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PROCESS MONITORING USING A QUALITY AND TECHNICAL SURVEILLANCE PROGRAM*

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Abstract

The purpose of process monitoring using a Quality and Technical Surveillance Program was to help ensure manufactured clad vent sets fully met technical and quality requirements established by the manufacturer and the customer, and that line and program management were immediately alerted if any aspect of the manufacturing activities drifted out of acceptable limits. The Quality and Technical Surveillance Program provided a planned, scheduled approach to monitor key processes and documentation and certification systems to prevent noncompliances or any manufacturing discrepancies. These surveillances illuminated potential problem areas early enough to permit timely corrective actions to reverse negative trends that, if left uncorrected, could have resulted in deficient hardware. Significant schedule and cost impacts were eliminated.

INTRODUCTION

Successful manufacturing of clad vent set (CVS) hardware used in the Radioisotope Thermoelectric Generator for conversion of thermal energy into electrical power is crucial for the success of deep space missions such as that of the Cassini spacecraft. This joint United States - European mission to Saturn and its moon, Titan, designed to provide insight into the origins and evolution of the solar system, will be launched in October 1997.

Martin Marietta Energy Systems, Inc. has been manufacturing CVSs for the Cassini mission at the Oak Ridge Y-12 Plant. Figure 1 is an expanded view of the iridium-alloy CVS, and shows the components used to encapsulate the plutonium fuel pellet. The various features referred to in this document are illustrated.

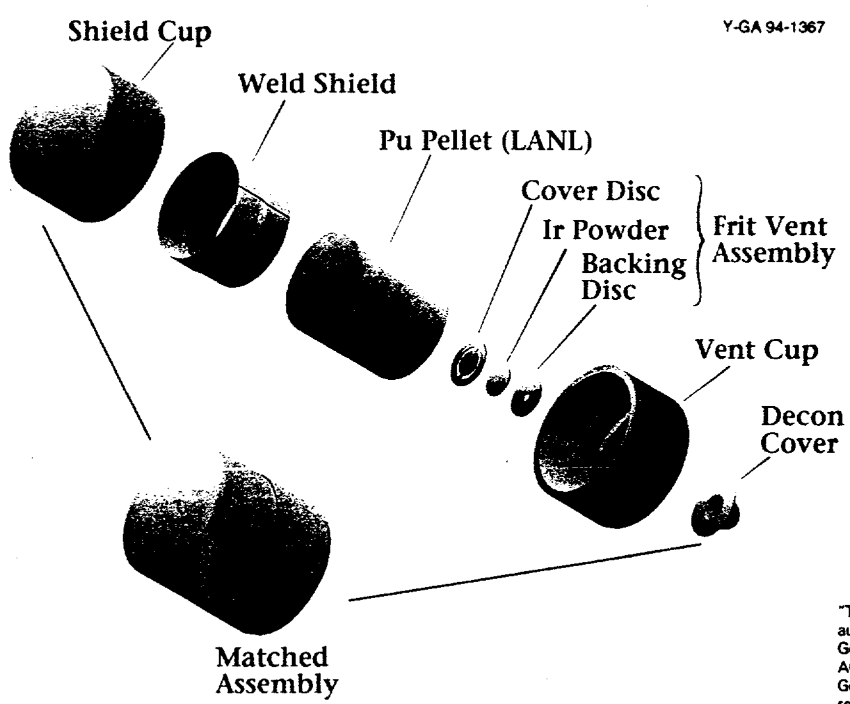

FIGURE 1. General Purpose Heat Source Clad Vent Set Hardware.

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To achieve manufacture of quality CVSs several techniques were required. In addition to following detailed procedures based on specifications, drawings and requirements, monitoring these processes was necessary to ensure the clad vent sets were manufactured to completely meet the technical and quality requirements established by the customer and the manufacturer. Line and program management needed to be alerted immediately if any aspect of the manufacturing activities drifted out of acceptable limits. Process monitoring using a Quality and Technical Surveillance program accomplished these functions.

METHODS

A Quality Assurance surveillance plan was developed and documented through Quality Engineering to periodically review hardware component manufacturing and certification activities. The plan defined the affected activities, a description of and responsibility for each surveillance, and scheduled date for performing each surveillance.

A Technical Surveillance plan was also developed and documented to provide rigorous and frequent review of all crucial process setups, performance and product evaluations. These surveillances were performed by personnel with technical expertise in the various processes, such as welding, heat treating, forming, machining, cleaning, and metallurgical properties.

RESULTS

An average of nine technical and two quality surveillances was conducted each month for the last 21 months of the Cassini program resulting in approximately 230 surveillances. Four quality discrepancies and twelve technical discrepancies were discovered. Types of corrective actions implemented varied with the root cause for each discrepancy. Table 1 presents examples of the types of discrepancies, root causes and corrective actions taken to prevent recurrence. Also included is an estimate of time saved through prevention of unnecessary part replacement.

An example of a discrepancy that was discovered and corrected was the increased frequency of decontamination (decon) cover rewelds. The process allows for up to two rewelds on each decon cover and still yields an acceptable assembly. More than two rewelds results in downgrading a flight unit to an Engineering Use unit. Therefore, minimizing rewelds is preferred. For several consecutive months the reweld rate was averaging less than ten percent. This rate more than doubled (23%) one month, and led the weld engineer to determine the cause. Investigation revealed that some of the decon covers were not setting completely flush with the vent cup surface during the welding operation. Some decon covers were being rejected in the welding area for lack of flatness and not setting flush. Welding personnel were made aware of the need for increased selectivity to assure flush fitting of the decon covers during the welding setup. The following month resulted in less than ten percent reweld frequency, and was attributed to the skill of the welder and greater attention to weld setup details.

DISCUSSION

Both Quality and Technical surveillance plans were achieved through close coordination of the technical expertise, Quality Assurance engineering, and program management. Subjects to be reviewed and the frequency of surveillances were determined by these disciplines based on in-process and end item requirements, and on the relative importance and impact any given process had on the product during each step of fabrication, assembly, and test. This information was then used to develop the Quality and the Technical Surveillance schedules, thus providing a clear outline of the items to be examined periodically (weekly or monthly) to help maintain process control.

These surveillance activities were performed in concert with, and made use of data collected from, re-inspection of product dimensions and quality trending information obtained using standard statistical process control methodology. Re-inspection evaluated the effectiveness of inspection operations, not manufacturing operations, using randomly selected, previously inspected parts submitted for re-inspection on a routine basis. Statistical process control is used extensively throughout industry to provide process monitoring, problem detection and process improvement to manufacturing operations.

TABLE 1. Examples of Discrepancies, Root Causes, and Corrective Actions.

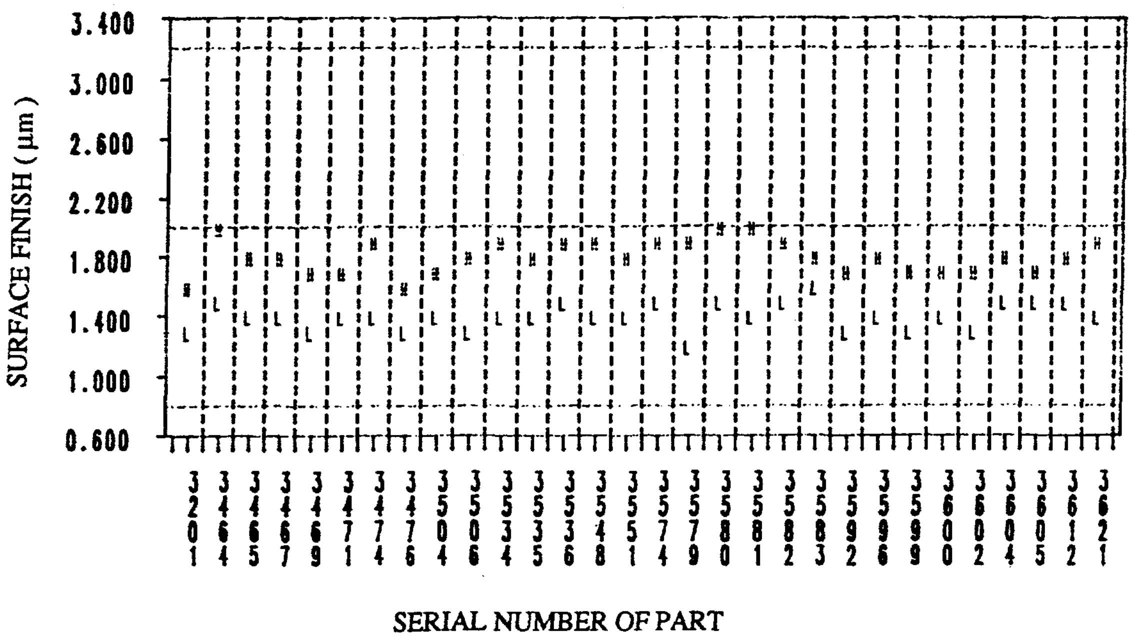
Type of Discrepancy	Quantity	Root Cause	Corrective Action	Replacement Time Saved per Unit (hrs) (If Required)
TECHNICAL				
Increased decon cover reweld frequency	1	Equipment/Material, Decon cover to Cup fit not flush.	Increased selectivity to assure flush fit of decon cover.	8.5/ decon cover
Electron beam welder arcing, requiring increased rewelds.	1	Equipment/Material, Welder upper column required cleaning.	Preventive Maintenance frequency increased.	8.5/ decon cover 54 /vent cup + frit
Heat treat witness specimen had Al, Ca and Si particles.	2	Procedure inadequate, Deburring tooling was depositing particles.	Procedure changed, specimen preparation changed, cleaned electrolytically with KCN.	16 each specimen
Average surface finish steadily decreasing for 5 months. (In specification)	1	Defective/failed tool, Profilometer measuring stylus (tip) worn.	Replaced tip and initiated control chart for the process.	31 / cup finish
QUALITY				
Iridium foil marking of identification (I.D.) incomplete.	1	Inadequate procedure, Foil marking requirements not clear.	Revised marking procedure to clarify I.D. requirements, and inspection documents to verify I.D. of foil.	1.5 foil marking • certification / shipment delay
Training records missing on one inspector from central training files.	1	Implementation of procedure change inadequate, Records lost during transition from area to central control.	Responsible area process engineer prepared duplicate training documents, and sent to central files.	• certification / shipment delay

All critical features (such as dimensions, finishes, marking, condition of frit iridium powder) of each subassembly and part were analyzed on a monthly basis. Charts were prepared which graphically illustrate measurement data used in monitoring various part features for in-process checks, process control, and analysis of certification requirements.

As a typical example, Figure 2 shows exterior surface finish data for shield cups that were tungsten carbide grit blasted. This process produces a specified range of surface roughness that provides particular heat transfer characteristics. These data were used to calculate process capability estimates by part feature, high and low repeatability, and estimated acceptance rate. These 30 cups were all measured during a one month time period. The high and low readings for each cup were plotted, and each cup serial number was displayed along the abscissa. Surface finish in micrometers (μm), or microns, was displayed along the ordinate.

The center horizontal dashed line represents the middle acceptable surface finish value of 2.0 μm. The upper horizontal dashed line at 3.2 μm, and the lower dashed line at 0.8 μm represent the upper and lower acceptance limits of surface finish. The range of surface finish data falls within the upper portion of the lower half of the acceptance limits, between 1.2 and 2.0 μm. The Average High (Low) is the arithmetic average value of all the high (low) readings. The Average Surface Finish is the arithmetic average value of all surface finish readings.

High (Low) Repeatability is represented by plus or minus half the difference between just the high (low) readings. Process Capability is the measured, inherent reproducibility of the product turned out by a process, and is represented by plus or minus half the difference of the full range of surface finish readings, highest to lowest, of all parts examined during the month. The Estimated Acceptance Rate is an estimate of the percentage of all parts produced by the process that would meet acceptance requirements based on the results of just the parts examined during the current month.



Number of Parts: 30
Average High = 1.8 micrometers (µm)
Average Low = 1.4 µm
Average Surface Finish = 1.6 µm
High Repeatability = +/- 0.3 µm
Low Repeatability = +/- 0.3 µm
Process Capability = +/- 0.5 µm
Estimated Acceptance Rate = 100 %

H = High Reading
L = Low Reading

FIGURE 2. Surface Finish in Grit Blasted Area of Shield Cups by Serial Number.

Results from the surveillance activities were documented and submitted to program management, the affected line management and to the Quality Assurance engineer. The responsible line organization developed and implemented a corrective action plan for deficiencies discovered during surveillances. Validation of the corrective action plan to potentially and reasonably correct the deficiency and preclude future recurrence was performed in accordance with quality documentation. After completion of the corrective action, validation was followed by documented verification from the Quality Engineer that all proposed corrective action steps had been completed satisfactorily. Program management presented the results and status of Quality and Technical surveillances to the Configuration Control Board. All surveillance results and documentation are quality records, and were filed and maintained in accordance with program requirements and company quality procedures based on applicable national standards including NQA-1 and DOE Order 5700.6C.

CONCLUSION

A conscientiously applied Quality Assurance and Technical Surveillance program, developed in conjunction with design, manufacturing, and process critical requirements, will help ensure that the product meets established quality and technical requirements in a timely and cost effective manner. These surveillances illuminated potential problem areas early enough in the production process to permit timely corrective actions that were used to reverse negative trends. This prevented deficient hardware from being manufactured.

Line and program management were immediately alerted when any aspect of the manufacturing activities drifted out of acceptable limits. Significant schedule and cost impacts were eliminated. On schedule delivery of hardware was possible in large part due to early detection and correction of conditions deleterious to compliance, thereby reducing loss of time, labor, and material required to recover from production of unacceptable hardware.

Acknowledgments

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