Bendix

Aerospace Systems Division

Bendix Data Transmitter
Housing Material Change

NO. ATM-917

REV. NO.

PAGE 1 OF 14

DATE 11-5-70

This ATM presents a comparison of Bendix Data Transmitters with housings machined of aluminum versus those with housings machined of magnesium. This study was requested by action item at the transmitter △FTRR/FACI on 6/15/70.

A second action item from the same meeting required an analysis of the effect of increasing the countersink diameter of two mounting plate holes. This analysis is also summarized in this ATM. The due date for these actions is that they be presented prior to or at the transmitter QAR.

Prepared by D A Courtois

D. A. Courtois

INTRODUCTION

The purpose of this ATM is to document the action required per the transmitter Δ FTRR/FACI relative to the change in transmitter housing metal. In the initial design the housings and some other parts were machined from magnesium. Later the design was changed to aluminum as a result of recommendations made during an investigation of plating problems.

The qualification transmitter, S/N 21, was made from the initial drawing release and is made of magnesium while the A-2 flight units and subsequent units are made of aluminum. The action requires a comparison be made of the magnesium and the aluminum designs so that it can be shown that the two designs are equivalent as far as performance is concerned.

SUMMARY

Several advantages were gained as a result of the change in housing material from magnesium to aluminum:

1. Increased protection from corrosion in the event of plating faults,
2. Increased strength, and
3. Slightly lower operating temperatures because of the higher thermal conductivity.

The principal disadvantage is the increased transmitter weight.

ELECTRICAL PROPERTIES

The properties of the transmitter of interest herein can be categorized as electrical, thermal and mechanical. An electrical property related to the housing metal change is electrical conductivity. Two cases are of interest, the DC resistance of the base metal and the surface conductivity at the several frequencies used in the transmitter multiplier. The DC resistance of aluminum is less than half that of magnesium so that in places where the case is used for DC return the performance would not be expected to degrade.

At the oscillator frequency of 38 MHz, and above, the currents flow within 0.0005 inch of the surfaces of the cavities and since the gold plating is 0.0005 inch thick the change in base metal has no effect on RF performance.

The EMI characteristics of the transmitter would not be expected to change as a result of the base metal change because EMI characteristics are determined by the physical design, layout of components, the fit of subassemblies, use of filters, etc. none of which were affected in the subject change of the transmitter base material.

THERMAL PROPERTIES

The changes in thermal properties were evaluated by re-running a thermal analysis which had been performed initially for the aluminum case. The magnesium thermal properties were inserted into the computer program for the thermal analysis. The results show that all transmitter temperatures are lower for the aluminum case as would be expected because of the higher thermal conductivity. The largest temperature difference between the aluminum and magnesium designs is 2.4°C for the multiplier diode, CR1. A summary of the thermal analysis is appended which gives the results at the worst case baseplate temperature of 70°C.

MECHANICAL PROPERTIES

The main mechanical properties of interest are strength and weight. A mechanical analysis was performed in which the material strengths were compared. This analysis, which is attached as Appendix B, shows that all of the strength properties are higher for the aluminum case and therefore the aluminum transmitter is stronger than the magnesium transmitter.

The mounting plate stress analysis was reviewed, using aluminum properties. This analysis shows that the yield margin of safety is higher for aluminum than for magnesium. It also shows that the maximum deflection in the mounting plate increases in the case of aluminum because of the increase in weight, however the amount of deflection is still not significant.

A disadvantage of the material change is the increase in transmitter weight which went from about 1.5 pounds to 1.9 pounds. This increase in weight is not significant in considerations of the strength of the thermal plate and the worst result is that the weight of other components must be decreased accordingly if the total payload weight is to remain constant.

WALL THICKNESS ACTION ITEM

A second action item from the Δ FTRR/FACI required that an analysis be made of the effect of the reduction in wall thickness as a result of increasing countersink dimensions on two mounting plate holes. This change was made at the same time as the change from magnesium to aluminum.

The stress analysis, also summarized in Appendix B, shows that there is a very low probability of local deformation at the countersink holes.

Memorandum

Systems Division

Date 9/22/70 **Letter No.** 9712-24 **Ann Arbor, Michigan**

To J. McNaughton/D. Courtois

From E. Granholm

Subject ALSEP, Array A-2, Thermal Analyses Comparison of Aluminum and Magnesium Data Transmitters.

REF: (1) Letter No. 70-210-261, "ALSEP, Array A-2, Thermal Analysis of Data Transmitter", dated 10 August 1970

(2) ATM-241, Rev. "C", "ALSEP Acceptable Parts List", dated 15 December 1969.

Per an action item originating from the Δ FTRR/FACI meeting on 15-16 June 1970, a thermal analysis has been completed which predicts maximum electronic part temperatures for a magnesium (AZ31B) Data Transmitter design. A direct comparison between previously determined (Reference 1) temperature levels, corresponding to a 6061-T6 aluminum design, and the estimated magnesium temperature levels is presented herein.

The Data Transmitter contains high power dissipating silicon semiconductors mounted to a chassis which is mechanically attached to a temperature controlled surface maintained at 70°C (158°F). The analyzed configuration of the Data Transmitter showing location of analyses nodal points is presented in Figure 1. The surrounding pressure was assumed to be 1×10^{-6} torr so that gaseous conduction and natural convection within the package was ignored. Radiation heat transfer from the transmitter exterior surfaces was considered negligible due to the low emittance ($\epsilon = 0.05$) of Gold Plating. Total electronic power dissipation was conservatively calculated to be 12.5 watts.

Results of the thermal analysis comparison of aluminum and magnesium designs are presented in Table I which depicts chassis and electronic part operating temperature levels. It is noted that all magnesium transmitter operating temperatures are slightly higher than those previously reported for the aluminum package. The largest chassis temperature difference is approximately 2°C and occurs within the X6 multiplier. For electronic parts, the greatest temperature difference between the aluminum and magnesium design is 2.4°C for the X6 Multiplier diode CR1. The maximum temperature electronic part is the power amplifier transistor Q4 whose operating junction temperatures are 135.2°C and 136.7°C corresponding to aluminum and magnesium, respectively. The maximum allowable temperature level for silicon power semiconductors is 140.0C as defined in Reference 2.

Results of the thermal analysis indicate that all electronic part temperatures for the magnesium transmitter are below Reference 2 specified maximum limits. However, from a thermal standpoint the aluminum data transmitter design is more desirable since the associated electronic parts operate at lower, more reliable temperature levels.

E. Granholm
E. Granholm

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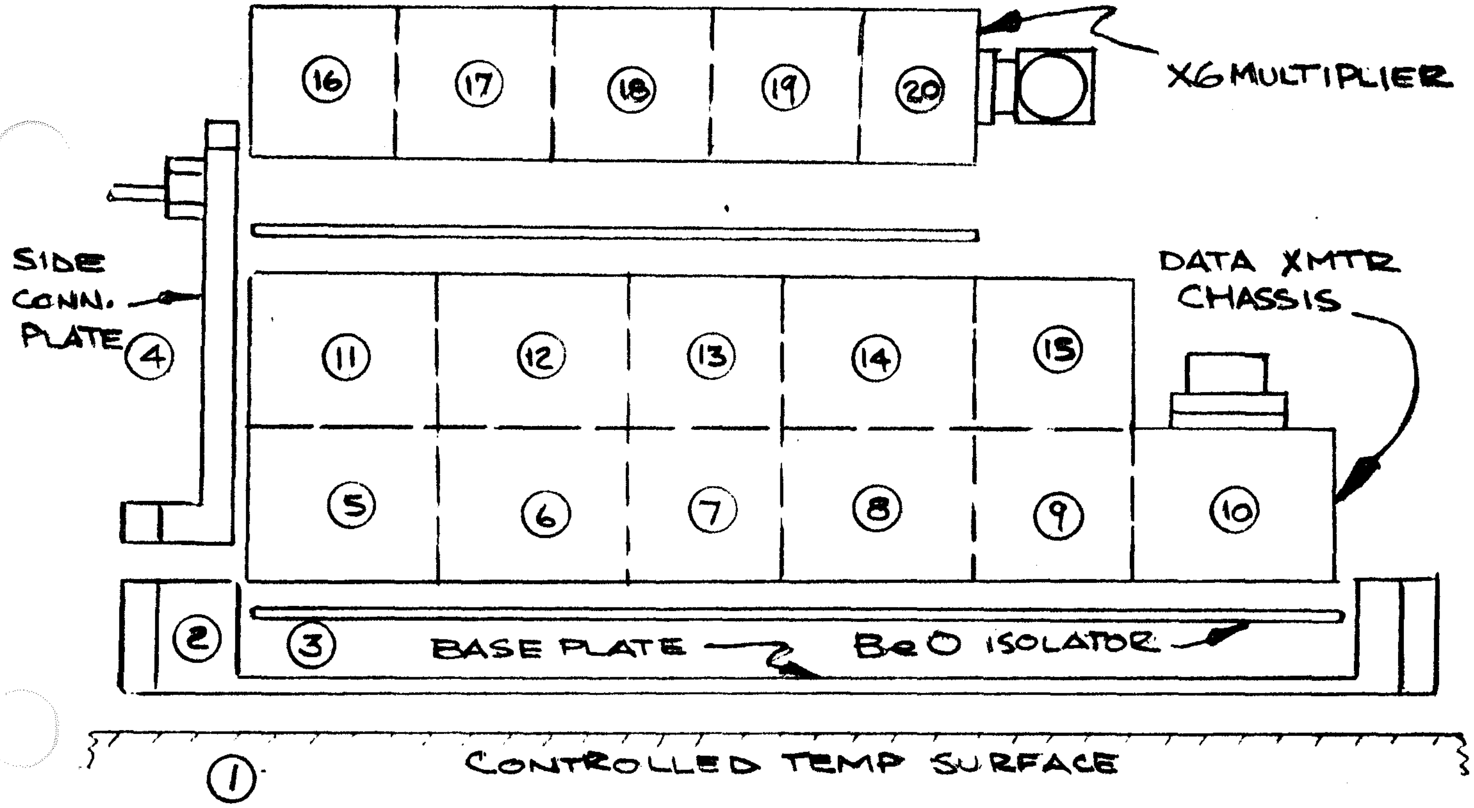
ALSEP, ARRAY A-2, DATA TRANSMITTER
NODAL LAYOUT FOR THERMAL ANALYSIS



ADDITIONAL NODES (NOT SHOWN)	DESCRIPTION
㉑	PREAMP CKT BOARD
㉒	Q3 JUNCTION, PREAMP
㉓	TELEMETRY, CKT BOARD
㉔	CR1 JUNCTION, X6 MULT
㉕	CR2 JUNCTION, X6 MULT
㉖	Q1 JUNCTION, PWR AMP
㉗	Q2 JUNCTION, PWR AMP
㉘	Q3 JUNCTION, PWR AMP
㉙	Q4 JUNCTION, PWR AMP

ALSEP, ARRAY A2, DATA TRANSMITTER
RESULTS OF THERMAL ANALYSIS

NODE NO.	DESCRIPTION	AL XMTR MAX TEMP (°C)	MAG XMTR MAX TEMP (°C)
1	CONTROLLED TEMP SURFACE	70.0	70.0
2	TRANSMITTER BASE PLATE	70.2	70.2
3	BERYLLIUM OXIDE ISOLATOR	70.5	70.5
4	SIDE CONNECTOR PLATE	72.3	72.9
5-10	TRANSMITTER, LOWER TIER	71.2*	72.0*
11-15	TRANSMITTER, UPPER TIER	72.5*	73.8*
16-20	X6 MULTIPLIER CHASSIS	73.8*	75.7*
21	PRE-AMP PC BOARD	76.5	76.9
22	Q3 JUNCTION, PREAMP PC BOARD	113.2	113.6
23	TELEMETRY PC BOARD	90.3	90.5
24	CR1 JUNCTION, X6 MULT	132.8	135.2
25	CR2 JUNCTION, X6 MULT	132.7	134.9
26	Q1 JUNCTION	76.0	76.6
27	Q2 JUNCTION, PWR AMPLIFIER	93.2	94.4
28	Q3 JUNCTION, PWR AMPLIFIER	99.6	101.3
29	Q4 JUNCTION, PWR AMPLIFIER	135.2	136.7

TABLE I

*AVERAGE TEMPERATURES

Date 28 September 1970 Letter No. 70-210-304

To D. Courtois

From R. Greeson and H. Wiger

Subject Transmitter Mechanical Analysis

This memo covers the subject mechanical analysis which was requested. The analysis includes the effects of a wall thickness reduction at countersink holes in the Mounting Plate (Dwg. No. 2345252) and the mechanical and structural effects of changing the material from magnesium alloy AZ31B to aluminum alloy 6061.

Mounting Plate Edge Distance

A stress analysis of the mounting plate, P/N 2345252, indicates that there is a very low probability of local failure at the edge of the plate if the screw torque values do not exceed the drawing call-out of 8.0 ± 1.0 inch pounds. Bulging of the thin section of material adjacent to the hole would be a possibility due to bending moments and shear forces if the screw was adjacent to the base-plate metal. This is not the case with this plate because there are nylon cup insulators between the screw and the hole countersink. These insulators will compress to relieve some of the loads and therefore the probability of metal failure is low.

If metal failure did occur the worst result would be local deformation adjacent to two holes. In regard to the question of catastrophic failure, it can be stated with reasonable assurance that the mounting plate will remain firmly secured to the transmitter housing.

Material Change Analysis

In order to evaluate the mechanical and structural effects of the change from magnesium alloy AZ31B to aluminum alloy 6061, a direct comparison was made for each part. This included comparing the materials for each part with regards to their probable starting blank thickness since considerable variation in properties with each thickness exist in the magnesium alloy. This same degree of variation with thickness is not evident for the aluminum alloy.

A compilation of the drawings which were reviewed along with the specific material and condition is shown in Table I. It is understood that these are all the drawings which were changed in the transition from magnesium to aluminum.

Table II is a breakdown for each part with respect to their probable starting material thickness. This table also includes the material conditions (heat treatment and/or strain hardening) for each thickness.

Table III is a direct comparison of the material properties for each starting material thickness and condition. The percentage increase from the magnesium alloy to the aluminum alloy are also included for all the properties. As can be seen, all properties show higher values for the aluminum alloy than for the magnesium alloy. Based on this comparison, it can be concluded that the mechanical performance has been improved by the change from magnesium to aluminum.

For the final evaluation, a comparison was made with the original calculations by D. Chang for the Mounting Plate (Drawings 2344604 and 2345252). It should be noted that these calculations represent a very conservative approach as a simple fix-ended beam under uniform dynamic load and does not take into consideration the support from the thermal plate or the additional mounting screws into the housing.

The increased transmitter weight will not significantly affect the maximum deflection or probability of failure of the central station thermal plate because of the rigidity of the thermal plate. and the proximity of the transmitters to the edge of the thermal plate where fasteners tie the plate to the structure.

R. Greeson
R. Greeson

H. Wiger
H. Wiger

elg

TABLE I

DRAWINGS REVIEWED

Drawing Title	Change	Drawing No.	Materials
ALSEP Data Transmitter	Now	2345250	All Aluminum
	Was	2344600	Aluminum & Magnesium
Housing Assembly, X6 Multiplier	Now	2345261	All Aluminum
	Was	2344613	All Magnesium
Plate, Mounting, ALSEP Data XTMR	Now	2345252	AL 6061-T651
	Was	2344604	
Chassis, Elect. Equip., Power Amp.	Now	2345256	AL 6061-T651
	Was	2344641	MAG AZ31B-H24
Plate, Mounting, Elect. Conn.	Now	2345267	AL 6061-T6
	Was	2344611	MAG AZ31B-H24
ate, Retaining, Elect. Conn., X6	Now	2345268	AL 6061-T6
	Was	2344612	MAG AZ31B-H24
Housing, X6	Now	2345262	AL 6061-T651
	Was	2344614	MAG AZ31B-H24
Post A, X6	Now	2345263	AL 6061-T651
	Was	2344615	MAG AZ31B-F
Post B, X6	Now	2345264	AL 6061-T651
	Was	2344616	MAG AZ31B-F
Cover, Rear, X6	Now	2345269	AL 6061-T6
	Was	2344632	MAG AZ31B-0
ver, Front, X6	Now	2345270	AL 6061-T6
	Was	2344634	MAG AZ31B-0

TABLE II

MATERIALS—ALSEP TRANSMITTER FABRICATION

Starting Material	Material Types And Condition	Drawing Titles	Drawing Nos.
2.0 Thick Plate	AL 6061-T651 MAG AZ31B-H24	Chassis, Elect. Equip., Power Amp.	2345256 2344641
		Housing, X6	2345262 2344614
0.5 Thick Plate	AL 6061-T651 MAG AZ31B-H24	Plate, Mounting, ALSEP Data XMTR	2345252 2344604
		Plate, Mounting, Elect. Conn.	2345267 2344611
		Cover, Housing, X6	2345271 2344633
0.1 Thick Sheet	AL 6061-T6 MAG AZ31B-H24	Plate, Retaining, Elect. Conn., X6	2345268 2344612
0.04 Thick Sheet	AL 6061-T6 MAG AZ31B-0	Cover, Rear, X6	2345269 2344632
		Cover, Front, X6	2345270 2344634
0.3 Diameter Rod	AL 6061-T651 MAG AZ31B-F	Post A, X6	2345263 2344615
		Post B, X6	2345264 2344616

TABLE III

COMPARISON—MECHANICAL PROPERTIES

Material	Mech Prop (Mil-HDBK-5)	Original AZ31B-H24	Present 6061-T651	Percent Increase
2.0 Thick Plate	F_{tu} (KSI)	34	42	20
	F_{ty} (KSI)	20	36	80
	F_{cy} (KSI)	10	35	250
	F_{su} (KSI)	18	27	50
	E (PSI x 10^6)	6.5	9.9	52
	E_c (PSI x 10^6)	6.5	10.1	60
	G (PSI x 10^6)	2.4	3.8	58
0.5 Thick Plate	F_{tu} (KSI)	37	42	13
	F_{ty} (KSI)	24	36	50
	F_{cy} (KSI)	16	35	120
	F_{su} (KSI)	18	27	50
0.1 Thick heet	F_{tu} (KSI)	39	42	8
	F_{ty} (KSI)	29	36	24
	F_{cy} (KSI)	24	35	46
	F_{su} (KSI)	18	27	50
		Original AZ31B-0	Present 6061-T6	
0.04 Thick Sheet	F_{tu} (KSI)	32	42	31
	F_{ty} (KSI)	18	36	100
	F_{cy} (KSI)	12	35	190
	F_{su} (KSI)	17	27	59
		Original AZ31B-F	Present 6061-T651	
.3 Diameter od	F_{tu} (KSI)	35	42	68
	F_{ty} (KSI)	22	35	59
	F_{cy} (KSI)	12	34	174
	F_{su} (KSI)	18	27	50

TABLE IV

STRESS ANALYSIS

ALSEP TRANSMITTER | R. Greeson 9-21-70

Ref.: D. Chang Analysis 9-24-69

MOUNTING PLATE

Ref. Drawings:

2344604 - Mag. Alloy AZ31B-H24
2345252 - Alum. Alloy 6061-T651

MIL-HDBK-5 PROPERTIES

	AZ31B-H24	6061-T651
Density - $lbs/in.^3$	.064	.098
F_{tu} - $lbs/in.^2 \times 10^3$	37	42
F_{ty} - $lbs/in.^2 \times 10^3$	24	36
F_{cy} - $lbs/in.^2 \times 10^3$	16	35
F_{su} - $lbs/in.^2 \times 10^3$	18	27
E - $lbs/in.^2 \times 10^6$	6.5	9.9
E_c - $lbs/in.^2 \times 10^6$	6.5	10.1
G - $lbs/in.^2 \times 10^6$	2.4	3.8

COMPARISONS - STRESS ANALYSIS

	MAG ALLOY AZ31B-H24	ALUM. ALLOY 6061-T651
	Transmitter wt. = 1.5 lbs	Est. Transmitter wt. = 2.1 lbs

FOR LIMIT LOAD OF 27 g

	MAG ALLOY AZ31B-H24	ALUM. ALLOY 6061-T651
Maximum Load:	w = 1.5 x 27 = 40.5 lb	w = 2.1 x 27 = 56.7 lb
Moment:	$M_{max} = \frac{1}{12} \times 40.5 \times 7 = 23.63$ in.-lbs	$M_{max} = \frac{1}{12} \times 56.7 \times 7 = 33.1$ in. lbs
Applied Bending Moment Stress:	$f_b = \frac{23.63}{0.00278} = 8500$ psi	$f_b = \frac{33.1}{0.00278} = 11,900$ psi
d Bending Stress:	$f_b = 1.15 \times 8500 = 9775$ psi	$f_b = 1.15 \times 11,900 = 13,695$ psi
Yield Margin of Safety:	$M.S. = \frac{F_{cy}}{f_b} - 1 = \frac{16^*}{9.775} - 1 = .59$	$M.S. = \frac{F_{cy}}{f_b} - 1 = \frac{35}{13.695} - 1 = 1.55$
Effective Modules of Elasticity:	$E^1 = \frac{E}{1-V^2} = \frac{6.5 \times 10^6}{0.88} = 7.39 \times 10^6$ psi	$E^1 = \frac{E}{1-V^2} = \frac{9.9}{.91} - 1 = 10.9 \times 10^6$ psi
Deflection:	$\delta = \frac{1}{384} \frac{40.5 \times 1.5 \times 7^3}{7.39 \times 10^6 \times 0.00278} = 0.0027$ in.	$\delta = \frac{1}{384} \frac{56.7 \times 2.1 \times 7^3}{10.9 \times 10^6 \times .00278} = 0.0052$ in.

*Error in orig. calc. F_{cy} = 16 not 24