MEASURING THE EFFECTIVENESS OF MAGNETIC DISK CLEANING AND CLEANING PROCESSES

BY

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ABSTRACT

Non-destructive in-process ultra violet exoelectronic measurements of production magnetic disk surfaces can be used to qualify cleaning equipment, evaluate new cleaning processes, and track production surface cleaning quality. This paper briefly describes the methodology used to implement a production oriented disk cleaning quality measuring system.

INTRODUCTION

The re-qualification of production magnetic disk cleaning equipment after routine maintenance is a major production concern for magnetic disk manufacturers. Effective surface cleaning of residual contamination is crucial in eliminating potential interference between the recording head and magnetic surface. Variables in cleaning equipment can be out-of-tolerance mechanical adjustments, worn components, or errors in operating parameters. Any of these can degrade many lots of disks before the error is identified through the analysis of declining finished product certification yield data. Data collected on controlled experiments with changing cleaning machine adjustments showed final disk certified yield variations of more than 30 percent. At the manufacturing cost level, a one percent final process yield change could equate to $1500 to $3000 per day.

Censtor Corporation of San Jose, California, desired to install cleaning equipment qualification procedures as part of an overall yield improvement program. One phase was to examine exoelectronic emission measurements as a means of detecting changes in residual contamination on thin film disk surfaces when processed through faulty production disk cleaning equipment.

EXOELECTRONIC EMISSION

Exoelectron emission is the spontaneous release of electrons and positive ions from a surface during some type of stimuli. Electrons and ions can be detected in a vacuum from some materials after bending, abrading, heating, or exposure to particular wavelengths of radiation.

When specific materials are irradiated in air with short wavelength ultra violet energy, the electrons can be collected across an air gap and measured. This type of exoelectronic behavior is called optically stimulated electron emission (OSEE or UVSEE). [1,2] The conditions which favor the occurrence of this emission depend upon the exposed composition and treatment of the material surface and the wavelength and intensity of the ultra violet radiation. This exoelectronic phenomena has been used for many years in spectrographic applications, and as of today, the source of the emission is still not entirely defined or understood.[3]

In general, the low work function (below 4 electron-volts) conductive class of materials emits significant quantities of electrons in the range of Pico-amperes, while insulating materials of higher work function emit very few electrons. If an electrometer detector/amplifier is connected to a positively biased collector placed near the UV irradiated surface, these emitted electrons can be attracted and amplified to provide an output voltage proportional to the surface electron/ion emission. This is the principle applied to a class of patented instruments manufactured by Photo Acoustic Technology of Westlake Village, California.[4]

The application of this equipment to contamination detection of the space shuttle rocket booster casings and to the measurement of magnetic disk lubrication thickness has been extensively reported and documented. [5,6]

In magnetic disk manufacturing, the substrate material and each particular disk treatment during the processing may have a unique UVSEE response range. Fig. 1 shows the relative voltage output of the Photo Acoustic OP1020 UVSEE system when measuring 2 suppliers of aluminum substrates, 2 alloys of polished base undercoatings, texturing process, magnetic film with carbon overcoat, and final lubricated disk surfaces. Generally speaking, mechanically abraded surfaces such as generated in a turning or texturing process produce higher levels of emission, while inorganic and organic coatings such as oxides, carbon, and lubricants inhibit emission.

Since most disk contamination of interest consists of very low emitting films on top of a higher emitting metallic material, a given surface area will emit less electrons when there is a non-conductive surface film present than when the surface is “clean”. There are, however, some plastics, epoxies and ink films (Sanford Major Marker Blue #2500 - 1985) which emit more electrons when irradiated than the conductive surface they cover. These are useful when applied as surface marker materials because their presence is easily detected by their higher emission compared to the base material.

ULTRA VIOLET STIMULATION LIMITATION

There is a serious repeatability problem with UVSEE when attempting to take successive emission measurements on a stationary surface. As a surface area is exposed to ultra violet energy, the quantity of electrons emitted per unit time continually decrease following a time dependent exponential decay. (Fig.2) Unlike classical electron circuit behavior, the electrons emitted from the irradiated surface of some materials (i.e. nickel-iron) behave as if they are never entirely replaced through the connected electrometer/bias supply circuitry. Neither long-term withdrawal of ultra violet exposure, or exposing the surface to thermal or electrical treatment seems to restore the surface emission to its initial rate.

In reported measurement applications using UVSEE equipment, the decay effect is minimized by exposing a given area to ultra violet radiation for very short durations. This is accomplished by increasing the relative velocity between the detector and the surface being measured. Unfortunately, although usable peak data can be collected at higher surface speeds (>150 inches/minute), the surface resolution is seriously degraded for small anomalies or abrupt reductions in surface emission. It was important for this disk application to view the detail surface behavior of circumferential scans on the disk surface. A major effort of the program involved finding an alternative solution to this decay effect so that very slow speed surface scans could be made.

The UVSEE measurement method is non-contact, non-destructive, clean room compatible, relatively inexpensive compared to other instruments, and uncomplicated. The apparatus for slow velocity surface investigations includes:

- Photo Acoustic Technology Mod. OP1020 Surface quality Analyzer with single-surface sensor, sensor mount, gas nozzle, gas transport tube, and 0.125 in. diameter aperture plate
- Servo speed regulated disk spin stand (0-50 RPM)
- Envelope integrator
- Digital control interval timer
- Six color pen X-Y plotter with internal offset voltage control; H.P. Model 7090
- Argon bottle gas supply, regulator, and flow meter
- PC XT type computer
- R.E.L. Statistical software

A standard UVSEE measurement is taken at a fixed 2 inch radius on one side of the disk during precisely one 30 second revolution (25 inches/minute). The Photo Acoustic OP1020 Quality Surface Analyzer has a full-scale output of 0-12.000 volts. At this slow scanning speed, the output voltage can change over a 4000 millivolt span during a single rotation. It was considered important to have a quantitative measure of this changing signal. This is done by integrating the varying output voltage during the 30 second rotation and computing an average output value. The instantaneous output voltage is converted to a 0-50 kilo-hertz frequency using a voltage to frequency converter. The output variable frequency is summed with a resetable electronic counter. The integrator has a resolution of 14.3 counts per millivolt per 30-second period and a stability of 0.05%. The accumulated counts for each measurement, divided by 30 seconds, results in the average counts for that circumferential surface area. These counts are converted to millivolts of emission using a scaling factor of 0.07 millivolts per count.

The use of Argon gas, introduced through a small nozzle attached to the UVSEE sensor and directed between the UV source/collector and the disk surface, controls the degree of decay. (Fig.3) The UVSEE signal can be made to remain constant on a stationary surface by adjusting the flow rate near 75 c.c. per minute (2.65 X10-3 scfm) and directing the flow relative to the sensor geometry. A beneficial by-product of using Argon is an increase of the detected electron surface signal (5 - 10%) without adding distortion to the same signal measured without Argon.

A 0.125 inch round orifice aperture plate is attached to the sensor between the UV source and disk surface. The purpose is to further improve the surface resolution by restricting the UV exposed area. The resultant reduced electron emission can be overcome by making a moderate increase in sensor gain. The measured data now represents emission from a much smaller surface area. With the highest resolution achieved, it was not sufficient to resolve isolated individual particulate contamination.

CLEANING MACHINE QUALIFICATION

A disk surface cleaning machine can be composed of several mechanical elements which move, rotate, scrub, rinse, and frequently dry the disk. The selection of optimum combinations of cleaning chemicals, operating temperatures, wash, and rinse cycle times is usually a process of identifying the most likely contamination, adopting vendor operating suggestions, and interpreting results of production experimental designs. The selected optimized equipment parameters are driven by the analysis of data taken from the final disk certification results. The efficiency of a cleaning step early in the process, therefore, can be masked by a combination of manufacturing operations and operator handling steps, which precede certification tests. Clear-cut, timely answers to cleaning efficiency questions are difficult and expensive to obtain from analyzing certifier results alone.

The UVSEE measurement gives additional information for cleaning optimization and control by providing quantitative data. The data gathering technique involves cleaning a known contaminated disk and directly measuring the effect of cleaning equipment process changes on removing the contamination. Additional benefit can be gained from long-term monitoring of samples of uncontaminated production passing through the cleaning process. By using classical statistical quality control methods on data from UVSEE measurements made routinely in the process cycle, deviations from expected cleaning results become very visible. (Fig.4)

The qualification of a cleaning machine after routine maintenance is a two-part task, evaluating a contaminated glass disk and evaluating a contaminated production disk. The glass disk provides the maintenance technician with the opportunity to observe and evaluate the mechanical aspects of the machine for the cleaning action on both sides of the disk. If a sample contaminant is selected which is typically found in the process and its use does not compromise the integrity of the machine/components for production cleaning, then actual cleaning action can be observed and more effective mechanical adjustments made. Such a contaminant is found in several commercial indelible and erasable ink markers. These markers also have the advantage of being positive UVSEE emitters and, therefore, small film residue on a cleaned glass disk is still detectable with UVSEE.

When the maintenance technician is satisfied the cleaning system is adjusted to the specification, he/she can further qualify the system by processing a production disk. The machine acceptance test requires the complete removal of a sample contaminant which a (qualified) production cleaner will always remove. A standard contaminant, consisting of 1 part silica polishing slurry to 1000 parts isopropyl alcohol by volume, is applied as a radial stripe 1/32 inch wide.

The first UVSEE test and plotted results confirm the circumferential location and magnitude of the manually applied contamination. After the disk is processed through the cleaning equipment, another UVSEE test is performed at the same starting index and radius as before. The resultant plot should show the removal of the contaminant (Fig.5). If any contaminant is found by the second UVSEE measurement, then more machine analysis, adjustment, and qualification testing is needed before the cleaner can be returned to production.

UVSEE CLEANING PROCESS CONTROL

Collected UVSEE data from surfaces of production lots can be informative in controlling the cleaning process. (Fig. 6) Lower output trends and "out of control" limit points are helpful in the proper maintenance and operation of the cleaning equipment. Because the test is non-destructive and performed in a clean environment, samples used for measurement can be processed to completion with minimal yield impact. The measurement history on a particular cleaning machine can also be used to predict the need for mechanical component replacement or other operating problems.

UVSEE CALIBRATION

It was a required goal of this program to establish the means for the operator to check the measurement system frequently. The following tests can be performed by an operator once each shift:

> The servo controlled spin-stand speed is timed and adjusted to take 30 seconds +/- 0.1 seconds per revolution with a mounted disk and clamp.
>
> The Photo Acoustic OP1020 controller has a switch selectable internal constant output voltage of 5003 millivolts. This fixed voltage signal is counted by the integrator for a 30-second interval controlled by the solid state Eagle timer. The resultant count is recorded and compared with historical data for consistency. System acceptance occurs when 5003 millivolts to the integrator results in 73,700 counts ± 150 counts in 30 seconds.
>
> Glass has near zero UVSEE emission, is rigid, and easily cleaned. An acid cleaned

glass 5¼ inch diameter disk was given a vacuum deposited gold coating of about 750 angstroms. The resultant UVSEE response is only related to the gold surface since no emission comes from the sub-surface. This stable base and conductive surface became a “standard” disk. The surface is measured each day and the results recorded and compared. (Fig. 7) The lower reading on April 12th was traced to an Argon nozzle placement problem at the sensor. Otherwise, standard #3 maintains an emission of 3650 ± 115 millivolts.

CONCLUSIONS

The application of UVSEE measurements to magnetic disk surfaces can improve the control of disk cleaning equipment. By comparing the cleaning action on a known contaminated disk with the disk after cleaning, a quantitative measure of improvement is available for analysis. A view of the plot of the before and after emission can confirm the presence or absence of the contamination. This same strategy is used to evaluate cleaning equipment, select and optimize equipment operating parameters, and measure on-going production cleaning processes. The measurement equipment is readily available and the operation can be performed by operators in a clean room.

ACKNOWLEDGMENTS

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References:

1. A.J.B. Robertson, Int. J. Electronics, vol. 51, pp. 607-619 (1981).
2. T. Smith, Photoelectron Emission from Aluminum and Nickel in Air, J. Appl. Physics, Vol. 46, No. 4, April 1975, pp 1553.
3. A.R. Krasnaya, L.N. Oster, Izvestiya Akad. Nauk. SSSR, vol. 49, pp. 1837 (1985).
4. United States Patent 4,590,376, May 20, 1986.
5. R.L. Gause, NASA Technical Memorandum, NASA TM-100361 (1989).
6. K.T. Mahmud, M.K. Chawla, Solid State Technology, Sept. 1989, pp. 135.

LIST OF FIGURES AND CAPTIONS

Figure 1: Surface electron emission from several disk materials and processes.
Figure 2: Electron emission decay from a stationary disk surface.
Figure 3: Electron emission decay modified by Argon gas flow.
Figure 4: Texture process control chart based on UVSEE measured lot data.
Figure 5: Plot of cleaner qualification by removal of contamination.
Figure 6: Box Plot quality control chart for in-process UVSEE measured lot data.
Figure 7: Periodic UVSEE emission measurements for Gold Standard Number 3.

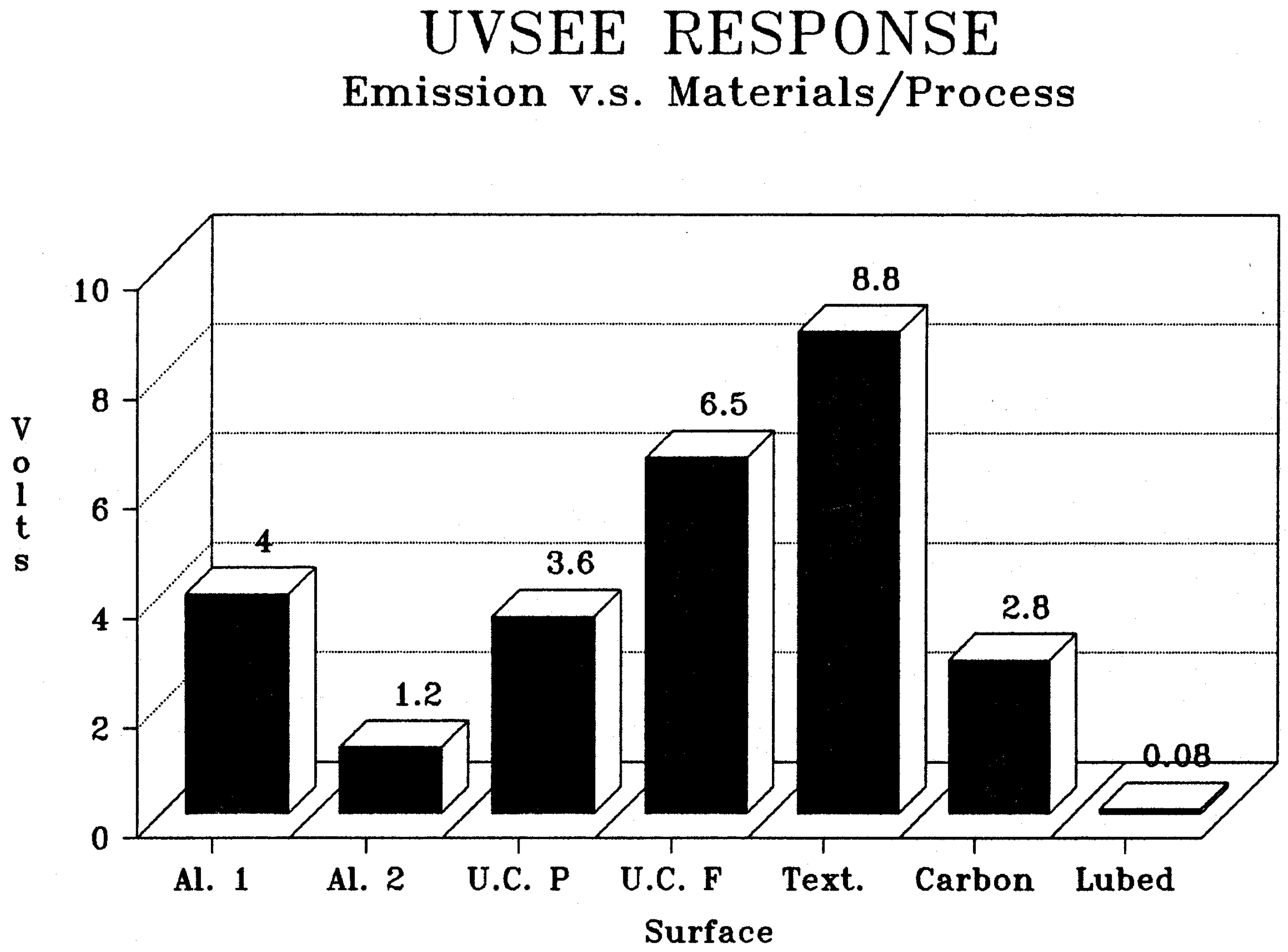
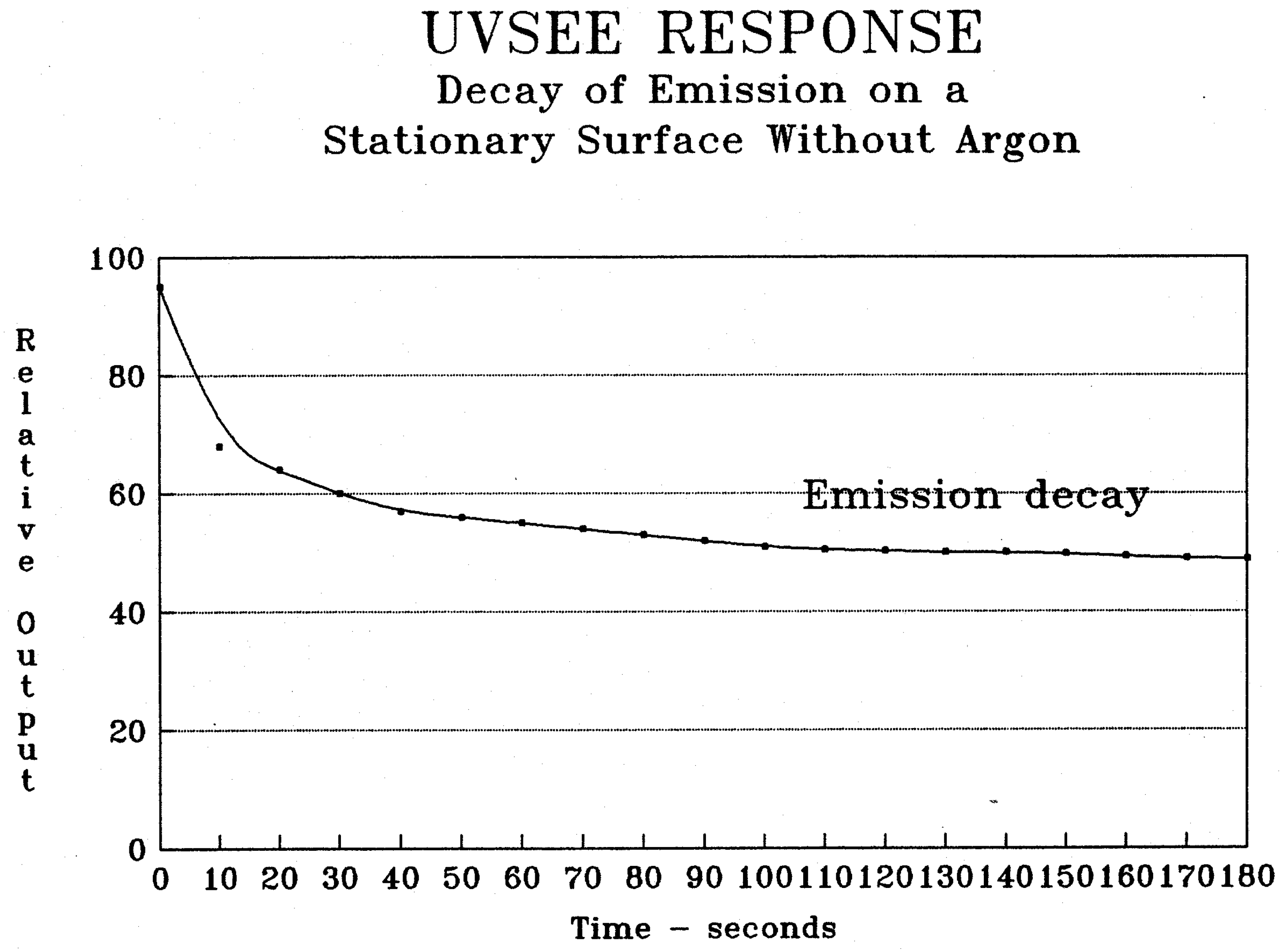


Figure 1
Gain=6
Flow Rate = 75 cc/min.



UVSEE RESPONSE
Decay of Emission on a
Stationary Surface Without Argon

Figure 2
Gain=6

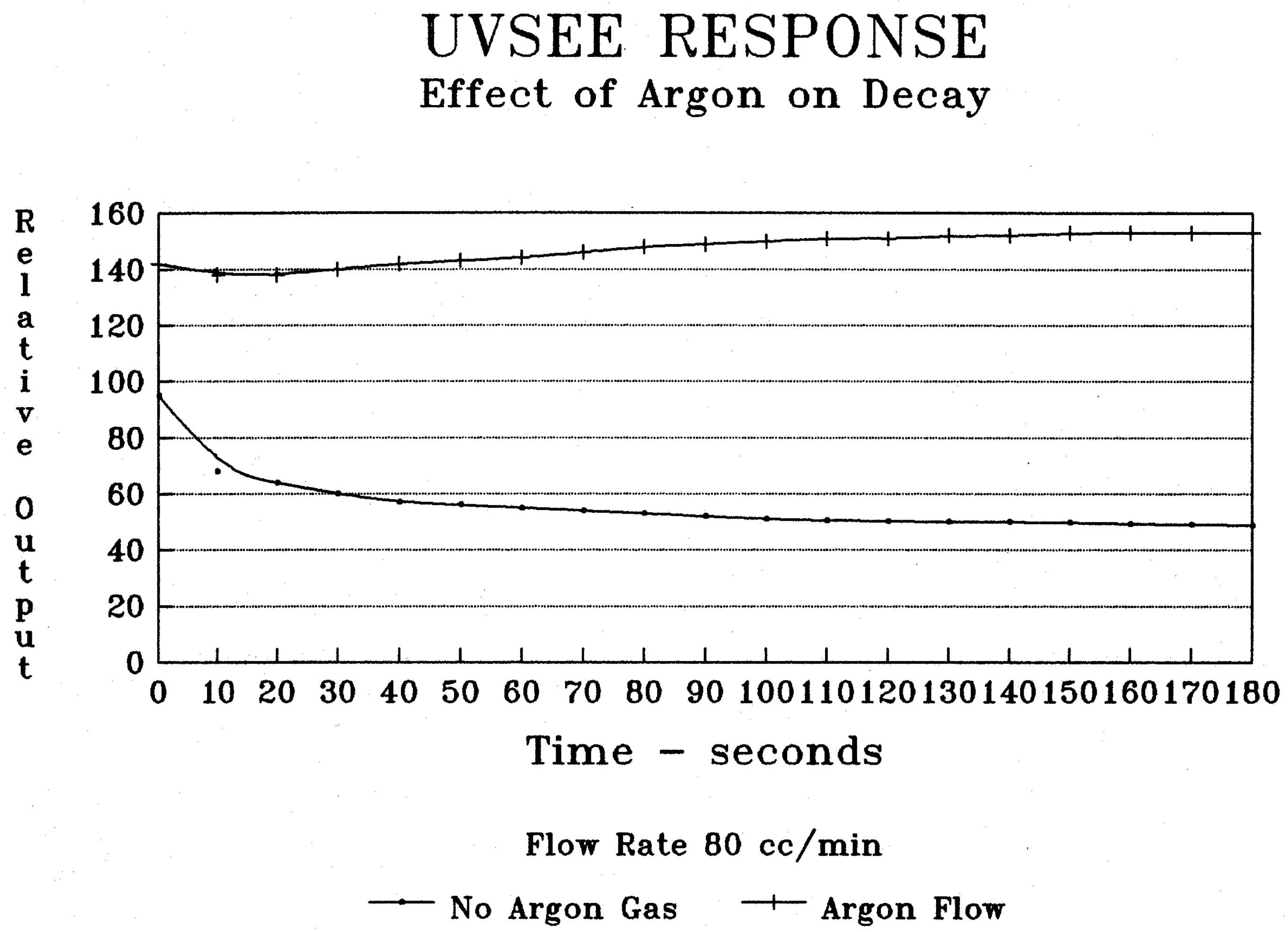


Figure 3
Gain=6

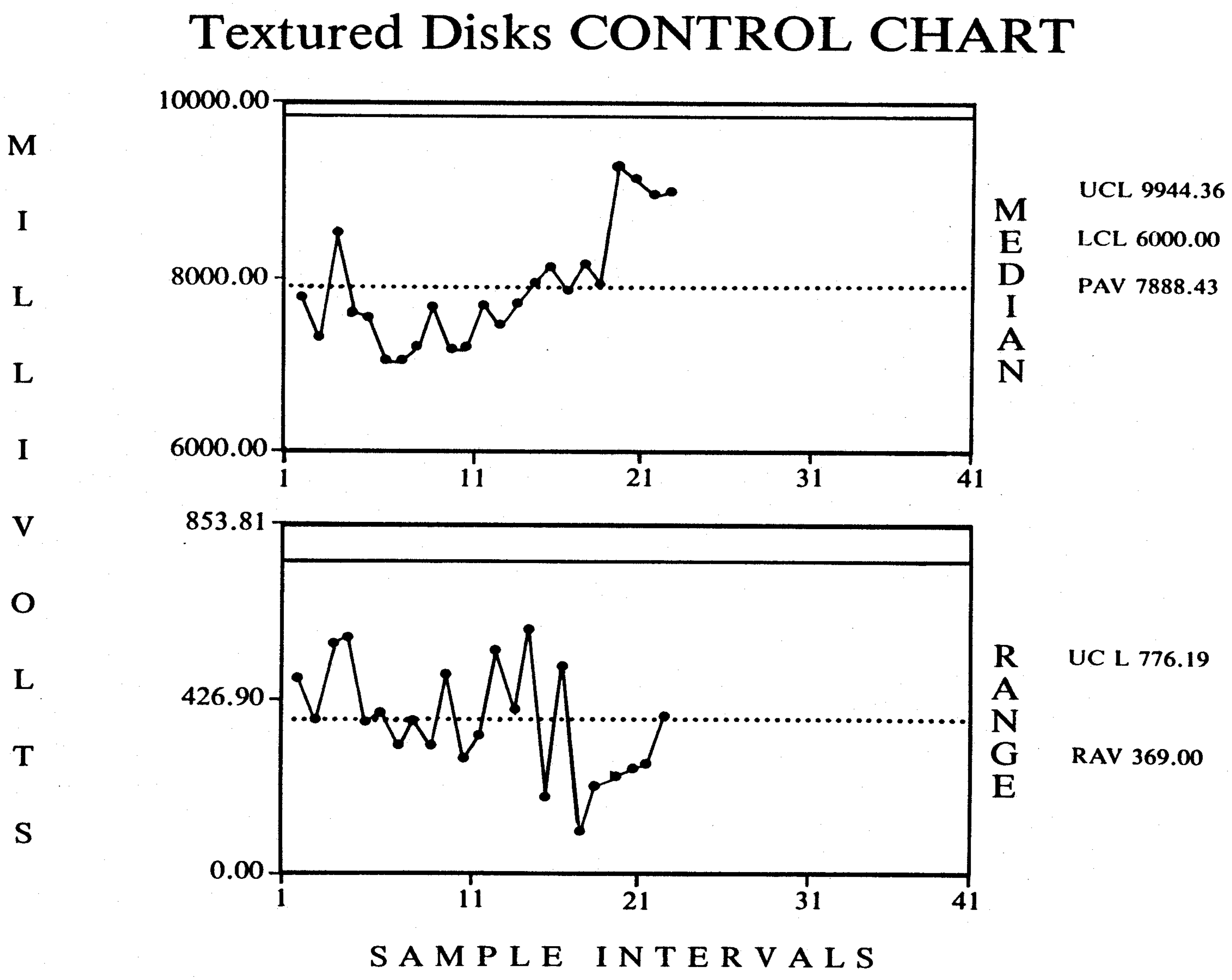

Textured Disks CONTROL CHART
M I L L I V O L T S
10000.00
8000.00
6000.00
1
11
21
31
41
M E D I A N
UCL 9944.36
LCL 6000.00
PAV 7888.43
853.81
426.90
0.00
1
11
21
31
41
R A N G E
UC L 776.19
RAV 369.00
SAMPLE INTERVALS

Figure 4.

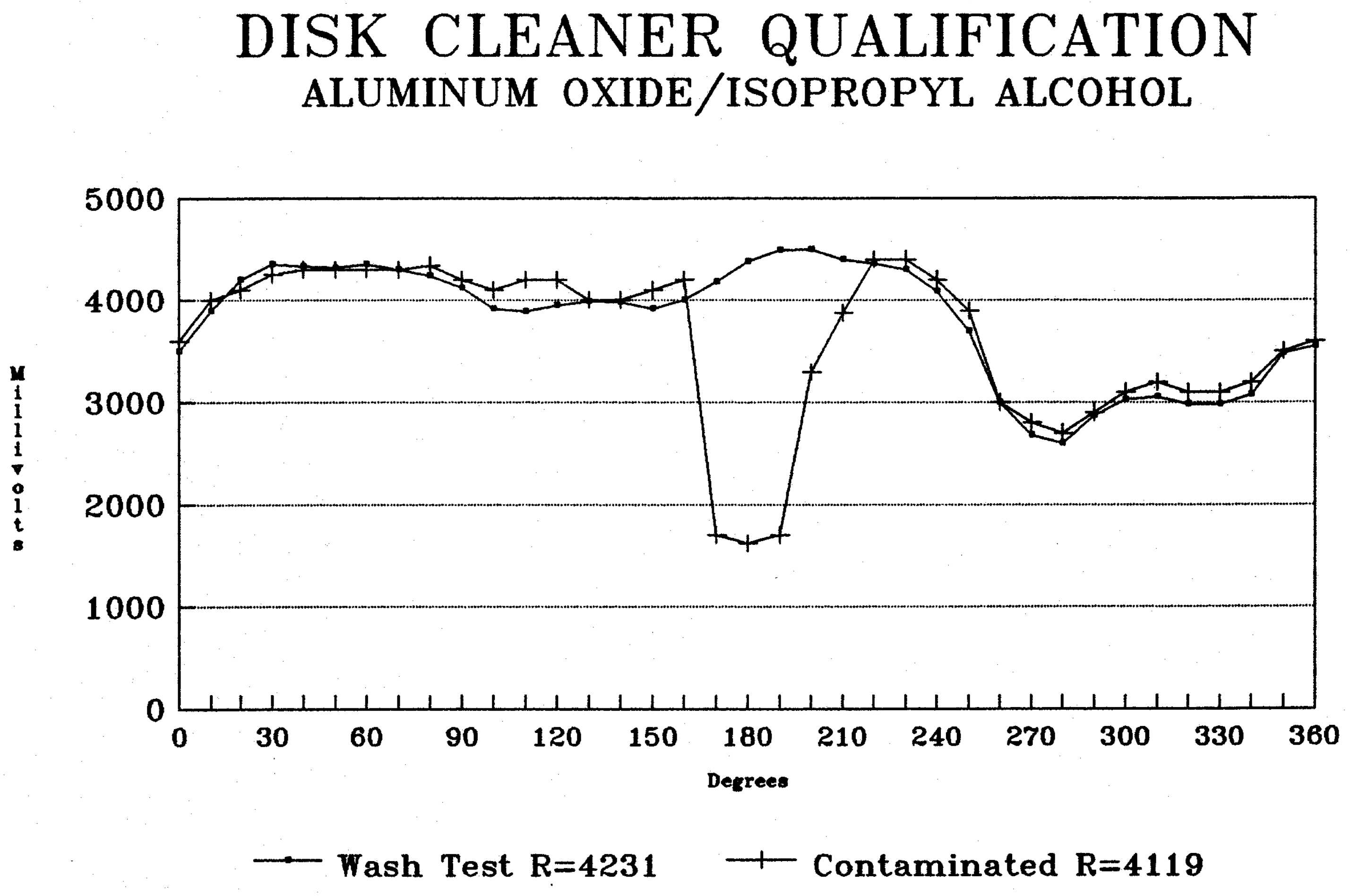
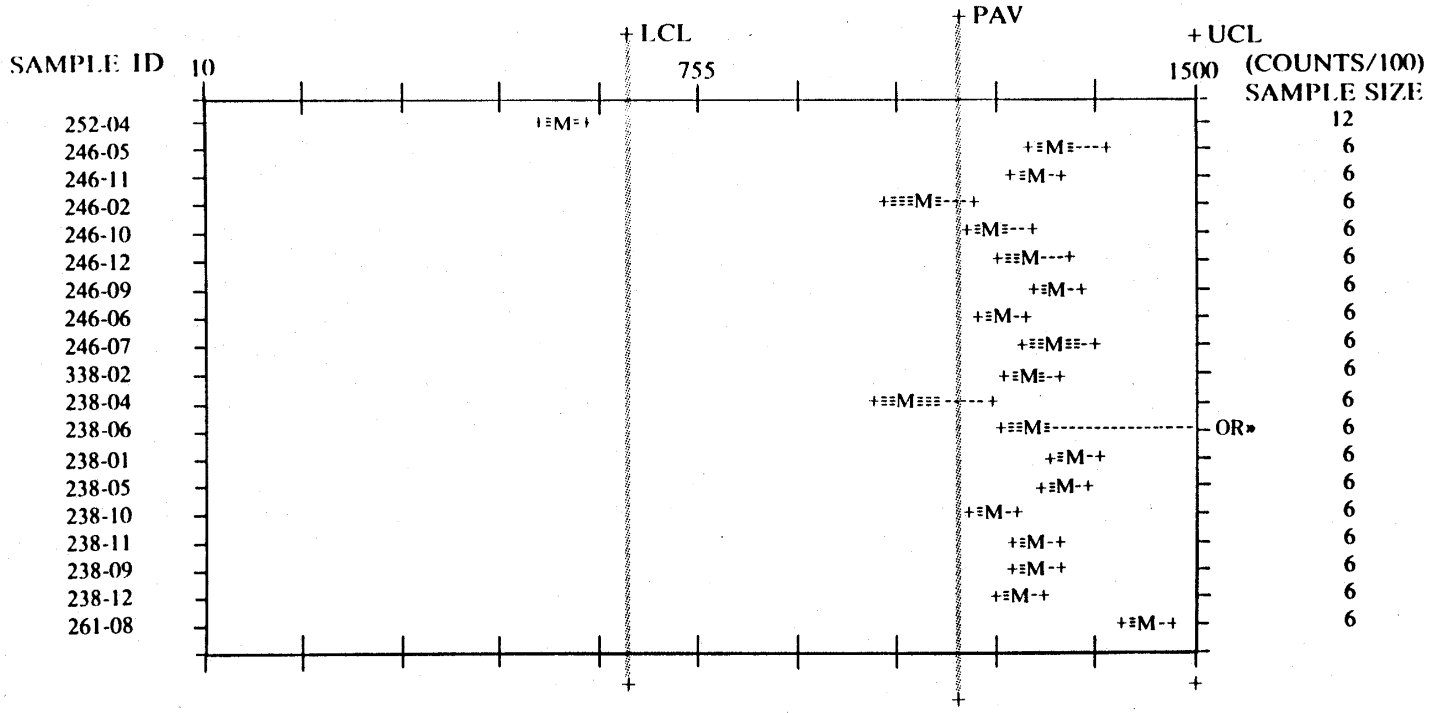


Figure 5
Gain=6
Flow=75 cc/min.

REL BOX PLOT CHART

UVSEE Data Control Chart (Polished Disks)

Date: 05-23-1990 Time: 10:30:13 Filename: (UVPOLISH)



Legend +--------------≡≡≡≡≡≡≡≡≡≡≡≡M≡≡≡≡≡≡≡≡≡≡≡≡--------------+ «OR»

Low Val Low Hinge Median High Hinge High Val. Extreme Value Out Of Range

Process Average = 1184.44
Std Dev of Pav. = 172.03

Upper Control Limit = 1500.00(+ 3 X Std Dev of Pav)
Lower Control Limit = 668.35(- 3 X Std Dev of Pav)

Figure 6

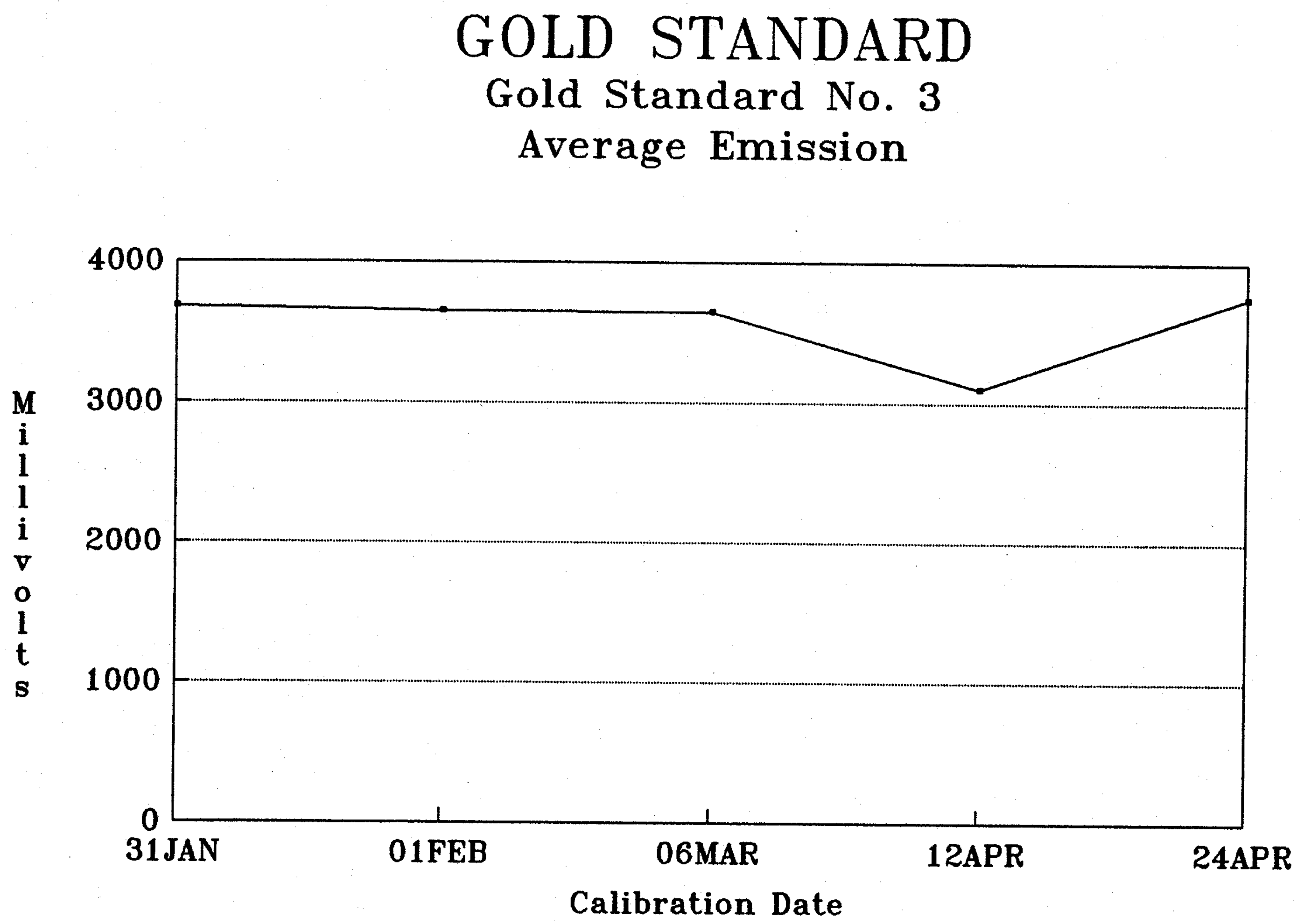


Figure 7
Flow= 75 cc/min.
Gain=6