RECORDING AND WEAR CHARACTERISTICS OF 4 AND 8 MM HELICAL SCAN TAPES

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INTRODUCTION

Performance data of media on helical scan tape systems (4mm and 8mm) is presented and various types of media are compared. All measurements were performed on a standard MediaLogic model ML4500 Tape Evaluator System with a Flash Converter option for time based measurements. 8mm tapes are tested on an Exabyte 8200 drive and 4mm tapes on an Archive Python drive; in both cases the head transformer is directly connected to a Media Logic Read/Write circuit and test electronics. The drive functions only as a tape transport and its data recovery circuits are not used.

Signal to Noise, PW 50, Peak Shift and Wear Test data is used to compare the performance of MP (metal particle), BaFe (Barium Ferrite), ME (metal evaporated). ME tape is the clear winner in magnetic performance but its susceptibility to wear and corrosion, make it less than ideal for data storage. (See also : Corrosion of MP and ME Tapes, D. Speliotis and K. Peter, Journal of the Magnetics Society of Japan Vol. 15 Supp. S2 1991)

EXPERIMENTAL DATA

Fig. 1 shows PW50 performance comparison between MP, BaFe and ME tapes. PW50 is the pulse width in nano seconds measured at 50% amplitude of an isolated flux reversal; a narrow pulse width is required for high recording densities when as many pulses as possible are squeezed closely together. In addition, the write current was varied over a 6 mA range, roughly covering the broad peak of a saturation curve, to show how sensitive performance is to write current variations (see Fig. 2).

ME tape not only easily outperformed all other tapes but also showed the least sensitivity to write current variations, making it ideal from the drive designers' point of view. The reason for this is most likely the extremely thin magnetic layer and corresponding low SFD (Switching Field Distribution). PW50 typically was 115 nsec at 16 mA write current; at a head/media velocity of 3.8 m/sec, this translates to a PW50 of 43.7 um. Barium Ferrite came in second at 148 nsec (56.2 um), but showed the characteristic slope which all thicker coated media exhibited. This means that PW50 becomes worse as write current increases, making drive and head design more critical. HI 8 MP (fine grain MP) had a PW50 of 154 nsec (58.5 um), while regular MP was approximately 160 nsec (60.8 um).

Fig. 3 to 6 compares peak shift between types of tape; again, ME is the clear winner with 26.3 nsec peak shift while MP is second with 40 nsec. BaFe had the highest (worst) peak shift at 51.2 nsec which is counter to what one would expect based on PW50 and frequency response data. Peak shift was measured using a 00110011 repeating pattern at 4 MHz which means that the unshifted spacing between flux reversal pairs is 125 nsec. The reason for more than expected peak shift on BaFe tape is not clear and more work needs to be done. One possible explanation may be that the samples tested had more surface roughness (see fig. 7 HF modulation) and in effect increased the head/media spacing or that some as yet unidentified negative interactions are occurring between particles.

Signal to Noise ratio was measured up to 10 MHz to compare the potential suitability of various tapes for higher recording densities. The measurement is made at any spot frequency over a 10 KHz bandwidth; the bandpass filter used has a 30 dB per octave rolloff. The S/N contribution of the low noise read preamp is 0.5 nV/rt Hz; this represents 50 nV over 10KHz bandwidth, allowing an 80 dB dynamic range below a 500 uV signal which is well below media noise.

Fig. 8 is the S/N data for 8 mm tapes; ME again is the star performer, with HI-8 MP 6dB below ME at 9.5 MHz. BaFe is only 2 dB below HI-8 MP at high frequencies but performs worse at low frequencies due to lower output amplitude. Regular MP is last with about 12 dB below ME.

4 mm S/N data (Fig. 9) gives much the same picture except that no ME tape was available. S/N curves drop off faster at high frequencies partly due to a lower head/media velocity (16%) and possibly due to head performance. It is significant that despite lack luster low frequency S/N performance, BaFe appears ready to overtake all other tapes when the graph is extended beyond 10 MHz. No double layer BaFe tapes with better surface finish were available at the time the data was taken, but in the near future we expect to fill in this gap. The coated double layer MP tape used a low coercivity underlayer (gamma ferric oxide) and MP as upper layer; the performance appears to come close to ME when interpolated to 8mm data.

Signal to noise measurements are difficult to perform accurately on helical scan systems since only 16.7 mS for 8mm and 7.5 mS for 4mm is available to allow write/read recovery, set VCO frequency, allow RMS detector to settle and take reading. The repeatability of S/N measurements on our tester was within 1/4 dB. With a spectrum analyzer, the sweep must be triggered by the start of the read track and the bandwidth and sweep rate settings carefully chosen to obtain accurate S/N data.

The wear test data was obtained by making repeated passes over the same 1000 tracks of tape in a continuous write/read process, i.e. the pattern was rewritten each time and dropout errors counted. For dropout error measurement, an all 1's pattern is recorded; on read, the analog head signal is amplified and the peak amplitude of each positive and negative flux transition is compared to the TAA (track average amplitude), and if it is below 50% of TAA, a single bit error is generated. The dropout error block definition Bad/Good/Max allows the user to set the error block size or duration; for example, a setting of 1/5/180 means that an error block count is initiated when a single flux reversal is below the set threshold (50%) but a second error block is only counted after 180 bad flux reversals; after 5 good flux reversals, the bit error counter is reset. A setting of 125/16/250 means that an error block is counted only after 125 bad bits, and a second error block is counted after 251 bad bits; if 16 good bits occur, the bad bit counter is reset.

Fig. 10 shows a typical wear test result on 8 mm tape of 1000 passes over 1000 tracks. Due to burnishing effects of head and drum, the dropout error rate of a new tape will typically drop by as much as a factor of 10 after a few hundred passes. The 4 mm wear test shows a similar reduction of errors due to the burnishing effect of head/drum rotation (see fig. 11). Except for a few mechanical cartridge failures, most brands of MP and BaFe tapes endured the entire 20,000 passes they were subjected to without catastrophic failure, however some tape brands exhibited substantial error rate increases after a few thousand passes. We attributed this sudden rise in error rates to a form of stiction caused by particles adhering to the head due to extreme smoothness of head and media interface (see fig. 12).

One type of tape which failed catastrophically after about 700 passes, is ME (see fig. 13). In this case, the thin evaporated metal coating just wears through much sooner than the thicker coated substrates and makes this type of tape not really suitable for applications requiring many passes. For video applications it may be good enough.

Another interesting phenomenon noticed on some brands of 4 mm tapes was termed "end of test problem". As fig. 14 through 18 shows, there is a continuous increase in large dropout errors from 81 to 454 over 40,000 tracks; the increase is concentrated at the end (right hand edge) of the error map. In fig. 17, this "end of test problem" is clearly visible since the error map was extended to 45,000 tracks which is beyond the original test. The reason for the bunching of errors at the end of a test must be explained by additional wear caused by stopping/reversing and rewinding of the tape.

It is interesting to note that no inherent advantage in wear characteristics were evident due to a smaller wrap angle (90 deg) of 4 mm versus 8 mm (180 deg). Could it be that the larger wrap angle provides a more stable air bearing? The raw uncorrected dropout error rate of 4mm is an order of magnitude higher than on 8mm when measured under the same conditions which is the reason an extra level of error correction is used in 4mm systems. This however does not imply that 4mm is in any way inferior, it only means that recoding density and error correction were optimized differently.

To summarize, in order to evaluate tape performance and compare apples and apples, a common reference point and test method needs to be established. Despite the complexities of helical scan recording and the availability of many types and brands of tape, it is possible to collect valid data which can be used to make logical choices for one's own application.

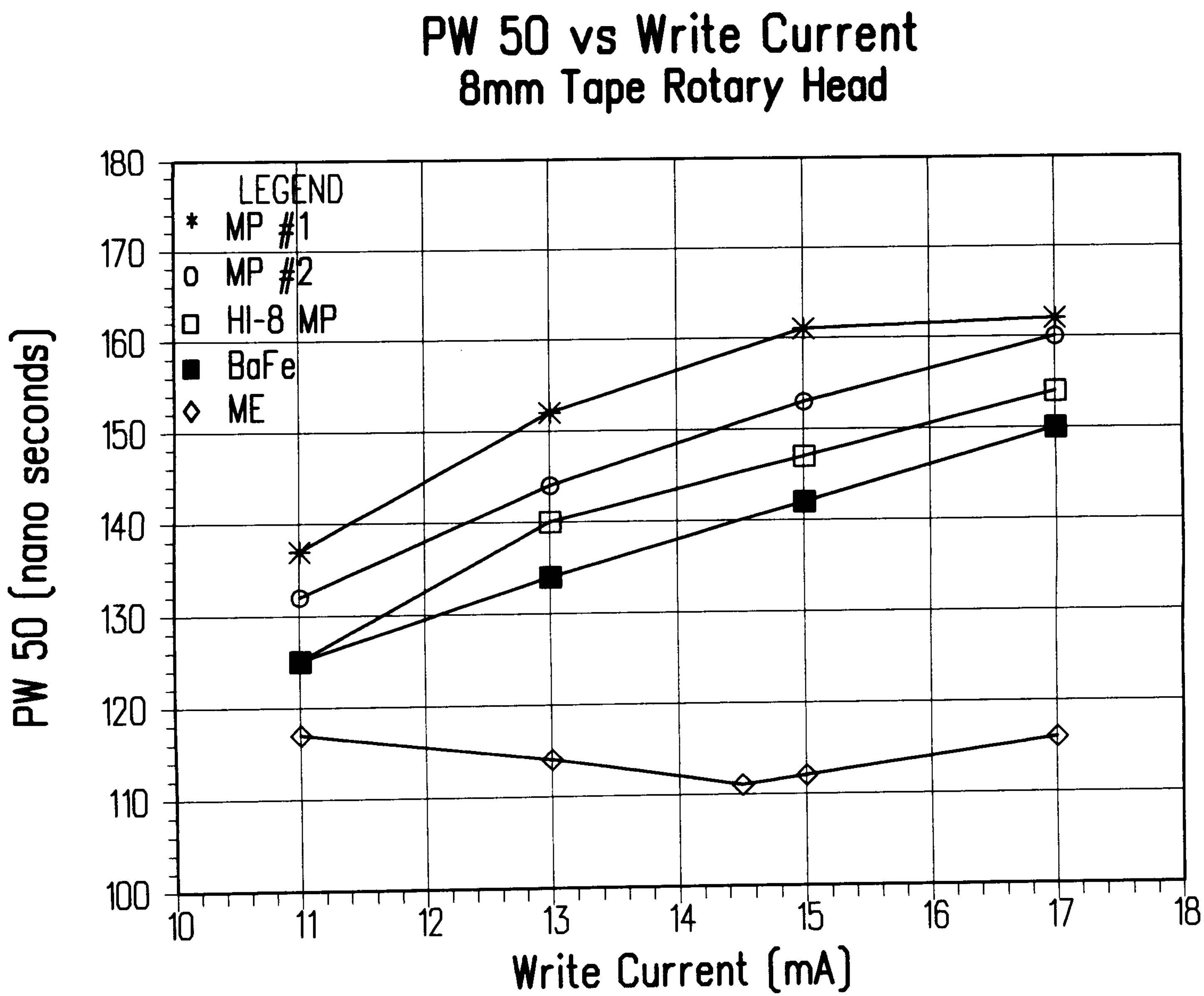

PW 50 vs Write Current
8mm Tape Rotary Head
LEGEND
MP #1
MP #2
HI-8 MP
BaFe
ME
PW 50 (nano seconds)
180
170
160
150
140
130
120
110
100
10
11
12
13
14
15
16
17
18
Write Current (mA)

FIGURE 1

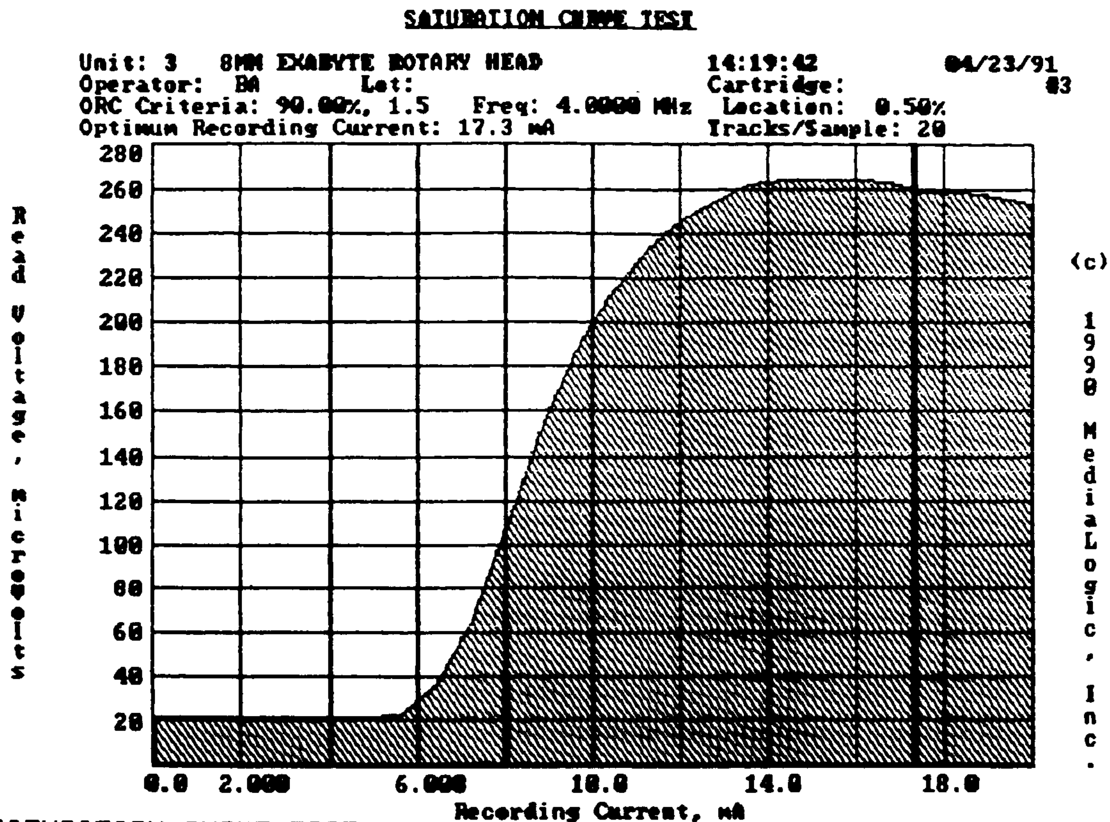
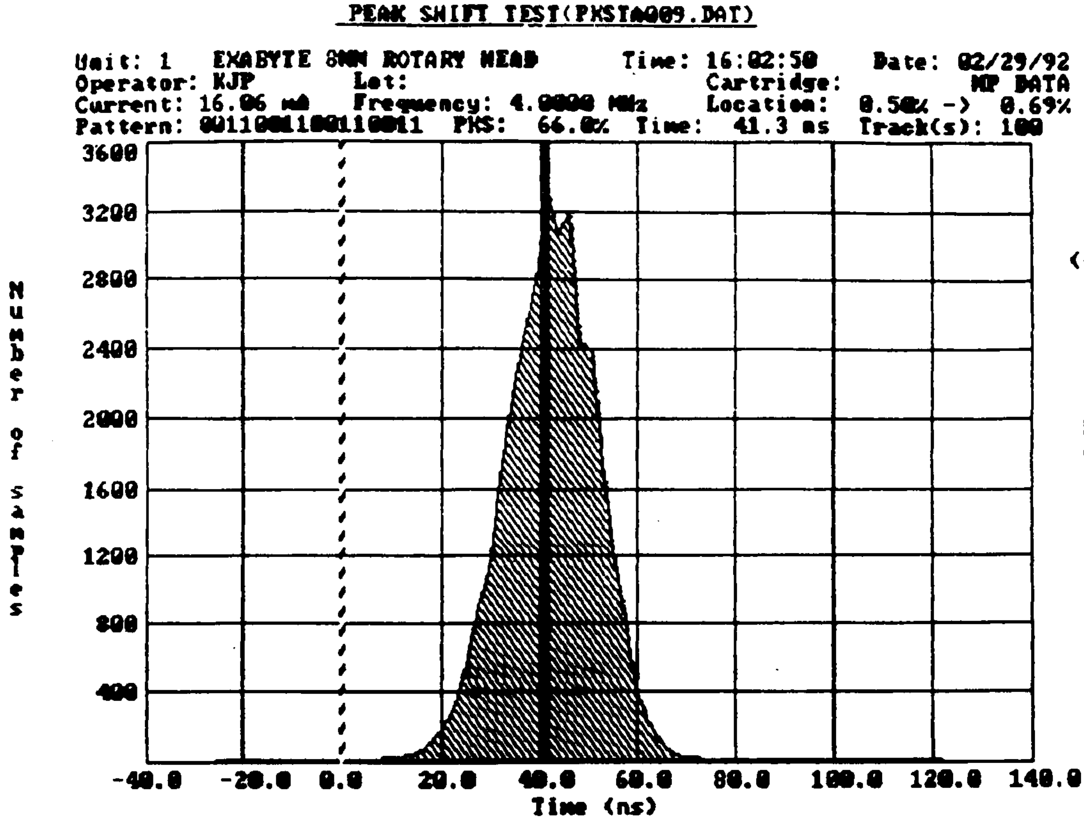


FIGURE 2

SATURATION CURVE TEST

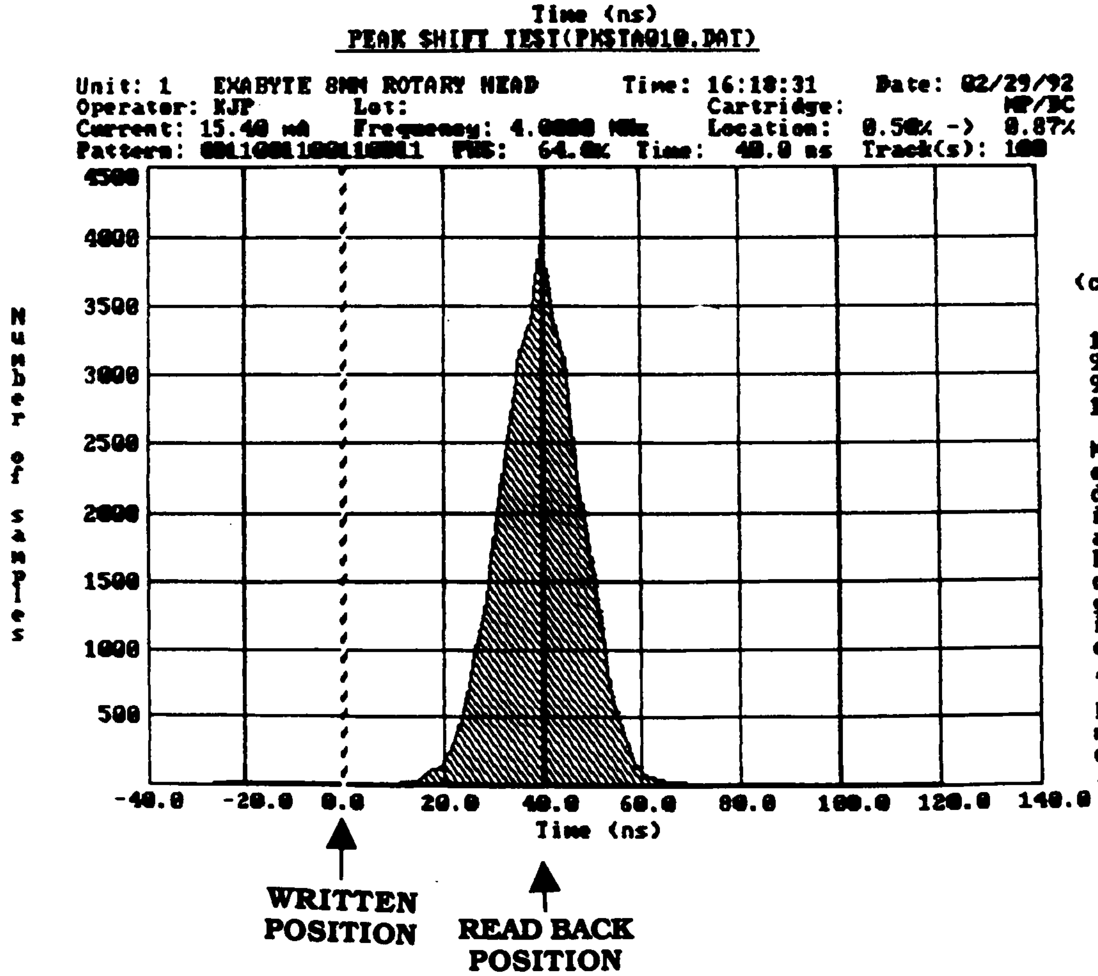
Unit: 3	8MM EXABYTE ROTARY HEAD	14:19:42	04/23/91
Operator: BA	Lot:	Cartridge:	#3
ORC Criteria: 90.00%, 1.5	Freq: 4.0000 MHz	Location: 0.50%	
Optimum Recording Current: 17.3 mA		Tracks/Sample: 20	

0)	current = 0.00 mA,	read voltage =	21.1 microVolts
1)	current = 0.80 mA,	read voltage =	21.1 microVolts
2)	current = 1.60 mA,	read voltage =	21.1 microVolts
3)	current = 2.40 mA,	read voltage =	20.7 microVolts
4)	current = 3.20 mA,	read voltage =	21.1 microVolts
5)	current = 4.00 mA,	read voltage =	21.1 microVolts
6)	current = 4.80 mA,	read voltage =	21.1 microVolts
7)	current = 5.60 mA,	read voltage =	22.1 microVolts
8)	current = 6.40 mA,	read voltage =	34.6 microVolts
9)	current = 7.20 mA,	read voltage =	62.9 microVolts
10)	current = 8.00 mA,	read voltage =	106.4 microVolts
11)	current = 8.80 mA,	read voltage =	150.4 microVolts
12)	current = 9.60 mA,	read voltage =	187.1 microVolts
13)	current = 10.40 mA,	read voltage =	212.5 microVolts
14)	current = 11.20 mA,	read voltage =	232.5 microVolts
15)	current = 12.00 mA,	read voltage =	246.4 microVolts
16)	current = 12.80 mA,	read voltage =	255.0 microVolts
17)	current = 13.60 mA,	read voltage =	262.1 microVolts
18)	current = 14.40 mA,	read voltage =	264.3 microVolts
19)	current = 15.20 mA,	read voltage =	265.4 microVolts
20)	current = 16.00 mA,	read voltage =	265.4 microVolts
21)	current = 16.80 mA,	read voltage =	263.6 microVolts
22)	current = 17.60 mA,	read voltage =	259.6 microVolts
23)	current = 18.40 mA,	read voltage =	258.9 microVolts
24)	current = 19.20 mA,	read voltage =	256.8 microVolts
25)	current = 20.00 mA,	read voltage =	253.9 microVolts



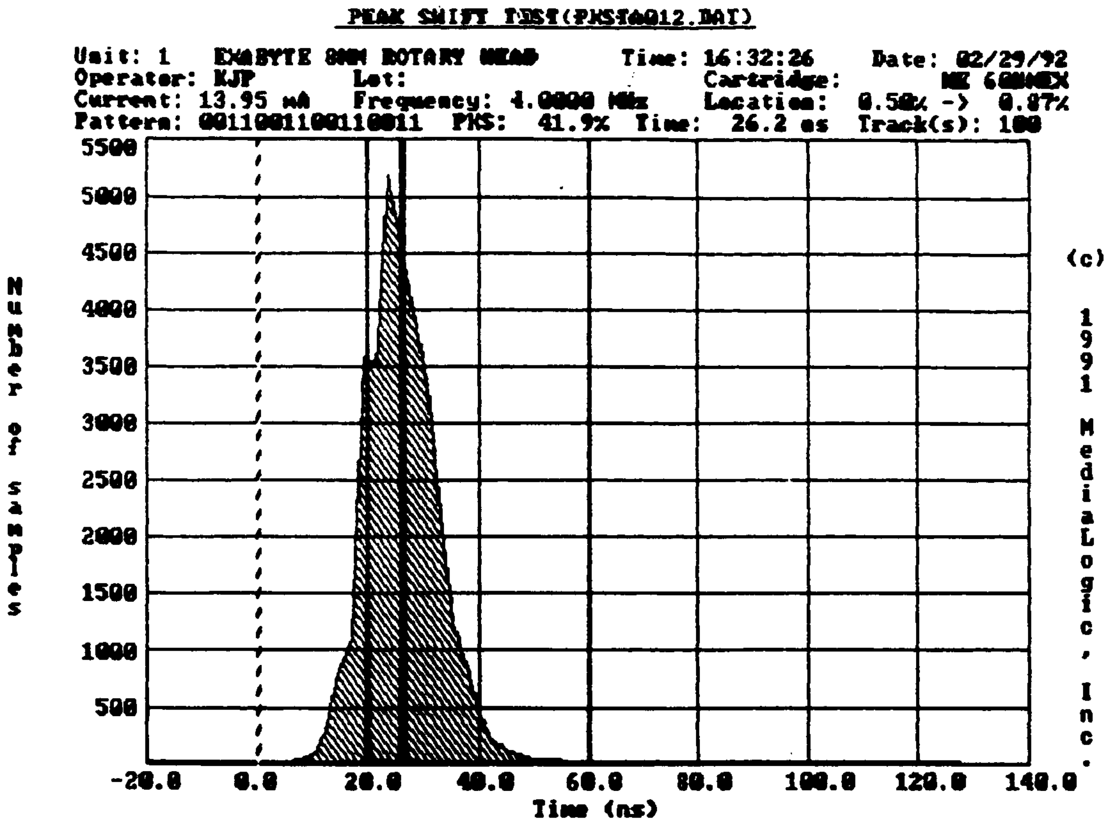
8 MM MP

FIGURE 3



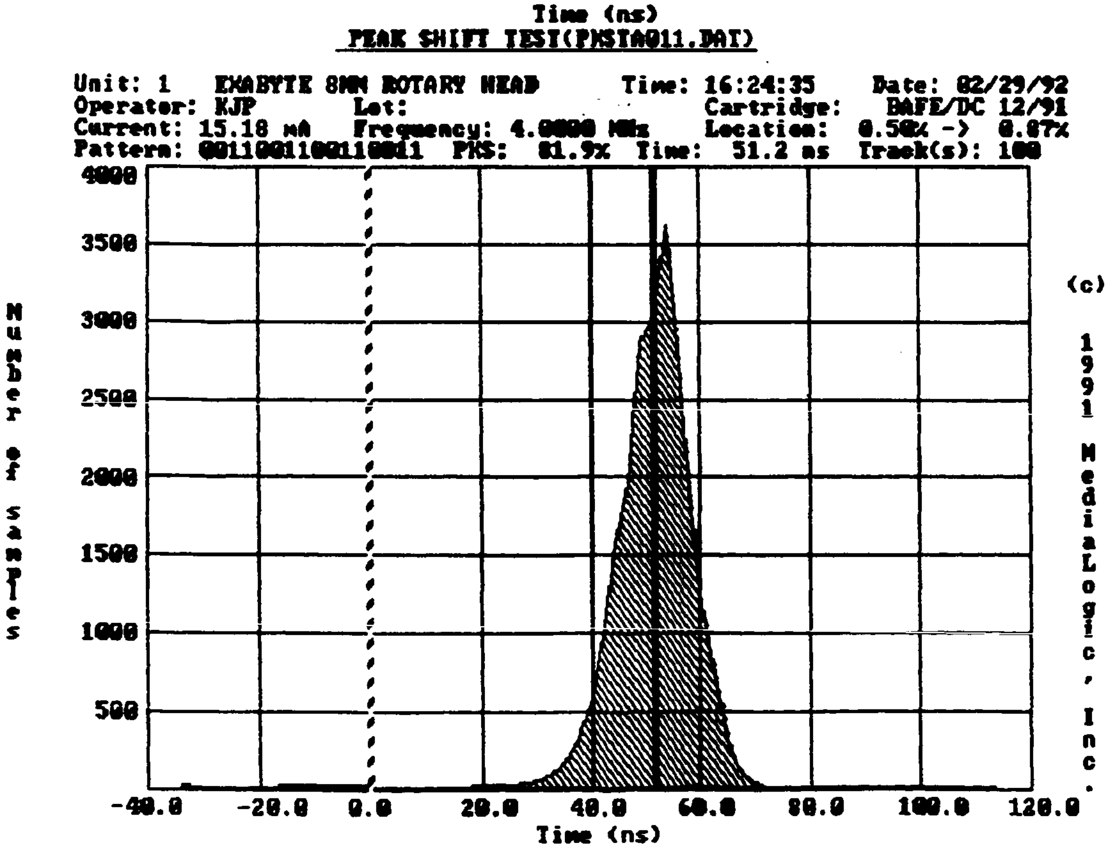
8 MM MP

FIGURE 4



8 MM ME

FIGURE 5



8 MM BAFE

FIGURE 6

```
TAA AND MODULATION TEST (TAAMA019.DAT)
Unit: 1    EXABYTE 8MM ROTARY HEAD        Time: 14:16:21    Date: 03/12/92
Operator: KJP         Lot:                      Cartridge:
Current: 16.00 mA    Frequency: 4.0000 MHz      Location:  1.00% ->   1.28%
                                                Tracks: 100
Track Average Amplitude : 178.17 uV  <-----
ANSI Modulation         :   3.24 %                          SAFE
ECMA Modulation         :   4.82 %
HF   Modulation         :  15.28 %   <-----
========================================================================

TAA AND MODULATION TEST (TAAMA020.DAT)
Unit: 1    EXABYTE 8MM ROTARY HEAD        Time: 14:29:01    Date: 03/12/92
Operator: KJP         Lot:                      Cartridge:
Current: 16.00 mA    Frequency: 4.0000 MHz      Location:  1.00% ->   1.41%
                                                Tracks: 100
Track Average Amplitude : 174.12 uV  <-----
ANSI Modulation         :   2.40 %                          SAFE
ECMA Modulation         :   3.10 %
HF   Modulation         :   9.96 %   <-----
========================================================================

TAA AND MODULATION TEST (TAAMA022.DAT)
Unit: 1    EXABYTE 8MM ROTARY HEAD        Time: 14:36:23    Date: 03/12/92
Operator: KJP         Lot:                      Cartridge:
Current: 16.00 mA    Frequency: 4.0000 MHz      Location:  5.00% ->   5.42%
                                                Tracks: 100
Track Average Amplitude : 183.16 uV
ANSI Modulation         :   3.79 %
ECMA Modulation         :   4.92 %                          SAFE
HF   Modulation         :  10.81 %   <-----
========================================================================
```

FIGURE 7

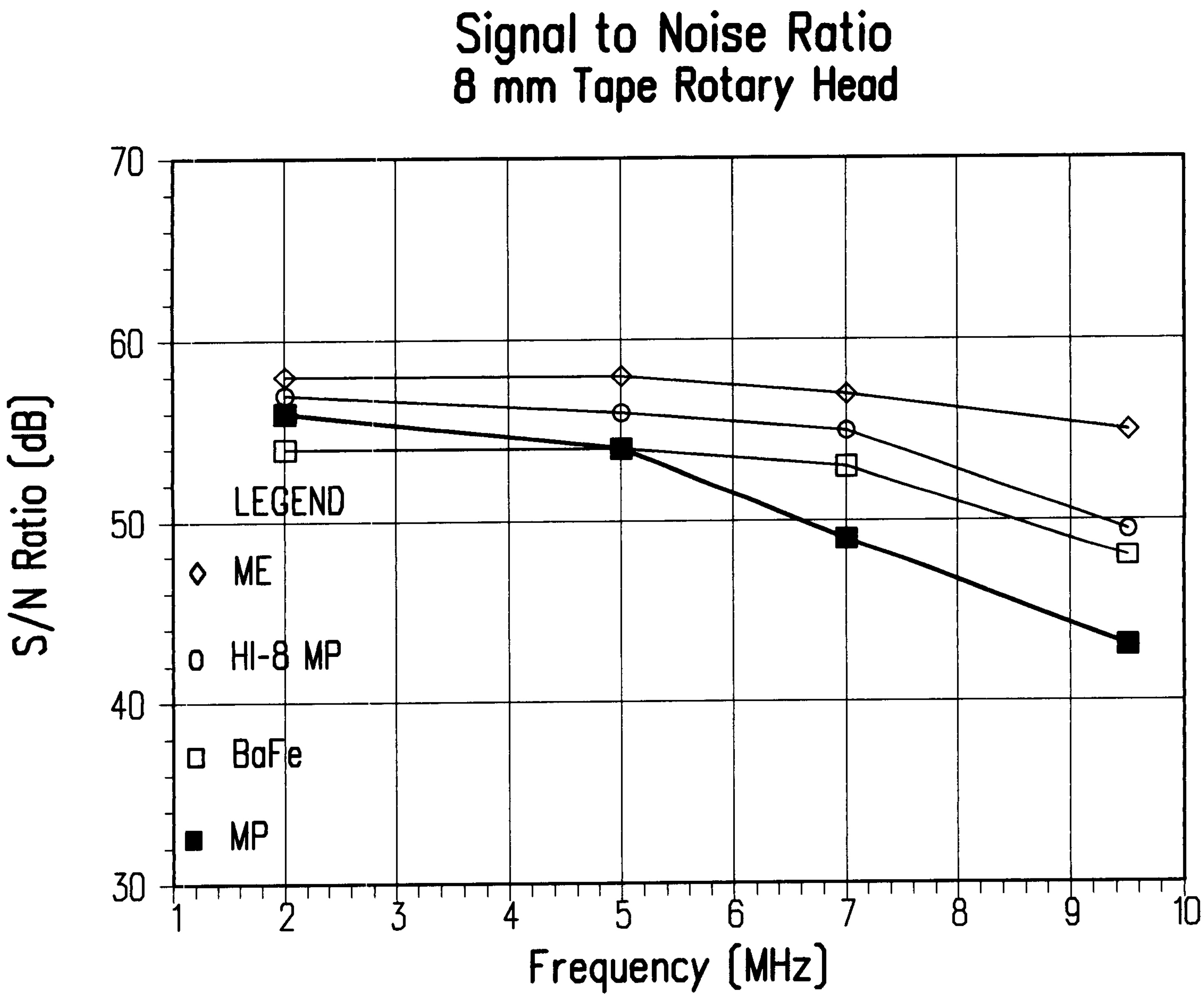
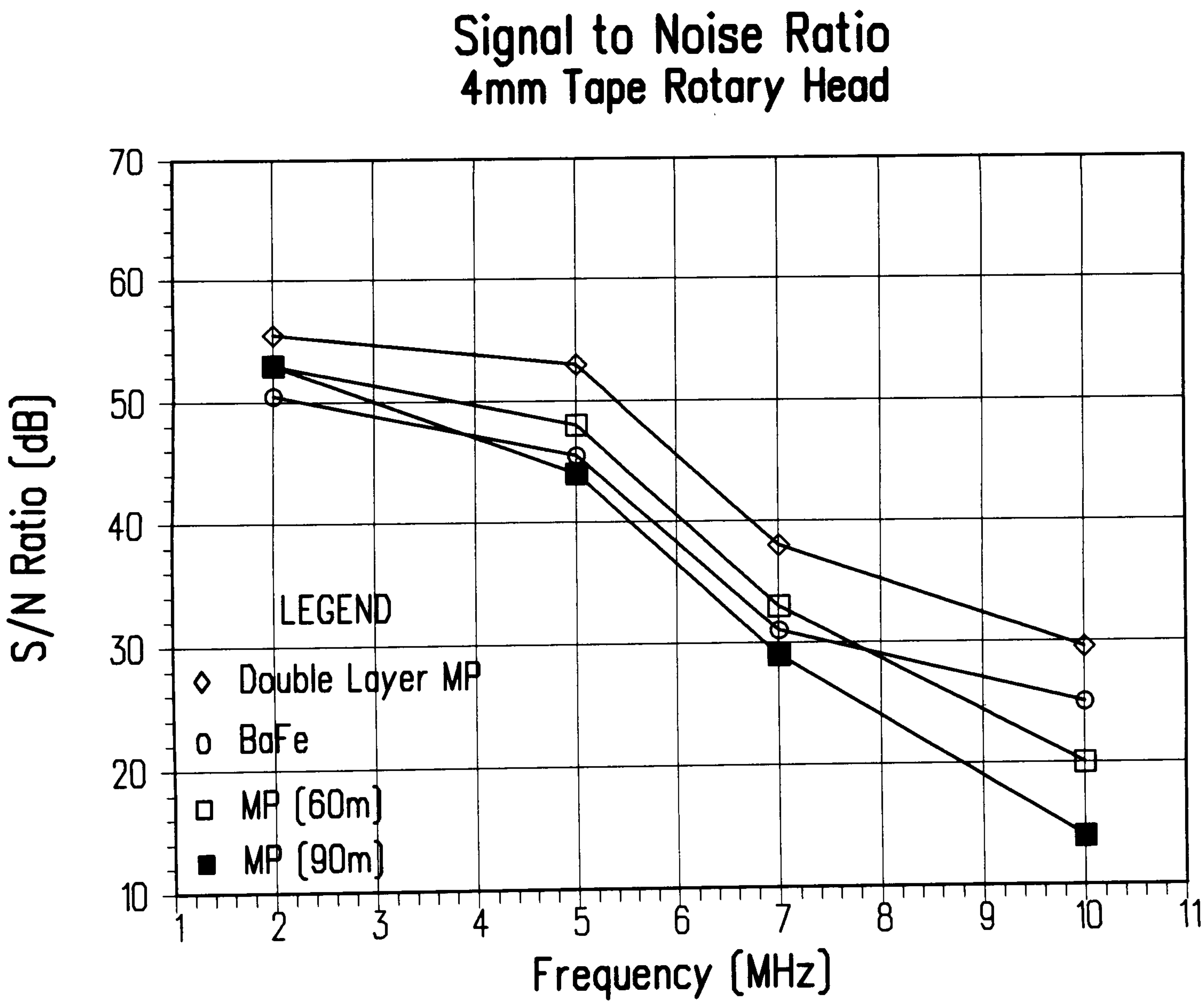

Signal to Noise Ratio
8 mm Tape Rotary Head
S/N Ratio (dB)
70
60
50
40
30
1
2
3
4
5
6
7
8
9
10
Frequency (MHz)
LEGEND
ME
HI-8 MP
BaFe
MP

FIGURE 8

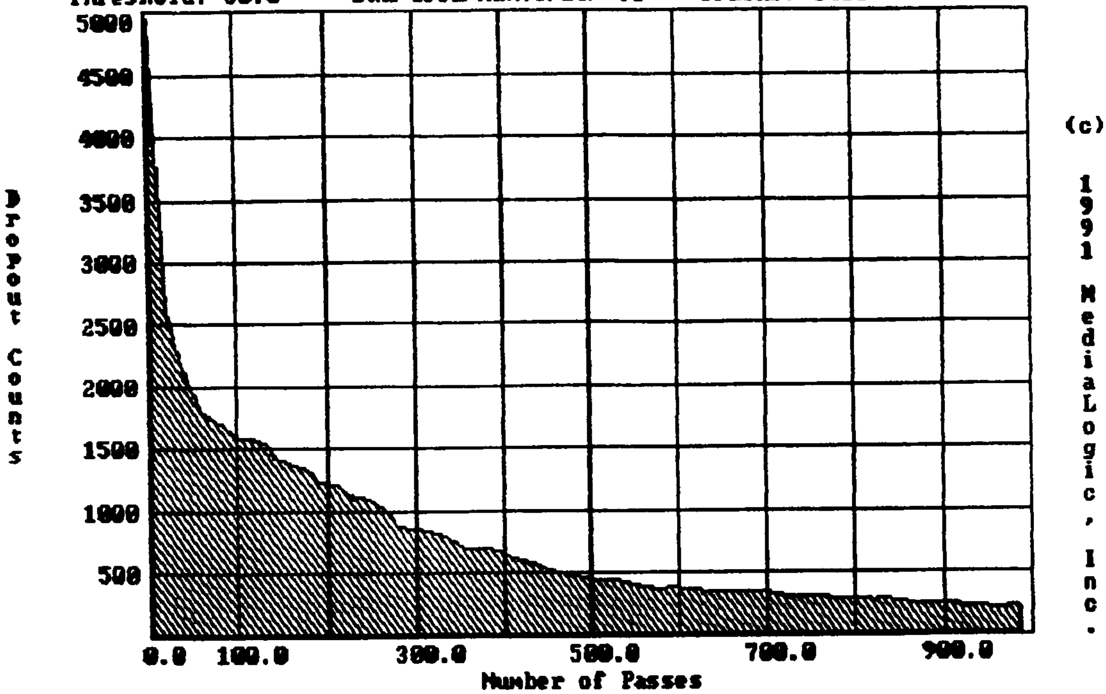


Signal to Noise Ratio
4mm Tape Rotary Head
S/N Ratio (dB)
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
Frequency (MHz)
LEGEND
Double Layer MP
BaFe
MP (60m)
MP (90m)

FIGURE 9

WEAR TEST (WEARA002.DAT)

Unit: 1 EXABYTE 8MM ROTARY HEAD Time: 14:07:23 Date: 03/15/92
Operator: SWS Lot: Cartridge: TAPE #135
Current: 15.77 mA Frequency: 4.0000 MHz Location: 0.50% -> 1.00%
Threshold: 50.0 Bad/Good/Max:8/28/ 80 Tracks: 1000



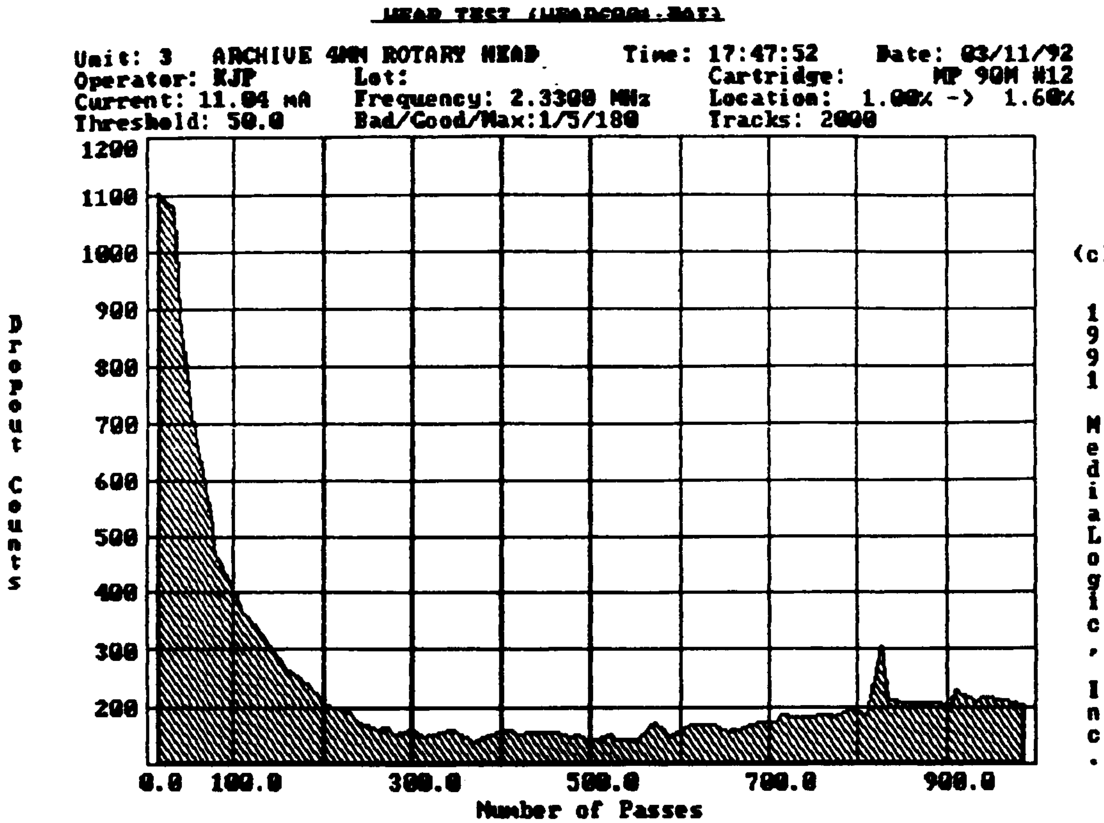
8 MM MP

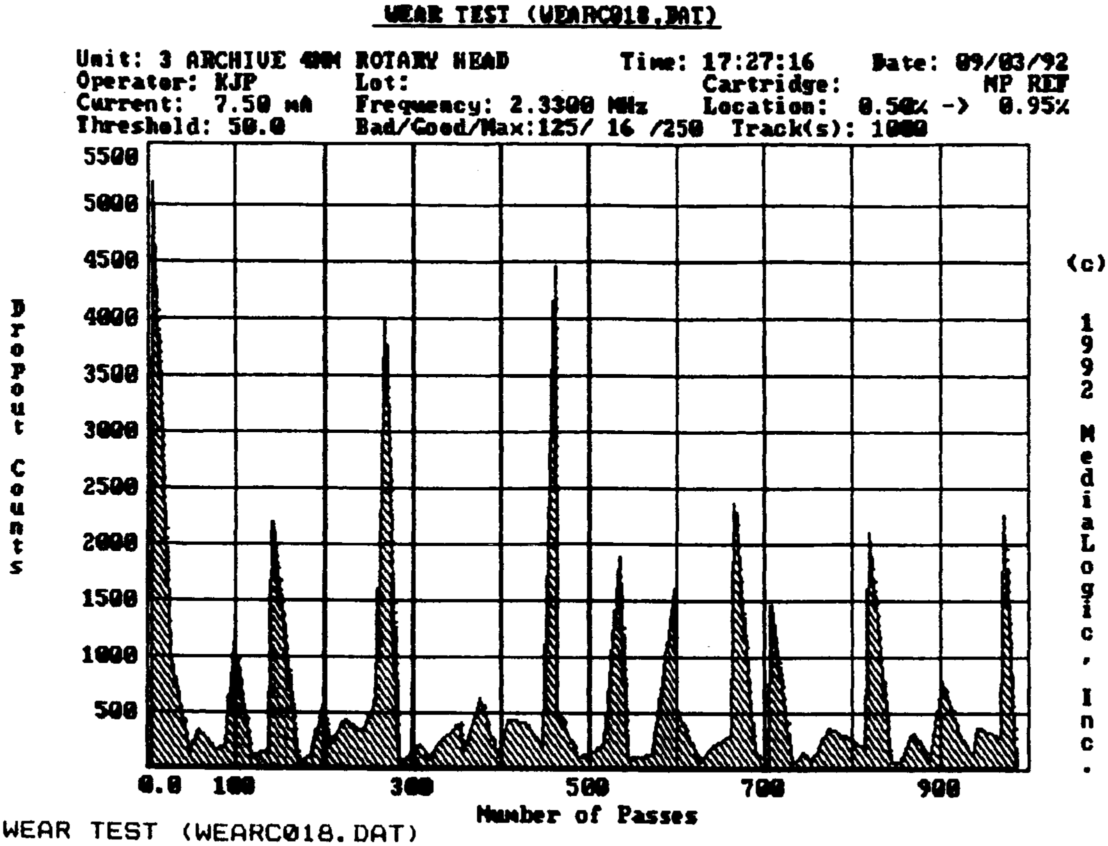
FIGURE 10

WEAR TEST (WEARA002.DAT)
Unit: 1 EXABYTE 8MM ROTARY HEAD Time: 14:07:23 Date: 03/15/92
Operator: SWS Lot: SONY Cartridge: TAPE #135
Current: 15.77 mA Frequency: 4.0000 MHz Location: 0.50% -> 1.00%
Threshold: 50.0 Bad/Good/Max:8/28/ 80 Tracks: 1000

Pass Num.	Counts	Pass Num.	Counts	Pass Num.	Counts
1	4976	393	673	785	263
18	2607	404	617	796	264
34	2164	417	579	816	263
59	1797	432	567	821	254
72	1712	452	512	833	263
85	1680	464	486	851	241
97	1576	480	477	869	235
113	1578	505	432	883	234
129	1531	521	429	897	233
140	1423	527	430	913	227
169	1343	548	390	925	206
181	1302	562	372	940	208
189	1229	578	354	962	196
210	1208	599	362	985	202
229	1091	601	349	988	191
237	1094	621	347		
251	1060	633	327		
270	961	651	325		
278	864	670	327		
300	840	679	329		
312	825	701	325		
326	803	709	301		
341	755	729	289		

FIGURE 11


Unit: 3 ARCHIVE 4MM ROTARY HEAD
Time: 17:47:52
Date: 03/11/92
Operator: KJP
Lot:
Cartridge: MP 90M #12
Current: 11.04 mA
Frequency: 2.3300 MHz
Location: 1.00% -> 1.60%
Threshold: 50.0
Bad/Good/Max:1/5/180
Tracks: 2000
1200
1100
1000
900
800
700
600
500
400
300
200
Dropout Counts
0.0 100.0 300.0 500.0 700.0 900.0
Number of Passes
(c) 1991 MediaLogic, Inc.



20 K PASSES

FIGURE 12

WEAR TEST (WEARC018.DAT)
Unit: 3 ARCHIVE 4MM ROTARY HEAD Time: 17:27:16 Date: 09/03/92
Operator: KJP Lot: Cartridge: MP REF
Current: 7.50 mA Frequency: 2.3300 MHz Location: 0.50% -> 0.95%
Threshold: 50.0 Bad/Good/Max:125/ 16 /250 Track(s): 1000

Pass Num.	Counts	Pass Num.	Counts	Pass Num.	Counts
2	5173	395	75	775	340
24	995	407	401	797	253
47	95	427	375	816	134
57	312	447	174	821	2077
75	140	461	4443	847	43
86	170	463	487	857	43
97	1100	488	69	871	304
116	88	505	131	890	65
136	153	518	212	905	765
140	2170	535	1856	923	323
170	21	542	48	937	111
183	101	570	103	944	342
198	540	571	155	970	251
206	187	598	1574	974	2246
221	416	601	507	987	19
242	293	629	31		
258	579	640	177		
267	3976	662	268		
283	19	666	2343		
307	181	690	114		
317	63	706	38		
329	204	709	1426		
353	375	733	23		
355	93	746	120		
375	600	755	43		

WEAR TEST (WEARA004.DAT)

Unit: 1 EXABYTE 8MM ROTARY HEAD Time: 15:08:40 Date: 03/22/92
Operator: SWS Lot: Cartridge: ME - HI8
Current: 15.77 mA Frequency: 4.0000 MHz Location: 1.00% -> 2.00%
Threshold: 50.0 Bad/Good/Max:8/28/ 80 Tracks: 1000

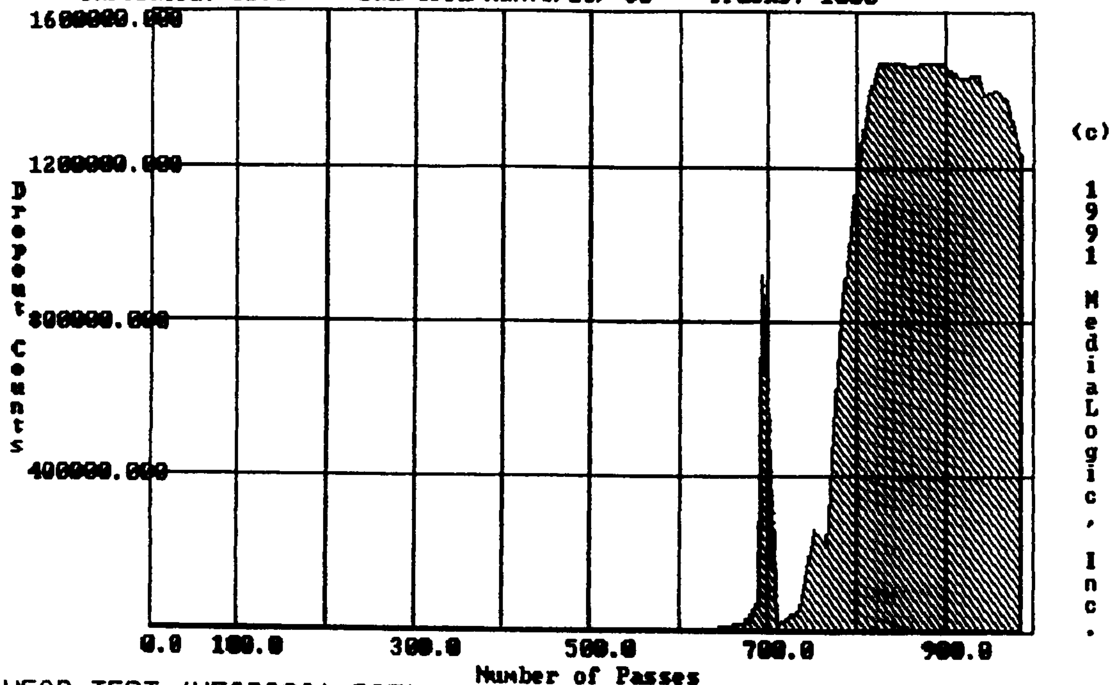


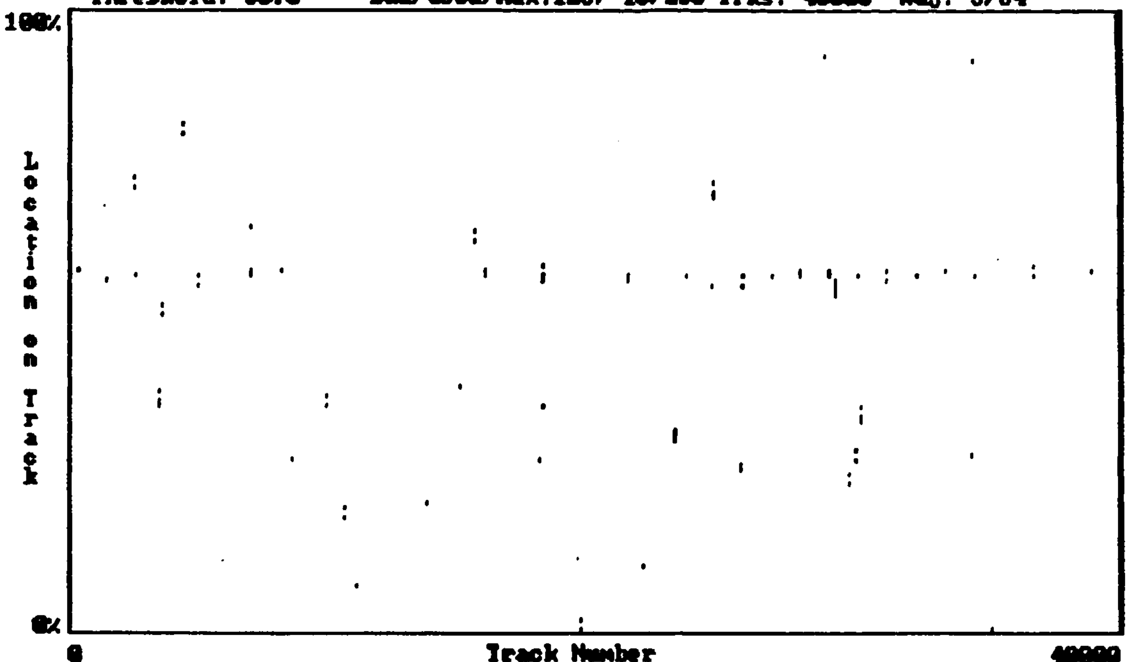
FIGURE 13

WEAR TEST (WEARA004.DAT)
Unit: 1 EXABYTE 8MM ROTARY HEAD Time: 15:08:40 Date: 03/22/92
Operator: SWS Lot: Cartridge: ME - HI8
Current: 15.77 mA Frequency: 4.0000 MHz Location: 1.00% -> 2.00%
Threshold: 50.0 Bad/Good/Max:8/28/ 80 Tracks: 1000

Pass Num.	Counts	Pass Num.	Counts	Pass Num.	Counts
1	37	400	41	785	814773
23	36	406	27	800	1158717
42	35	418	29	814	1384420
57	35	434	30	826	1473750
63	34	448	23	844	1474072
86	34	463	26	851	1473706
98	32	492	26	863	1471346
110	33	497	23	880	1473884
126	31	513	22	894	1472254
149	31	537	26	921	1437701
167	30	545	28	938	1440926
173	31	562	27	946	1390048
197	33	576	26	960	1403681
202	33	588	23	971	1379884
226	30	602	44	987	1232467
238	36	622	30		
258	30	642	406		
271	32	651	1058		
286	26	674	8604		
307	26	691	59384		
316	27	695	925003		
327	26	712	5831		
347	26	739	47945		
355	25	754	256125		
383	29	768	210260		

[illegible]

Unit: 1 ARCHIVE 4MM ROTARY HEAD Time: 13:25:09 Date: 06/02/92
Operator: xxx Lot: L Cartridge: xxxxxxxxxxxxxxxx
Current: 7.10 mA Frequency: 2.3300 MHz Location: 5.00% -> 22.15%
Threshold: 50.0 Bad/Good/Max:125/ 16/250 Trks: 40000 Adj: 3/64

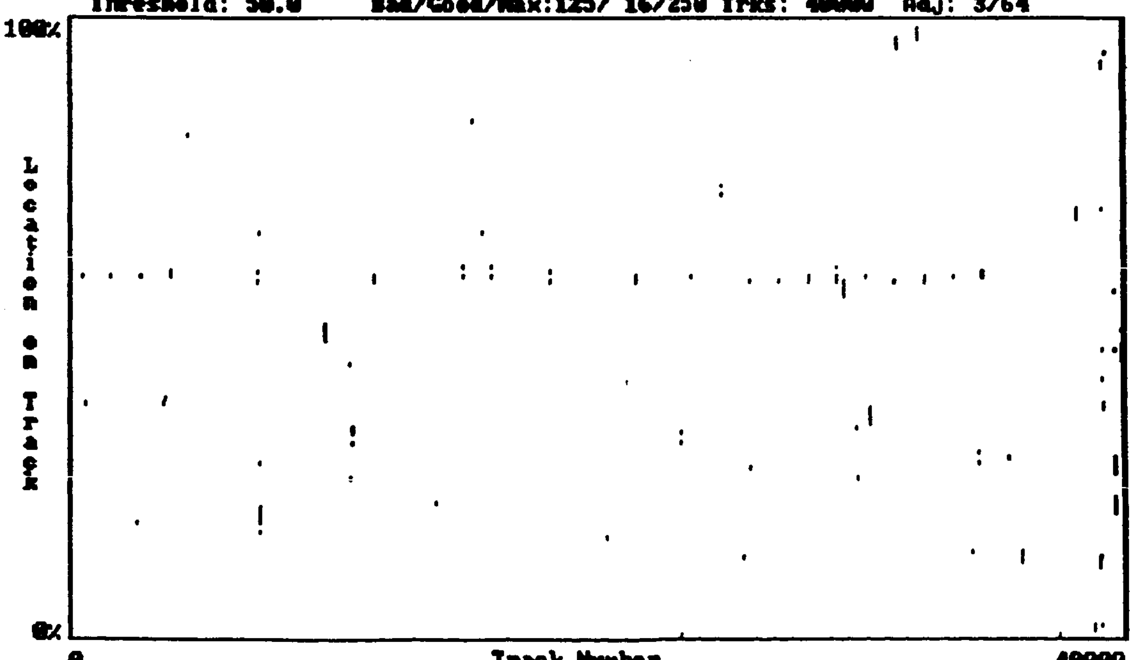


Adj. Errors: 0 Total Errors: 81 (c) 1990 MediaLogic, Inc.

FIGURE 14

DROPOUT MAP (DMAPA008.DAT)

Unit: 1 ARCHIVE 4MM ROTARY HEAD Time: 14:31:07 Date: 06/02/92
Operator: xxx Lot: L Cartridge: xxxxxxxxxxxxxxxx
Current: 7.10 mA Frequency: 2.3300 MHz Location: 5.00% -> 22.15%
Threshold: 50.0 Bad/Good/Max:125/ 16/250 Trks: 40000 Adj: 3/64

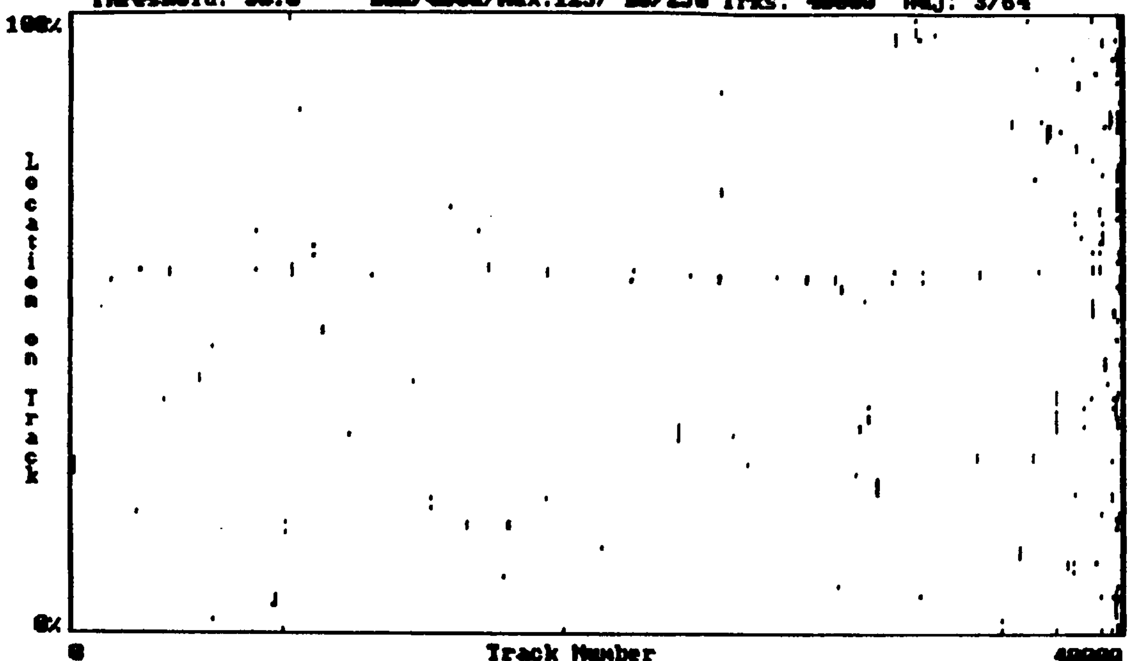


Adj. Errors: 0 Total Errors: 122 (c) 1990 MediaLogic, Inc.

FIGURE 15

DROPOUT MAP (DMAPA089.DAT)

Unit: 1 ARCHIVE 4MM ROTARY HEAD Time: 08:12:00 Date: 06/03/92
Operator: xxx Lot: xxxxxxxxxxxxxxx Cartridge: xxxxxxxxxxxxxxx
Current: 8.30 mA Frequency: 2.3300 MHz Location: 5.00% -> 22.20%
Threshold: 50.0 Bad/Good/Max:125/ 16/250 Trks: 40000 Adj: 3/64

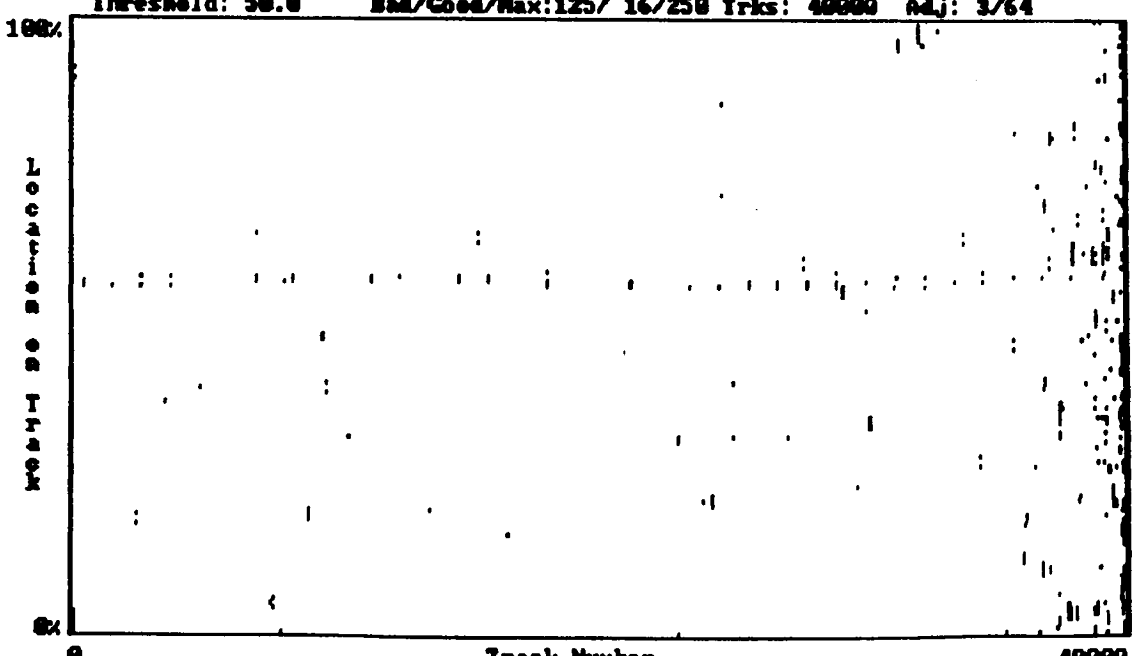


Adj. Errors: 0 Total Errors: 290 (c) 1990 MediaLogic, Inc.

FIGURE 16

DROPOUT MAP (DMAPA090.DAT)

Unit: 1 ARCHIVE 4MM ROTARY HEAD Time: 08:56:51 Date: 06/03/92
Operator: xxx Lot: xxxxxxxxxxxxxxx Cartridge: xxxxxxxxxxxxxxx
Current: 8.00 mA Frequency: 2.3300 MHz Location: 5.00% -> 22.21%
Threshold: 50.0 Bad/Good/Max:125/ 16/250 Trks: 40000 Adj: 3/64



Adj. Errors: 0 Total Errors: 362 (c) 1990 MediaLogic, Inc.

FIGURE 17

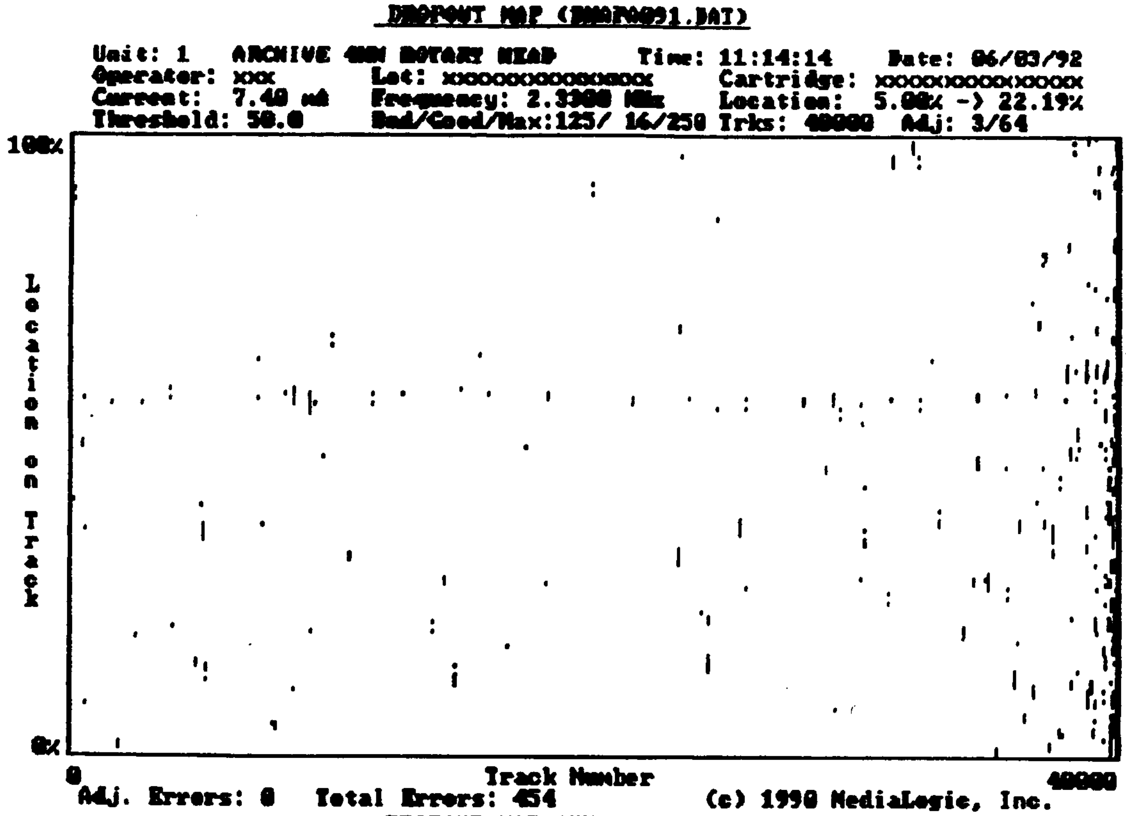


FIGURE 18

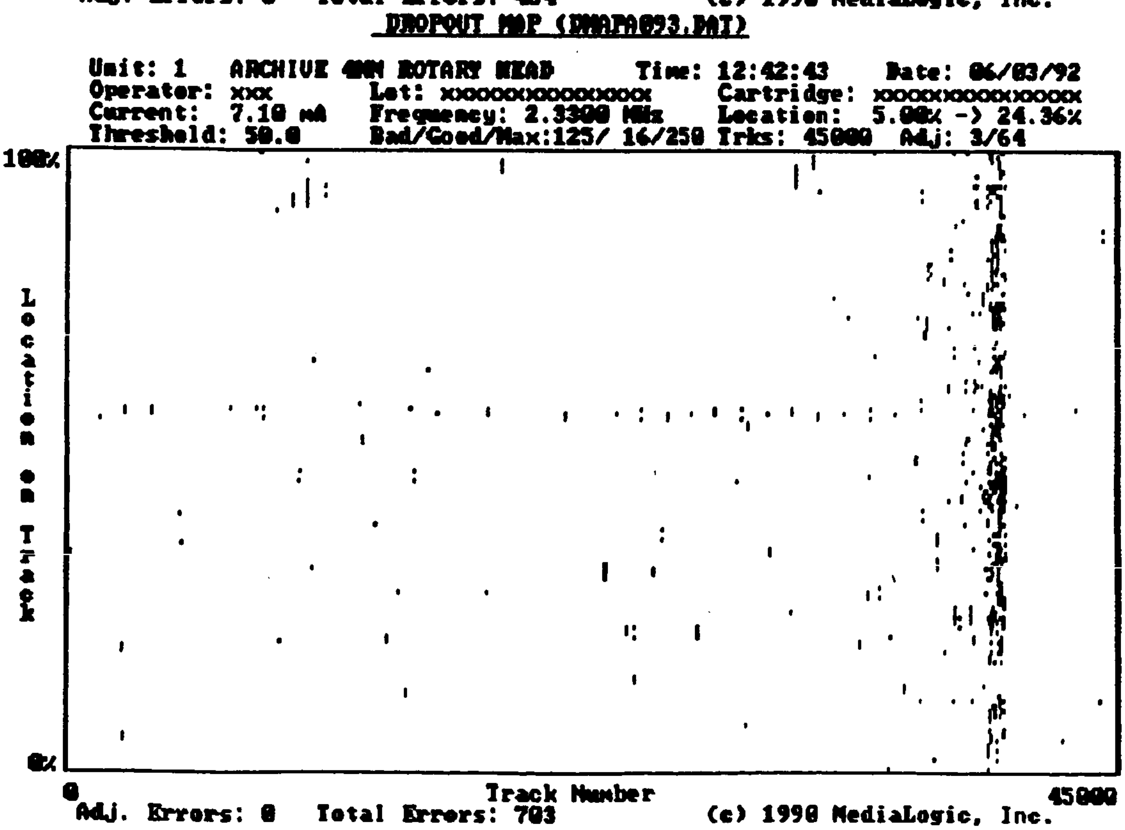


FIGURE 19