CHAPTER 6

DESIGNED EXPERIMENT

6.1 Factor Selection

The number of particle on Base motor surface is use to indicate how cleanliness of Base motor is. Zero particle is the best cleanliness that we want to have, but actually the part in production line was assembled under contaminant environment. The contamination may come from cleanroom environment or manufacturing process. Therefore, we allow to use part with minimum particles as much as possible.

Cleaning process optimization The factors which affect cleaning efficiency are basically snow particle mass and size, particle density, and particle velocity. These factors are controlled more or less by the following conditions and discussed below:

- Mixing Nozzle Type
- Nozzle to Substrate Distance and Incidence Angle
- Propellant Temperature and Pressure
- Snow Particle Concentration

To study an appropriate CO_2 cleaner conditions, design and analysis of experiments are applied for factor selection. Factorial designs are used by considering for CO_2 cleaner implementation. The factors are influence for CO_2 cleaner implementation as follows:

6.1.1 Completed Dry Air Heater Temp.(C) (80 min - 120 max)

Completed Dry Air Heater Temperature is one of factor that we consider it probably influence to cleaning condition. We

- Propellant Supply

A regulated gas supply is required with an inlet pressure of between 70 PSI (minimum) and 150 PSI (preferred). The gas must be clean and dry, having a maximum of 10 PPM moisture vapor, 1 PPM oil vapor, and 5 micro maximum particulate matter. Since most plant air systems cannot supply air to these specs, either special dryers must be employed or bottled gas may be used. The propellant supply may be CDA, carbon dioxide, argon or nitrogen gas. In this CO_2 cleaner, we use Completed Dry Air (CDA) with dryers, Uttrafiltration package, and pressure regulators with safety pressure relief devices.

6.1.2 Pressure (PSI) setting (650 min - 950 max)

Snow Particle (Liquid CO_2) Supply An unregulated liquid CO_2 supply is required with a pressure of between 650 and 950 PSI and a temperature of between 50 and 75 F°. The supply must be clean and dry, having a maximum of 10 PPM moisture content, 1 PPM oil content, and 5 micron maximum particulate matter. These are purification systems to meet more stringent snow supply specifications. Bottles liquid

CO_2 equipped with siphon tubes may be used. No regulator should be used. A high pressure interconnection kit is required and is supplied with the system.

Spray Pressure Normally, for a given nozzle, the simplest method of changing cleaning speed or quality is to vary the gas pressure to the tank with the " Thrust Control" knob. The higher the pressure, the faster the object will be cleaned. The snow and the gas supply must be clean and dry. Moisture and other contaminants will adversely affect the quality of cleaning. If compressed air is to be used in precision cleaning application, it must be filtered using activated carbon, dried using a molecular sieve, and filtered using a microfilter (5 micron minimum).

6.1.3 CO_2 amount setting (0.1 min - 1 max)

Snow Particle Concentration The cleaning time and cleanliness are both related to the concentration of the active cleaning agent (snow) within the propellant and delivered to the surface of a substrate. Adjusting the micrometer value controls the concentration (and use rate) of cleaning agent (snow). As a general rule, experiment with the system and determine the minimum amount of snow concentration required to meet our specification; cleaning time and cleaning quality.

6.1.4 Distance of CO_2 nozzle (Inch) (0.5 min - 2 max)

The cleaning power will vary with distance and angle of the nozzle. The optimum cleaning action is obtained when the nozzle is approximately 0.5 – 2 inch from and at an angle to the surface.

- **Nozzle type** with larger snow to propellant ratios, although more particles are delivered, they generally have lower velocities, decreasing cleaning energy. As such, it is recommended that a mixing nozzle which can deliver the highest velocity spray be used for any given application. Generally small snow tube-large propellant tube ratios increase cleaning rate and efficiency.

As shipped from the factory, the PS6000 has a medium to high flow (TSA-CF-75-38) pencil applicator which contains a 75 lb/snow nozzle installed in a 3/8" pencil applicator with a convergent flow (high pressure) PROPELLANT nozzle. This combination will provide the most rapid cleaning for general cleaning applications. Additional PROPELLANT nozzles are available to reduce spray pressure and pattern for this applicator.

- **Spray Distance** As the nozzle is moved closer to the object, the rate with which contaminations will be removed increases, until it reaches a maximum when the spacing between the nozzle tip and the work is about 10 to 15 times the nozzle opening diameter. Moving the nozzle closer than this tends to start slowing the cleaning rate due to back pressure (pressure wall of expanding snow and gas) between the substrate and the tip and lower kinetic energy

- **Spray Angle** At a distance of perhaps 2 inchs from the surface, and as the nozzle is tipped at an angle that is incident to a surface, the cleaning action will generally improve. In most cases, it is far more effective to clean a surface with a nozzle positioned at an angle.

6.2 Experiments and Statistical Tools

In this thesis, there are 16 designed experiments consist of 16 trials for preliminary experiments. The purpose of this trial is to screen the significantly improvement factor. Then, selecting the significantly factor to confirm with 6 samples for determining appropriate conditions. The statistical tools of these experiments are described as follows,

6.2.1 Factor Screening Experiments

In the factor screening experiment, the 2^k factorial design for the four factor (k=4), each at two levels that are minimum and maximum level is employed to determine which factors affect the cleanliness of reworked part.

6.2.2 Preliminary Experiments

The method of 2^k factorial design for the four factors (k=4), each at two levels, is used to ensure the effect of Completed dry air heater temperature, Pressure (PSI) setting, CO_2 amount setting and Distance of CO_2 nozzle. Select at maximum and minimum of each factor for finding suitable conditions will be performed, so this experiment is called the preliminary experiment.

6.2.3 Experiments for Finding appropriate Conditions

In this experiment, the four –factors factorial design for 2 levels of Completed dry air heater temperature, Pressure (PSI) setting, CO_2 amount setting and Distance of CO_2 nozzle are employed to find suitable conditions in each level of the two factors.

6.2.4 Confirmation Experiment

The method of factorial designed analysis is applied to test the cleanliness of reused part. The difference of each factors: Completed dry air heater temperature, Pressure (PSI) setting, CO_2 amount setting and Distance of CO_2 nozzle. The material analysis is performed at Material Laboratory. The samples from our experiment were sent to Material Laboratory for Liquid Particle Count (LPC) measurement. Then we collect all data to conclude our experiment. The measurement result is depend on each condition of experiment.

6.3 Equipment and Measuring Equipment for experiments

6.3.1 Measurement Equipment

The reworked part cleanliness will be analyzed by Liquid Particle Count (LPC) in order to get the quantity of particle on Base Motor. The lower quantity means part cleanliness level is good. Liquid Particle Counter (LPC) : An instrument used for counting the amount of particles and identify the size of particles contained in liquid sample. The measurement result is quantitative data.

The HIAC/ROYCO Model 8000A counter is a digital 8 channel particle counter that provides processing, control, and flexibility for use in batch or on-line particulate contamination analysis. The counter and operator input/output are controlled independently by integral microprocessors that communicate with each other when required over an interconnecting bus structure.

The model 8000A provides external connections for the following:

- 3000A Liquid Syringe Sampler
- Serial I/O for computer interface
- HRLD-150 Sensor input
- Three environmental transducer inputs
- Sampler I/O

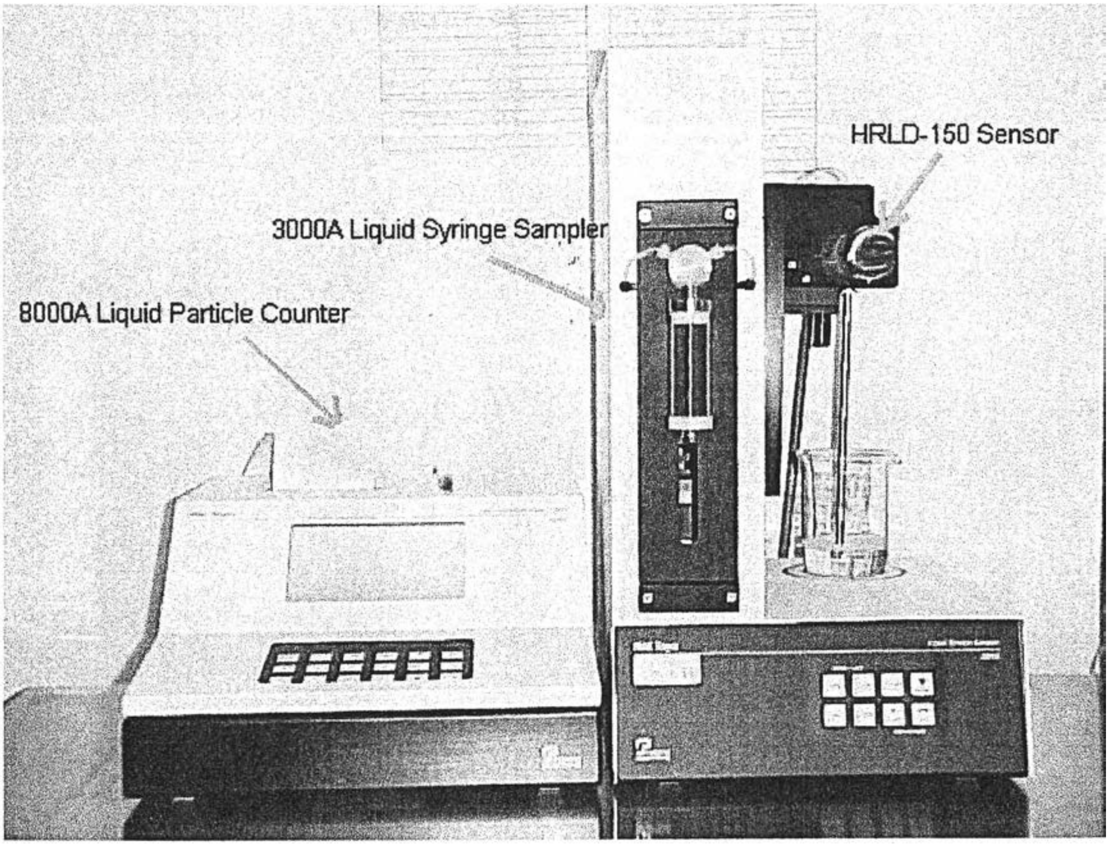

Figure 28 illustrated 8000A Particle counter and 3000A Liquid Syringe Sampler
Source : Operations Manual, HIAC/ROYCO division, Pacific Scientific

6.3.2 Measuring Design and Instruction

We use Fan Spray/LPC technique for cleanliness analysis of Base Spindle. The instruction of Fan Spray/LPC is described as below,

Fan Spray/LPC Preparation

The pressure vessel is filled with DI water + 0.004% Micro-90 detergent, the flow rate is calibrated to 65ml/min. The sample is extracted into a clean 1000ml beaker by the Spraying System Co. 250017 nozzle for two minutes, the extracted solution is then diluted with 70ml pure DI water to form a total volume of 200ml, follow by HIAC Royco LPC measurement.

Part Preparation

Leave all through holes open and Using EP330 to seal the following items

A) Tightening three screw holes for Top Clamp

B) Machining area of Rotor assembly

C) Tightening screw hole for Ramp

D) Tightening two screw holes for flex and 2 holes above those flex screw holes

E) Using leak seal to seal six tightening screw holes for top cover

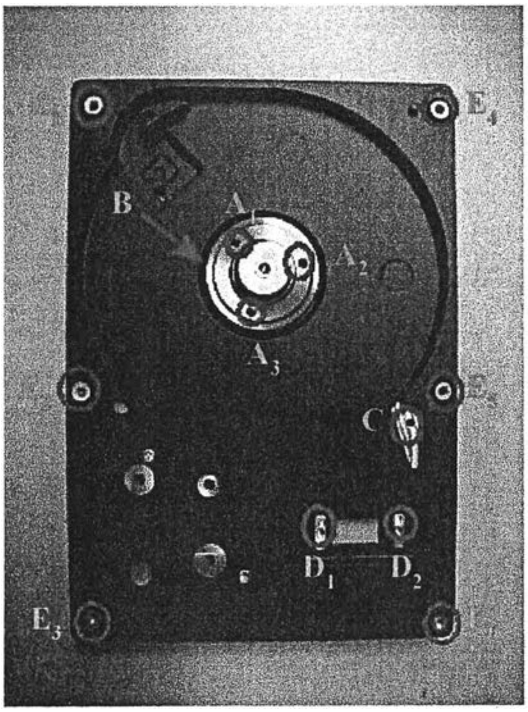

Figure 29 illustrated seal and screw fastening of Base Spindle preparation
Source :Material Laboratory, IBM Storage Products (Thailand) limited

Fan Spray Extraction Instruction

Spray Target / Location of Part	Spray time
i) Spray motor top side, including screw holes area	30sec
ii)Spray into machining area of rotor assembly	30sec
iii) Spray inner surface of base in up and down with zigzag motion, including motor top side and screws holes area	60sec

Table 6 illustrated Base Spindle Fan Spray Extraction Instruction
Source :Material Laboratory, IBM Storage Products (Thailand) limited, Fan Spray Extraction instruction & Proceudre from IBM Japan.

6.4 Procedure for Experiments

The following procedure are detailed of 16 designed experiments.

At Manufacturing

1. Check CO_2 cleaner ready for cleaning trial reworked part
2. Use CO_2 cleaner to clean reworked part (Base spindle) with quantity 16 samples and 6 samples for experiment result confirmation.
3. The samples must be packed into clean package condition before submitting to Material Laboratory for particle analysis.

At Material Laboratory

1. Preparing Fan Spray/LPC for part cleanliness analysis
2. Preparing part by screw hole sealing and fastening in order to protect some oil contamination may generate from screw holes and machine holes.
3. Do Fan spray on the position and defined spray time as previous instruction.
4. Report result of LPC for experiment result analysis.

6.5 Data Analysis

The data collected from the sixteen experiments are analyzed by statistical tool as below,

6.5.1 Factor Screening Experiments

The analysis of variance (ANOVA) technique is applied for factor screening experiment. It can be concluded the effect from sixteen experiments. The analysis of variance in main effect, interaction effect and residual are taken consideration after getting experiment result.

MINITAB's ANOVA capabilities include procedures for fitting and more complicated ANOVA models, a test of equal variance, and graphical procedures for viewing the data and understanding the fit of a model.

6.5.2 Estimating the Model Parameters

The parameters in the effects model for two-factor factorial

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \varepsilon_{ijk}$$

To examining a normal probability plot of the estimates of the effects. The effects that are negligible are normally distributed, with mean zero and variance σ^2 and will have nonzero means and will not lie along the straight line. Thus the preliminary model will be specified to contain those effects that are apparently nonzero, based on the normal probability plot. The apparently negligible effect are combined as an estimate of error.