Practical and Effective Accelerated Techniques and Fixturing

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Accelerated Reliability Improvement

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Reliability Testing Paradigm Shift

Traditional Approach

- Test to design limits
- If it meets specifications its "good enough!"
- Combined environments rarely applied
- Testing requirements defined by the customer

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Paradigm Shift

- Engineers trained to mathematically model - Much more intellectual satisfaction - confidence in prediction.
- Mathematical models are good for design of electronics and mechanical or chemical wear out processes.
  - Limited for predicting most electronic failures.
  - Most electronic failures are by defect in design or manufacture, not wearout.
- Experimental Approach more "brute force"
  - Intellectual satisfaction is found in the investigation of root cause - component and physics of failure.

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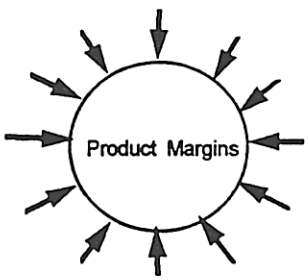
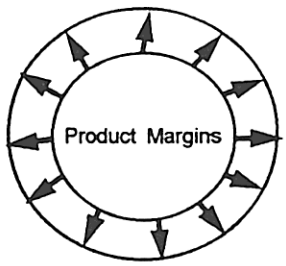
System Robustness



Design Specification



ALT, RET, Step Stress Testing

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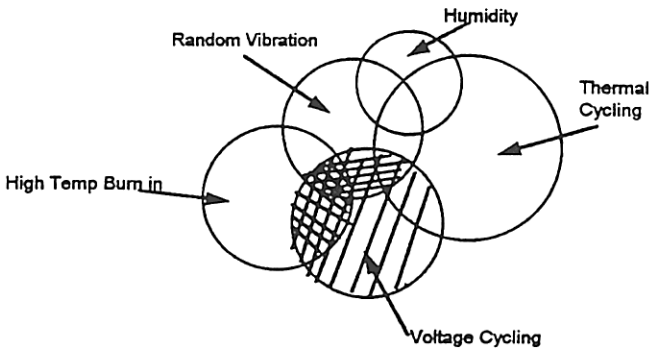
Flaw Precipitation - Stimulus



Most effective stimulus depends on failure mechanism

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Electronics Today

- Wear out mechanism for well designed, defect-free solid state electronics is well beyond its technological obsolescence.
- Low design margins and Special cause variation is the majority reason for field failures.

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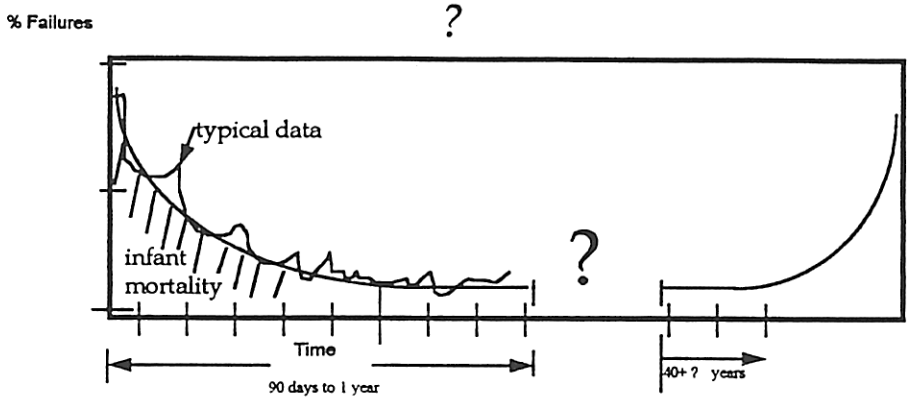
A Good Stress Screen

- Precipitates Design and Manufacturing Flaws Rapidly.
- Does not Use a Significant Portion of Fatigue Life.
- Is Based on the Products Capability at the Fundamental Limit of Technology (FLT).
- Is Not a Test Specification.

Paradigm Shift

- Stimulate not simulate.
- Determine actual operation limits.
- Apply simultaneous environmental stimuli.
- Stresses well beyond end use environment.
- Find weak lengths and fix them.
- Root cause analysis and closed loop corrective action.

Reliability Bathtub Curve - What is realistic ?



Change in Burn-in Techniques

- **Past -**
  - Accelerate chemical reactions, based on arrhenius equation.
- **Current and Future**
  - Earlier Design Margin Evaluation, eliminate design related defects.
  - Rapid temperature, combined vibration and thermal stimuli.
  - Search for discriminators, earlier prediction of out of control processes affecting reliability, quality.

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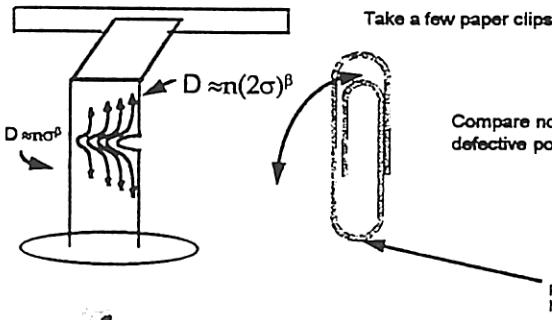
Miner's Criteria Demonstration
or
*Paper Clip Push-ups**

- Mechanical stress, σ, concentrates around a defect.

$$D \approx n\sigma^{\beta}$$



Take a few paper clips and make a small (very small) nick at end of outside loop

Compare non-defect population to defective population survival

put nick (defect) here

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*created by John Stahl, Ph.D., StorageTek.

Thermal Equipment

- Mechanical Refrigeration -
  - ✓ low transition rates on UUT
  - ✓ High maintenance
- Liquid - Inert Fluid - power, not monitored.
  - ✓ AT&T major user
  - ✓ More uniform thermal distribution
- LN2 - air change rates up to 135 C/min.
  - ✓ Higher thermal Stresses
  - ✓ Simple delivery system

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Vibration Equipment

- Electro Dynamic (ED) - large audio speaker
  - ✓ 20-2.0KHz
  - ✓ 3σ limited
- Repetitive Shock (RS) - Pneumatic
  - ✓ 200-2.5 KHz
- Servo Hydraulic (SH)
  - ✓ Large payloads - low frequency
  - ✓ 0-200 Hz
- Distributed Vibration - for large assemblies, structures

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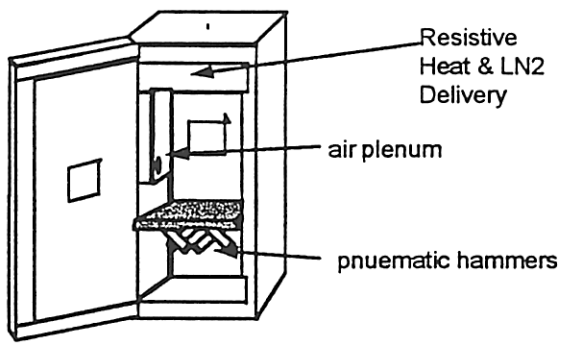
Combination RS + LN2



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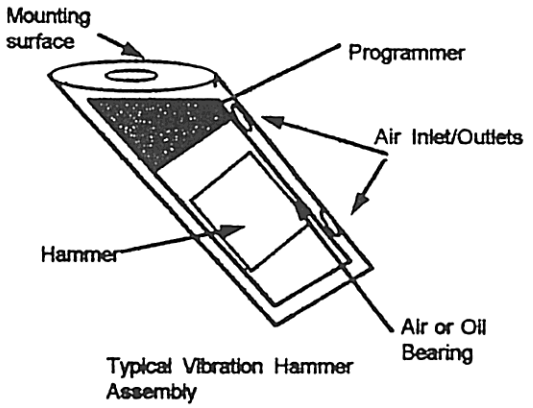
RS Machines

- RS machine stress loading per unit time is very high.
- Typical Hammer oscillation rates of 30 - 50 Hz.
- Programmer - table make fixed frequency spectrum.



Typical Vibration Hammer Assembly

From G. Henderson's "Dynamic Characteristics of Repetitive Shock Machines", 1993 IES Proceedings.

Highly Accelerated Life Test (HALT)

- Used in the design stage
  - Uncovers design problems before they become field failures
  - Establishes stimulus limits for HASS

Highly Accelerated Stress Screens (HASS)

- Used in manufacturing stage
  - Monitor manufacturing processes.
  - Ensures product reliability is not affected by variations in the manufacturing process.
  - Combined environmental stresses, short duration.

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Highly Accelerated Stress Audit (HASA)

- Used to monitor the products current and future quality.
- Statistical evaluation for shifts in margin that may affect reliability.
- For products with current acceptable quality level - HASS during development.
- Key for high volume manufacturing.

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From "Statistical Methods in ESS" by Isabel Rosenblitt, IES ESSEH Workshop notes, March 17-19, 1992, Vancouver, WA

Highly Accelerated Stress Audit (HASA)

- Sample size statistical evaluation - depends on many factors.
  - Size of shift in defect level you are trying to detect
  - Total production volumes
  - Confidence level
- Reduce risk by
  - Knowing Vendor capability
  - SPC on critical process parameter
  - Find good discriminators - measure and monitor
  - Educate, remember sample to field population scale

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From "Statistical Methods in ESS" by Isabel Rosenblitt, IES ESSEH Workshop notes, March 17-19, 1992, Vancouver, WA

Stresses Used in Advanced HALT

- High rate thermal cycling
- 6 axis vibration
- Humidity
- Electrical overstress
- Power cycling
- Other stresses as appropriate for the product
  - ✓ altitude, particulate, etc.

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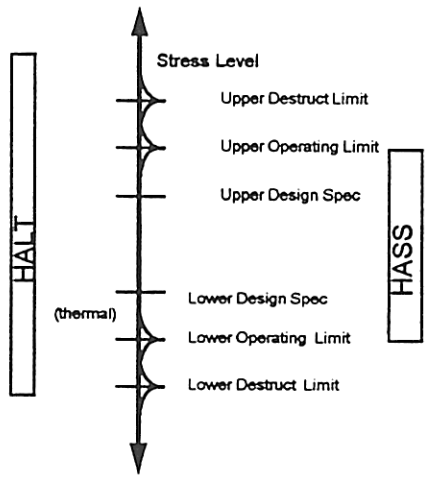
Stress Levels for HALT and HASS



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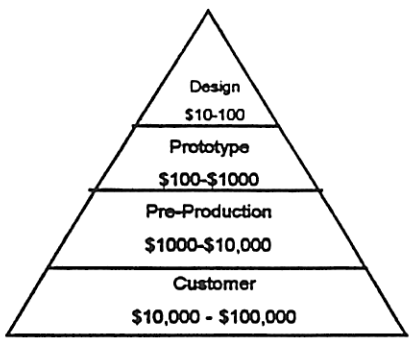
What Stage of Product Development Should HALT be Performed?

First prototype or pre-production units

- Very few temporary "fixes", loose Jumper wires, temporary socketed components.
- Somewhat representative of manufacturing line capability.
- Vibration can be useful before diagnostics can be run.



The Cost of Failures Pyramid

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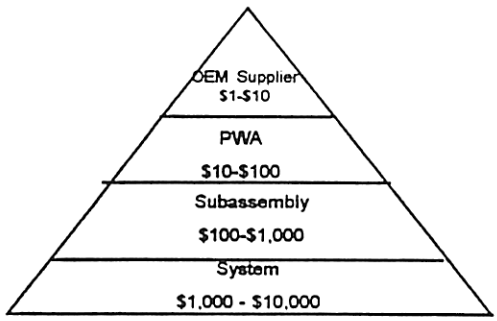
What Level of Assembly Should HALT be Applied ?

- Lowest functional level that problems are generally found.
  - Circuit cards that can remotely be functionally tested or have BIST.
  - Card Cages - Testing of Inter-functionality and variation.
  - Power Supplies.



The Cost of Repair Pyramid

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What Stage of Manufacturing Should HASS be Applied ?

Considerations for maximum test efficiency

- Complete systems evaluate large number of stack-up tolerances.
  - ✓ Simple geometry's make hold down and airflow less complex.
  - ✓ Larger numbers of units can be tested - higher production.
  - ✓ Better detection of operating margin shift.
  - ✓ Trade off - longer diagnostics, high mass.
- Systems may be limited to less effective screen if:
  - ✓ There are limits that cannot be strengthened - i.e. disk drive and vibration levels, tape and tape head temperature.
  - ✓ Limiting sub-system cannot be remotely operated - i.e. signal path timing problems.

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Thermal HALT

- **Product should be powered and monitored.**
  - ✓ Unpowered and monitored may be worse than no screen.
  - ✓ Will miss margin shifts that may impact field reliability.
- Steps of 10 °C, hold until system reaches equilibrium (~10 minutes).
- Analyze each failure to root cause. Determine whether cause is a latent defect, operating limit, or destruct limit.

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Vibration HALT

- Steps of 3 gRMS.
- Hold approximately 10 minutes.
- Continue steps to operational failure or chamber limits.
- Analyze each failure to determine whether latent defect, operating limit, or destruct limit.

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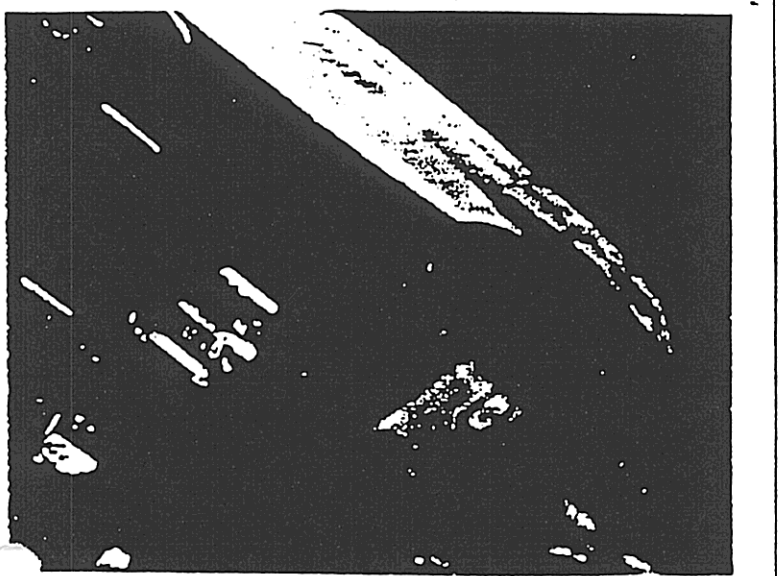
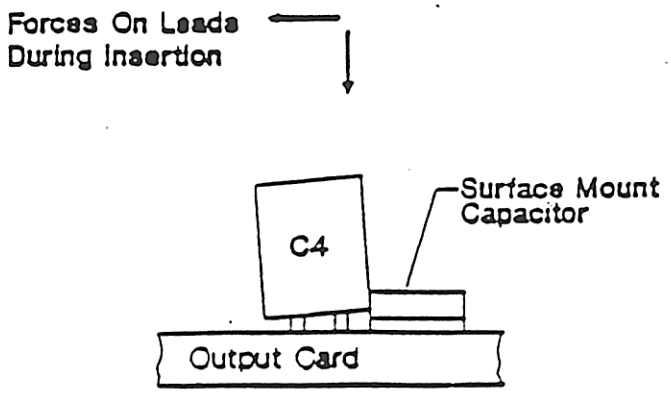
(14) Low Pass Filter Bent Over to Accomodate Pots on Driver Card:
Bent leads can cause internal damage to component. If bending is absolutely necessary, it should be done in a fixture designed to relieve strain to internal component assembly prior to assembly/soldering to P.C. card.

(15) C4 Capacitor on "Output" Board Failures:
Capacitor is loaded both axially and radially (see Illustration and photo below) during insertion, causing internal cracks between leads and plates. This two plane loading is due to the close proximity of a surface mount capacitor that interferes with proper capacitor assembly to card.
Capacitor "opens" at elevated temperature (Approx. 70 C ambient per StorageTek F. A.) and during vibration screening.

StorageTek Component Engineering has been requested to research alternative capicitor packages to correct this problem. Will advise of progress.





Keys to Successful HALT

- Having a HALT Champion is key to holding the paradigm shift perspective.
  - ✓ Some will never see the paradigm shift
- Address all failure modes
  - ✓ Almost all failures are relevant to the field reliability - remember there is a distribution and the tails will extend into the operating range for very small operating shifts.
  - ✓ Remember lessons learned - Distribute information to designers

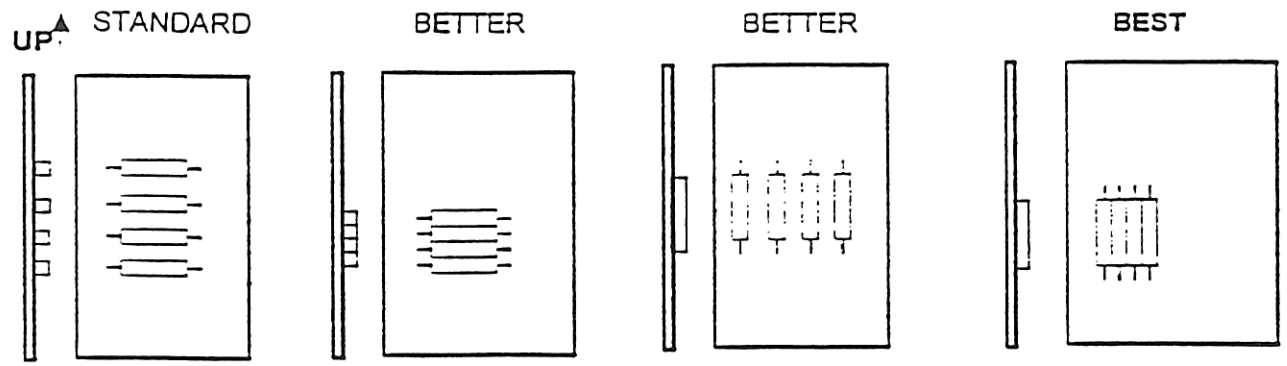
Successful HALT

- Ask the five why's - Leader must drive to root cause.

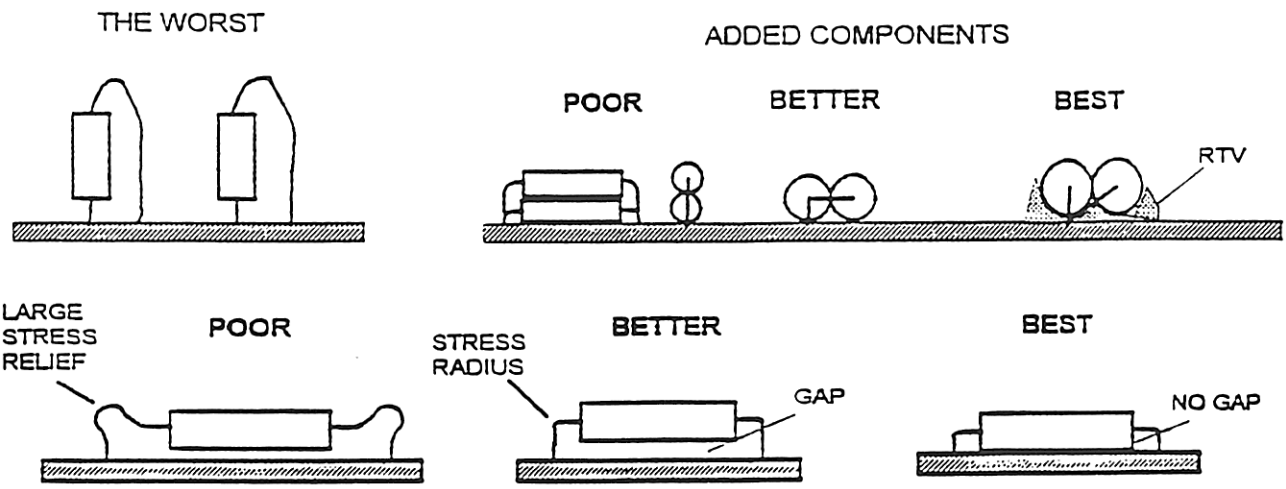
Engineer	Manager
The 8510 failed	Why?
Bad microprocessor board.	Why?
EPROM Died	Why?
Electromigration on buried metalization layer.	Why?
Violation of current densisty rule	Why?
Chip designer didn't catch the violation	Why?

From "Achieving Phenomenal Reliability Growth" by Clifton J. Seusy, Hewlett Packard Company

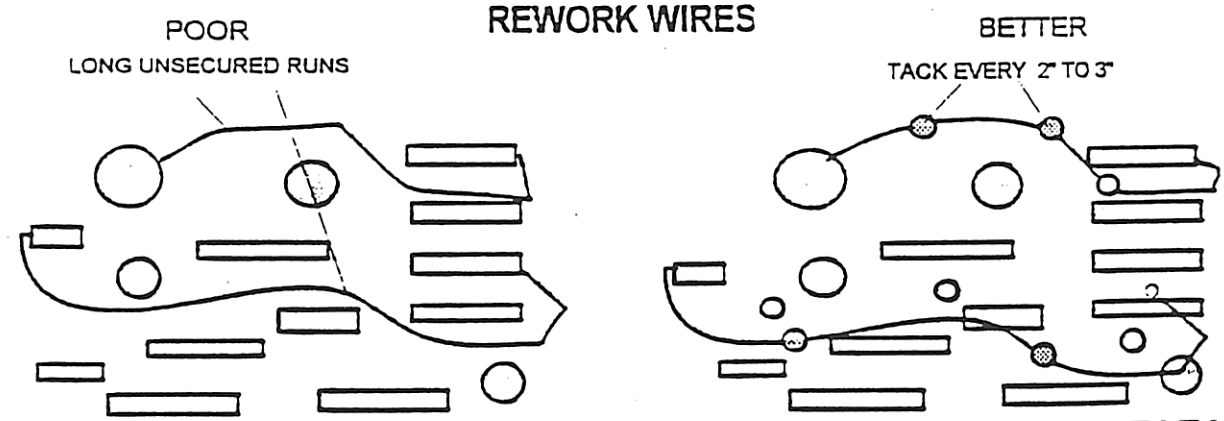
COMPONENT ORIENTATION



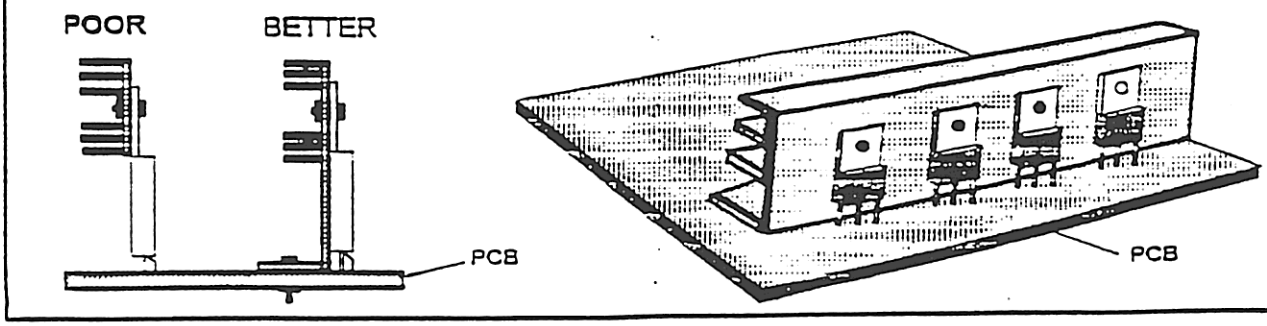
COMPONENT MOUNTING



REWORK WIRES



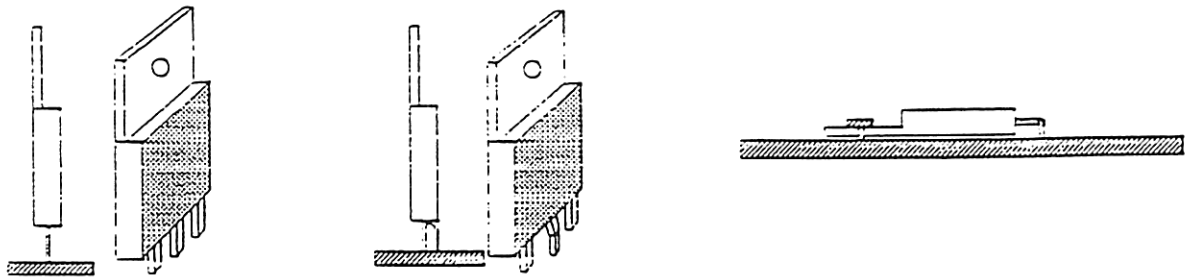
HEAT SINKS



THREE TERMINAL REGULATORS

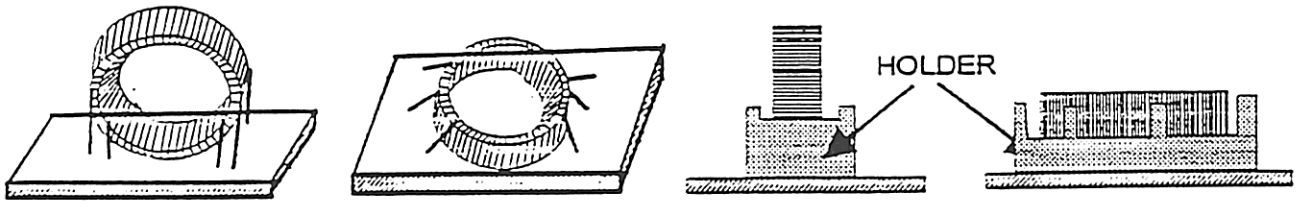
FILE: COMPMNT.DRW

POOR BETTER BEST



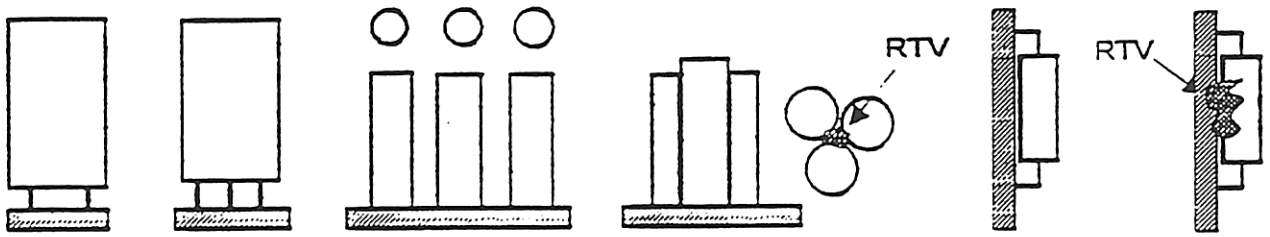
WIRE WOUND INDUCTORS

POOR BETTER BETTER BEST

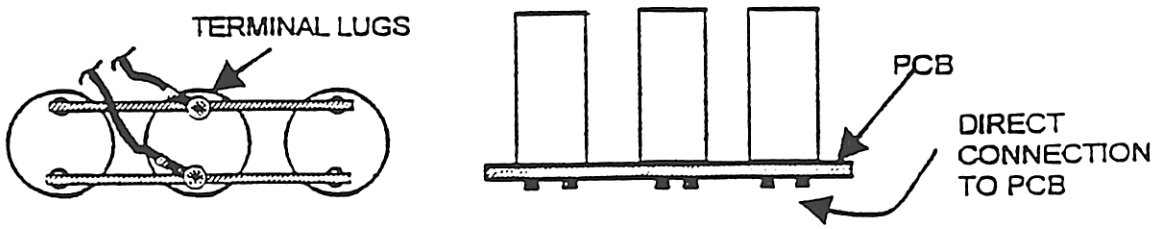


LARGE CAPACITORS

POOR BETTER POOR BETTER POOR BETTER

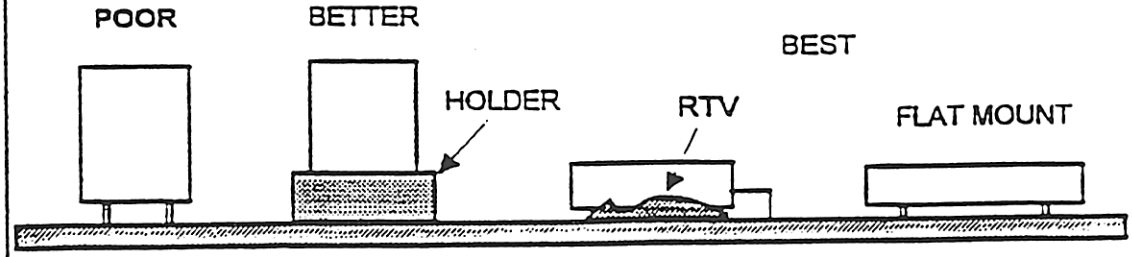


POOR BETTER



CRYSTALS

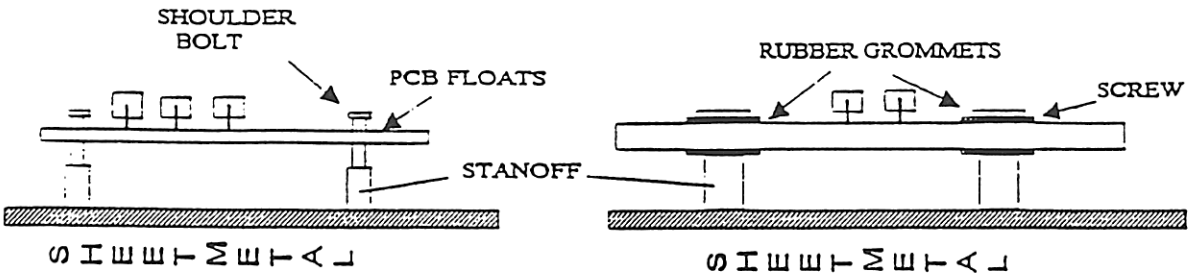
POOR BETTER BEST



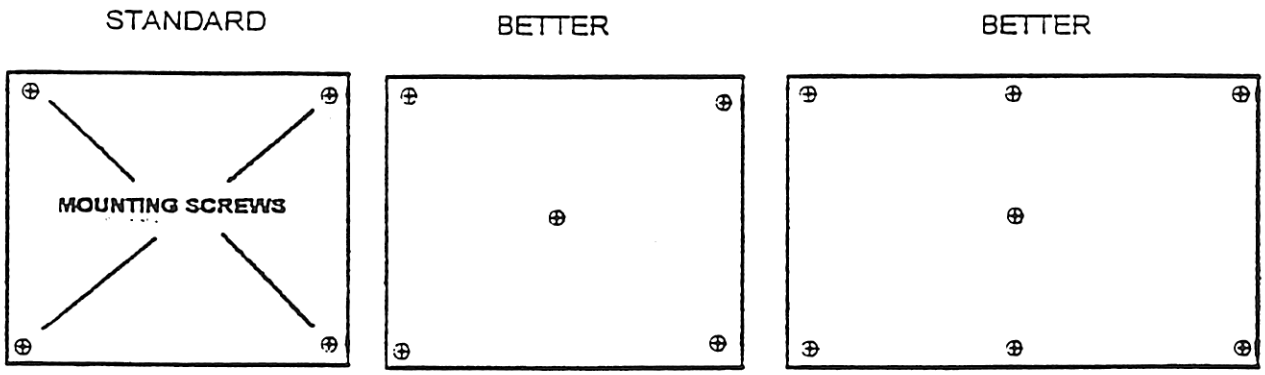
STAND ALONE PCB MOUNTING

PCB'S THAT HAVE COMPONENTS THAT CAN'T BE RUGGEDIZED

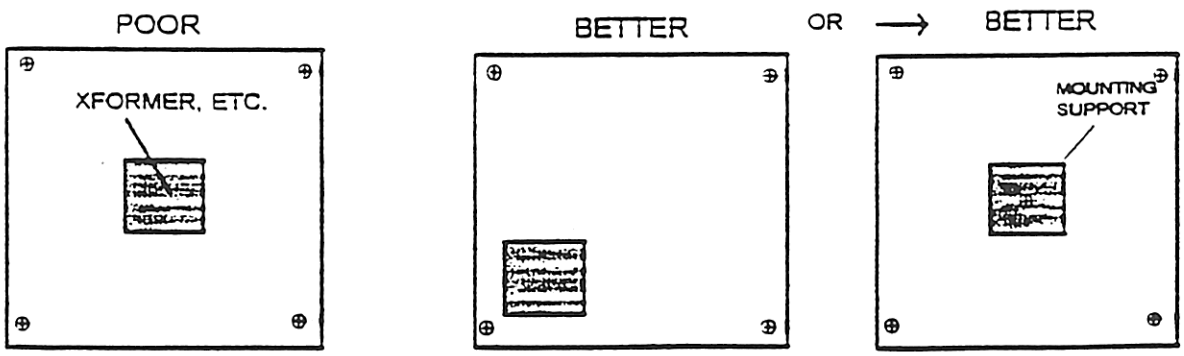
ISOLATE BOARD TO REDUCE VIBRATION



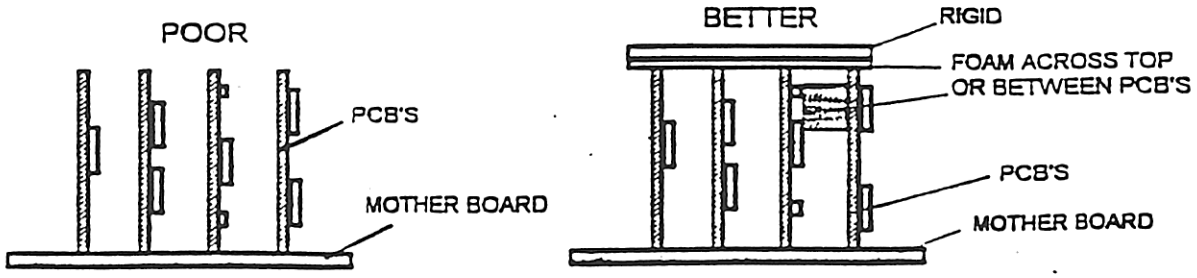
BOARD SUPPORT



HEAVY COMPONENTS



SMALL DAUGHTER BOARDS



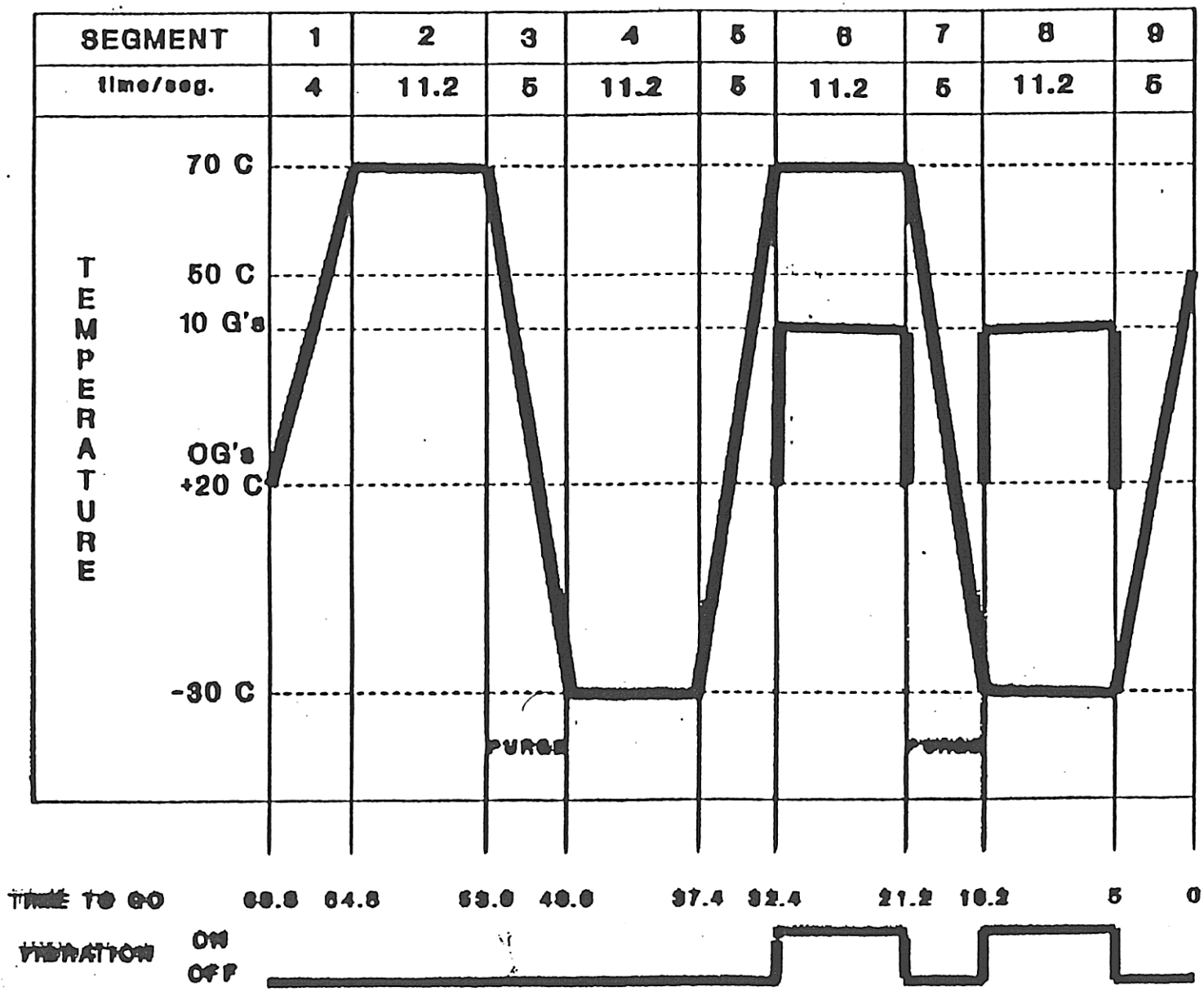
HASS Development

- Combine environmental stimulus.
- 50% of Vibration destruct limit.
- 20% below thermal destruct limit (high temp.) .
- 100 °C delta as fast as possible.
- 2 to 6 thermal cycles - vibrate at different levels - sinusoidal sweep of vibration level.

Proof of Screen

- **Proof of Screen is used to verify the HASS will not damage good hardware.**
  - Performed by running 3 to 4 samples 10 to 20 times through the production screen.
  - Run Proof of Screen in all positions that will be used in production.
  - Seeding samples can demonstrate screen effectiveness.

R33 ALB DRIVE TEMPERATURE / VIBRATION PROFILE



Types of Defects found in HASS

- Loose connectors
- Improperly torqued screws
- Weak switches and circuit breakers
- Overstress on connector-board interface

Types of Defects found in HASS

- Folded integrated circuit legs
- Poor solder joints
- IC Package defects
- Excessive pre-forming of component leg
- Material interface defects

DASD ESS QRS 100

FALLOUT (JANUARY THRU DECEMBER 1990)

CONTROL NUMBER	ASSEMBLY LEVEL	CARD TYPE	AMBIENT	HT	LT	TRANS	HTV	LTV	TEST CODE	DEFECT	COMP LOCATION	TEST STATUS
42501	306	DEF			-30				E3T6-030B	10048164	FB98	2001
42636	306	DEF		70					E3T6-030B	10048157	DM81	2001
42653	306	DEF			-30				F2T3-C312	10048164	C37	2120
42891	306	DEF		70					NDF	NDF		2000
43228	306	DEF	20						E2T5-0314	10067173	DL20	2010
43289	306	DEF						-30	E3T6-030B	10048152	C37	2001
44278	306	DEF		70					LOST	LOST		2000
27341	404	DFI			-28				E2T5-0357	305837803	FH31	2100
28461	404	DFI	20						TRIP CS31A	REVERSED	C11	2120
28705	404	DFI			-30				E2T5-0357	305837803	FH31	2001
28714	404	DFI						-30	E7T2-82BD	305846001	FJ14	2010
28714	404	DFI		58					NO READY	OPEN NS PIN8	KD08	2001
28814	404	DFI		58					E2T5-0314	10067146	FF80	2100
29224	404	DFI		70					TRPCB500	10050070	C11	2100
29285	404	DFI					70		NDF	LOST AT QRS		2222
29309	404	DFI		70					TRPCB500	REVERSED	CS	2100
29530	404	DFI		70					NDF	NDF		2000
29890	404	DFI						-30	E2T5-0357	305837803	FH31	2001
30294	404	DFI			-30				E3T7-0314	10067295	BJS67	2001
30403	404	DFI			-30				E4T1-038C	305837803	FH31	2001
30770	404	DFI					70		NO READY	10050070	CS1	2100
30884	404	DFI	20						NDF	NDF		2000
30886	404	DFI	20						NO READY	OPEN	KD08	2001
30912	404	DFI				70			NDF	NDF		2000
31068	404	DFI		-30					NO READY	10058528	L3	2120
32140	404	DFI				70			E7T1-0314	10086057	HD86	2010
32172	404	DFI		70					NDF	NDF		2000
32337	404	DFI	20						NO READY	SHORTED		2001
32352	404	DFI		70					NO READY	10086057	HD86	2001
32806	404	DFI	20						NO REAY	10104175	DJ44	2010
33004	404	DFI				70			E2T5-0314	305846001	FJ44	2010
33025	404	DFI					70		NO READY	101041752	DJ44	2100
33463	404	DFI	20						E4T6-568D	10104175	DJ44	2001
33731	404	DFI		70					E3T6-030D	10086057	HD86	2001
33757	404	DFI						-30	E3T7-0314	LEG FOLDED	HE92	2001
33803	404	DFI				70			NO READY	10086057	HD86	2120
34085	404	DFI					70		E2T2-0271	10087103	BL14	2120
34135	404	DFI		70					F2T3-C311	10086057	HD86	2221
1584	412	DG			-30				E5T1-7193	OPEN		2001
9436	312	DG	20						E5T17193	OPEN PIN 7	FG39	2001
9763	312	DG							E5T1-1793	OPEN	FN39	2001
16251	312	DG			-30				E5T1-7193	10053105	CR300	2001
18293	312	DG				-30			F2T3 C026	10084191	DJ57	2001
19325	312	DG						-30	E5T1-719F	OPEN PIN 5	FG27	2001
19547	411	DG					70		E5T7-77CA	OPEN COLLECTOR	Q403	2001
19675	412	DG		70					F2T3 C026	10058077	HD99	2100
20074	312	DG	20						E5T1-7193	10084191	HE25	2001
20198	412	DG	20						E5T1-7193	OPEN PIN 7	FG38	2010
21072	411	DG	20						E5T1-7193	OPENNSPIN08	FH31	2001
21115	311	DG					70		E5T1-7193	OPEN		2221
24602	412	DG	20						E5T1-7193	10084191	HE31	2120
33355	411	DG						-30	NDF	NDF		2000
41235	411	DG		70					E5T1-719F	SHADJ32-DJ32		2001
43750	412	DG	20						E5T2-72C7	10104176	HE78	2120
44232	312	DG					70	-30	E5T1-719F	WENT AWAY		2000
44374	412	DG	20						E5T1719F	10054104	Q404	2120
45093	312	DG			-30				E5T1-7193	WENT AWAY		2000
46302	412	DG						-30	NDF	NDF		2000

STORAGETEK

FAR NUMBER: T8331
TAG NUMBER: 01685
FDR NUMBER:

TAPE FAILURE ANALYSIS LAB
SUMMARY REPORT

ARTICLE NAME: CAMERA

PRODUCT TYPE-S/N: 4410-

PART NUMBER-S/N: 410325203 -4524

ORIGIN/TEST TYPE: ESS

EC LEVEL:

DATE RECEIVED: 09/17/90

SUPPLIER: PULNIX/16296

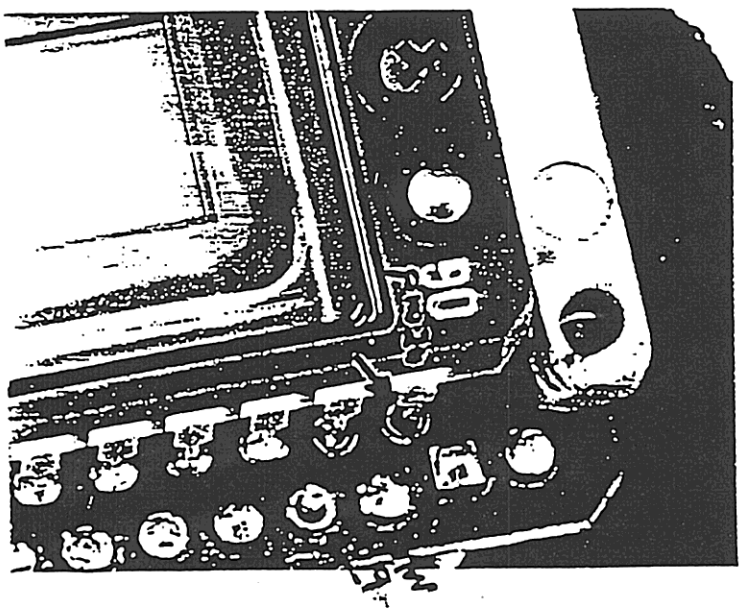
DATE REJECTED: 09/17/90

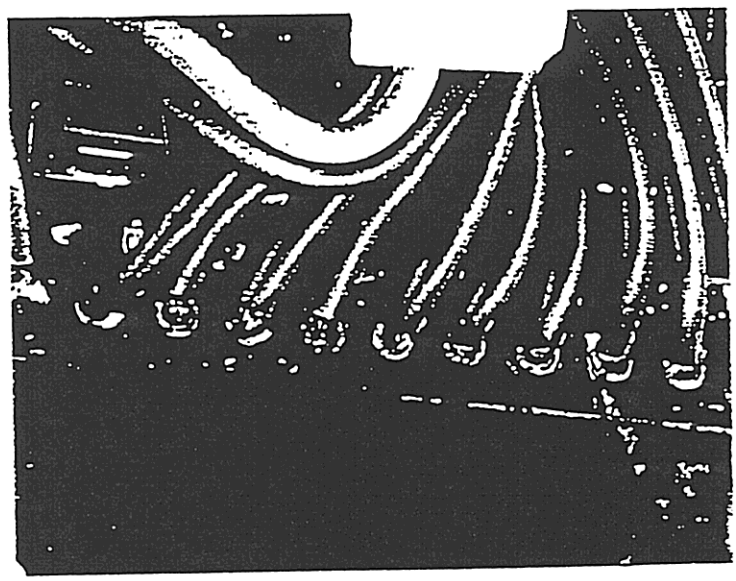
DATE CODE: A0360

REJECT TYPE: UTR

DESCRIPTION OF FAILURE: VERY LIGHT OR NO VIDEO

RESULTS OF ANALYSIS: THERE WERE TWO OPENS BECAUSE OF NO SOLDER.
FIRST OPEN 1) CN1-9 (ED,0FD,BLUE WIRE) OPEN ON AAE CCD PWB.
SECOND OPEN 2) PIN 10 (+20 VOLTS) OF IC1 ITSELF TO AAE CCD ARRAY CHIP.





DISPOSITION OF ARTICLE: RETURN TO LINE

ANALYSIS CONDUCTED BY: KIRK H.

DATE: 09/19/90

APPROVED BY: _____

DATE: _____

STORAGETEK

FAR NUMBER: T8332
TAG NUMBER: 01687
FDR NUMBER:

TAPE FAILURE ANALYSIS LAB
SUMMARY REPORT

ARTICLE NAME: CAMERA

PRODUCT TYPE-S/N: 4410-

PART NUMBER-S/N: 410325203 -4527

ORIGIN/TEST TYPE: ESS

EC LEVEL:

DATE RECEIVED: 09/17/90

SUPPLIER: PULNIX/16300

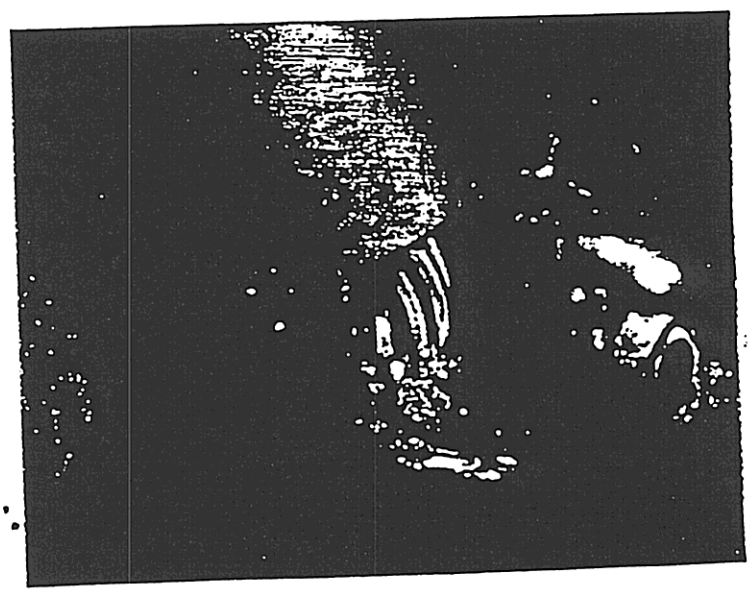
DATE REJECTED: 09/17/90

DATE CODE: A0370

REJECT TYPE: UTR

DESCRIPTION OF FAILURE: PICTURE BLANK/FLICKERS IN VIB/HOT

RESULTS OF ANALYSIS: THERE WAS A COLD SOLDER JOINT ON THE CCD ARRAY PWB WHERE THE SIGNAL WIRE ATTACHES. WHEN THE WIRE IS VIBRATED THE MONITOR FLICKERS.



FAILED COMPONENT DESCRIPTION:

PART NUM.	TYPE	MANUFACTURER	D/C

DISPOSITION OF ARTICLE: RETURN TO RSA

ANALYSIS CONDUCTED BY: KIRK H. DATE: 09/19/90

APPROVED BY: _____ DATE: _____

4480 CD (CARDS)
PROCESS IMPROVEMENT

PART NAME	PART NUMBER	S/N	PROD. FAMIL	FSC	PROBLEM	ACTION	RESP.	OPEN DATE	CLOS DATE
DM	402724405	42869	TRANS	4511	Failed in post. MSN 38160	In process.	Rice	7/15/91	
DB	410541301	70556	TRANS	E089	Failed in vib. E00 test fails in bring ups if shook. MSN 34539	In process. Open solder on pin 22 & 23 chip 1 track 4.	Dodenhoeft	4/18/91	
DB	410541301	76083	TRANS		Trk 17 fails/verified on 34662. MSN 34648	In process. Open solder on chip 1, pin 11, track 17.	Dodenhoeft	4/18/91	
DB		75613	TRANS	21E5	FAiled C40, verified. MSN 34714	In process. Verified. Open solder on chip 1, pin 11, track 18.	Dodenhoeft	4/19/91	
DB		75750	TRANS	E089	Failed during D10, loc & rem. MSN 34724	In process. Open solder on chip 1, track 1, pin 25.	Dodenhoeft	4/22/91	
DB	410541301	63326	TRANS	B143	Failed on power up - verified. MSN 340.	In process. FRU ID not programmed.	Dodenhoeft	4/25/91	
DB	410541301	77478	TRANS	21E1	Eng. trouble shot - failed. MSN 34907	Verified. Insufficient solder on C9A & C9B, trk 1.	Dodenhoeft	4/26/91	
DB		77628	TRANS	E089	Fails D00 trk 10 - verified. MSN 35084	Locate. No solder on chip 1, trk 10, pin 25.	Dodenhoeft	4/29/91	
DB	410541301	77659	TRANS		Dead trk #12 in both post test and offline tests. MSN 35013.	Insufficient solder chip 1, track 12, pin 28.	Dodenhoeft	5/1/91	
DB	410541301	84674	TRANS	E088	Fails on vib E00, trk 18 in vib. only	Chip 1T trk 18, pin 12 open - solder defect - rework issue. No rework in Bldg. 9	Dodenhoeft	5/6/91	
DB	410541301	82940	TRANS	E089	High read corr dead trk#10 during run D10	In process. Chip 1K 110007802 D/C9105	Henry	7/8/91	
DB	410541301	83918	TRANS	E088	E00,D00, LCL/RMT. interm hard, verify in 38040	Incomplete tag, back to UT. Back to F/A NDF Technician error and procedure change - scrap.	Rice	7/8/91	7/18/91
DB	410541301	83630	TRANS	READ	2nd ver. D0A at start of burn.	Incomplete tag, back to UT. Chip1 Trk 5	Henry	7/8/91	

SLAVE CARD DATA
1991

SER #	CARD TYPES	TOTAL RUN
116	DEF	625
117	DEF	621
118	DEF	618
126	DFI	593
127	DFI	589
128	DFI	565
129	DFI	540
121	DEF	522
120	DEF	507
123	DEF	468
131	DFI	462
119	DEF	451
132	DFI	445
122	DEF	428
133	DFI	416
130	DFI	415
160	PAR	338
161	PAR	333
156	PAR	275
170	PTR	268
138	DGB	261
162	PAR	261
60	PAR	253
213	PAR	251
51	PAR	249
183	DBF	246
184	DBF	246
124	DEF	246
171	DAF	243
140	DGB	242
108	DB3	241
107	DB3	241
181	DBF	241
172	DAF	238
185	DBF	238
137	DGB	238
205	PAR	236
109	DB3	235

SER #	CARD TYPES	TOTAL RUN
165	PAR	233
157	PAR	233
186	DBF	230
141	DGB	230
136	DGB	225
110	DB3	224
174	DAF	223
173	DAF	221
187	DBF	221
212	PAR	219
175	DAF	217
176	DAF	214
182	DBF	214
169	PTQ	208
188	DBF	206
159	PAR	205
139	DGB	202
163	PAR	202
142	DGB	192
177	DAF	187
102	DA3Q	186
143	DGB	186
178	DAF	184
103	DA3Q	182
101	DA3Q	178
59	PAR	175
169	PTR	175
158	PAR	174
125	DEF	170
98	DA3Q	165
97	DA3Q	155
11	DB3	154
104	DA3Q	153
215	PTQ	150
167	PTR	150
204	PTR	146
148	HZF	142
52	PAR	138

SER #	CARD TYPES	TOTAL RUN
168	PTQ	137
55	PAR	135
20	DB3	134
25	DEF	134
214	PAR	133
39	DFI	131
24	DEF	130
56	PAR	130
23	DEF	128
26	DEF	128
27	DEF	127
28	DEF	126
79	DBF	124
202	PTR	124
210	DB3	123
78	DBF	122
81	DBF	122
105	DA3Q	120
211	DB3	120
216	PAR	120
64	PTR	120
76	DBF	119
57	PAR	119
58	PAR	118
77	DBF	116
82	DBF	116
66	DAF	113
149	HZF	113
168	PTR	113
68	DAF	111
67	DAF	111
69	DAF	110
164	PAR	109
33	DFI	106
219	PAR	105
71	DAF	104
80	DBF	104
21	DEF	104

Field Survival of HASS Vs. Non-HASS Processes

Confirmed Field Failures for Non-HASS (control group) (sample-1200)

- Four Field Failures 30-90 days
  - ✓ Card Types DA-3, DB-3, DEF, DG

Confirmed Field Failures for HASS (test group) (sample-1200)

- One broken axial lead on resistor, visually detected.

In-house HASS Failures (68.8 Minutes)(sample Pop.-2400)

- 5-DE(X) 3-DB(X) 2-DF(X)
- 3 -DA(X) 3-DE(X) 1-PA(X)

AcceleRel

Fatigue Life and Screens

625 Cycles @ 68.8 minutes each

= 29 Days (24 hr.) in HASS conditions.

=8.6 days (24 hr.) with 10 gRMS input vibration

AcceleRel

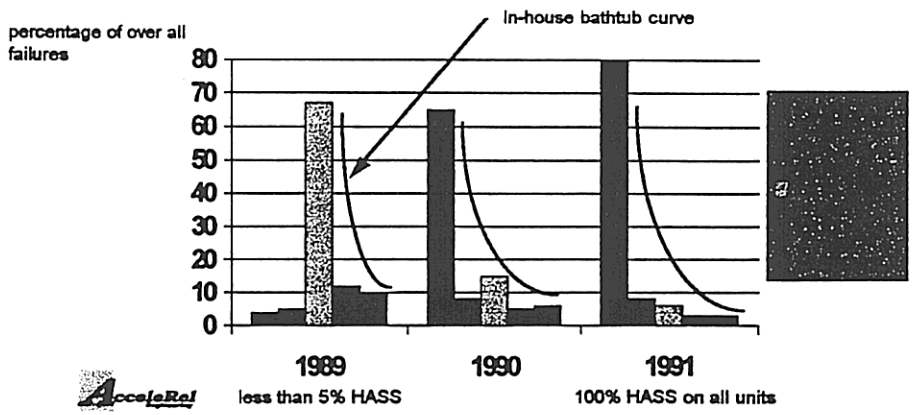
Industry Successes

- **Infrared Thermometer - 400 % reduction in field failures- warranty increased to three years**
- **700/million ⟶ 33/million defect reduction in 6 months. Major Telecom Supplier.**
- **Power supply plug and play 99.7 % within two months start of production - Zytec, 1985.**
- **Hundreds more unpublished.**

AcceleRel

[2]From paper written by Harry McLean in *Medical Device & Diagnostic Industry, April 1994*

DASD Failure Precipitation and Detection Shift



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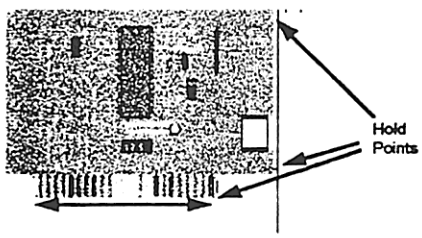
The Purpose of HALT and HASS

- Reduce product development time.
- Reduce field returns, warranty costs.
- Increase product integrity and robustness
- Increase customer satisfaction.

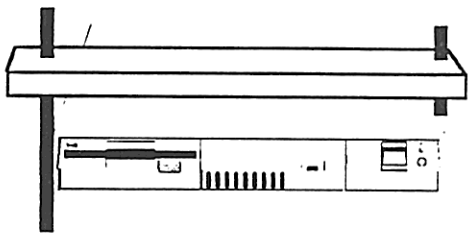
Vibration

- Same Boundary Conditions as In Normal Use - To Produce Same Resonance Modes.
- Fundamental Resonant frequency of Fixture should be significantly higher than UUT
- Card cages can make good fixtures. May need slight ruggedization.



Vibration

- Simple Geometric shapes can be clamped.
- Light solid metal brackets - some reinforcing maybe needed - least is best.
- Insure fixtures resonant frequency is much higher than UUT's resonant frequency.



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Vibration

- Vibration Survey of Product during HALT very beneficial benchmark for later manufacturing and product changes.
- Measure product to product vibration signature during HALT evaluation.
- Vibration measurement of product response during production is difficult. Use input levels as metric.

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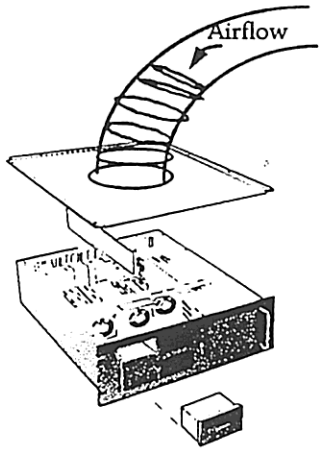
Thermal

- Direct air flow to UUT
  - Heating, cooling chamber walls is expensive.
- Air flow - do not choke - may want to use special covers.
- Reduce unnecessary thermal mass



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Thermal

- Turbulent Air flow much more effective than Laminar airflow.
- Remove covers - faster thermal change on product less overall mass. Vibration fixtures not needed.
- Simulate small thermal mass that parallels the product temperature change. Attaching TC to production units during HASS is difficult.

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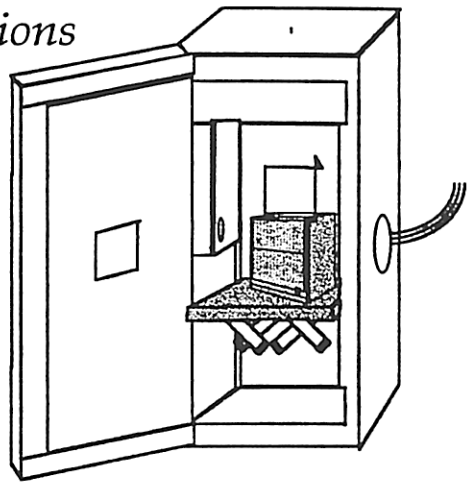
General Considerations

- **Power on and monitor**
- Accessibility critical
- Ruggedize the cables connectors on backplanes
  - Avoid cables across sharp edges
- Chamber space utilization important in production HASS
- Ergonomics important in high volume production



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Key Benefits of HALT and HASS

- Higher MTBF
- Reputation for Reliability
- Better Market Share
- Mature product at release
- Competitive advantage

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Other HASS & HALT Beneficial Uses

- Benchmarking of potential suppliers.
  - ✓ Comparison of suppliers -keep confidential to prevent pre-HALT ruggedization
  - ✓ Wider operational margin = higher potential reliability
- Benchmarking with your competitors.
- Stimulus of "No Defect Found" to detect intermittent or failures of marginal systems.

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References

1. Hobbs, G.K. , Highly Accelerated Life Tests - HALT, unpublished, contained in seminar notes, HALT & HASS, copyright September ,1993
2. Gray, K. A., "HALT and HASS at StorageTek", unpublished seminar notes -IES Workshop on ESSEH, March, 1992.
3. McLean, H., Exceeding the Limits of Traditional Reliability Tests, *Medical Device & Diagnostic Industry,* April 1994.
4. Hobbs, G. K., Evaluation of Stress Screens, 1988 Proceedings Institute of Environmental Sciences, pgs. 47-49.
5. Hopf, A.M., Highly Accelerated Life Test for Design and Process Improvement, 1993 Proceedings Institute of Environmental Sciences, pg.. 147-155.

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6. Condra, L.W. ,"Reliability Improvement With Design of Experiments",Marcel Dekker, Inc. New York, Basel, Hong Kong, 1993.
7. Clifton J. Seusy, "Achieving Phenomenal Reliability Growth", Proceedings of ASM's 1987 Conference on Reliability.