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OPERATING MANUAL

FOR FLOW SORT'S

FLUORESCENT PARTICLE ANALYSER

MODEL FPA-1

1. WHAT A FLUORESCENT PARTICLE ANALYSER (FPA) IS USED FOR!

1.1 FLOW SORT'S Fluorescent Particle Analyser (**FPA**) is exactly what the name says:

1.2 A tool that allows **A**nalyses of the **F**luorescent properties of **P**articles when irradiated by X-rays. And further, it is an instrument, which produces data for diamonds (and other minerals) that can be used directly for setting up of FLOW SORT X-ray diamond recovery machines!

1.3 X-ray fluorescence based diamond recovery machines exploit the very fact that diamonds do emit light (fluoresce) at a specific energy spectrum (typically at 450nm) when excited by suitable X-ray radiation.

1.4 The amount of light emitted (magnitude of fluorescence) by a diamond depends on many factors such as:

1.4.1 Size of the Diamond

1.4.2 Impurities (Inclusions) in a Diamond

1.4.3 The Transparency-Index (Translucency-Index), of a Diamond at the colour spectrum of its fluorescence

1.4.4 Faults in the Diamond's crystal structure

1.4.5 Temperature of the Diamond

1.4.6 The "Type of Diamond" i.e. 'Type 2B' diamonds are for instance known to fluoresce far less then other types of diamonds

1.4.7 The exposure time of a Diamond to X-rays

1.4.8 The spectrum of the X-ray radiation used to excite a Diamond

1.4.9 The intensity of the X-ray radiation used to excite a Diamond

1.5 It is well known that many minerals other than diamonds also possess fluorescent properties when exposed to X-ray radiation.

1.6 Some of these minerals emit light of a similar energy spectrum to a diamond, but many of these minerals emit light of a different wavelength thus making it possible to distinguish them from diamonds by means of using a narrow band-pass filter that allows only the wavelength of a fluorescent diamond to pass.

1.7 The magnitude of fluorescence of such 'interference-minerals' is determined by much the same criteria as listed for diamonds above.

1.8 There are concentrates that are ideally suited to X-ray fluorescent-based diamond recovery machines, i.e. the material to be sorted contains only "well-fluorescent" diamonds and they contain no other fluorescent 'interference-minerals'!

1.9 But, on the other-end of the scale, the material to be sorted may contain "low-fluorescent" diamonds, as well as a high percentage of other fluorescent interference-minerals.
In the worst case, such 'interference-minerals' fluoresce at a similar wavelength as a diamond does, thus making optical filtering of little use!

1.10 However such extreme cases are seldom found in practice. In reality the characteristics of diamond-concentrates are found somewhere between these two extremes.

1.11 The properties of diamond concentrates however do often vary substantially, even if they originate from the same area.

1.12 To achieve a good and consistent diamond recovery with an X-ray fluorescence based sorter it is therefore important to recognize and understand the properties of diamond concentrates (and changes thereof). Only then is it possible to set up an X-ray diamond recovery machine for maximum performance.

1.13 An X-ray fluorescence based diamond recovery machine can be set up without the aid of a FPA. However, to optimise the set-up of a diamond recovery machine, requires experience and a solid understanding of X-ray fluorescence diamond recovery principles. The use of an FPA makes this task a lot easier and takes all the 'guesswork' away!

1.14 An operator often blames poor diamond recovery on a 'faulty sorting machine' or claims that diamonds that were not recovered by the X-ray sorter are not fluorescing. (The later being very rare indeed!)

1.15 A typical cause for poor diamond recovery is that the sorter generates too much yield. In this case an operator typically

reduces the sensitivity of the sorters optic system so that the machine does not eject 'too much' material. Otherwise there is too much material for hand sorting!

1.16 What the operator has achieved by lowering the sensitivity of the sorters optic system is a reduction in yield indeed. Many of the 'interference-minerals' are no longer being ejected to concentrate. However, at the same time, the sorter no longer recovers the weaker fluorescing diamonds either!

1.17 With the support of an FPA all this 'fiddling' and dangerous experimenting can be eliminated.

1.18 Fluorescent levels of Diamonds, as well as the fluorescence of other 'interference-minerals', that are present in a sorter's feed material can be measured.

1.19 An optimum X-ray sorter set-up can be established. (I.e.: filter or no filter?… optimum sensitivity …optimal size range … etc.). The expected yield and optimal feed rate can be calculated … and so on.

1.20 Actual fluorescent levels of particular diamonds can be accurately measured.

1.21 The effectiveness of optical filters can be established.

1.22 FLOW SORT'S FPA is also a very useful tool when it comes to measuring the fluorescent properties of tracers. The FPA can be used to sort tracers into various fluorescent intensity categories which in turn makes tracer tests much more meaningful.

1.23 The conclusion from the above is that for the professional, serious user of X-ray fluorescent-based diamond recovery machines a Fluorescent Particle Analyser is a very important and useful tool.

1.24 For a mine operating a single FLOW SORT machine it is difficult to justify the cost of an FPA (unless it is used for delicate exploration or sampling work). For mining houses that operate multiple FLOW SORT machines at different sites and

under changing conditions, an FPA is a must. FLOW SORT'S FPA is transportable and can therefore serve many different mining sites.

1.25 The FPA is the only way to quickly establish facts about various concentrates and so provide the necessary information that is needed to optimise the performance of FLOW SORT X-ray diamond recovery machines in the field.

1.26 Note that at the FLOW SORT factory in Sebenza, Johannesburg, South Africa there is an FPA available for analysis work of customer concentrates.

1.27 Further, take note that FLOW SORT'S FPA is also useful for on-site testing of Photo Multipliers as well as X-ray tubes. And further, FLOW SORT'S FPA utilizes essentially the same components as FLOW SORT'S X-ray diamond recovery machines. This fact should be taken into account when setting up sorter spares on site.

2. GENERAL DESCRIPTION OF FPA-1

2.1 The FLOW SORT Fluorescent Particle Analyser, FPA, is designed to allow quick and accurate X-Ray fluorescence analyses of individual or groups of particles.

2.2 The unit is specifically designed and set up to show the fluorescence level that can be expected from the same particle(s) when passed through a FLOW SORT X-ray Diamond Recovery Machines, (Such as Models XR 2/19 D/W, TSXR 2/19D/W etc.).

2.3 This is achieved by utilising the same basic components in the FLOW SORT FPA that are used in FLOW SORT X-ray diamond recovery machines such as model XR 2/19W, etc. Note that it is also possible to use FPA components as spare parts for FLOW SORT XR machines and vice versa.

2.4 The FPA'S main components are:
(SEE FIG1, FIG2 & FIG3)

2.4.1 X-Ray Tube (SEIFERT) FS Part # 3222

2.4.2 X-Ray Tube Adaptor FS Part# 3037

2.4.3 X-Ray HT-Cable FS Part# 3020

2.4.4 PM Tube (6097) FS Part # 2070

2.4.5 PM Tube Filter (K45) FS Part# 2220

2.4.6 PM Tube Power Supply FS Part # 2090

2.4.7 PM Tube Amp PC88 FS Part # 2100

2.4.8 SEIFERT X-Ray Generator Model ISOVOLT MF 1 FS Part # 3035

2.4.9 Sample Presentation Carousel (Unit)

2.4.10 Control Module with Interlocking Electronics

2.4.11 PICO SCOPE Analogue Signal Analysing Software and Hardware
(PICO SCOPE is a Registered Trade Mark)

2.4.12 Signal Display and storage LAPTOP PC

2.4.13 Stainless Steel FPA Stand and FPA X-RAY Enclosure

RADIATION PROTECTION INFORMATION

ANY FPA OPERATOR MUST FULLY UNDERSTAND AND FOLLOW ALL SAFETY ASPECTS APPLICABLE WHEN OPERATING X-RAY RADIATION EMITTING EQUIPMENT.

THE FPA OPERATOR MUST FURTHER UNDERSTAND AND FOLLOW ALL SAFETY ASPECTS APPLICABLE WHEN OPERATING HIGH VOLTAGE GENERATING EQUIPMENT.

ANY OPERATOR OF FLOW SORT'S FPA MUST READ AND OBEY THE RADIATION PROTECTION INSTRUCTIONS / INFORMATION CONTAINED IN THE FLOW SORT XR2/19DW DIAMOND RECOVERY MACHINE MANUAL AND IN THE SEIFERT ISOVOLT MF1 OPERATION MANUAL

ONLY FULLY TRAINED AND SUITABLY QUALIFIED PERSONNEL ARE ALLOWED TO OPERATE A FLOW SORT FPA.

NEVER TURN THE FPA'S X-RAY GENERATOR OFF BY MEANS OF ACTIVATING ANY SAFETY INTERLOCK SWITCH. ALWAYS USE THE CORRECT ON/OFF SWITCH PROVIDED.

3 THE BASIC OPERATION OF THE FPA:

3.1 Before Powering-Up the FPA

3.1.1 Ensure that all access panels of the FPA are in place.

3.1.2 Ensure that the X-ray compartment cover is closed and the SAFETY SCREW is fully screwed in.
(SEE FIG 6)

3.1.3 Ensure that both X-ray compartment cover PADLOCKS are securely in place.
(SEE FIG 6)

3.1.4 Connect the FPA to a water tap that can deliver 5 litres of potable water per minute at a min pressure of 400 kPa. The water temperature must not exceed 30 deg C.
(SEE FIG 6)

3.1.5 Ensure that the Mains Isolator Switch, located on the right side panel of the FPA, is in the OFF position.
(SEE FIG 6)

3.1.6 Ensure that the Emergency Stop (key-release) mushroom push button, located at the control panel of the FPA, is in its non-active (released) state.
(SEE FIG 4)

3.1.7 Ensure that the ON/OFF key-switch, located at the front panel of the FPA, is in its OFF position.
(SEE FIG 4)

3.1.8 Ensure that the EMERGENCY STOP button on the control panel of the ISOVOLT MF 1 X-ray generator is released (inactive).
(SEE FIG 5)

3.1.9 Ensure that the key-switch of the ISOVOLT MF 1 X-ray generator is in the OFF position.
(SEE FIG 5)

3.1.10 On first time use of the FPA or if no record of the previous set-up is available turn the 'OPTIC ADJUST" dial to "0" (zero).
(SEE FIG 4)

3.1.11 Ensure that 2 sample holder cups (with inserts) are placed into the sample presentation disk.
(SEE FIG 7, 8, & 9)

3.1.12 Connect the FPA to a 220 Volt (10 Amp) 50Hz power point.

3.1.13 Connect the Laptop power supply to the 'LAPTOP POWER' Outlet (located at the FPA control panel).
(SEE FIG 4)

3.1.14 Connect the printer-port of the Laptop Computer to the PICOSCOPE port of the FPA control panel.
(SEE FIG 4)

3.2 Putting the FPA into operation:

3.2.1 Turn the Mains Isolator Switch, located at the right side panel of the FPA, to "ON".
(SEE FIG 6)

3.2.1.1 The RED “POWER-OFF” indicator on the FPA control panel is illuminated.

3.2.2 Turn the ON/OFF key-switch at the FPA’S control panel ‘ON’.

3.2.2.1 The RED “POWER-OFF” LED on the FPA control panel is turned off.

3.2.2.2 The GREEN “POWER-ON” LED on the FPA control panel is illuminated.

3.2.2.3 The GREEN “X-R COVER” light is illuminated.

3.2.2.4 The GREEN “THERMO FUSE” LED is illuminated.

3.2.2.5 The GREEN “OPTIC ON” LED is illuminated.

3.2.2.6 The GREEN “EXTERN” interlock LED is illuminated. NOTE that for this condition the ‘external interlock loop must not be broken’!

3.2.2.7 The GREEN “X-R GEN ON” LED is illuminated.

3.2.2.8 The GREEN “X-R LAMPS” LED is illuminated.

3.2.2.9 Depending if the sample presentation disk is in a

locked position or not, is either the GREEN or RED "DISK LOCKED" indicator illuminated,

3.2.2.10 Depending if a sample holder cup is locked in position or not, either the GREEN or RED "CUP LOCKED" indicator is illuminated. NOTE that a sample presentation cup can only be locked after the sample presentation disk itself is locked.

3.2.3 Turn the key-switch at the ISOVOLT X-Ray generator to "STAND-BY".

3.2.3.1 The Display window of the ISOVOLT is illuminated. *(SEE FIG 5)*

3.2.3.2 The two AMBER "X-RAY ON" warning lights illuminate. NOTE THAT FROM THIS POINT THE FPA MUST BE SEEN AS GENERATING X-RAY RADIATION!

3.2.3.3 Depending on the X-ray shutter position either the left or the right half of EXPOSURE button will be illuminated.

3.2.4 Turn the key switch at the ISOVOLT X-Ray generator to "ON".

3.2.5 FOR SETTING-UP AND OPERATING THE ISOVOLT-MF1 X-Ray generator please refer to the Operation Manual for Industrial X-Ray Equipment ISOVOLT MF 1 60-4 issued by RICH. SEIFERT & CO.

3.2.6 In particular refer to SECTION 1 "RADIATION PROTECTION INFORMATION" of this manual!

3.2.7 The standard setting of the X-ray generator is 36 000 Volt (36 kV) and 0.004 Ampere (4 mA)

3.2.8 An AMBER X-RAY warning light, located at the ISOVOLT generator's control panel will flash when X-rays are generated. *(SEE FIG 5)*

3.2.9 An external AMBER X-RAY warning light, to be located in the area were the FPA is being used will flash when X-rays are generated!

3.3 Boot-Up the Laptop PC (this unit is linked to a PICOSCOPE Data Analyser of the FPA). The operator must have a sound knowledge of the MICROSOFT WINDOWS operating system as well as the PICOSCOPE application software. **Refer to the relevant manuals for detailed information!**

3.3.1 The PC will boot directly into the PICOSCOPE application.

3.3.2 The PICOSCOPE application will wake-up with the last stored set-up parameters.

3.3.3 The standard FLOW SORT factory set-up of the PICOSCOPE (stored by FLOW SORT during pre-delivery factory testing is: *(SEE FIG 10)*

3.3.3.1 Time Base = 100 ms/div

3.3.3.2 Time base magnification factor = 1x

3.3.3.3 TRIGGER MODE = ‘REPEAT’ or ‘AUTO’ with Auto trigger set to 30 000ms (see also Para 4.7.9)

3.3.3.4 TRIGGER SOURCE = CHANNEL A

3.3.3.5 TRIGGER DIRECTION = ‘FALLING’

3.3.3.6 TRIGGER LEVEL = -500 mV

3.3.3.7 TRIGGER DELAY = -20%

3.3.3.8 Channel A =‘5V’
Multiplication = x2
Left scrollbar = down to approx 20% (left Y-axis BLUE signal volt scale ranges from -4.5V to 0.5V)
Signal Voltage = “scale value x 1.

3.3.3.9 Channel B =‘2V’
Multiplication = x2
Right scrollbar = fully up (right Y-axis RED HT-Volt scale ranges from 0.0V to 2.0 V) PM tube EHT Voltage = “scale-value” x 1000.

3.4 Pull out the optical FILTER knob. (Situated on the right front corner of the FPA’S X-Ray compartment.

(SEE FIG 3)

3.5 SLOWLY turn the 'OPTIC ADJUST' knob until the "OPTIC" kV meter reads approx. 0.7 kV

3.5.1 For accurate work calibrate the FPA.

3.5.2 The simplest way of calibration is to place a FLOW SORT "CALIBRATION TRACER" into a sample presentation cup and then adjusting the 'OPTIC ADJUST' knob until a signal peak of 2.0 Volt is obtained when exposing the "CALIBRATION TRACER" to x-rays.

3.5.3 This setting now serves as a reference point for any other fluorescent particles (including diamonds).

3.5.4 Any particle producing a signal peak greater then 2.0 V will trigger the ejector gate of a FLOW SORT XR 2/19DW or XR15/35DW diamond recovery machine.

3.5.5 Any particle producing a signal peak less then 2.0 V will not trigger the ejector gate of a FLOW SORT XR 2/19DW or XR15/35DW diamond recovery machine.

3.6 The FPA is now ready for use

4 MEASURING THE FLUORESCENCE OF A PARTICLE

(SEE FIG 7, 8, & 9)

4.1 Push the 'LOCK SAMPLE' lever fully to the right.

4.2 Place the Particle to be analysed into sample holder cup (always use a sample holder cup insert that is appropriate for the particle size).

4.3 There is no limit to the minimum particle size that the FPA can handle (The optics sensitivity however limits the useful range at about 1mm). The maximum particle size is however restricted by the sample holder cup size. Without a cup-insert particles up to about 30 mm in diameter can be analysed.

4.3.1 WARNING: A PARTICLE PROTRUDING ABOVE THE TOP OF THE SAMPLE HOLDER CUP WILL DAMAGE THE FPA'S SAMPLE PRESENTATION SYSTEM!

4.4 Place the 'loaded' sample holder cup into position "A" or "B" of the sample presentation disk.

4.5 SLOWLY rotate the sample presentation disk in a CLOCKWISE direction until the second sample holder cup appears in front of the FPA (the two cups are 180 deg offset from one another).

4.5.1 A positive 'click' will be noticed when the presentation disk (cups) have reached the correct position.

4.5.2 The GREEN 'DISK LOCKED' LED will illuminate when the sample presentation disk is in the correct position

4.5.3 WARNING: ATTEMPTING TO TURN THE PRESENTATION DISK IN AN ANTI-CLOCKWISE DIRECTION WILL CAUSE DAMAGE TO THE SAMPLE PRESENTATION SYSTEM!

4.5.4 Slowly and without excessive force push the 'SAMPLE LOCK' lever fully to the left.

4.5.5 When the sample holder cup is securely (radiation leak proof and light tight) locked below the X-ray exposure shutter the GREEN 'CUP LOCKED' LED will illuminate.

4.5.6 If resistance is felt before the GREEN 'CUP LOCKED' LED is illuminated on the FPA'S control panel stop immediately and pull the lever fully back to the right. Repeat step 4.4, check for obstructions and try again!

4.5.7 WARNING: Attempting to push the 'LOCK SAMPLE' lever to the left without the GREEN 'DISK LOCKED' LED being illuminated WILL CAUSE DAMAGE to the in the FPA'S sample presentation system!

4.6 The FPA is now ready to measure the fluorescence of the particle in the locked-up sample holder cup.

4.6.1 Make sure that the PICOSCOPE displays a red "STOP" at the bottom left corner of the screen and next to it the current status reads "Running".*(SEE FIG 10)*

4.7 Press the 'EXPOSURE' button.

4.7.1 This will cause the bi-directional shutter to move to its opposite position. During the shutter movement the particle in the sample holder cup will be exposed to X-rays for

approx 300 milli seconds. For the same duration of time is the P.M. tube window is open so that the P.M. tube can register any light emission from the irradiated particle.

4.7.2 The magnitude of fluorescence of the particle (trace A in BLUE) as well as the operating voltage of the PM tube (trace B in RED) are displayed on the screen of the PC. Renewed pressing of the EXPOSURE button will, if the PICO SCOPE registers signal larger then the preset trigger level, over-write the 'old' trace with a new one.

4.7.3 NOTE: The PICO SCOPE screen will only be updated when the PM tube generates a signal larger in amplitude than the preset trigger-level of the PICO SCOPE!

4.7.4 NOTE: Step 4.7 can be repeated with the Optical Filter inserted or removed.

4.7.5 For DATA storage to disk and / or producing hard copies refer to the PICOSCOPE user manual and / or PICOSCOPE Help Menu.

4.7.6 HINT: If individual screen displays are to be printed or they should be protected from being overwritten by a new signal (a new screen) use the "SINGLE" TRIGGER mode rather then the "AUTO" TRIGGER mode.

4.7.7 HINT: The PICO SCOPE program can only be shut down, or parameters changed within this program, when the programs parallel port (LPT1) scanning loop has been interrupted, i.e. the scope status has changed from "Running" to "Stopped". The simplest

way of achieving this is by pressing the function button F10.

4.7.8 HINT: Another way of ending the PICO SCOPE'S parallel port (LPT1) scanning loop is by left-clicking the red STOP button, at the left bottom corner of the screen. (Note that there is no immediate response from the program at this point!) However as soon as a new signal triggers the PICO SCOPE, its status will automatically change to "Stopped". To return to the PICO SCOPE'S "Running" mode "left-click" the green "GO" button.

4.7.9 HINT: It is also possible to automatically 'self-trigger' the scope when set to AUTO TRIGGER mode, by pressing F4 i.e. entering the TRIGGER Setting option and ticking 'Auto trigger after'. The max time interval that can be entered is 30 000 milli sec. If set to this value the PICO SCOPE will automatically trigger every 30 seconds, regardless of any specified trigger conditions.

5 SHUTTING THE FPA DOWN

5.1 Turn the key switch of the ISOVOLT X-generator to the OFF position and remove the key. ALWAYS REMOVE THIS KEY AFTER USING THE FPA AND KEEP IT IN A SAFE PLACE!

5.2 Turn off the water supply to the FPA.

5.3 Close down all programs running on the Laptop PC and switch off the Laptop's power. REFER TO THE RELEVANT MANUALS.

5.4 Turn the key switch of the FPA (operating panel) to the OFF position and remove the key. ALWAYS REMOVE THIS KEY AFTER USING THE FPA AND KEEP IT IN A SAFE PLACE!

5.5 If the FPA is to remain shut down for any length of time it is recommended to disconnect the unit from the Mains Supply.

For understanding, interpretation and applying the information obtained from the FLOW SORT Fluorescent Particle Analyser please refer to FLOW SORT'S write up entitled: **PUTTING FPA DATA TO PRACTICAL USE**.

6 SAFETY AND OPERATIONAL INTERLOCKS

6.1 COOLING WATER INTERLOCK. The water flow switch in the x-ray tube cooling water circuit will shut down the x-ray generator if there is insufficient (below 4 l/min) cooling water flow.

6.2 MAGNETIC X-RAY COMPARTMENT INTERLOCK SWITCH. This safety switch will disconnect the power to the x-ray generator when activated.

6.3 X-RAY COMPARTMENT SAFETY LOCKING SCREW. It is not possible to open the access hatch of the FPA'S x-ray compartment without first removing this safety screw. Any attempt to remove this safety-screw activates a micro-switch which in turn will shut down x-ray generation via one of the "door-interlocks" of the x-ray generator.

6.4 SAMPLE PRESENTATION DISC POSITION INTERLOCK. A micro-switch will only allow the x-ray exposure shutter to be activated if the presentation disc is in its correct position.

6.5 SAMPLE PRESENTATION CUP POSITION INTERLOCK. A micro-switch will only allow the x-ray exposure shutter to be activated if a sample cup is present in its fully locked-up position.

6.6 SHUTTER END POSITION INTERLOCK. The x-ray shutter activates an end-position micro-switch when it reaches one of its two end positions (shutter fully closed positions). Any attempt to unlock a sample presentation cup without one of the two shutter end position switches being activated will shut down the x-ray generator.

6.7 X-RAY WARNING LAMP FAILURE. Should any of the 4 (four) x-ray warning lights fail to operate the x-ray generation will be stopped.

7 ALARM AND FAULT CONDITIONS

7.1 For alarm conditions and monitoring of operating parameters please refer to the operating manual of the SEIFERT x-ray generator operating manual.

7.2 For fault finding of the computer monitoring system please refer to instruction manual of the computer supplied with the FPA and the manual and help files of the PICO-SCOPE monitoring system supplied with the FPA.

7.3 For fault finding of the dedicated FPA electronics, electrical, and electro-mechanical components refer to the FLOW SORT diamond recovery machine technical manual. (All FPA components are covered in this manual)

8 TECHNICAL SPECIFICATIONS

8.1 For technical specifications of x-ray generator, x-ray tube, P.M.-tube, monitoring computer and software refer to the relevant component specifications supplied with our FPA.

8.2 For technical specifications of all FLOW SORT manufactured components refer to the relevant sections in the FLOW SORT diamond recovery machine technical manual.

8.3 For physical dimensions and weights please refer to the FPA general arrangement drawing FPA_GA_01.DWG.

9 DRAWINGS AND DIAGRAMS

9.1 General Arrangement Drawing FPA_GA_01.DWG.

9.2 PM tube pre-amplifier tube schematic PC88

9.3 Display and interlock PCB schematic PC82

9.4 SEIFERT'S Operating manual for ISOVOLT MF1 60-4

9.5 FLOW SORT'S XR 2/19DW diamond sorter manual.

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