval or frequency at which measurements are taken and compared. Intermittent monitoring generally includes overall values to which spectra and cepstra are added for the earliest recognition of specific flaws, trends to predict the development of a fault, and process information for an assessment of total condition and performance.

The interval between successive intermittent measurements will depend on the method of data collection (permanent or portable), number, type and complexity of the comparison, and the number of channels when the measurements are made on-line.

Permanent (On-line) monitoring
Permanent intermittent monitoring with the COMPASS system uses permanently installed transducers, Multiplexer Modules and a Signal Analyzer Module.
On-line measurements are advisable when changes can develop quickly or machine components are inaccessible or cannot be reached safely.

	Permanent (On-line)	**Portable (Off-line)**
Protective	Continuous	—
Predictive	Continuous /Intermittent	Intermittent
Performance	Intermittent	Intermittent

Table 1 Continuous and intermittent monitoring in the COMPASS System

Portable (Off-line) monitoring
Portable intermittent monitoring utilises a 2526 Series Data Collector to gather measurements. Once the measurements are transferred to the master computer (Central Vibration Monitor – CVM), the monitoring and comparison process proceeds identically to permanent intermittent monitoring.

Portable monitoring is effective when changes develop slowly, and machine components are readily and safely accessible.

COMPASS Components — Building-block Approach

The COMPASS system includes all equipment necessary for a complete, comprehensive monitoring system, from front-end transducers, sophisticated monitoring and analysis hardware/software to alarm relays. The basic system components can be distributed anywhere around the site and can include –

- Central Vibration Monitors – CVMs (i.e. master computers)
- Slave terminals (i.e. X-terminals)
- Machine monitoring software
- One or more Vibration Monitors (VMs)
- Portable data collectors
- Front-end accessories

The system can be configured to suit any application by selecting the appropriate monitoring software for the CVM and modules for the Vibration Monitor. A 'building-block' approach enables a user to start a monitoring programme with portable measurements and then later expand to permanent monitoring as confidence and knowledge grows and the numerous benefits of condition monitoring are demonstrated. Likewise, a user may extend a permanent on-line system to include portable off-line measurements. In all cases, the data is fully compatible throughout the monitoring system.

Central Vibration Monitor (CVM)
The CVM is the master computer for the monitoring system and provides setup and user-interface facilities for integrated solutions, and setup facilities for stand-alone systems. The monitoring software and database operate in the CVM, where monitoring setups are made, data is stored and displayed, diagnostics performed, and certain post-processing functions and trending are done.

Interfacing
The CVM uses UNIX and X-window on a TCP/IP Ethernet network. UNIX provides true multi-tasking, multi-user capability, while X-window allows the graphical user-interface to be displayed on other dissimilar PCs (X-terminals) on different networks and with different operating systems (UNIX, Windows 95, 98, NT). An X-terminal user can also remotely access the CVM by *modem*. Refer also to the section 'Type 2520 Vibration Monitor'.
One other special interface features of the CVM is that it can use *remote data acquisition* to automatically or manually send measurement and alarm data from the CVM database to a text file anywhere on the network (to a DCS, for example). Moreover, text files can also be imported from control systems or other monitoring systems for post processing, database storage, display, and/or alarm annunciation.

Machine Monitoring Software
The *Type 7615 Machine Monitoring Software* is a group of integrated UNIX-based programs that provides COMPASS with almost limitless flexibility for a wide variety of applications and configurations.

For more detailed information on these packages, please refer to the 'Type 7615 Machine Monitoring Software' product data sheet.

Application flexibility
7615 software packages allow you to customise the COMPASS system to a specific application and configuration in the most efficient and economical way possible.
A range of optional 'building-block' *application software and database packages* give you the ability to automatically monitor machine performance and faults for a specific application, and to analyse and diagnose the faults. The main user functions of the application software are reporting and displaying alarms, performing manual measurements and trending, displaying a wide variety of highly informative graphic plots, and the general setting up of the COMPASS system.
In addition, *system configuration packages* allow you to configure the COMPASS system to your specific installation, networking, and interfacing needs.

Powerful user-interface
The system's operation interface is entirely via software in the CVM – no hardware operations are required for setting up or operating the system. The software is extremely user friendly, mouse driven with window item selection, and includes extensive help text and dialogue boxes.
View windows show operators at-a-glance, all machines, transducers and measurements that go to make up a *hierarchical* plant structure. Status 'traffic-light' alarms at each level provide a simple means of tracing an alarm through the entire plant structure and down to its channel measurement source (see Fig. 3). These can be toggled to display also the measurement values (see Fig.2).

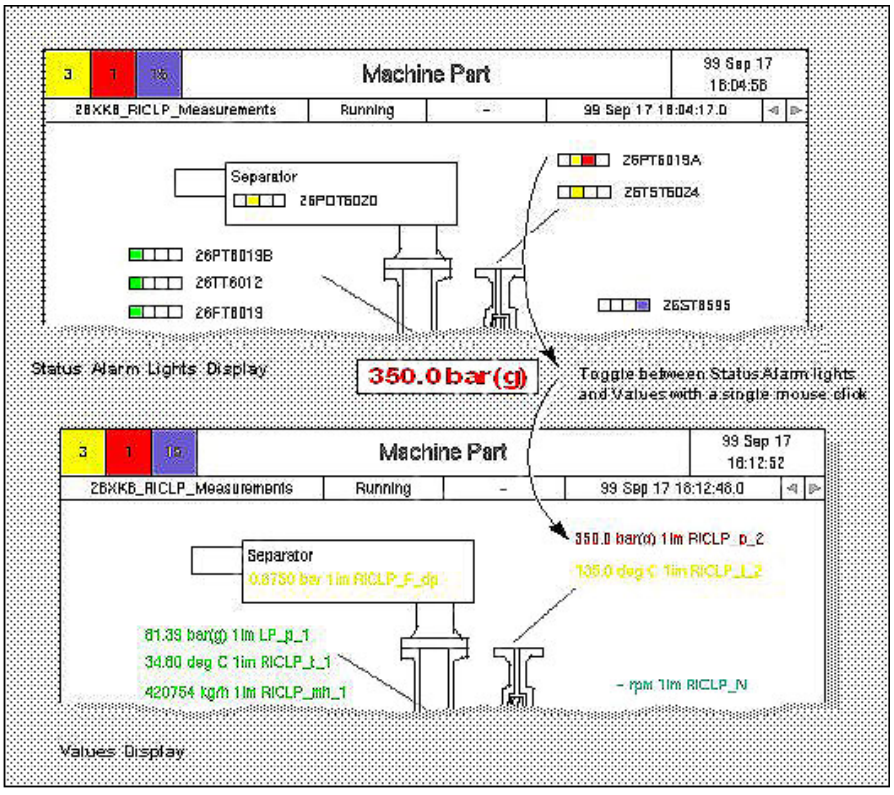

Fig. 2 Toggling between the Status 'Traffic Light' alarms and the measurement value

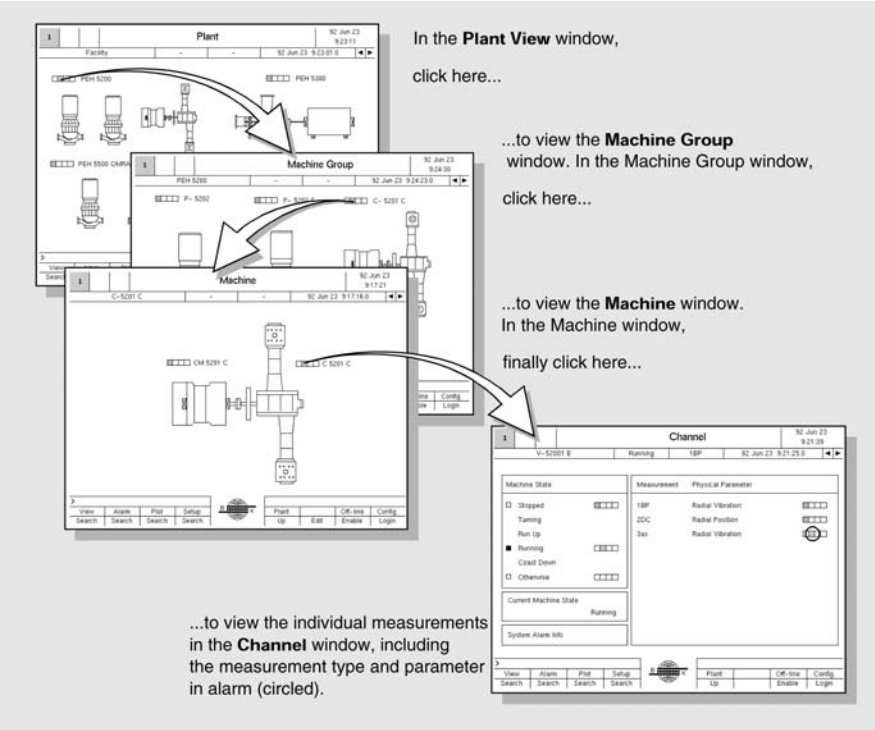

Fig. 3 A 'traffic light' alarm light next to each transducer informs the operator of any alarms at that point, and provides a simple way of navigating through the plant

Plotting facilities
Measurements can be displayed in a wide range of 2-D, 3-D, circular and specialised performance plot formats to ease analysis of data. Multiple trend plot displays are also possible for easier correlation.

Automatic machine diagnosis
Using ADVISOR™, Brüel & Kjær Vibro's neural-based machine diagnosis software, COMPASS can automatically diagnose a wide range of incipient faults on all types of commonly used rotating machinery.
For more detailed information, refer to the 'ADVISOR™ Machine Diagnosis Software' product data sheet.

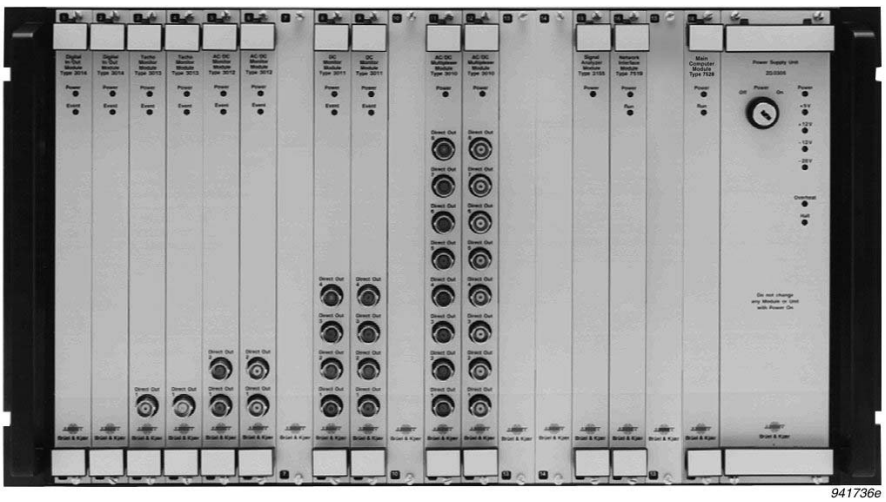

Fig. 4 The modular Vibration Monitor

Type 2520 Vibration Monitor (VM)
The Vibration Monitor, shown in Fig. 4, provides the entire signal processing and event handling for the monitoring system. All signals are digitised and processed in the Vibration Monitor before being sent to the CVM containing the user-interface and database.
For detailed information on the VM, refer to the 'Type 2520 Vibration Monitor' product data sheet.

Modular design
Designed for installation in a standard 19" rack, the modular VM can be quickly and easily expanded with modules dedicated to one or more processing tasks. Together with five system modules, the VM can accommodate up to 14 application input/output modules to provide up to 84 continuous channels, 112 intermittent channels, or a combination of both. The optional modules can be installed in any configuration, providing a highly versatile and flexible system capable of being customised to meet almost any application.

Reliable monitoring
The Vibration Monitor is a self-contained system. It continues to do all automatic condition monitoring functions and store data, even if the CVM breaks down!
Also to avoid false alarms and ensure reliable machine monitoring at all times – whatever the application – the VM uses adaptive monitoring. Refer to 'Adaptive Monitoring Strategy'.

Interfacing
Any number of Vibration Monitors can be used with one system and located anywhere around the site. The VM uses several means of communication to interface to the CVM and to a DCS.
TCP/IP LAN network is a flexible solution that can accommodate any number of VMs, CVMs, X-terminals, and other devices, all on the same net (X-terminals are linked to the VM(s) only via the CVM).
The single RS232D standard serial interface on the VM allows one of the three different interfaces to be used –

- **Direct** two-way communication from a single VM to the CVM.
- **Dial-up** by modem for remote communication from the CVM to any number of VM's. Data can be automatically sent to the CVM, or manually requested for testing and diagnosis purposes.
- **Multidrop Modbus** communications for providing current measurement values and alarm information from a VM to a DCS system (a LAN network in this case is used to connect the VM(s) and the CVM).

The VM also provides relay outputs for remote warnings; a change in the machine's running state; or for automatic machine shutdown. To ensure that a machine will trip in the event of an abnormal system condition, relays can also be set up in *failsafe* mode.

Stand-alone operation
In applications where protective monitoring only is required, the VM can be configured to operate as a totally independent machine surveillance system. With the Non-volatile Memory Module installed, system and monitoring setups are locally stored on the Memory Module's interchangeable PCMCIA card, for totally independent VM operation.

Type 2526 Data Collector
For portable measurements, the Data Collector is a cost effective way to provide predictive monitoring on less critical, spared machinery.
The Data Collector is a lightweight hand-held instrument that can both collect and analyse machinery data, change setups in the field, and provide balancing. The same setups and measurements can be used for the Data Collector as the Vibration Monitor, and it operates with the same CVM and a common database.
The Data Collector is loaded with a measurement route directly from the CVM, or via modem/phone, or over the network from another PC (X-terminal). When the route is finished the operator transfers the measurements and setup changes to the CVM, where they will be handled as other data in the system.
For more detailed information, refer to the '2526 Series Data Collectors' product data sheet.

Front-end
COMPASS has the flexibility to utilise a wide variety of transducers for input to the system, including

- Accelerometers
- Displacement transducers
- Other AC Transducers, such as velocity pick-ups and microphones
- Tachometers, such as non-contact eddy current probes
- Digital inputs from process instrumentation (on/off or trigger signals)
- Analogue inputs from process instrumentation (e.g. analogue temperature transducers)
- Values measured and transferred from the Data Collector
- Values imported from other systems (e.g. DCS)

The front-end of the system can also include charge amplifiers, barriers, junction boxes and a wide range of cables, connectors and mounting plates. Front-end accessories can also be provided for specialised environments such as intrinsically safe, explosive, or high radiation areas.
For further details, refer to the 'Industrial Transducer Overview' and 'Vibrosensors' product data sheets.

Automatic Machine Monitoring

The COMPASS system measures and automatically monitors a wide range of machinery.
To optimise the monitoring strategy for each machine, a number of proven fault detection methods are available. Each channel input can be monitored simultaneously with as many as 12 different measurements to ensure sensitive and reliable fault detection.

Standard monitoring techniques
The type of measurement automatically monitored by the COMPASS system ranges from the simplest to the most advanced.

Overall (scalar) monitoring
Overall (scalar) values are single value measurements (vibration and process parameters), typically used for protective machinery monitoring to prevent catastrophic failure, and for performance monitoring. See Fig. 5.

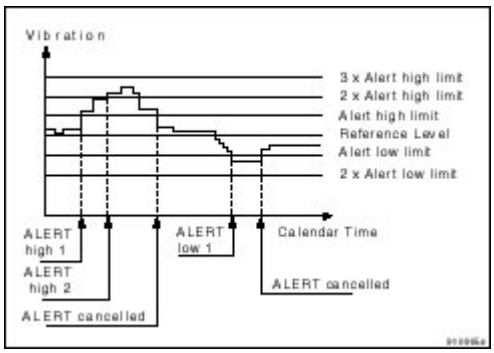

Fig. 5 Overall-level monitoring for a wide variety of safety and performance applications

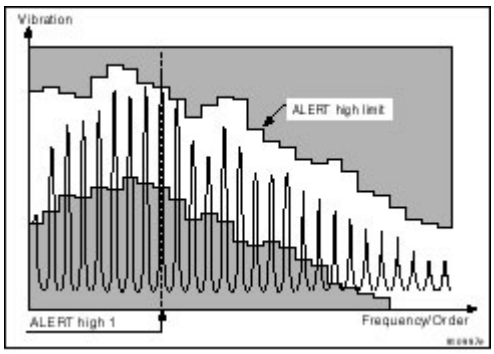

Fig. 6 Spectrum monitoring for earlier fault detection and detailed analysis

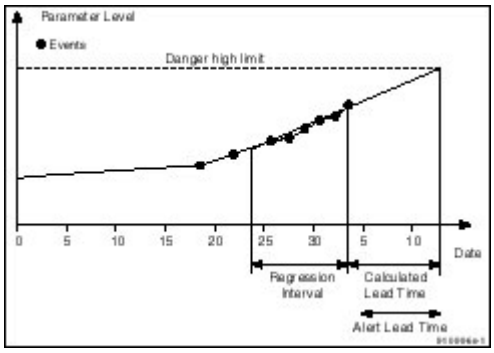

Fig. 7 Manual or automatic trend monitoring for predicting trouble

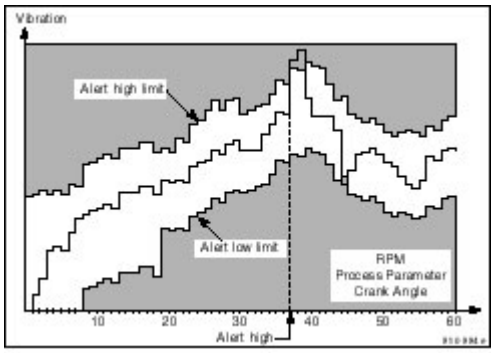

Fig. 8 Profile measurements for transient speed machinery

Spectrum (array) monitoring
Although overall values are good indicators of common faults such as unbalance and misalignment, spectrum comparison enables each frequency component to be accurately identified for earlier fault detection and more powerful diagnostic capability. See Fig. 6.

Trend monitoring
Trending is one of the more important functions of predictive monitoring. Trends are monitored using historic scalar data to predict when a particular signal will exceed a predefined limit. See Fig. 7.

Adaptive monitoring techniques
To gain maximum sensitivity to small changes, without generating false alarms, the COMPASS system employs *Adaptive Monitoring Strategy (AMS)*. This technique is used in protective and predictive monitoring to automatically adapt the reference and alarm levels to any given machine condition for *reproducible* results.

Machine states
The definition of strictly-defined machine states in a monitoring system, is an adaptive monitoring technique that uses speed and/or digital inputs to automatically recognise a change in a machine's operating regime. Once the operating state is recognised, COMPASS automatically switches to the correctly defined monitoring strategy for that state.

Profile monitoring
Used for transient-speed states, Profile Monitoring automatically monitors, in real time, a standard scalar parameter (e.g. a vector) with respect to increments in RPM instead of time (see Fig. 8). This allows individual alarm limit values can be set up such that they follow the contours (the 'profile') of the measurement, making it possible to quickly detect the smallest signal level or phase change, at any speed!

Process (restricted) classes
Changes in the process operating conditions can affect the vibration characteristics of a machine. To recognise and compensate for vibration changes not related to mechanical faults, one or two process variables which influence the machine's vibration (for example, temperature and pressure), are used to classify a machine's operating conditions into a number of operating ranges over which the vibration level does not vary appreciably. Different measurement setups, reference levels, etc. can then be assigned to each of the defined classes.

Triggered measurements
Used for machines that operate for sporadic, brief periods of time rather than continuously (e.g. a robot arm in a car assembly line), For rod-drop monitoring, for example, a measurement is triggered at a user-defined crank angle each rotation. Other triggered measurements can utilise the digital (logic 'on/off') signals from the machine's control system to recognise the period of stable operation, and to then 'trigger' the monitoring system into action.

Imported measurements
Overall value measurements can be automatically imported into COMPASS from other systems. These are transferred over the network in the form of a text file, and then used in plots, trends, for activating alarms, or used as variables in calculated measurements.

Calculated measurements
A calculated measurement is defined by a formula that can use constants, overall value measurements or even other calculated measurements as variables. Thermodynamic and statistical parameters can be calculated in this way, and can be compared to alarm limits, stored in the database, trended and displayed in plots as other measurements.

Performance monitoring
COMPASS also provides facilities for performance monitoring of turbines, compressors, pumps, etc. Machine baseline data, gas properties and thermodynamic calculations are fine-tuned to your specific application as a standard service.

Event Detection and Data Storage

The *event principle* of COMPASS allows the vast amount of transducer data normally generated by an automatic monitoring system to be screened and optimised so that only the most significant data is stored.

No data overkill
Event-controlled data processing is carried out in the Vibration Monitor, where incoming data is screened so only those signals of interest are stored by the system.

During monitoring, input signals are compared against an *event window* which has a pre-set, user-defined width, automatically centred around the last value. If violated, the system will register an event consisting of the value and a time stamp which are stored in the CVM.
In this way the Vibration Monitor does not become overworked by processing insignificant data, and the communication between the Vibration Monitor and the CVM and database is reserved for important data.

Compressing data for long-term access
The event principle forms the basis of a highly effective method of *data compression*, which ensures only relevant data, is stored.
This feature provides a store of relevant data going back up to 30 years, while having a time resolution of 0.1 second where it's needed most, i.e., shortly after the fault is detected.
All permanent measurement data coming from the Vibration Monitor is stored in the database in a remarkably efficient manner that provides detailed time resolution of measurements and data over a period of several years without unduly filling up the database.
The high-resolution buffers can be user-defined so all data can be stored in the finest resolution from one to 200 hours.

User-initiated Measurements

The automatic monitoring features of COMPASS operate without user-interaction to detect incipient faults and to provide machine safety. However, the user is free to access the system at any time to manually carry out measurements.
Typically, this would be made when a fault has been detected by COMPASS. The user can then freely access the high-powered measurement and plotting facilities to perform a detailed analysis of the signals from the offending machines to determine the exact nature of the fault.
All intermittent monitoring measurements offered by COMPASS can be manually initiated.

COMPASS System Design Features

The power of DSP
The extensive use of *Digital Signal Processing (DSP)* in the Vibration Monitor provides COMPASS with revolutionary capabilities. DSP allows a wide variety of different measurements to be made with the same hardware, with the change in setup occurring almost instantaneously. All filtering, signal and weighting functions etc. are made using DSP in the individual input modules. Any new measurements that need implementing into the system in the future

can be done by simply downloading the measurement software to the input modules from the CVM.

Reliability
It is of paramount importance that the equipment used to monitor machinery is itself highly reliable. Any system failure must be detected very quickly and reported immediately.
The design philosophy of COMPASS has produced a highly reliable system that continuously checks its own operation and has a variety of reliable fault detection techniques.

In the event of an alarm, relays may be actuated by a single violation or require two simultaneous violations (i.e. *voting logic*). If voting logic is used, the relays actuate only when two variables jointly agree on an abnormal condition – a single violation cannot trigger a machine trip in this case. And to ensure that a machine will trip in the event of an abnormal system condition, relays can alternatively be set up in failsafe mode.

Security
The integrity of COMPASS is ensured by the use of *restricted privileges* for different users. All users have their own username, password, and a specific user-privilege assigned to them that restricts them to performing only specific tasks. This feature prevents unauthorised access.

Dynamic Support & Service

COMPASS is backed by an extensive range of support and service packages.

Product Services
Product Services provide full support for Brüel & Kjær Vibro's range of condition monitoring equipment. PS offers all aspects of supply and installation, from factory system testing and project management to commissioning and personnel training.

Consultant Services
Consultant Services provide the assistance and specialist knowledge needed to make the right decisions, before you invest in a monitoring system. CS staff are also on hand to participate in factory and site acceptance testing of critical machinery.

Specifications 3540 — Version 6.X or higher

Computer Workstation Requirements

The COMPASS Software has been tested to run successfully on several different workstations for both the Central Vibration Monitor (CVM) and X-terminals. Call Brüel & Kjær Vibro for a current list, plus the minimum workstation requirements and peripherals in general.

User Network:
TCP/IP protocol is used over an Ethernet Local Area Network or Tokenring.

Program Security

Every user has a login username, password, a set of preferences, and a set of privileges.

Vibration Monitor Setups/Limits

To ensure the most effective system performance, the following limits should be observed for each Type 2520 Vibration Monitor:

- A maximum 112 machines, where a maximum of 20 can have machine state setups
- A maximum of 112 channels
- A maximum of up to 12 measurement setups per channel for each machine state
- A maximum of 1500 measurements can be setup in a Vibration Monitor

The event buffers in the Type 2520 will hold the following number of measurements before a 'Buffer Full' message is issued:

- A maximum of 500 Spectra and/or Profiles
- A maximum of 10000 scalars

Other Product Data Sheets

In addition to the COMPASS Product Data sheets described in this booklet, there are other products that can be used directly with COMPASS. Further information on these can be obtained by requesting the relevant literature number, specified below.

Portable Systems:
2526 Series Data Collector System.....Product Data Lit. No. BP1287

Front End:

Industrial Transducer Overview	Product Data Lit. No. BP1509
Vibrosensors	Product Data Lit. No. BV-P1001