Computer Aided Interactive Wear Debris Analysis Training

After completing the **V4L CADET** Program, end users will understand:

- The classes of wear and contaminant particles in ASTM D7684-11 'Standard Guide For Microscopic Characterization Of Particles From In-Service Lubricants'.
- The wear and contamination situations that commonly occur in engines, gearboxes and hydraulic systems.
- How examination of the wear and contaminant particles recovered from fluid samples, filters and magnetic plus can reveal machine faults.
- The way in which appropriate and timely corrective action can prevent faults escalating into failures.

By *V Leavers*

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C*omputer* **A***ided*
D*ebris* **E***valuation* **T***raining*

What is C*omputer* A*ided* D*ebris* E*valuation* T*raining* (CADET)?

The **V4L CADET** Program is interactive software for training maintenance professionals in wear debris particle classification and root cause diagnosis. The software is built around a knowledge base resulting from years of dedicated research at **V4L** and is compliant with the ASTM D7684-11 standard guide for microscopic characterization of particles from in-service lubricants. The training method was designed in consultation with experienced educators and educational psychologists in order to offer the best possible learning experience and knowledge transfer outcome. Once the training is completed the software can continue to be used as a unique, supportive resource; especially where maintenance professionals are forced to work in remote locations without being able to send samples to a specialist laboratory for analysis.

Wear debris analysis and root cause diagnosis research

The starting point in **V4L**'s research was to ask the following questions:

- What does the expert do?
- Why does the expert do that?
- What knowledge and experience does the expert use?
- What information does the expert extract?

To answer these questions the activities of various experts were observed and the resulting diagnostic information noted. During the research thousands of wear debris particle images were collected and analyzed. At each stage of an analysis the experts were questioned about the experience used to make their decisions. The result is an extensive knowledge base representing the combined expertise of a number of highly trained analysts, each with decades of experience.

Effective training principles

Before developing the **CADET** software **V4L** consulted with experienced educators and educational psychologists. The outcome is an effortless, positive learning experience based on the following principles:

'Learning by doing' — is the most effective and efficient way of acquiring and retaining knowledge and transferable skills. The end user engages and interacts with the **V4L CADET** software replicating, step by step, the activities performed by the expert.

'Information in context' — only facts relevant to the analysis at that point are presented to the end user on distinctive, yellow guidance notes. This use of brief, contextual snippets of information means that facts and concepts are more easily understood and remembered. There is never the possibility of exposure to the negative impact of 'information overload'.

> 3-body abrasive wear particles (often called 3-body cutting wear) are produced when hard, free-moving particles are trapped between two machine surfaces, resulting in removal of material from one or both surfaces.

'Immediate Auto Correction' — in tutorial mode the program auto corrects at each stage of the analysis should an error be made. This trains the end user to recognize the various parameters that the expert uses to classify particles.

'Instant Feedback' — at each stage of the training automatically generated expert-guidance notes support the end user in their decision making by letting them know exactly what the expert would be thinking at that point in the analysis. This helps to correct misconceptions, resolve ambiguities and offers alternatives choices.

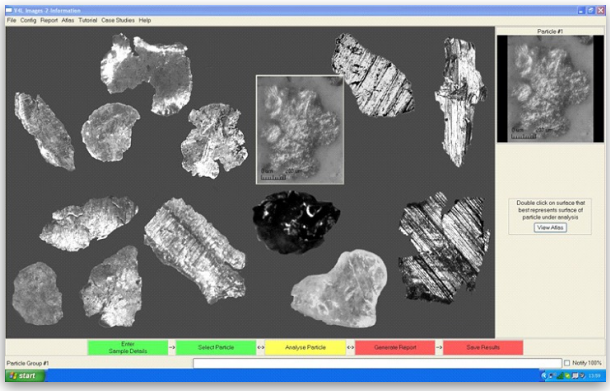
'Self Pacing' — the best learning outcome is achieved when end users are allowed to work at their own pace taking as little or as much time as is needed.

'Large, Diverse Data Set' — to avoid the formation of narrow generalizations that do not represent the true variety within a particle classification category requires exposure to a large number of examples. The number and variety of particle images in the program allows the end users to see the full range of wear and contaminant particles — something that would normally take months or years in a laboratory setting.

'Practice Makes Perfect' — the end user has a set of test images and can also integrate particle analysis into the daily work flow of the laboratory, acquiring skills in a practical work setting.

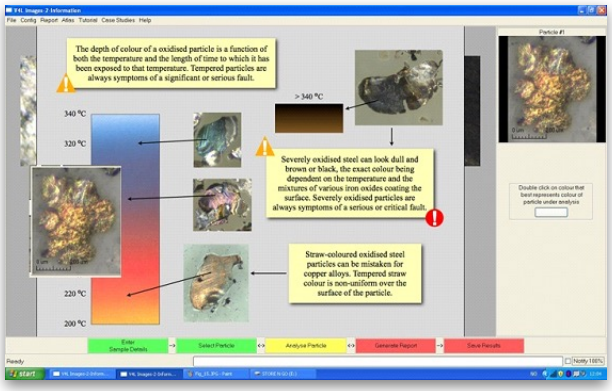
The V4L CADET Program in action

Shape and Edge Profile — to begin the analysis a particle of interest is selected from the image. The end user is then required to find a match to the particle's shape and edge profile from a variety of candidate images.



Surface Texture — a choice of surface textures associated with the chosen shape and edge profile is presented. The software makes it easier to find a match by allowing the end user to move their chosen particle image around the screen and compare it to the different options.

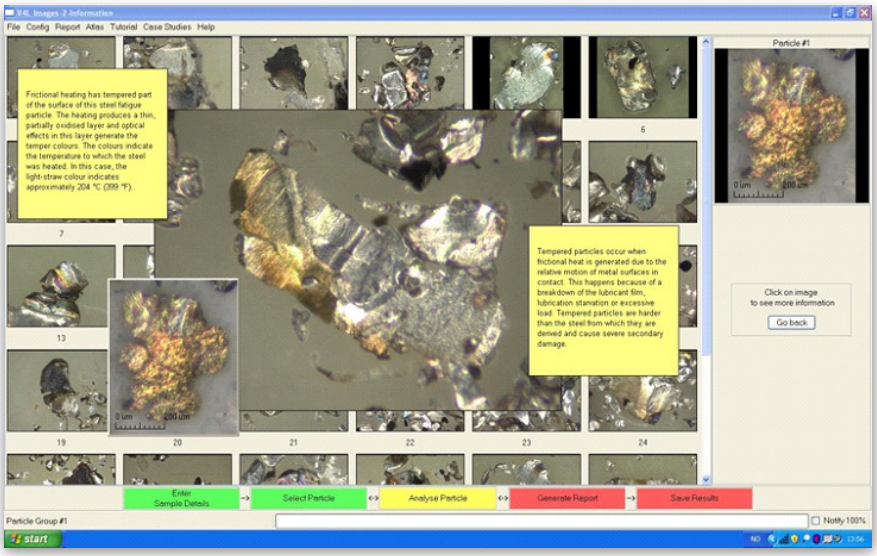
Color — an expert uses the color of the particle as an indispensable aid to root cause diagnosis. Thus, the V4L CADET software presents a choice of colors. Clicking on a color swatch allows the end user to see the expert-guidance notes and to know how particular colors are essential clues for root cause diagnosis.

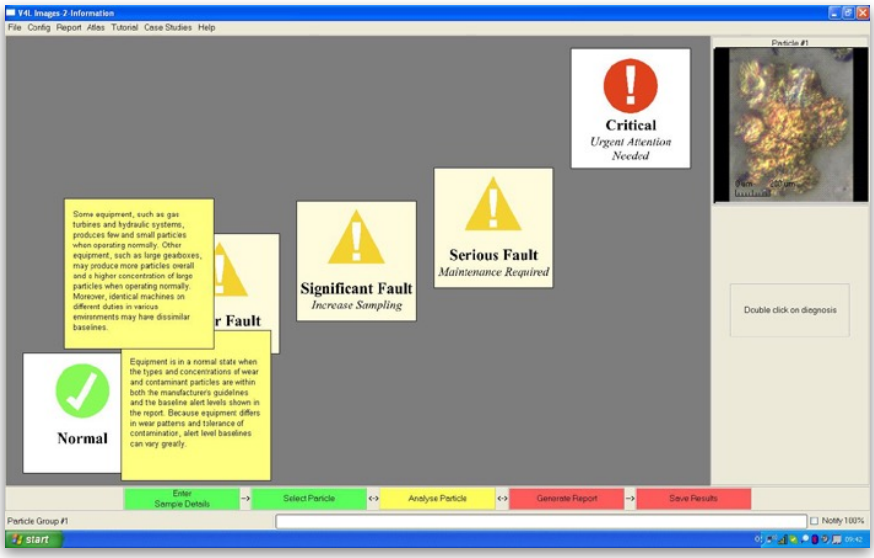


Particle Type Classification — following the choice of shape, edge profile, surface texture and color the wear debris type of the particle is automatically determined according to the ten, visually discernible, particle categories given in the ASTM D7684-11 guide.

Expert-Guidance Notes — supportive expert-guidance notes appropriate to each stage of the analysis are automatically generated. In particular, once the end user has completed the particle classification and before they have committed it to the report, they are automatically offered feedback concerning the choices they have made. It may be that they are obviously mistaken in their choices or there may be some ambiguity in the particle classification. The expert-guidance notes automatically offer assistance appropriate to that particular particle analysis in order to help resolve such issues.

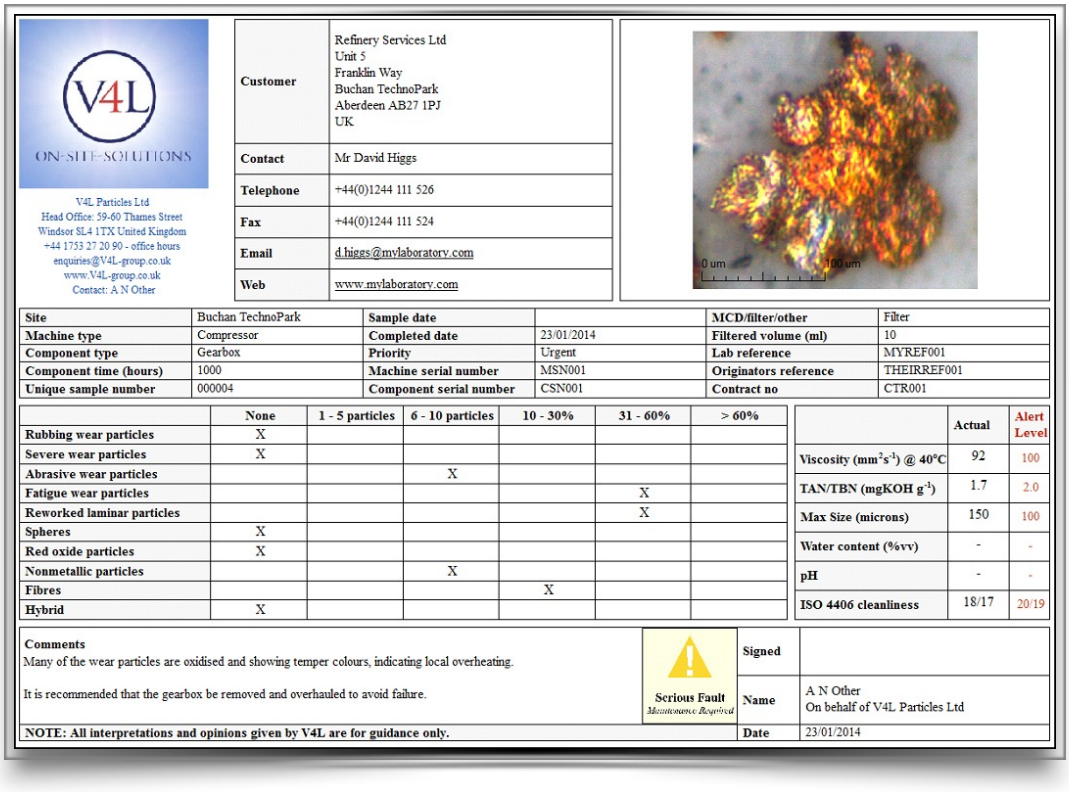
Wear Debris Atlas — following each particle analysis, if any uncertainty concerning the particle classification remains, the end user has the choice to consult the extensive wear debris particle atlas according to the categories suggested by the expert-guidance notes. This acts as a final check and safety net for the end user as it is then possible to choose by inspection of a number of particle images, that which is most similar to the particle under analysis and to commit that classification and diagnostic information to the report in place of the original analysis.





Alert Levels — the ASTM D7684-11 guide advocates a five level relative severity rating for the condition of equipment. The **V4L CADET** software correspondingly has five alert levels. A single click on any of the alert level options will bring up the expert-guidance-notes, which provide information about why that particular alert level might be the optimum choice. The expert-guidance notes can be moved around the screen by clicking and holding down the mouse or tracker pad. A double click on a particular option confirms that alert level for insertion in the report.

Automatic ASTM D7684 Compliant Report — the results of the analysis are automatically presented in an ASTM D7684-11 compliant report, which can be used to add comments or to record other condition monitoring test results relevant to the root cause diagnosis.



V4L ON-SITE-SOLUTIONS

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Site	Buchan TechnoPark	**Sample date**		**MCD/filter/other**	Filter
Machine type	Compressor	**Completed date**	23/01/2014	**Filtered volume (ml)**	10
Component type	Gearbox	**Priority**	Urgent	**Lab reference**	MYREF001
Component time (hours)	1000	**Machine serial number**	MSN001	**Originators reference**	THEIRREF001
Unique sample number	000004	**Component serial number**	CSN001	**Contract no**	CTR001

	None	1 - 5 particles	6 - 10 particles	10 - 30%	31 - 60%	> 60%
Rubbing wear particles	X					
Severe wear particles	X					
Abrasive wear particles			X			
Fatigue wear particles					X	
Reworked laminar particles					X	
Spheres	X					
Red oxide particles	X					
Nonmetallic particles			X			
Fibres				X		
Hybrid	X					

	Actual	Alert Level
Viscosity (mm^2s^{-1}) @ 40°C	92	100
TAN/TBN ($mgKOH\ g^{-1}$)	1.7	2.0
Max Size (microns)	150	100
Water content (%vv)	-	-
pH	-	-
ISO 4406 cleanliness	18/17	20/19

Comments
Many of the wear particles are oxidised and showing temper colours, indicating local overheating.

It is recommended that the gearbox be removed and overhauled to avoid failure.

Serious Fault
Maintenance Required

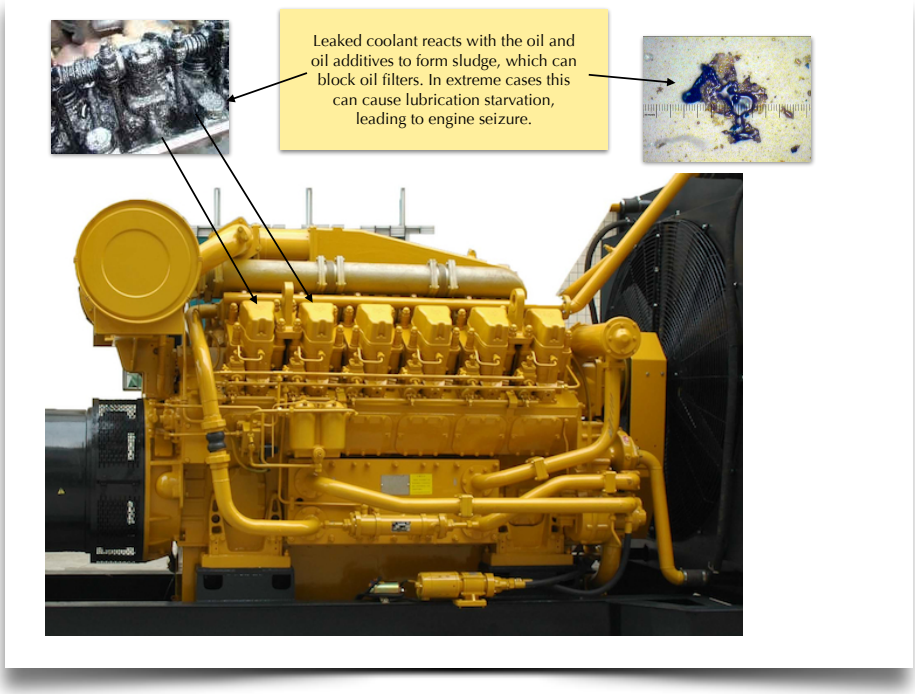
Signed

Name A N Other
On behalf of V4L Particles Ltd

NOTE: All interpretations and opinions given by V4L are for guidance only.

Date 23/01/2014

Case Studies — the **V4L CADET** software offers the optional capability of reviewing case studies of previous diagnoses concerning the same or similar type of equipment. This provides the bridge from the theory to the engineering practice.



Who Should Use the V4L CADET Program?

Trainee technicians in specialist laboratories and maintenance professionals in the following industries, who need to work on-site and are unable to send samples to a specialist laboratory:

- Construction
- Mining
- Power generation
- Offshore oil and gas exploration
- Aerospace
- Marine

Advantages of using the V4L CADET Program

- In depth knowledge of the wear and contaminant particles in the ASTM D7684-11 standard guide for microscopic characterization of particles from in-service lubricants.
- The quickest and most effective way for new staff to become acquainted with wear and contaminant particle analysis — indispensable in organizations with high staff turnover and varying levels of training and experience.
- Allows end users to see the full range of wear and contaminant particles — something that would normally take months or years in a laboratory setting.
- End users can learn at their own pace — anytime and anywhere.
- Training can be integrated with day-to-day workflow. .
- No additional travel or accommodation overheads for staff training
- Can be used as an on-site resource once training is completed.
- Results of using the software on-site can be easily transmitted and verified remotely.
- Provides end users with a unique in-depth knowledge of the subtle differences between particles - revealing much more about machine condition.
- Encourages the end user to consider wear processes and contamination scenarios in the context of the machine leading to pre-emptive rather than forensic diagnoses.
- The analysis takes only 5 – 10 minutes to complete making it faster and more informative than current particle analysis techniques.
- The **V4L CADET** software does not require any specific imaging hardware as test images are incorporated in the training package
- If required, live images can be video streamed to the software from microscope cameras with a TWAIN interface. For those without a TWAIN interface The **V4L CADET** software will accept particle images saved in .tiff format.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