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PROFILE OF A CELL TEST DATABASE AND A CORRESPONDING RELIABILITY DATABASE

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Abstract

The development of computerized control, and data retrieval for aerospace cell testing affords an excellent opportunity to incorporate three specific concepts to both manage the test area and to track product performance on a real-time basis: [1.] DoD 5000.51-G: The adoption and incorporation of precepts fostered by this TQM initiative are critical to us for retaining control of our business while substantially reducing the separate QC inspection activity; [2.] CLASSIFICATION OF TEST DISCREPANCIES: Test Discrepancies are all "equally bad" in cell Acceptance Testing because, for example, we presently do not discriminate between 1mV or 25mV for an overvoltage condition. We must take leadership in classifying such discrepancies in order to expedite their clearance and redirect our resources for prevention activities.[3.] ENGINEERING ALERTS: The development and use of engineering alerts [or guardbanding] which more closely match our product capabilities and are toleranced tighter than the required Customer Specification are paramount to managing the Test Unit in order to remain both quality and cost effective.

Introduction to the current GAB Test Unit:

The GAB Test Unit is a 3,750 square foot facility located on the first floor of the GAB Aerospace complex. It is equipped with 550 ambient temperature test stations for NiCd Pre- Acceptance Testing and 330 environmentally controlled test stations for NiCd Acceptance Testing. There are an additional 192 test stations dedicated to NiH2 Cell Activation and Acceptance Testing; these stations are 100% computer controlled including active temperature control and pressure monitoring via strain gages. There are additional test positions utilized for electrode stress testing and for flooded electrode capacity testing. This Test Unit operates 24 hours a day, 7 days a week and is staffed by a crew of fifteen operators over three shifts. Each shift includes three Test Operators, one Lead Technician, and one Quality Inspector. The Test Unit is supported one a full time basis by an Electronic Technician, a Refrigeration Specialist, and an Equipment Development Engineer. Test capability spans a range of designs from 0.25 amp-hour to 150 amp-hour capacity over a temperature regime of -10 to + 35 C. Test capability also covers 40 different NiCd and NiH2 programs for commercial and military programs. The Test Unit is a dynamic, state-of-the-art facility which performs its own maintenance (tracked on a computerized database), develops their own test equipment, and is increasing their capability on a daily basis for computerized data retrieval, information handling, and test control.

Total Quality Management Guide DoD 5000.51-G

This TQM philosophy fosters continuous improvement by the real-time recognition of improvement opportunities through the use of data collection, various statistical or mathematical tools for the identification and analysis of variation, and thereafter providing guidance for reduction and elimination of this variance depending upon the nature of the common cause or special cause. Specific improvement opportunities addressed within the Test Unit include: a] reduction in test discrepancies; b] reduction in performance variation within a lot; and, c] reduction in lot-to-lot performance variation.

Reduction in Test Discrepancies

Over the past three years, the Test Unit has significantly reduced the number of test anomalies through the elimination and reduction of Special Causes. Chart No. 1 graphically displays how personnel in the Test Unit lowered the number of discrepancies by the applied analyses of Man, Method, Machine, Materials, and Environment in order to understand the role of each, and their associated interactions:

MAN: The Test Unit now employs skilled, trained and competent technicians. On each of the three shifts, there is a Lead Technician, three Test Technicians, and one dedicated QC Inspector. In addition, there is a full time maintenance technician and refrigeration specialist.

MACHINE: Numerous equipment additions include 1] Failsafe Devices for preventing cell reversal, for ensuring proper transitions of test procedure, audible warning devices; and, usage of data loggers; 2] charge/discharge status indicators; 3] refurbishment of existing equipment and adoption of customized environmental chambers; and, incorporation of computer control on 40% of the environmental chambers.

METHOD: We are constantly improving our method of operations by reviewing our training and by the validation of functional procedures, adoption of trend analyses, standardization of temperature control, and standardization of test instructions. One specific example is the Extended Pre-ATP wherein 32F and 86F performance tests are used to emulate the forthcoming acceptance test.

MATERIAL: Product as well as the accompanying data package undergoes a substantial review prior to transfer from the fabrication shop into the Test Unit. The concept of internal customers within Gates disallows the unilateral transfer of material internally and this concept will be formalized into a series of Delivery Review Boards throughout the entire fabrication and test process.

ENVIRONMENT: The physical environment in the Test Unit has expanded and substantially improved to maintain more stable temperature and humidity. This was accomplished by improvement and dedication of the air conditioning units, usage of more humidity monitoring devices, and a restructuring of the coolant control systems for the environmental chambers.

Reduction in Performance Variation

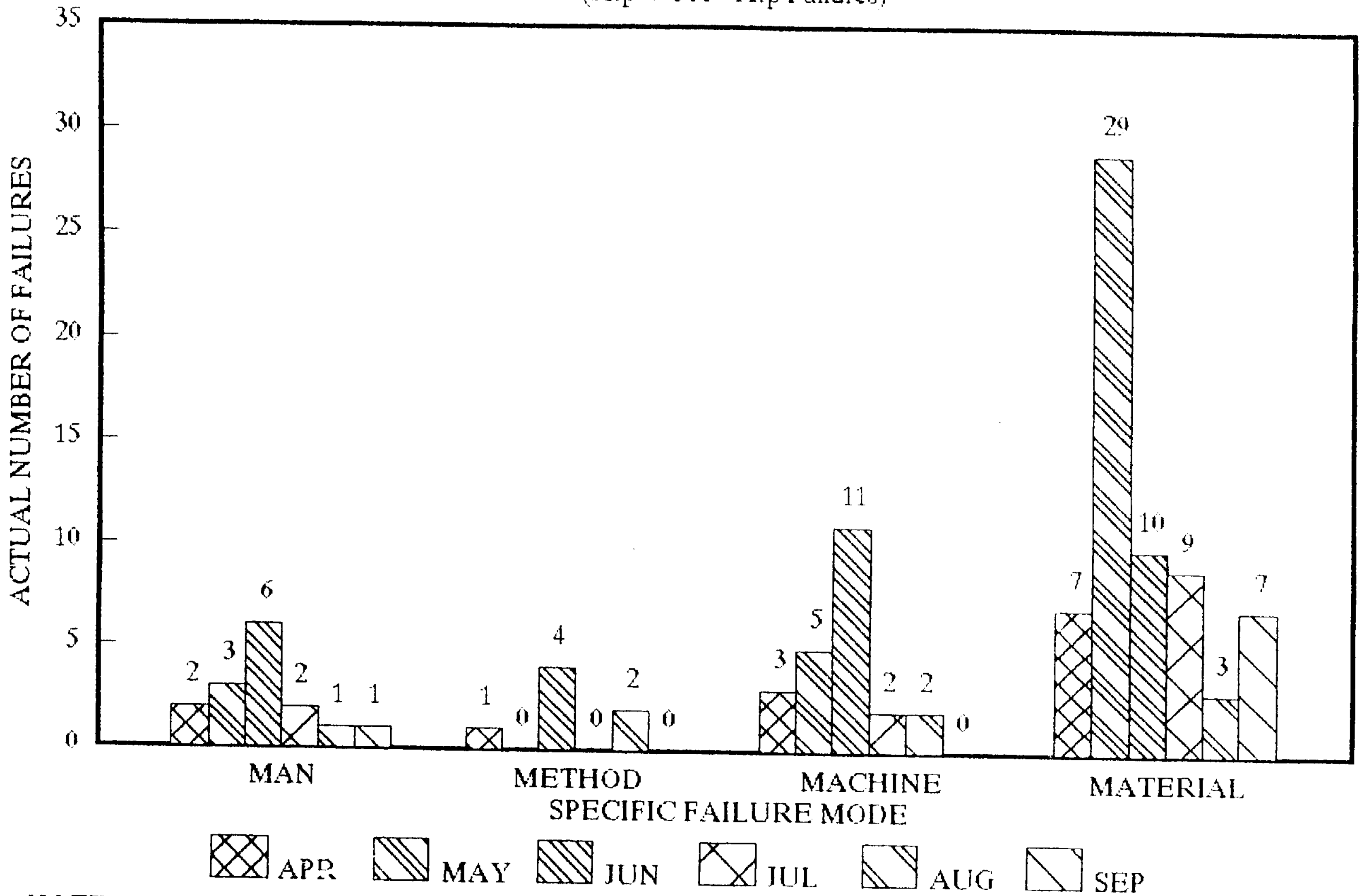
Further reduction of variation within the Test Unit is hampered somewhat by the currently imposed contractual obligations and restrictions. Whether we consider performance variation within a lot or consider lot-to-lot performance variation, two additional steps must be taken. These steps include the adoption of a classification scheme for test discrepancies, and the incorporation of internal performance guidelines. The present Failure Reporting and Corrective Action System (FRACAS) is both labor and time intensive. Presently our FRACAS is a conglomeration of inputs from MIL-STD-1520C (Corrective Action and Disposition System for Nonconforming Material) and 40 plus Program Offices. The MIL-STD states in part that a Minor Nonconformance does not adversely affect any of the following: [a] health or safety, [b] performance, [c] interchangeability, reliability, or maintainability, [d] effective use or operation, [e] weight or appearance. Most of the customer contracts parrot some or all of this specification; but, no where are definitive examples provided to guide the shop, test, or inspection personnel. To compound this issue, one customer specification spends 20 plus pages defining failures, power-on failures, discrepancies, nonconformances (Type 1 & 2), deviations (functional and performance), anomalies, and out-of-family conditions while still not providing for quantitative descriptions to be used at the shop level. By default, all Test Discrepancies in cell Acceptance Testing become Major Nonconformances and are "equally bad." For example, we presently do not discriminate between 1mV or 25mV for an overvoltage condition, nor do we discriminate between 1 amp-minute or 10 amp-hour for low capacity.

Classification of Test Discrepancies

The standardized definition , and classification of discrepancies occurring in cell Acceptance Testing is necessary for us to manage the Test Unit and to avoid the untimely delay of customer level material review for insignificant issues. As regards our example of low capacities of 1 amp-minute versus 1 amp-hour, both conditions are subject to a Gates Anomaly Report, an internal Material Review meeting, customer contact and approval to continue, and Customer Material Review. Table Nos. 1 & 2 contain standardized definitions which should be applied to discrepancies which occur within acceptance testing,and are endemic to starved NiCd cells and NiH2 cells.Thereafter, discrepancies are classified as to whether they are Critical, Major or Minor; and, then to whether the discrepancy is a Cell Response Discrepancy [such as pressure or capacity], or a Test Control Discrepancy [such as time or temperature]. By this classification scheme then, our example for discrimination of overvoltages shows 1mV to be a Minor Discrepancy versus the 25mV as a Critical Discrepancy. The use of this classification scheme must respect the Customer Specification, and the use of potential Engineering Alerts. There is provision for an automatic retest when any of the defined Minor Discrepancies occurs. Obviously these definitions and the retest provisions require customer approval; however, the presentation of these definitions at the NASA Battery Workshop is expected to expedite their acceptance. The adoption of these or similar standardized definitions will significantly improve the resolution of discrepancies when they do occur.

TEST FAILURES BY CATEGORY (1991)

(Atp + Pre – Atp Failures)



NOTE: INFORMATION TAKEN FROM GAR DATABASE
Created by: Richard Calloway

CHART 1

TABLE 1

Acceptance Testing: NiCd Discrepancy Definitions

	CELL RESPONSE DISCREPANCIES	TEST CONTROL DISCREPANCIES
CRITICAL	1. Overvoltages > 25mV 2. Pressures ≥ 80 PSIG	1. Cell Case Temperature excursion ≥ 10° C [and never above 30° C] 2. Cell reversal [< 0.000 volts] 3. Cell charged in reverse 4. Cells overcharged at > C/5 rate 5. Any hard or direct short
MAJOR	1. Overvoltages > 10mV but ≤ 25mV 2. Overpressures > 5 PSIA 3. Capacities ≥ 2.0% below specification 4. Cell Impedance over specification 5. Pulse Disc : minimum voltage not met	1. Cell Case Temp. excursion > 5° C but < 10° C 2. Resistor on cell during charge 3. Charge rate > 10% above specification 4. Discharge rate > 20% above specification 5. Delta pressures > 3 PSIG
MINOR	1. Overvoltages ≤ 10mV 2. Overpressures ≤ 5 PSIA 3. Capacities < 2.0% below specification 4. Capacity over "Max. Allowable" spec. 5. Capacity dispersion out-of-specification 6. EOCV Dispersion out-of-specification 7. Failure to meet 24 Hr minimum OCV 8. Excess residual pressure on Internal Self-Discharge	1. Cell Case Temperature excursion ≤ 5° C 2. Charge rate ≤ 10% above specification 3. Discharge rate ≤ 20% above specification 4. Insufficient shortdown voltage (EOSV) 5. Interrupted Burn-in cycle ≥ 30 minutes 6. Interrupted test sequence: < 30 minutes on charge cycle, < 10 minutes on discharge cycle 7. Improper Open-Circuit time 8. Incompleted/truncated test paragraph

NOTE: [1] Any Minor Discrepancy is subject to an automatic retest after customer notification; Minor Discrepancies are automatically advanced to a Major Discrepancy following a second failure to perform.
[2] All Major Discrepancies, whether a first time occurence or whether an upgraded occurrence from a Minor Discrepancy, will be subject to immediate Customer notification as described within relevant contract documentation.
[3] All Critical Discrepancies are subject to emergency Material Review Board.

TABLE 2

Acceptance Testing: NiH_2 Discrepancy Definitions

	CELL RESPONSE DISCREPANCIES	TEST CONTROL DISCREPANCIES
CRITICAL	1. Overvoltages > 25mV 2. Pressures ≥ 20% above MOP 3. Hydrogen leakage	1. Cell Case Temperature excursion ≥ 10° C [and never above 40° C] 2. Cell reversal [< 0.000 volts] 3. Cell charged in reverse 4. Cells overcharged at > C/5 rate 5. Any hard or direct short
MAJOR	1. Overvoltages > 10mV ≤ 25mV 2. Overpressures > 50 PSIA 3. Capacities ≥ 2.0% below specification 4. Cell Impedance over specification 5. Max. Allowable Strain Gage voltage is violated	1. Cell Case Temp. excursion > 5° C but < 10° C 2. Resistor on cell during charge 3. Charge rate > 10% above specification 4. Discharge rate > 20% above specification
MINOR	1. Overvoltages ≤ 10mV 2. Overpressures ≤ 50 PSIA 3. Capacities < 2.0% below specification 4. Capacity over "Max Allowable" spec. 5. Average Capacity out-of-specification 6. Capacity Range out-of-specification 7. EOCV Range out-of-specification	1. Cell Case Temperature excursion ≤ 5° C 2. Charge rate ≤ 10% above specification 3. Discharge rate ≤ 20% above specification 4. Insufficient shortdown voltage (EOSV) 5. Improper Open-Circuit time 6. Interrupted test sequence: < 30 minutes on charge cycle, < 10 minutes on discharge cycle 7. Improper Open-Circuit time 8. Incomplete/truncated test paragraph

NOTE: [1] Any Minor Discrepancy is subject to an automatic retest after customer notification; Minor Discrepancies are automatically advanced to a Major Discrepancy following a second failure to perform.
[2] All Major Discrepancies, whether a first time occurence or whether an upgraded occurrence from a Minor Discrepancy, will be subject to immediate Customer notification as described within relevant contract documentation.
[3] All Critical Discrepancies are subject to emergency Material Review Board.

TABLE 3

NiCd Pre-ATP Test Performance: Engineering Alerts (non-normalized)

TEST	DATA REQ'D.	PERFORMANCE STD
Set Neg. Pre-Chg.	time to first vent	normality of times & review of lot-to-lot data
	time to last vent	normality of times & review of lot-to-lot data
	O_2 weight loss	±0.5 amp-hour (O_2 equivalent) from lot average
Room Temp. O/C [after KOH adj.]	EOCP	range of 20 to 45 PSIG & delta P $\leq$ +3 PSI in last 8 hours
72° F Capacity	EOCP	range of 20 to 45 PSIG
	EOCV	±12mV from lot average
	Capacity	±3.0% from lot average
32° F Test	EOCP	range of 10 to 35 PSIG
	EOCV	±12 mV from lot average
	Capacity	±3.0% from lot average

TABLE 4

NiCd ATP Test Performance: Engineering Alerts (non-normalized)

TEST	DATA REQ'D.	PERFORMANCE STD
Each capacity test	EOCV dispersion	$\pm$12mV from lot average
	EOCP ranges	20-45 PSIG @ 75° F; 10-35 PSIG @ 32° F
	Capacity dispersion	$\pm$3.0% from lot average
Each overcharge test	EOCV dispersion	$\pm$12mV from lot average
	EOCP ranges	20-45 PSIG @ 75° F; 10-35 PSIG @ 32° F
	EOCP	delta P $\leq +3$ PSI in last 8 hours
	Capacity dispersion	$\pm$3.0% from lot average

More importantly, we will benefit by applying our resources to the prevention of Major and Critical discrepancies.

Engineering Alerts

This rededication or redirection of the Technical Staff to resolving and preventing Major and Critical Discrepancies allows the development and internal implementation of Engineering Alerts. Much like Upper and Lower Control Limits in classical Shewhart Analysis, the Engineering Alert [previously called Tollgates or Guardbanding] provides performance limits which more closely match our product capabilities and are toleranced tighter than the Customer Specification. This is the first step in identifying and reducing Common Causes and the accompanying variation, or performance dispersion. Tables 3 & 4 contain the Engineering Alerts to be applied to NiCd Pre-ATP and to NiCd ATP performance testing. These are non-normalized limitations for several reasons: [1] this removes one more crutch or excuse for non-performance; and, [2] software sub-routines for real time normalization of multiple data points appears counterproductive and very demanding of computer memory. Similar Engineering Alerts for NiH2 performance testings are being developed and will be implemented following successful implementation of those for the NiCd cell product line. Necessarily, the entire program is dependent upon the continued implementation of computerized control and data loggers.

Reduction of Lot-to-Lot Performance Variation

The full implementation of computerized control and data retrieval allows the development of databases that allow us to track and reduce performance variation in long term multi-year programs. By definition, this database becomes the baseline or embryo for the Reliability Database. Further development of this Reliability Database is dependent upon development of indexing schemes by cell configuration or by plate type since there exists little parity between plate design and cell design.

Conclusions and Recommendations

1. We have introduced you to the current Test Unit and shared the plans for improvement; we have discussed the Improvement Opportunities available through reduction of Test Discrepancies, and through the reduction of variation within a lot and variation from lot-to-lot.

2. Standardized definitions of test discrepancies for both product lines in Acceptance Testing have been proposed; implementation will begin on an individual program basis via customer approved Engineering Change Notices.

3. Engineering Alerts are proposed for internal usage and are already being implemented on the NiCd product line.